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Survey of Intelligent Collaborative E-Learning Systems

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Abstract—**In recent years, agent technology is used to design solutions that facilitate the implementation of new concepts, especially in the field of E-learning. It is widely used to model the different actors of E-learning systems and manage their interactions, to meet their dynamic and execution needs by their innovative features like intelligence and autonomy. In education field, multi-agent systems makes a great change in the society in the fact that the conventional education system requires the presence of both student and instructor at same place, the same time and at the same interval of time. This kind of system equips with these characters; and provides many advantages like autonomy, reactivity, social ability and proactivity. There are several collaborative E-learning environments using multi-agent technologies that included I-MIND, MASCE, ALLEGRO, etc.**

Our work aims to define the importance of a collaborative learning system, to define the roles of each actor and the different possible communications between them, to determine the tasks of the agents that can be automated. Furthermore, an analysis of existing multi-agent based collaborative E-learning systems on the basis of their various features covering collaboration features, student-tutor interaction, adaptability measurement and security in order to identify your strengths and weaknesses to determine the most suitable model to our system.

I. INTRODUCTION

Over the last few years, Collaborative e-learning becomes a major cornerstone in e-learning systems. Many studies have focused on the collaborative E-learning system that is defined as the learning strategy where several learners interact with their partners, share ideas, and where everyone should be involved in the social interaction in order to achieve their common goals [2]. This mode of learning follows a learner-centered approach by involving new roles for teachers, accompanists and learners. Consistent with this context and precisely with the accelerated development of information technologies and the acceptance of smart devices, collaborative work becomes much intelligible and more persistent. In collaborative E-learning actors can work together regardless of geographic location / location or time limitation. These educational environments are designed and dedicated to encourage individual work and group work in various fields involving the domain of instruction.

To make a collaborative learning system more productive and efficient, modern learning uses artificial intelligence as an appropriate solution [3]. Consequently, multi-agent systems offer an original approach to designing intelligent and collaborative systems. They are characterized by the distribution of the global control of the system and by the presence of autonomous agents evolving in a shared and dynamic environment. Multi-agent systems are well suited to designing a learning environment where each member must manage and exchange knowledge and collaborate with others to achieve its goals. The fundamental aspects of these intelligent E-learning systems are the ability of perception, inference, learning, reasoning, and knowledge-based systems [4].

This paper is divided into four main parts. Section 2 present general principles of agents and multi Agents systems concepts in order to indicate its importance. Section 3 present the advantages and limitations of E-learning system; it also specified collaborative online learning by presenting the different activities of these actors as well as the interaction between them. Section 4 define some existing agent-oriented collaborative learning system and compares between them on the basis of a multitude of criteria covering collaboration features, student-tutor interaction, adaptability measurement and security. In addition, it represent an analysis that determines the most suitable model to our system.

II. AGENTS AND MULTI-AGENT SYSTEMS

Multi-agent systems (MAS) are currently considered as the most active research discipline which they relate to several areas, in particular of artificial intelligence, distributed computing systems, robotics and software engineering. These systems are made up of several flexible and autonomous entities interacting with each other and called agents. According to Ferber, a multi-agent system can be considered as a macro-system composed of autonomous agents that interact in a common environment in order to achieve a coherent collective activity [9].

In artificial intelligence field, the concept of agent has started to grow rapidly and to succeed in recent years. In this section, we discuss the definition, classification and benefits of agents in collaborative e-learning systems.

A. Definition of agent

The notion of agent remains relatively vague to define. It is found that several researchers have defined this concept in different ways. All of these definitions look the same, but they also differ according to the application context for which the agent is designed. According to Ferber an agent is defined as a physical or virtual entity, autonomous, located in an environment, capable of acting in an environment, communicating with other agents, perceiving its environment, reproducing itself [9]. This

definition is supported by Wooldridge [2] that present an agent as computer system located in a certain environment capable of autonomously performing actions in that environment, achieve its goals. Another frequently cited definition is presented by Russel [1]; he provides that an agent is all that can be seen as perceiving its environment through sensors and acting on this environment through effectors.

B. Classification of agents

Agents can be classified based on the technology used to implement the agent, on the type of the agent or on the application domain itself. According to Wooldridge, agents can often be classified according to their individual behaviors. Generally, two main categories of agents can be distinguished [2]:

- **Reactive agents:** have not any representation of other agents or their own environment as well as their inability to account for its past actions. They behave in a "stimulus-response" way in the face of what they perceive. These kind of agents argues that it is not necessary for agents to be intelligent individually for the system to behave intelligently [9]. In general, Multi agent systems consisting solely of reactive agents have a large number of agents that can work together collectively to solve complex problems. This category of agents only has a reduced communication protocol, which shows its weak communication capacity [5].

- **Cognitive agents:** are most represented in the field of artificial intelligence distributed. They are composed of a set of agents "intelligent" that include memory, attention, communication and learning. Each agent has a knowledge base comprising all the information and know-how necessary to carry out its task and to manage interactions with other agents and with its environment [9]. These agents have a global representation of themselves, their environment and other agents with whom they communicate. They also have an explicit representation of beliefs, desires and intentions.

This definition shows that an agent is capable of acting autonomously according to the goals that it pursues. We can summarize many advantages that a cognitive agent has over a reactive agent. For this reason we are interested in systems based on cognitive agents because in this kind of architecture is characterized that each agent simulating a human must be a cognitive agent (memorize, communicate, learn ...) and requires more resources than reactive agent architectures. However reactive agents imposes more rigid behaviors, which shows that the reactive agents are not very powerful since they are reduced to their own means [9], it does not have a complete representation of its environment and other agents.

III. E-LEARNING AND COLLABORATIVE E-LEARNING SYSTEMS

A. Features and advantage of E-learning

E-learning is becoming an increasingly popular educational system used in the world, which facilitates the process of learning and makes it possible anywhere and anytime [14]. It is considered as an efficient and attractive way for computer education. E-learning is a software environment specifically designed to meet the needs of distance education, accessible via the Internet in order to be able to remote consultation of pedagogical contents and to individualization of learning by including the necessary tools for the main users of a device.

E-learning researchers aim to improve distance learning systems in two areas; organizationally by noting the standardization of self-training materials and a quality approach, providing training opportunities and broadening the prospects for dissemination to employees, suppliers and customers [12], and functionally by trying to personalize the learner's profile according to training, to reduce costs, to save time and to make learning more effective.

Actually, E-learning is dominated by the Learning Management Systems (LMS), such as Moodle, Edmodo and Blackboard. It is refers to educational content or learning experiences delivered or mediated by means of digital technologies. These systems are in the first place software packages that allow organizing the on-line content in which the authors have a simple interface to deposit their articles within predefined themes, organized in categories, they can associate one or several downloadable files to their articles. They can be characterized also by the public on-line (with readers) which can be preceded by a phase of validation of the information [14]. These systems are characterized by a number of advantages like:

- The ease of sharing, exchanging and using varied learning modalities (audio sequences, videos, animations, diagrams);
- Flexibility and adaptability according to availability (for example, allowing the learner to learn at his or her own pace and in an individualized way or by providing "just in time" training);
- The relative reduction of costs for learners and trainers (elimination of accommodation and travel costs) and increased accessibility of training.

B. Functionalities of E-learning

Online education systems revolve around a set of functionalities such as administrative management of the platform; it deals with the management of registration in training and the management of administrative data of the training. Creation of courses and training plans (creation of teaching scenarios, curricula and preparation of the various evaluation tests) as well as changing or add course content and activities, schedule management, training path planning. It allows the management of pedagogical materials that focuses on the classification, indexing and administration of teaching materials besides the management of learning through distance consultation of educational content, communication between trainers and learners and between learners, individualization of learning.

E-learning determinate roles of teachers, groups of students and their access, types of content, modes of communication, types of tests and facilitates communication with learners or between them by messaging and forum. It authorizes creation and modification of individualized training paths as well as

follow-up of the activities of learners on the platform (time spent online in the course notes, dialogues, work deposited on the platform...).

C. Definition and principles of collaborative learning

Collaborative learning is a construct based on several sources. It feeds on the values of constructivism and relies on cognitive theories to explain the mechanisms of learning. Collaborative learning is a learning strategy where many learners interact with one another to achieve their common goals. According to Walckiers and De Praetere in the case of collaborative work, there is no a priori distribution of roles: individuals are gradually subsumed into a group that becomes an entity in its own right [11]. In this system, the learning responsibility is global and collective, all the members of the group stay in regular contact, each one brings to the group in action, and each can contribute to the action any other member of the group to increase its performance. The interactions are permanent: it is the coherence of the collective that makes it possible to achieve the objective.

Since the evolution of the web, the semantic field of the word "collaboration" has evolved considerably, learning objects are becoming increasingly hypermedia intelligent and collaborative, which allows putting initiative and power in the hands of learners to access the information. Roschelle [10] report that students can undertake problems that are more complicated and gain a better understanding of the material by working collaboratively.

In the field of E-learning, the effectiveness of collaborative learning depends on the motivation of its members to collaborate. It also depends on their skills, the quality of the collaboration tools they have, and the time they can devote to exchanges.

Collaborative E-learning provides learners with a great flexibility of time and place as well as excellent asynchronous interaction [13]. It promotes the cultural and social integration of students from minority groups, aims to develop critical thinking in the learner, the emotional and pedagogical support of weak students, it is a source of motivation, it allows the improvement of communication skills, it supports the realization of a continuous formative evaluation and ensures the development of a System of values.

D. Principle actors of a collaborative E-learning system

Collaborative E-learning follows a new economic model of production in which a large number of people join with new communication tools. The work is often naturally collective and collaborative, that is to say that it makes interact several actors for the realization of tasks to reach a common goal. Collaborative learning is an active process where the learner assumes the responsibility for building his knowledge. The trainer plays the role of facilitator of learning while the group participates as a source of information, as a motivator, as a means of mutual support and support and as a privileged place of interaction for the collective construction of knowledge. The collaborative approach recognizes the individual and reflexive nature of learning as well as its social anchoring by clinging to group interactions. E-learning collaborative system facilitates interaction between the main actors: the tutor, the learner and the teacher.

The tutor:

In the context of distance learning, the tutor plays a leading role in training to help advance learners by placing more emphasis on monitoring, accompanying rather than transferring expertise. The quality of the follow-up makes it possible to guarantee the motivation of the learner and to avoid that he quits his training along the way.

The e-tutor occupies several goals:

- It determines with the learner the training course most adapted to him and offers him the help in his first steps;

- It ensures the pedagogical follow-up of the training (personalized advice, analysis of the progression, answers to the questions of the learners);

- It animates the group or the community of learners: the possible affinities between the learners can be a "pedagogical" relay and a support to the motivation.

There are several methods to implement their goals including "Managing group", "Managing Learning Resource", "Tracking and evaluating" and "Holding a Seminar".

The teacher:

In traditional learning systems, the teacher was previously the sole holder of knowledge. On the other hand, in these systems, its role is to be a learning facilitator that guides learners to make good use of the knowledge available outside of it. It also makes it possible at any time to observe the state and activities of each learner. This allows the teacher, according to the progress of the observed work of the group, to motivate and guide them to prevent the failure or the abandonment of the learners.

The learner:

In the context of online collaborative work, the learner is no longer the traditional mode whose role is to memorize the knowledge transmitted by his teacher for a restitution on the day of the examination, but he governs his process learning by transforming information into knowledge and creating interactions with other members of the group.

Learner goal could be archived principally through one or several tasks, such as "Questioning", "Reading Literature", "Joining group", "Taking Exam" and "Taking Practice"; Before learning, students set goals and learning tasks of the plan; during learning, they work together to accomplish tasks and monitor their progress; And after learning, they evaluate their performance and plan for future learning [12].

During the communication, the learner can either be a transmitter who must be listened to and be understood to express himself as succinctly as possible in order to avoid encroaching on the expression time of the other members of the team. To express it clearly and precisely and to use an accessible language.

IV. TOWARDS AN AGENT-ORIENTED COLLABORATIVE LEARNING SYSTEM

A. Existing intelligent collaborative E-learning system

Many multi-agent systems that focus on the collaborative E-learning domain have been designed and

implemented by integrating a wide range of functionalities. These systems offer an original approach to designing intelligent systems and provide an interesting solution for both problems of structuring and exploiting knowledge. Agent-oriented collaborative learning system offer many appropriate tools for designing a learning environment or each member must manage and exchange knowledge and collaborate with others to achieve its goals. The common goal of these systems is to improve the learning ability of the student/learner. There are several systems that meet these objectives, among which we can distinguish:

1) ALLEGRO

Allegro was developed by Rosa Maria Viccari et al. [15]. This system gives flexibility, autonomy and adaptability to the E-learning environment. It offers an individualized learning to the manner of CSCL. It is based on three theories of learning behaviorism, cognitivism and historic-social.

Agent Used and their working:

- **Student Agent:** aims to preserve the learning student model

- **Interface Agent:** Interface allowing interaction between the user and the artificial agents

- **Expert Agent:** manages the content for a specific purpose of learning and teaching

- **Tutor Agent:** Will guide the learning process, decides what action to teach, how and when;

- **Diagnosis Agent:** is responsible for classifying and selecting the knowledge level of the learner;

- **Collaboration Agent:** it try to find students who are interested in the same subject in order to create synchronous or asynchronous collaborative communication.

2) I-MINDS

Intelligent Multi-agent Infrastructure for Distributed Systems (IMINDS) was developed by Leen-Kiat Soh et al. [6]. It provides a multi-agent infrastructure for Computer-Supported Collaborative Learning (CSCL). This system allows the learner to learn, interact with other learners as well as with the tutor and it also allows it to form group. I-MINDS provides standard online collaborative features. In this system, intelligent agents interact to serve tutors and learners. This architecture provides to teacher the ability to send their lectures directly from the classroom to the students via whiteboard technology. I-MINDS consists of a three intelligent agents:

- **Student Agent:** The student agent manages the interaction channels among students and exchange information between the teacher and the students and the group agent. It can also assesses and forms a buddy group for the student that it serves;

- **Group Agent:** It is designed to encourage collaborative learning groups. It controls the students' interactions to assess each student's contribution as a group member.

- **Teacher Agent:** assesses and categorizes questions asked by students, learns from the instructor to better measure the quality of questions and profiles students based on the quality of their questions

3) MASCE

Multi Agent System for Collaborative E-learning, it was developed by Hani Mahdi et al. [7]. This system is used in a blended learning environment as a supplement to the face-to-face and makes students learn with a peer. It aims to help the teacher during interaction with the students as well as allowing a group of students to work on the same assignment. It allows the learner to review course materials, ask for help and evaluate the help provided to enable the system to have a list of best assistants [7]. It also allows interacting with their tutors or the other learners using the tools of collaborative work (chat, email).MASCE considers two types of users; namely students and instructors. Each of these users has a corresponding agent. These are Instructor Agent and Student Agent.

MASCE has three agents:

- **Student agent:** Each student has the corresponding Student Agent that helps the learning process of the student. It provides mechanism to update the student's profile and preferences.

- **Instructor agent:** it provides pedagogical materials when requested by Assistant Agent for distributing to students' agents, evaluates the progress and participation of different students, and maintains course progress.

- **Assistant agent:** plays the most essential role in this system, It acts as mediator between Instructor Agents and Student Agent of a specific course. It is initialized as soon as any of the users starts to use the system.

4) MAS-PLANG

MAS-PLANG system was designed by Pena et al. in the year 2002 [16].The intention is to offer characteristic of adaptability based on styles of learning for supporting distance adaptive education via the Web. It system is based on the FIPA compliant multi agent system, using Java, JavaScript Flash and XML languages. It provides content, navigation strategy and navigation tools according to the students learning style. The environment is composed of two levels of agents: those of the higher-level agent programmable (SONIA, Synthetic SMIT, Monitors and Surfing), and the lower level (didactic agent, user).

- **Sonia Agent:** is a simple reflective agent that for its operation uses data for the tasks that the student or the professor wants it to carry out, as well as certain events happening in the learning environment.

- **Navigation agent:** organizes the navigation paths by directly interaction with databases and by communicating with the didactic agent and the user agent.

- **Synthetic agent:** presents the messages coming from other agents, in the form of suggestions or warnings when the student exhibits special behavior during the learning activity.

- **Supervisor Agent:** monitors the performance of JADE platform and other agents.

- **User Agent:** builds and maintains the student model
- **Didactic Agent:** is based on information provided by the user agent to select the appropriate pedagogical strategies for the organization of the learning resources.
- **Exercise Action Monitor:** monitors the student during the exercise solving processes.
- **General Action Monitor:** monitors the action of its user and update the user agent.
- **Pedagogic Agent:** evaluates the pedagogic decision rules, whenever student interaction with materials.
- **Controller Agent:** Controls the operation of the agents that are assigned to the students or teacher during the learning session.
- **Exercise Adapter Agent:** Builds the exercise according to the requirement of the student.

B. Measurement criteria required for a system

1) Collaborative tools

This section compares the most important features of collaborative E-learning systems that whether the system provides synchronous learning or asynchronous learning based on different tools of interaction provided to students for communication.

In this system, synchronous tools allow real-time communication between people remotely geographically: instant messaging, voice telephony, audio conferencing and videoconferencing, etc. Indeed, the actors must be at the same time facing their respective computers. While asynchronous tools allow for time-and-space exchanges are e-mail, forum discussions, portfolio, wiki and blog. In this type of system when a person sends a message, the receiver can read it for a few minutes, hours or days later.

2) Student-Tutor Interaction in Systems

The emergence and development of digital communication tools, which use the Internet network, make possible a faster and more frequent interaction between the tutor and the learner or between the different learners.

3) Adaptability Measurement of E-learning Systems

Adaptive hypermedia is an approach that expanding the functionality of hypermedia systems and minimizing their negative aspects. It improves the assimilation of knowledge and can significantly reduce the user's journey into hyperspace. The interest of adaptive hypermedia systems is to adapt their links, their contents and their presentations to the user in order to reduce the disorientation of the user and the risk of misunderstanding of the document that results most often.

In order to increase the profitability of application for a user or a group of users of different profiles, it is obviously necessary to adapt the system to the content level according to the aims, characteristics and interests of the user. This adaptation makes it possible for each user, based on his profile, to view a page that is different from that of the others [17]. There is also the navigation adaptation that is interested in helping the user to find himself in hyperspace or to oblige him to use certain links rather than others in order to follow the most relevant path [18]. This phase involves changing the navigation structure or how this navigation structure will be presented to the user.

4) Security Measurement of E-learning System

Computer security, in general, plays the most important role is to ensure that the hardware or software resources of an E-learning system are used only within the intended framework. The aim of security is to protect the most critical information for the conduct of learning activities. It is therefore essential to protect them against intrusions and unauthorized access.

In general, IT security is based on five main objectives:

- **Authentication:** ensuring that only authorized persons have access to resources;
- **Integrity:** aims to ensure that the data are indeed those that are believed to be;
- **Confidentiality:** ensuring that only authorized persons have access to the resources exchanged;
- **Non-repudiation:** to ensure that a transaction cannot be denied;
- **Availability:** to maintain the proper functioning of the information system;

C. Comparative Study of Existing systems

In the following table we will analyze and compare existing Multi-agent based E-learning systems on the basis of the criteria described above.

TABLE 1: COMPARATIVE MEASUREMENTS BETWEEN EXISTING INTELLIGENT COLLABORATIVE SYSTEMS

		ALLEGRO	I-MIND	MASCE	MAS-PLANG	SACA
Collaborative tools	Asynchronous	✓	X	✓	✓	✓
	Synchronous	✓	✓	✓	✓	✓
Student-Tutor Interaction	Human	✓	✓	✓	X	✓
	Artificial	X	X	X	✓	X
Adaptability Measurement	Navigation	X	X	X	✓	✓
	Presentation	✓	X	✓	✓	✓

Security Measurement	Authentication	X	✓	✓	✓	X
	Integrity	X	X	X	X	X
	Confidentiality	X	X	X	X	X
	Non-repudiation	X	X	X	X	X
	Availability	X	X	X	X	X
Open Sources		X	X	X	X	X

By reviewing the existing intelligent collaborative systems, we have seen that these systems have advantages as they have limits. Firstly, we have found that most of these systems are reinforced by the involvement of many collaborative tools, whether synchronous tools such as chat or asynchronous tools such as email, Whiteboard and forum discussion, in except the I-mind system which is just limited to asynchronous tools. In the other hand, the majority of these systems does not have any artificial intelligent interacting system except of MAS-PLANG. It can also be seen that there are systems that do not guarantee any aspect of adaptation neither presentation nor navigation such as I-mind, but in general there is a lack in adaptation that should not be left behind.

In this analysis we can distinguish also that MASCE allows a learner to evaluate the help provided by another learner and I-MINDS allows the tutor to monitor the activities of learners and groups. However, SACA does not offer a follow-up of the learners. I-MINDS also offers users the possibility of forming a group [6]. In ALLEGRO, there is no student-student interaction. I-MINDS and MASCE systems are used to evaluate learners. Allegro does not have any agents animated in comparison with MAS-PLANG.

Second, it is the basic project belief that one can cope with the complexity of the learner only if the design of E-learning environments takes the collaboration between artificial and human agents as a fundamental principle.

We can conclude that its systems are not strong enough to provide the minimum requirements for an interactive learning environment, and we find that most of them are expensive and not open source. I.e. they are not available for free to users.

V. CONCLUSION AND FUTURE WORK

This paper presents multi agent system that is in organization to establish interaction between different actors of E-learning systems that working with different goals and defines intelligent collaborative E-learning features and carries out an analysis of existing multi-agent based collaborative E-learning systems on the basis of their various characters. That may allow us to identify the most appropriate model for our system. In the next research, we will try to propose a new collaborative E-learning system that is respect all of features described previously.

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Mobile Technologies Education based on Smart Laboratory Models

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Abstract—**Mobile technologies represent an important part of ICT sector based on their ability to support effectively various tasks in domains like healthcare, Industry 4.0 or learning. This paper presents a project to build a new smart laboratory for mobile technologies education at Department of Cybernetics and Artificial Intelligence (DCAI). The concept is based on some practical use cases that can be simulated by developed laboratory models like regular measurement of medical data, use of data from different sensors or to control various smart devices. We identified these use cases as very important for current emerging domains like Industry 4.0, home automation or e-Health. Some of them are available now and we have been using the obtained experiences in preparation of project proposals for EU or national grants.**

I. INTRODUCTION

Mobile technologies are on the verge of taking over our daily tasks in our personal lives, as well as at work. Task automation is becoming an everyday necessity due to different priorities and lack of our time. The synergy between automation technologies and mobile technologies is attracting more and more attention because of its universal usage in different sectors and domains. Whether it is the Industry 4.0 concept, healthcare, entertainment, home automation, connected cars and pervasive environments, the combination of mobile and automation elements provides interesting possibilities for simplifying various tasks and thus, the users' lives.

There are several reasons why becoming a well-rounded person in this field is rather difficult. One of them is that both fundaments of software and hardware development are necessary. Moreover, to be able to understand the data gained from these systems, one must have at least fundamental knowledge of data analysis, processing, and visualization, including some knowledge of the particular implementation field.

At the Department of Cybernetics and Artificial Intelligence (DCAI), both the mobile technologies and automation are taught separately mostly due to historical and practical reasons. However, no class addresses the composition of these two subjects, which means that the importance of their mutual combination is not clear to graduates. Our main motivation lies in creating a laboratory that will merge knowledge from both subjects and allow students to perform automation tasks with a focus on mobile technologies. The automation section will be handled by simple smart equipment (scales, various sensors, and actuators, blood pressure meter, glucometer, etc.), whereas the mobile section will be handled by microcomputers and smartphones. The broad diapason of this field allows us not to focus on a single application use case but rather to create a set of laboratory models that represent various real-world use cases selected from different fields of industry, healthcare or pervasive computing.

The current study programs at DCAI included the basic knowledge about mobile technologies and smart equipment taught in different subjects. This situation motivated us to propose this concept, to develop an integrated framework consisting of necessary hardware and software components, that will be further improved and supplemented by new applications, data connectors and e.g. methods for analysis of collected data from various smart devices.

The paper is organized as follows: basic introduction containing the motivation and current trends; the second chapter is devoted to the presentation of the proposed concept with some already existing applications; discussion opens some questions that we want to address by our concept; and conclusion summarize the paper and outlines of some directions for our future work.

A. Related Work

The results of different surveys published by renowned analytical agency Gartner confirmed a fact that mobile technologies represent one of the main directions, in which the innovation will emerge and the business use will be increased[1,2,3,4]. The experts expect that in this year, the users will do more than 268 billion downloads of different mobile applications and these downloads will generate an income of more than 77 billion USD.

In the healthcare sector, the demand for new applications to teach the doctors increases year after year [1], mainly in the case of decision support for classifying the causes of illnesses [2] and recommendations for treatment. Another important task is carrying out and evidence of clinical tests. With the support of existing technologies and IoT hardware, such applications were already used as clinical systems for decision support (CDSS) [3] or to support the diagnostic process and enable a faster response to possible health problems [4][5]. Research in various fields allows generating value, which unlike in conventional IT applications (information systems, web applications, and local application) is gained in a much shorter time.

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[1] https://www.gartner.com/doc/3229717

[2] http://www.gartner.com/technology/webinars/mobile.jsp

[3] http://www.gartner.com/technology/topics/trends.jsp

[4] http://www.gartner.com/newsroom/id/2654115

The main trend in teaching in the IT field is taking online courses to rapidly gain knowledge of a specific technology. However, the aspect of personal involvement and contact with a physical device is omitted. According to research presented in [6], to understand all aspects and peculiarities of mobile development, the regular access to a physical device (smartphone or IoT hardware) for application development (debugging) phase during a practical class is essential. Although emulators provide quite an acceptable user experience and testing possibilities, they are not able to fully substitute for some key aspects of physical smartphones.

Apart from the general programming point of view, a lot of effort has been put in application and communication security and teaching about the ethical aspects of development [7] because the reach of applications is gaining momentum at a society level [8].

II. Smart Laboratory concept

A. Proposal

Connecting several smart elements does not necessarily create a smart environment. From this point of view, it is obvious that our aim is not to create a smart environment, rather create a space for designing smart environments. With this approach in mind, we selected several real-world cases that we want to mimic as specific student exercises. We call this approach "learning by building models". A model is a fairly isolated infrastructure (hardware) with a single meaningful purpose. A model should consist of different sensors, platforms, and possibly smart gadgets, in order to fulfill its purpose. On the other hand, the software should be specific for the particular model but still universal enough for solving the selected problem in general.

This is why we propose several models that enable us to create different sets of applications and model different hardware and software architectures, each of which is fairly common in business and specific for a particular set of problems. The following scenarios were selected:

1. Healthcare – there are several possibilities for addressing this scenario. One is by creating diagnostic applications for detecting the current patient's state while utilizing the smart hardware for blood pressure monitoring, blood glucose level monitoring or BMI evaluation. The second possibility is to enhance the diagnostics idea and collect measurements from a long time span. This will result in creating a diagnostic suite for collecting data from various patients, that can later be used for analysis and mining purposes. This scenario requires access to a smart blood pressure meter, glucose level meter, and a smart personal scale. By deeper analysis of historical data, various medical events and correlations can be detected that are not visible on basic ECG charts. For example, the reaction of the body to a weather change and correlation with the BIO risk level can be evaluated. The final solution should integrate data from all these gadgets for a unified diagnostic result.

2. Home automation – smart household includes various active and passive gadgets that are usually used to increase overall comfort of the people living in the house. In our case, several aspects can be addressed at a time. The usage of smart electric sockets allows us to control various devices, monitor electric power consumption and create recommendations for saving energy. Moreover, using active elements like servo motors and IR receivers, we are able to control different appliances in the household environment. For the purpose of creating a laboratory model, this scenario can be implemented in form of a smart room - laboratory (by means of controlling elements in the room, e.g. blinds, projector, projection screen, student card reader, etc.).

3. Lifestyle – this scenario slightly overlaps with the healthcare because of the usage of personal scales. However, in this case, the scenario expects the usage of personal scales for training and creating a healthy lifestyle through monitoring and planning of exercises and calorie intake. Moreover, the calories calculation scales (smart kitchen scale) is another gadget that will help us complete the model. We expect to include recommendations of a diet expert to get as close as possible to reality, thus create better teaching experience and make the scenario more viable for students not only in programming but also to use for their own purpose and enhancement of their personal lifestyle.

4. Real-time sensor systems – the last scenario is using a smartphone as a sensor platform. This case is rich in possibilities because it can be used either in sports, entertainment, healthcare, business and many other fields. A smartphone can provide a set of real-time sensor values for acceleration, lighting conditions, temperature, humidity, location, and orientation. If a required parameter is not supported by the sensor aperture of the smartphone, the real-time data provider can be substituted by mini-computer like Arduino or Raspberry PI. A connection with these systems is straightforward and can be established either by using the Bluetooth, creating a REST API or a socket server. All alternatives can be taught on different real-world use cases. In the conditions of the proposed laboratory, we expect to create a laboratory environment monitoring system as a model case with using a basic set of smartphone sensors (Lenovo Moto E4) and all additional parameters will be provided by a Raspberry PI by implementing a set of temperature, pressure, humidity and luminosity sensors.

Although all proposed models can currently be understood as an on-site teaching material, our final task is to create and provide a well-written, interactive and detailed tutorial to assemble, program, deploy the model in practice and to analyze the datasets obtained from the measurements. By providing this information, we can reach a broader audience while also supporting the

education of local students and later create web courses or distance and e-learning or m-learning programs for students, which adds to the interactivity of the "learning-by-doing" process.

B. Mobile application for managing a classroom

The concept of a smart classroom is not new and has been addressed for several years [9][10]. Most of the assumptions when creating a smart classroom are focused on having an Internet-connected space with interactive elements in the classroom [11][12]. Although the smart elements are essential, the software is the important bit that handles the smart environment in the classroom. There are a lot of software possibilities on how to enhance the overall view of the students on the lecturing process. For example, creating a common virtual workspace for sharing of knowledge and collaboration between students and between the teacher and students is the first and the most important step that should be addressed in every smart classroom or smart space environment. Other software solutions emphasize interactive presentation, which means that the main aim is to enable viewing of different content on different screens and allows the teacher to interact with the content by directly writing in comments or presentation remarks (interactive whiteboard).

Our understanding of the smart classroom mostly sticks with the idea that the software itself and the collaboration within the content and knowledge sharing is the most important key to success. Therefore, we proposed a smart classroom architecture solution based mainly on a server application a wireless router and a mobile application for filling in and sharing the content. The Raspberry PI can be used as a REST API HTTP server for managing the content or a separate server can be used. The hardware point of view is however not as important. Some requirements for a ubiquitous environment (e.g. opportunistic networking) [13] that are met by the smart classroom architecture also contribute to the smart "impression". The architectural view of the smart classroom architecture is presented in the Fig. 1. The first version of the mobile application is presented in Fig. 2, on which the teachers notes for classes are shown.
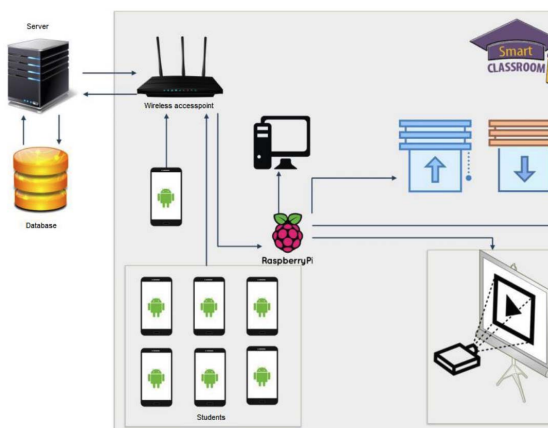
Figure 1.   Smart classroom architecture

Upon opening the application, a specific class is opened by searching the student's schedule and student's location. The application currently provides basic information about the class and allows to create notes,

comments and add emotions (like and dislike) to comments. The administrator (usually the lecturer) can moderate the inserted notes and comments with his mobile application.

Figure 1 Notes screen

Further mobile application development is required because it should also contain profiling for lecturers, where a default setting is applied when the lecturer comes to a specific class (e.g. starts the projector, enables the VGA input for a laptop, lowers the projecting screen and closes the blinds). The student section of the application will also be addressed (e.g. adding rich content, sharing notes from OneNote, Keep, Evernote and other applications, entering a report and feedback, filling polls, and many other).

C. Mobile application for blood pressure monitor

In the field of healthcare and healthy lifestyle, the mobile technologies allow moving a part of the duties directly to the patient through various wearable sensors or smart devices capable of communicating with mobile phones. This approach improves the healthcare and contributes to the cost containment. Since according to the OECD Health Records 2016[5] the cardiovascular diseases represent up to one-third of all diseases caused the death of people in European countries, we started with a blood pressure monitor to develop an application in the Slovak language customized for the elderly. The mortality rate for cardiovascular diseases of Slovaks is three times higher than for example in France or Canada.

Typical blood pressure (BP) monitors allow basic healthcare but at the end of the day, the user needs to record the collected measurements manually to be available for the doctor. If the patient is willing to pay for a higher range of the BP monitors, they offer a possibility for data exchange with native manufacturer applications. These applications are often available only in English and the GUI is not customized for the target group.

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[1]   [5] http://www.oecd.org/els/health-systems/health-statistics.htm

At first, we have investigated the BP monitors available on the Slovak market. The basic criterion was an availability of the wireless data transfer technology like Bluetooth. New, we compared their price, functions, battery life, developers support, existing documentation, open protocols, etc. The main output of this investigation confirmed our expectation, i.e. many manufacturers supply their devices with a native application and therefore they are not motivated to provide an open access to their protocols and devices. In the case of existing mobile applications, we selected those with a high ranking in the market such as My Heart (4.1), Runtastic Heart Rate (4.3), Blood Pressure Log – MyDiary (4.6).

The final version (Fig. 3) offers a simple application control without the use of complex multi-gesture gestures; an automatic receipt of measured data from a wireless BP monitor via Bluetooth technology; a possibility to manually add measurements from another (older) BP monitor without Bluetooth or to view statistics in user-friendly graphical form.

Figure 2   Example of offered functions by mobile application for home library

Figure 3   Example of offered functions by mobile application for BP monitor

D. Mobile application for home library

The barcode reader represents an interesting function, which can make some activities easier and friendly. As an example, we selected a problem of home library management. The passionate reader collects a lot of the books that complicate an orientation and adding the new titles. For this purpose, we designed a mobile application offering functions like adding a new book through its barcode; a recommendation of a new book based on analysis of user's interests; or renting books to a friend (Fig. 4).

We identified these functions as most interesting and important based on an interview with a potential target group of users and review of existing applications on the market, such as Book Catalogue (4.5), Goodreads (4.1) or My Library (3.7).

E. Applications for presenting a downhill competition

In the area of entertainment, mobile applications play a great role. Mostly mobile games are the leading-edge category. However, games are not entirely a general business case for most of the employers in the field. Other types of applications that indulge the entertainment area but are not exactly games or game types are interactive sports applications.

Wearable sensors are essential when it comes to analysing and presenting various sport results event in real-time. Based on this expectation there are various applications that track the movement, speed, heart rate and a lot of other parameters but the interactivity of a sports challenge is a totally different category.

Our problem was to analyse a downhill bike ride in details, track the rider and present raw data and other findings to the viewers. By using basic smartphone sensors (accelerometer, gyroscope, GPS, and orientation) it is possible to evaluate the weakest and strongest variables of a rider. Whether it is the acceleration, landing force after a jump, speed in different sections of the track or simply checkpoint times and previous rides (ghost rider).

After discovering these possibilities, the solution itself has been created as a set of applications. At first, a server
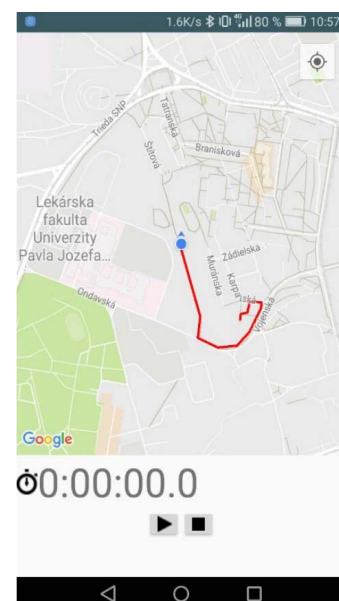
Figure 5   Minimalistic design of the mobile application

process (Node JS application) that supported the socket real-time data transfer between a mobile application (Fig.

Figure 2.   Web dashboard for fans

5), the web (Fig. 6) and other clients was created.

This application server works as the contact point for all clients and the entire communication. The second application is the mobile application which is used by the rider. At first, a track has to be recorded during the first ride. After the first ride is done and the track is saved, the rider can later pick the track and start the challenge. The fastest ride is automatically loaded from the server application and shown on the rider's smartphone screen as a ghost rider. In this manner, the split times can be also seen between the actual rider and the best time ghost rider. The mobile application is solely used by riders and it provides only basic information, in order not to distract the rider during a challenge.

Also, the mobile application is the main sender of the data. This means that the rider's sensor data from his smartphone are used to evaluate his current position on the track, his speed, times, acceleration, forces, etc. The data are transferred by a socket connection to the server and saved in a file in real-time. The entire connection relies on a wireless internet connection. This fact may endanger the integrity of data, however at bigger events that are prepared beforehand a WiFi coverage of the area (in downhills the area is usually rather geographically small).

The third and the last application is the web, which is intended as a dashboard for the fans. The fans can view all data without interacting with the ride progress.

The main development challenge was to connect three different frameworks, applications together. In a ubiquitous environment (pervasive computing), one of the most common problems that need to be solved is the mutual cooperation and communication between various devices. These methods are being taught in order to enable students to form a single platform for solving a specific task and not focusing on a single technology. The main focus is obviously the mobile application development; however, such a system cannot be created by solely relying on mobile applications. The application has already been tested on a test case scenario and will soon be used in a downhill challenge for further testing and debugging. To our knowledge, the testing resulted with sufficient application performance but mobile data transfer and battery consumption will require further optimization.

III.   DISCUSSION

Previous research activities have shown that the mobile technologies can significantly improve the teaching process. In this case, teachers and students use the applications and tools prepared by third parties based on their expectations and requirements. We focus not only on this approach but on the overall process of using mobile technologies to create user-friendly smart solutions. The proposed concept provides the environment for the design, implementation and testing purpose. Currently available devices like blood pressure monitors, intelligent weighting

scale, Raspberry Pi, temperature sensors or GPS modules represent good basics to support related human activities in practice. We are going to expand the available hardware in line with current trends and expectations identified in communication with cooperating IT companies and from our participation in important conferences in this field.

Some students got familiar with mobile apps development practices, but they did not consider other important aspects like security, user experiences or sustainability. Mobile device security has become increasingly important in recent years. Users and companies use mobile devices not only for communication but also to plan and manage their work or private life. It creates an increasing pressure to ensure the security of personal or business information stored on the mobile devices. The Google's 2016 Year in Review Report stated, that „About half of devices in use at the end of 2016 had not received a platform security update in the previous year.". The McAfee Mobile Threat Report: What's on the Horizon for 2016 states that „During the past year, there have been hundreds of apps pulled from both Google Play and the Apple App Store for security reasons.". We want to answer the question: how we can create an application meeting all the necessary safety requirements, but without limiting the user himself?

The other big problem why we all do not live in smart houses and use smart solution for every day is the variety of variable solutions. It is complicated to create an integrated system containing different components provided by various vendors. From this reason, our goal is to get the students more familiar with typical mobile technologies in line with current trends to improve their technological background and the employability of the labour market. The integration ability will be an important part of our curriculum and we will use our previous experiences from already implemented solutions like the mobile app for blood pressure monitoring and evaluation. We will try to find an answer if is it possible to develop integrated smart models, i.e. the vendors provide open API, protocols, and documentation, not only within their native apps.

IV. CONCLUSION

The proposed concept focuses on the development of a new smart laboratory in the domain of mobile technologies at the Department of Cybernetics and AI, Faculty of Electrical Engineering and Informatics, Technical university of Košice, which will allow students to acquire the practical knowledge and experiences in the domain that is described by several studies as the most dynamic in the ICT sector. We support the meeting of this objective in following three directions: a) provision of missing technical equipment required for planned improvement of relevant teaching process; b) proposal of a methodology for this process in accordance with the current trends in the domain of mobile technologies to ensure that students will be able to design, implement and test their own mobile applications at suitable intelligent devices in small teams or independently; c) electronic teaching materials containing detailed instructions and

tutorials with specific practical examples. The correctness of our approach is confirmed by increasing student interest in the relevant subject (+ 55%) and bachelor or master thesis (+50%) focused on this topic in the new school year.

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A Real-Time Tool Integration for Lectures

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Abstract— **Some decades ago there were only some dozens of students in the lecture rooms therefore professors usually knew them personally. Today the number of students following a lecture is several hundred and some of them are not even on the spot, so teaching has become more and more impersonal. In the same time everybody is surrounded by smart mobile devices which offer an immediate communication tool. Our aim was to design a real-time integrated tool which is able to provide a bidirectional communication possibility between the professor and the students during the lectures. This communication brings a refreshing interactivity to the auditoria and helps to keep the interest level high and gives a better learning efficiency.**

I. Introduction

The facts speak for themselves; every university teacher must have noticed the rapid changes in students' learning attitudes and learning methods during the last decade. The authors do not want to judge whether these new trends are better or not compared to the previous generation' but it is simply different. Citing from David Willet: *"the area of old-fashioned university lectures – with students sitting in rows listening to academics – may be over as research shows large numbers of undergraduates now access professors' notes online… universities will have to radically modernize lectures"* (Telegraph *http://bit.ly/1ntkoDX*). The question is just that: what we have to do to regain students' attention. Giving an interesting, entertaining lecture is one of the most important thing everybody can suggest to lecturers at first sight but nowadays it is far not enough. Why? Because students have a lot of smart mobile devices and they use them during lectures as well. Therefore the lecturer has to struggle for the students' attention against the always interesting things going on social networks (Facebook, Twitter) or against the always available online games etc. [4][5] We may accuse smart mobile devices about everything which is not comfortable for us but it will not help to find a good solution.

II. Paradoxes

Nowadays we may see all over the world that universities try to follow the needs of the new generation and they modernize their educational environment. There are a lot of ready-made applications for publishing course materials (e.g. well-known Moodle, or a 3D environment MaxWhere *http://www.maxwhere.com/*) or even to offer whole online courses. Let's get a deeper glance at the problem we are facing.

We often hear from students that internet gives the answer for everything so why do they have to listen to any courses while they may learn everything alone!

From one viewpoint the authors have to agree with students that there are almost everything available on the net within one click: but on the other hand we must argue with them on the necessity of lectures. The authors state that it is much easier to understand a topic if one gets a sketch about it from a practiced specialist. If somebody successfully seizes the substance of a topic by understanding the sketch the details may be added independently from the net or from anywhere else. Here is a loose translation of a Hungarian phrase: *to feed a goat and to keep the cabbage as well.* As university teachers on the field of informatics are in a very similar situation which is almost impossible to resolve. In one hand we require the usage of modern technologies, while on the other hand we see the problems that are caused by using smart mobile devices in the auditoria during the lectures. In one hand we are glad that there are more and more students who want to study informatics, while on the other hand we see the difficulties as well when education becomes impersonal. Therefore we have some paradoxes to resolve.

We do not want to focus simply to publish learning materials. The authors are more interested in students' learning attitudes. It was clear for us that it is very important to involve students deeper into the learning process to make the lectures more interactive and personal. [7] But with several hundreds of students it is too ineffective to wait for answers one by one. Overthinking the problems we got to know that we are not able to give a preferable solution using the old fashioned methods.

III. We need a tool

That is why the authors decided to design a tool which may help both the lecturers and students by showing a new possibility of teaching and learning and besides solves some administrative tasks as well. Naturally the authors do not state that we have found the philosopher's stone we only created useful new tool from the mixture of several ideas, methods and technologies.

We have a great chance by using students' own devices to achieve this goal. [6] The explanation is very simple: they love their smart phones, they are used to the continuous usage thereof. Young people use them in daily life, they connect to social networks to get help or to have a chat so it will be natural for them to use these devices the same way in education too. Therefore we should like to give some "social network" feeling to our tool – everybody can join to a discussion, can ask or answer. In this way students are able to think together and the common wise will produce the result – naturally with the lead of the lecturer. As they are working together with the lecturer, they also may feel a more personal care. They

will remember not only the result but the methods of thinking as well! The lecturer also profits from this interactive communication getting continuously to know the ideas of the students so it is possible to make some corrections, fine tuning immediately.

Our generation used to study from books however nowadays students watch videos about know-hows. Usually there are lots of video conferences, so videos as the source of knowledge is quite acceptable for everybody. With the "fashion" of MOOC courses it is not a quite crazy idea from students that they do not want to be on the spot but want to follow the lecture on-line. The authors thought during the planning that it would be nice if our tool was able to help them too. In this case it is very important that they can take part in the lecture the same way as the others, so the communication must go real-time.

The next idea is if we have a communication tool between the lecturer and the students then it gives the opportunity to guess who is not really engaged to follow the lectures. (Who is absent often or who is answering rare or never.) Practically it means that usually they need some vocational help. Moreover from this communicational flow we can build up a database about the students' questions and answers. The authors state that after some years of usage the collected data will show, which are the main detectable mistakes they do, what we have to put into focus. Naturally if we offer these "question banks" to students it may help them to prepare for the examinations.

IV. THE INTEGRATED TOOL

The starting steps of the planning was in 2014 when we began to make a survey on the mobile penetrance of our students. The authors got a nice result that above 95% of them have got some kind of smart device.

TABLE II.
PERSONAL MOBILE PHONES OWNED BY THE STUDENTS DUE TO THE SURVEY

	Total	Hungarian	Slovakian
Smart phone	95,4 %	92,4 %	98,7 %
Normal	3,9 %	6,3 %	1,3 %
Nothing	0,7 %	1,3 %	0,0 %

This was the starting kick for us because it means almost everybody can connect to us, to our tool. The tool itself was implemented as a real-time web-based application written is ASP.NET using SignalR modul [1][2]. The details of the survey and the implementation of the first version was already published in several papers. [8][9][10][11][12][13][14]

A. Catalog Module

The first module of the Election System that was ready to use was Catalog (https://catalog.inf.elte.hu) which was published as a standalone application first. This application helps teachers to decide in a very quick and easy mode to check who is in the auditorium. [12]

Students have to use the browser of their smart devices and log in to our web-application. Students could register to the system only from the university because their IP-addresses is checked. The application is able to work

parallel and serve any number of lectures in the same time. It had double aim, besides creating a registry list for administrative tasks it helped our university mentor system to find those students who are absent too much.
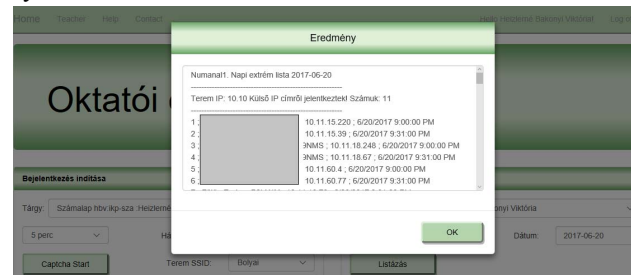
Figure 1.   Administration of attendances in Catalog

The first version started to work in the autumn of 2016 in our faculty. According to the university statistics, the compulsory lectures and the working of the mentor system resulted a measurable improvement in the learning efficiency.

TABLE I.
STUDENTS' LEARNING EFFICIENCY DATA FROM [3]

Year	2014	2015	2016
Percentage	66	80	87
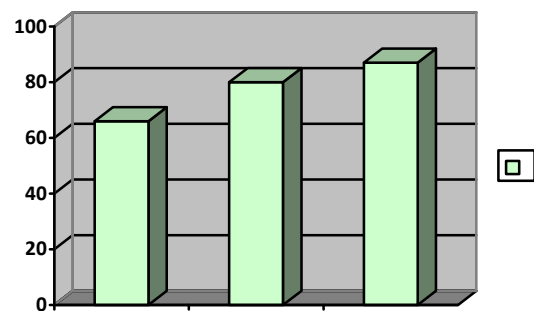
B. Streaming System

As we have mentioned previously the speed of networks let us to get a lot of information watching videos. There are a lot of solutions how it is implemented nowadays. One of the most modern possibility available from 2017 June is the Stream application by Microsoft (https://stream.microsoft.com). It offers some very interesting features like searching the text somebody said (voice recognition) or face detection. Our aim is to build it also into our project in the future, because it would help in the task of personalization, but for now our first solution is simpler.

The second version of the Catalog application is ready to start now. Some new features are added to it e.g. more detailed administrative possibilities etc. But one of the most interesting change is that from this September (2017) students may register from anywhere because the lectures will be streamed so students can follow them online too. (During the experimental period only some of the lectures will be available this way.)

C. E-Lection Project, The Bidirectional Connection

The implementation of a bidirectional real-time connection between the lecturer and the students was the

main idea of our concept. The first version of the application was under public testing in the autumn of 2016. (https://election.inf.elte.hu) [10][11]
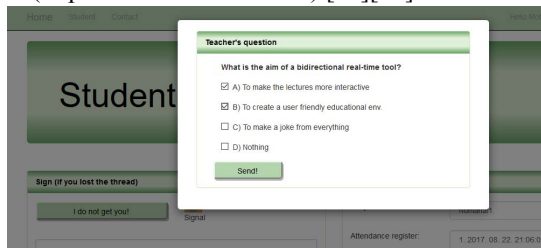
Figure 2. Students' device with teachers' question

The lecturer might send questions to the students who are logged in to the application. Students could see the questions not only in the lecturers' presentation but on their own device as well.
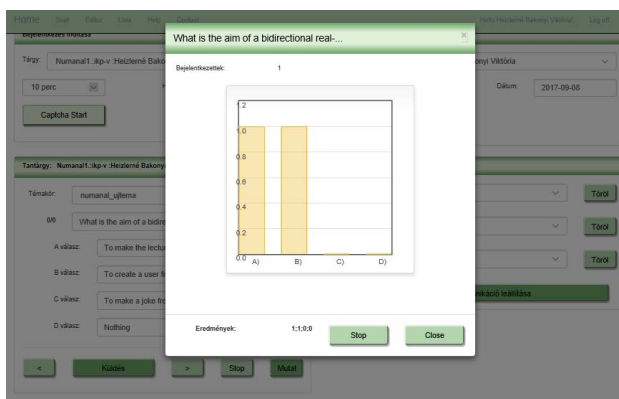
Figure 3. The summarized result

They may give an answer using their preferred browsers on their own devices. It worked as a standard voting system. It was much more interesting that students were also able to send questions to the teacher or send simple signals if they did not understand something.
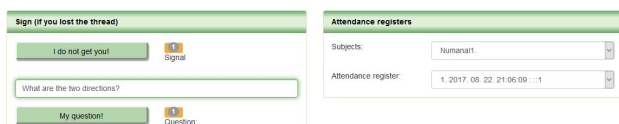
Figure 4. Students' user interface for signaling
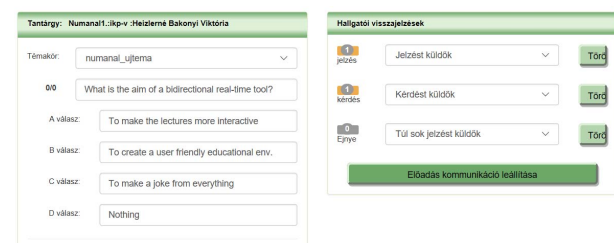
Figure 5. Teachers' user interface with questions and signals

They could see the summarized result of the answers and the number of signals of the others. It helped them to compare their knowledge to others' knowledge. They could see how much percentage of the auditorium things something wrong or good.

Which was the idea of the others. The authors kept students' anonymity before each other but the lecturer was able to find out who the questioner was.

The test phase showed that our original idea was correct, students enjoyed working together with others but it showed some problematic points as well. Some students' main aim was to show how tricky and skillful they are so they overwrote the client side parts of the application.

For example that is why now we have to check the number of button pressing (because one of the students sent so much signals using JavaScript code that the server slowed down). Another student overwrote his own name to a funny one and made the others laugh. The second version besides these serious changes in implementation which forbid a lot of illegal work got a newer fresher look as well.

At last, all of the three modules are ready to work together.

V. COMMON SURVEY ABOUT THE TOOL

We created a survey with which the authors wanted to measure whether our designed solution should help students or not in paying attention to the lectures or to understand it better. The survey consisted of 10 questions. The authors are waiting the answers scaling the students' opinion from 1 to 5. We asked the students before they start the usage of integrated election system and we should like to repeat it at the end of the term too.

1. Do you use computer or mobile device during lectures? (1 means never)
2. Would you consider it benefitting if you could use your own mobile device (phone, laptop, etc.) during lectures? (1 means no at all)
3. Would it facilitate your studies if the teacher asked questions about the material on lectures? (1 means it does not facilitate)
4. Would you consider it useful if you received the questions electronically which then could be answered electronically? (1 means it is not useful)
5. Would it facilitate the quicker understanding of the material if the answers were evaluated immediately? (1 means it does not help)
6. If you received answers immediately, would you ask questions on lectures more frequently? (1 means no)
7. How often do you lose the thread so much that you cannot even ask questions? (1 means never)
8. Do you usually ask questions during lectures or you rather keep silent because of shame? (1 means never)
9. Would you ask the lecturer more if it was anonymous for fellow students? (1 means no)
10. Would you consider it useful if bilateral communication happened between the lecturer and students? (1 means it is not useful)
11. Do you think it would help your preparations if you received the lecturer's and students' questions afterwards? (1 means it does not help)
12. Would you consider it useful if lectures were available online? (1 means it is not useful)
13. Would you rewatch an already seen lecture? (1 means never)

14. What would you suggest to make lectures more interesting and attractive?

A. Experiences at ELTE FI

The survey was filled out by 122 students attending the first year and 77 students of the third year. The answers of the first year students are interesting because it shows with which expectation they arrive into the university. The opinion of the third year students are based on their real learning methods during their university studies. At the row total we always give the average percentage of the answers.

Simplifying the grade of answers for ourselves the grade 1 and 2 may show for us that the students are against that solution, 3 means that they are not really interested in it and the grade 4 and 5 mean that they are agreeing with that kind of idea.

After all the authors can state, that the results proved our preconditions. Let us see them as follows:

TABLE III.
RESULT OF THE SURVEY

1. Do you use computer or mobile device during lectures?

Grade	1	2	3	4	5
1. year	1%	8%	16%	34%	40%
3. year	4%	5%	21%	29%	40%
Total	2%	7%	18%	32%	41%

2. Would you consider it benefitting if you could use your own mobile device (phone, laptop, etc.) during lectures?

Grade	1	2	3	4	5
1. year	0%	1%	4%	21%	73%
3. year	3%	1%	8%	13%	74%
Total	1%	1%	6%	18%	74%

3. Would it facilitate your studies if the teacher asked questions about the material on lectures?

Grade	1	2	3	4	5
1. year	6%	9%	25%	34%	24%
3. year	22%	13%	30%	18%	16%
Total	12%	11%	27%	28%	21%

4. Would you consider it useful if you received the questions electronically which then could be answered electronically?

Grade	1	2	3	4	5
1. year	2%	8%	17%	30%	41%
3. year	8%	8%	21%	29%	34%
Total	5%	8%	19%	30%	39%

5. Would it facilitate the quicker understanding of the material if the answers were evaluated immediately?

Grade	1	2	3	4	5
1. year	0%	2%	9%	20%	69%
3. year	4%	3%	13%	9%	70%
Total	2%	2%	11%	16%	70%

6. If you received answers immediately, would you ask questions on lectures more frequently?

Grade	1	2	3	4	5
1. year	9%	7%	26%	34%	23%
3. year	16%	8%	36%	18%	21%
Total	12%	8%	30%	28%	22%

7. How often do you lose the thread so much that you cannot even ask questions?

Grade	1	2	3	4	5
1. year	11%	38%	30%	15%	5%
3. year	6%	31%	27%	25%	9%
Total	10%	36%	29%	19%	7%

8. Do you usually ask questions during lectures or you rather keep silent because of shame?

Grade	1	2	3	4	5
1. year	19%	25%	27%	16%	12%
3. year	35%	13%	27%	12%	12%
Total	25%	20%	27%	15%	12%

9. Would you ask the lecturer more if it was anonymous for fellow students?

Grade	1	2	3	4	5
1. year	9%	16%	20%	34%	20%
3. year	26%	8%	22%	21%	22%
Total	16%	13%	21%	29%	21%

10. Would you consider it useful if bilateral communication happened between the lecturer and students?

Grade	1	2	3	4	5
1. year	3%	11%	25%	36%	24%
3. year	10%	9%	30%	21%	29%
Total	6%	11%	27%	30%	26%

11. Do you think it would help your preparations if you received the lecturer's and students' questions afterwards?

Grade	1	2	3	4	5
1. year	1%	2%	10%	25%	61%
3. year	3%	4%	12%	17%	64%
Total	2%	3%	11%	22%	62%

12. Would you consider it useful if lectures were available online?

Grade	1	2	3	4	5
1. year	0%	1%	5%	11%	82%
3. year	1%	0%	9%	8%	81%
Total	1%	1%	7%	10%	82%

13. Would you rewatch an already seen lecture?

Grade	1	2	3	4	5
1. year	1%	5%	18%	36%	39%
3. year	3%	8%	9%	39%	40%
Total	2%	6%	15%	38%	40%
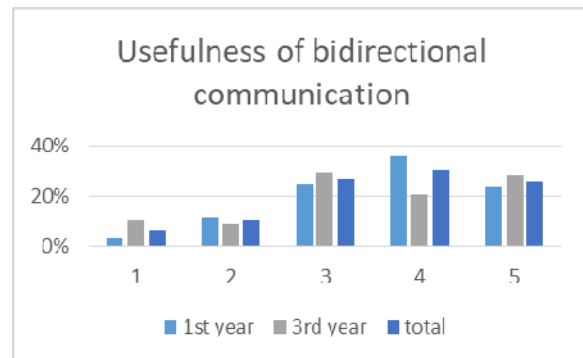
Figure 6. The answers for question 10th

First of all it seems that students' need to participate lectures in a more interactive way in lessons and they would like to use their mobile devices for this purpose as well. Question 1st, 2nd, 10th dealt with this and evaluating the grade 4 and 5 gives more than 70% on the 1st , more than 90% on the 2nd one and 56% on the last question.

Now we should like to focus the real specialities of our tool the question of bidirectional and real-time communication possibilities during the lecture.

Question 3rd, 4th, 5th are in connection with one-way connection from teacher to students (like a voting system). The results show that in each cases more than 50% think it useful. On the 4th and 5th question the results were better they show more than 70% and 80% - these questions highlighted that the questioning will be performed through their electronic devices and they would prefer such a method.
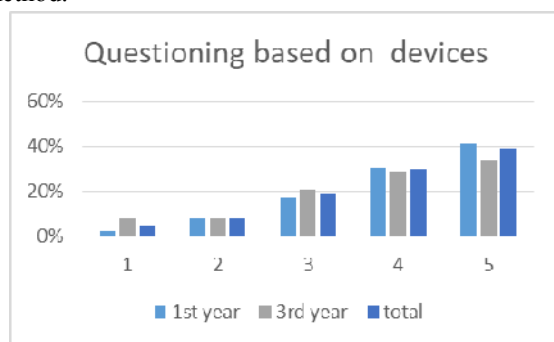
Figure 7.   Answers for question 5th

Questions 6th, 7th, 8th and 9th are questioning to the other direction from students to professors. The answers for these questions are not so obvious but it shows that 50% of the students think that it will be very helpful to them to get immediate answers (grade 4 and 5), 27% keep silent because of shame and anonimity would be encouraging for them 50%.
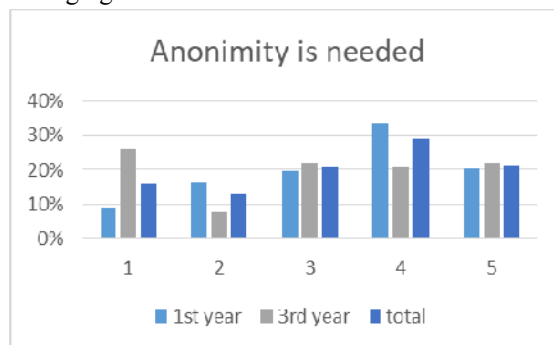
Figure 8.   The answers for question 9th

Question 12th and 13th ask about the usefulness and need of on-line streaming of a lecture. Almost everybody thought (more than 90%) that it would be nice to connect to the lecture on-line. This result can be translated in different ways - nowadays in our university students obligatory have to be present on the lectures and a lot of them do not like this rule. The 78% percent of rewatching a lecture (4 and 5 grade) is much more cheering for us.
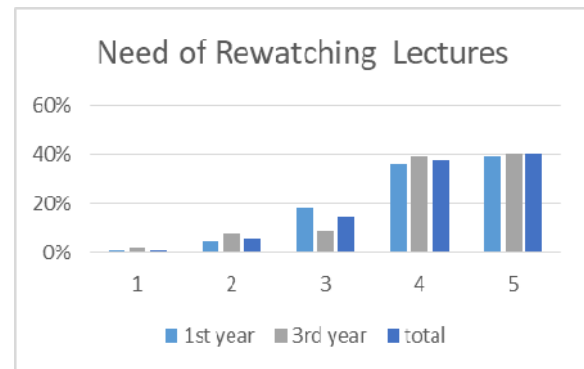
Figure 9.   The answers for question 13th

At last the authors asked some suggestions from the students. Some of them were only jokes like needing free beer forever. Some of them were about some technical problems in the last rows of big auditoriums not to see or hear everything excellent but we got useful remarks from our viewpoints as well. For example they would like smaller number of audience because in this case the professor can interact better with the students. (It was one of our starting idea to make the lectures more personable and interactive.) According to some remarks they would like if the downloadable presentations were more detailed.

B.   Experiences at Nitra

The system is currently available on the university intranet only; therefore IP filtering has not been applied. First time we used the system Election in the last semester at Constantine the Philosopher University in Nitra, on the lectures of Information Systems courses for Regional tourism students', the group consisted of about 60 students.

We found that the students were interested in the innovation, and they liked to join the classroom work using their own devices. Furthermore, we can clearly say that we received a lot more questions regarding the lectured subject than before. Based also on SOS signals, we returned to the things to be explained.

In the case of the students of mathematics, we cannot really talk about large groups, but in economics-related majors where lectures in mathematics can also be found, we already can. For this reason, we would like to incorporate a formula editor into the system, and enable the upload of images (as many use the formula editors with difficulties).

VI.   SUMMARY

All over the world in higher education lecturer work on modernizing somehow the whole educational process according to the need of students. One of the ideas are to involve students into the learning methods better changing the old fashioned lecture type teaching. The authors implemented a real time tool to make the lectures much more interactive by using the students' personal mobile devices. The first results were published earlier, now the authors added a new feature to it to the possibility to follow the lessons from far away on-line and meanwhile to be able to interact with the professor in real time. Collecting the students' opinions with the help of a survey we can state that our ideas were appropriate and the functionality of the application meets with the need of

most of the students. Our work is not finished yet. According to the remarks we are to develop it with new features and its fine tuning it in the future. Compared to expensive voting systems, the fact that it is economically far more beneficial speaks in favour of our system.

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The economic aspects of the electronization in Education process

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Abstract— **In out paper is demonstrated cloud /distributed infrastructure for education employees in Slovak environment. The LMS / Learn management system was implemented in cloud environment the e-lectures with different content was delivered as a Services. In parallel with delivery of e lectures was space to build Knowledge database of practical experiences which can be shaded in organization. The presented solution demonstrates flexibility, effectivity and low cost of delivered services which yearly is used more than 40 000 users.**

I. INTRODUCTION

Most of the organizations are aware of the need for continuous training of their employees. On the one hand it is the need, on the other, an investment in the future which reflects the strategy of organization, innovation and quality of supplied products and services. It means, each organization is forced to educate their employees in order to build up the flexibility of business and set up requirements for internal success (Bhandari et al. 2004).

Trainings are conducted for a variety of purposes, ranging from mandatory and professional to operational staff and motivational. Figure 1 illustrates this observation, including all identified reasons. It is up to an individual initiative of the organization which reasons for education are presented. Many of the people are looking for reasonable answer why there is such pressure on the need for education. The analysis of this topic identifying several explanations which are presented below (Balco 2013).

Fig. 1 The life cycle of education for commercial or non-commercial organizations

Unskilled Labour

The existing academic environment does not prepare sufficient number of graduates (high school or Universities) for businesses. The knowledge the students acquire have more academic value, with the lack of practical experiences and professional skills. If an organization wishes to make effective use of young or new employees there is almost always the need to train these as soon as possible for the desired job.

Legislation

Organizations have a legal obligation to educate their employees in order to eliminate accidents, comply with quality products and services or security.

Career Growth

Individual employees are interested in continuously improving their professional potential and thereby promote their career development.

The organizations must understand that education is not a privilege or obligation, but that it is a necessity. It is also necessary to realize the need to strike a balance between the needs of organization and individuals on the one hand and the existing resources of the organization on the other. It is therefore necessary to find a compromise that will satisfy both parties, in order to give priority to education for promotion of business or services in non-commercial environment.

The goal of this paper is to demonstrate the role of innovative services in education which are using the cloud infrastructure and their economic aspects to customers

II. FLEXIBLE MANAGEMENT IN EDUCATION (FMS)

An organization's ability to survive and grow is based on advantages that stem from core competencies. In the longer run the only source for being ahead of competitors is to learn faster than its competition. The climate of openness is a facilitating factor to create new knowledge

continuously that will be required to meet the future competitive environmental changes. The notion of flexibility in strategic management is highly relevant as it is important for surviving in present economic scenario of globalization and liberalization. Strategic flexibility provides a congenial environment for the development of core competence and plays a pivotal role to define where an organization must excel in order to maintain leadership (Kak 2004).

Following the previous statement the strategic management in standard organization has to include modern flexible education environment which is reflecting daily requirements of global business. Whereas organizations are differs in their product portfolio, it is necessary that the chosen solution in itself has included the necessary level of flexibility.

This flexibility must of course take into account the specificities of each organization in view the range of services offered, the size of the organization, the amount of such spatial distribution partners and customers but also the speed with which it is necessary to respond to market needs. Since it is necessary to meet the needs of both parties, business organizations as well as the market is essential in the strategy include a flexible learning and hence the tool that will support such a solution. Flexible learning is a set of educational philosophies and systems, concerned with providing learners with increased choice, convenience, and personalization to suit the learner.

In particular, flexible learning provides learners with choices about where, when, and how learning occurs (Shurville et al. 2008). A flexible education system (FES) is solution including open and distance learning with significant impact of technology. Open and distance learning has played a major role in extending educational opportunities in many parts of the world (2009). It allows the education to react in the case of changes, whether predicted or unpredicted. The flexibility is generally considered to fall into two categories, and can contain several subcategories.

– Flexibility of education environment it covers the system's ability to be changed and provide new functionalities in order to fulfil the operational requirements.

– Flexibility of content for education it consists of the ability to modify content of courses in database.

The main advantages of an FES are its high flexibility in managing in order to provide new spectrum of services and content of courses. In response to recent technological advances and the trend toward flexible learning in education, two factors which affect student satisfaction with flexible online learning were identified (Drennan et al. 2005).

They are:

– Positive perceptions of technology in terms of ease of access and use of online flexible learning material.

– Autonomous and innovative learning styles.

The FESs have several advantages but on the second hand naturally same disadvantages too.

Advantages of Education as a Service

- High flexibility in planning training
- Delivery of training is not tied to a specific location
- LMS environment allows you to run e-courses third parties, as well as courses that are formed by internal staff
- The delivered solution reduces the cost of training
- Portal can serve as HELP environment
- Courses are delivered as a service on the basis of the agreed SLA (contract between LMS environment and customers)
- The environment allows you to verify the acquired knowledge through a test to evaluate the quality of training as well as to monitor the effectiveness of training

II. CLOUD AS THE SUPORT OF NEW FLEXIBLE SERVICES IN EDUCATION

The market demand related to service providers is very uncompromising. On the one hand, there are ideas about low prices on the other hand, it is a requirement for differentiation related to the content area as well as add value and flexibility too [15]. The depth analysis of information shows, that today's end-user services, no matter what technology is used in the delivery of services, or the place from which the service is provided. The final customer needs to feel that the ultimate effects of services to meet their expectations and needs.

In terms of IT architecture comes to old-new cloud-based solution concept to achieve this balance

History of cloud concept dates back to the last century fifty when it began on a large scale in the academic world and intensive companies use mainframes , which are accessible via thin client / terminal computers , often referred to as " static terminals " because they were used for communication , and had no internal processing capacity [2]. The purpose of this approach was to share a number of computer terminals, as well as sharing of processor time. In the sixties of the last century, Professor John McCarthy at the Massachusetts Institute of Technology communicated sharing model of computer technology as a way to the sharing of electricity. In this case, it was presented that households that have purchased electrical appliances are not expended owners of electricity that is not owned power plant [2].

Old concept of sharing does more than sixty years, it is used in the creation of new advanced services based on cloud computing - in. This analogy helps to remove the old dogmatic approaches that each organization must own IT infrastructure which includes hardware and software

products. Approach based on old principles is very costly and inflexible, in addition accumulates in the IT infrastructure of the organization many funds whose return may be called into question many times. Enforcement of such an approach is not obvious, however, faces a number of problems often associated with individual as well as the Group's interests. These approaches are interpreted solutions based on cloud computing as inappropriate but also risky. Characteristics and, therefore, hence benefits of cloud concept can be interpreted as follows Figure 2.
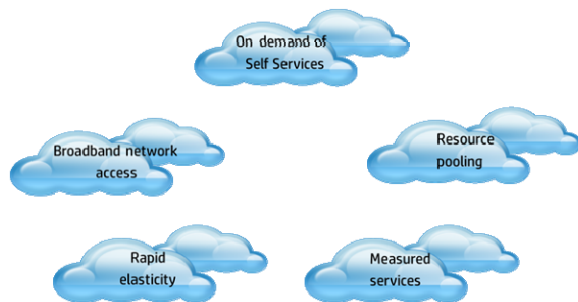
Fig. 3 Characteristics of cloud concept

A computing Cloud is a set of network enabled services, providing scalable, QoS guaranteed, normally personalized, inexpensive computing platforms on demand, which could be accessed in a simple and pervasive way [4]. Cloud services are popular because they can reduce the cost and complexity of owning and operating computers and networks. Since cloud users do not have to invest in information technology infrastructure, purchase hardware, or buy software licenses, the benefits are low up-front costs, rapid return on investment, rapid deployment, customization, flexible use, and solutions that can make use of new innovations [6].

III.   CLOUD THE EDUCATION AS A SERVICE

The cloud solutions are by many organizations presented as something new and innovative. A lot of opinions are speaking that those solutions will replace existing internal IT infrastructure and services in the short future. Except for the technical details there still exists among experts intensive discussion, whether just those solutions are cost-effective and whether the existing economic studies presented enough and real advantages of this approach (Mladenowet al. 2012).

Figure 3 presents the high level architecture of cloud solution adapted for process of education. The reconnection of servers depends on detail architecture

which is adapted to customer requirements and in generally it is private ownership of project sponsor The standard learn management system (LMS) environment in cloud does not include WEB cameras and external trainers reconnected through virtual classrooms because these devices require additional transmission capacity which has with impact on the price of solutions.
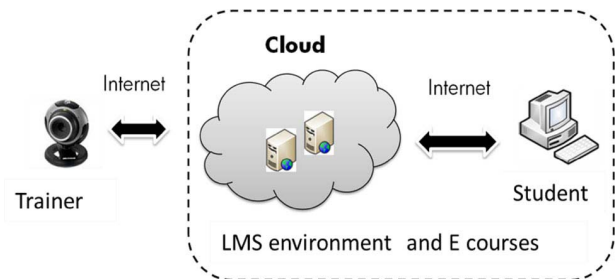
Fig. 3 The general architecture of solution Education as a Service

The Education as a Service based on cloud architecture is typical the FES which integrates the advantages presented in Table 1. The introduction of e-learning using LMS known qualitative change in any organization, and this brings a lot of advantages (Balco 2013). Lecturer in this case is a software application through which the required knowledge is transferred to an employee. The implementation of e-learning does not mean that all current courses implemented through the speaker will be automatically replaced by their electronic versions.

Courses that will change the shape will depend on the economic as well as strategic decision. Presented solution allows faster transfer of information from executives to ordinary; on the other hand, it allows employees to ask questions through superior communication portal, which is a part of the solution. Education as a Service supports targeted training, and in this framework it does not include only standard courses. Education is a daily process that is to be encouraged, in order to share practical experience which can have direct impact on the quality and efficiency of services delivered. The deployment of cloud services and solution has economic impact for each organization. The cloud solution offers a high degree of variability and therefore it is necessary to clearly know for which target group required solution is prosed and optimized.

TABLE I.
CHARACTERISTIC OF FES SYSTEM

Advantages of FES
Lower reduced times for education cost per student Improved quality of education Increased reliability in transfer of knowledge Shorter time for delivery of knowledge Greater productivity in education Greater efficiency in education
Disadvantages of FES
Cost to implement

Substantial pre-planning
Requirement of skilled employers or staff

III. KNOWLEDGE MANAGEMENT AS A SERVICE (KMAAS).

In a cloud environment the aim is to provide "everything as a service", including knowledge as a service (KaaS) and knowledge management as a service (KMaaS) which are part of education process too.

Knowledge as a Service (KaaS) is a subtype of SaaS (software as a service) provided by a knowledge service provider, in which, a knowledge provider answers queries presented by some knowledge consumers, via the knowledge services.

KMaaS is a SaaS, in which, knowledge management services are provided by KMaaS service providers and are consumed by KMaaS service consumers. The difference between KaaS and KMaaS is that the former provides facilities on knowledge itself, while the latter provides management services to the consumers. KaaS is a part of KMaaS. [11]

The following benefits can have knowledge management in cloud environment:

• Cloud computing greatly reduces the technology related costs. Synergies are created through reduction in computing resources, time and modelling process. The large and variable storage needs for maintaining huge knowledge management systems can be accomplished by the use of cloud storage models.

• It provides access to variety of services to the users.

• It opens gates to several options for the knowledge users, earlier unknown to them.

• Cloud computing is an effective way to streamline the knowledge and make it readily available also.

• It accelerates the development and acquiescence of the competencies and capabilities of knowledge works in any organization.

• It extends the use of open-source services and shared developments across the globe.

• It reduces the activities and costs related to management of infrastructure.

• The work structure is changing these days, where requirement of access to information could be anywhere and at any time. Cloud resources are the best answer to such indispensability.

• Through cloud computing, one can gain faster access to technology and the process of knowledge management becomes more connected and collaborative, as the structure is framed on highly scalable and reliable web oriented architecture.

• It improves access to data that corroborates the decision making process and consolidates the studies & research processes. Latest project status, innovative ideas, new experiences and finest practices can thus be shared within an enterprise. It even motivates the employees for bringing forth creative strategies while carrying out the regular work, and enjoying it as well.

• It enhances awareness about the processes as the experiences are gained in different regions, sectors & fields of the world.

• Search patterns in knowledge management systems may vary and may experience sudden fluctuations and hiccups and can be better managed with an elastic/scalable computing model.

• Majority of knowledge management activities are generic in nature for which SaaS applications may be provided.

• Enterprises refrain from employing knowledge management tools and techniques primarily due to the cost incurred, but with cloud computing, pay-as-you-go concept can help solve this problem, as the required and limited services or resources are available at hand.

• Access to knowledge can be allowed on the basis of user's permission level.

• With the aid of cloud computing, knowledge can be converted into an asset which acts as a stimulant for innovations and research. [12]

From above mentioned, we can say that there are many benefits in education in using knowledge management.

We recommend to use it any of discussed solutions of cloud based knowledge management, so Knowledge Management as a Service (KMaaS). This architecture of interactive knowledge database is innovative it is part of LMS solution, it develops social networks among the users, cuts the time spent on checking e-mails and searching for information, helps in problem solving etc.

IV. ECONOMIC ASPECTS OF LMS SOLUTION IN CLOUD

This part of paper present some economic aspects of electronic education by using cloud infrastructure. The solutions designed and implemented according to customer requirements provided very positive results from financial point of view and short ROI of presented solution. We can talk about immediate benefit, because in the project there was involved a large group of employees.

For evaluation of project there were used following key indicators:

- cost of training per user,
- number of employees trained per week,
- processing speed of test results,

and the Tables 2, 3 and 4 are presenting in detail obtained results.

Table 2 compares the cost of courses per user that have been delivered by using the LMS system and standard manner. The results show that the price of any of the standard training is several times higher. In this comparison it is important to see the impact of production costs of training. In our case, we considered a moderate level of training quality. Presented table is including the number of employees participated on this research too.

TABLE II.
NORMALIZED COST OF FOUR TRAINING DELIVERED STANDARD AND
ELECTRONIC WAYS

ID training	Number of users	Cost of e-training from cloud unlicensed environment (normalized)	Cost of standard f2f training (normalized)
Training 1	4,700	1	4.9
Training 2	1236	1	4.2
Training 3	6,700	1	7
Training 4	10,000	1	11

Next table, Table 3 compares number of participants on the LMS and standards training per week. By using LMS system we can train several times more employees. In addition, logistics concerning the preparation and management of any standard training is much more difficult.

TABLE III.
NUMBER EMPLOYEES WHO CAN BE TRAIN STANDARD F2F WAY AND BY
LMS WEEKLY

ID training	Number of employees trained f2f weekly	Number of employees trained by LMS weekly
Training 1	200	1200
Training 2	120	560
Training 3	200	2500
Training 4	100	3751

Last table in this section, Table 4 compares processing speed of test results for f2f and LMS solutions. The control of tests for f2f training and for large groups is time consuming, moreover, some error in the evaluation can be presented. The results of test by using the LMS environment are presented immediately.

TABLE IV.
NUMBER EMPLOYEES WHO CAN BE TRAIN STANDARD F2F WAY AND BY
LMS WEEKLY

ID training	Processing speed of test results for f2f (days)	Processing speed of test results for LMS (s)
Training 1	3	< 1
Training 2	0,5	< 1
Training 3	2	< 1
Training 4	2	< 1

IV. CONCLUSION

Implementation of cloud concept in education creates the space for wide range small companies which are able to provide to market lot of new services. Presented concept is very flexible solution that allows involving many parties.

Delivered services are including content interpretation and its modification. The primarily there are service for individual end-users who use them mainly for training of its staff, secondary it provides services for the creation of new courses, design of methodologies and linking through different types of terminals.

In the field of education is a lot of information that changes rapidly at the time they need to be processed and presented in a way that is acceptable to the final customers. It is necessary to vary the scope and content of education for different stakeholders.

From the perspective of the cloud concept regards the optimal solution , where the user gets on one side environment for creating and archiving of required knowledge and, second, the possibility to transmit the processed information requested in the form , which is used for video, audio , simulations , videos , etc. . By the user can use different types of terminal equipment and fixed or mobile.

From financial point of view it brings to organization cost saving. The analysis confirmed that e-learning based on cloud infrastructure in organization can generate the greatest savings [10]. The actual dimension of savings depends on the size of the organization, scale implementation of e-learning as well as the chosen solutions These savings can be replicated when the organization decides to implement the unlicensed model or on the side LMS and on the contents. However, this approach is not yet standard as most vendors now prefer just the way of charging licensed and not flat model.

Presented savings can be replicated when the organization decides to implement the unlicensed model or on the side LMS and on the contents. However, this approach is not yet standard as most vendors now prefer just the way of charging licensed and not flat model.

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Manufacturing Processes Simulation of Mass Customization Used by Education of Technical and Economical Subjects

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Abstract— The implementation of mass customization into a manufacturing enterprise brings with it, among other things, the introduction of new technical applications, software, through which the manufacturer gets closer to the consumer and on the other hand he can simulate the production process. Through a well-managed simulation, it can be prepare for future "unpredictable" situations in the production process and make the whole of the production economically as well. The aim of this paper is present the possibility of using simulations and managing the simulation of manufacturing processes during the study at the Faculty of Manufacturing Technologies with a seat in Presov, of the Technical University of Kosice. This paper presents a new approach to the subject of designing manufacturing systems and the management economy. The students of faculty teach the simulation problematic during their study field. Used simulation processes make changes to technology and manufacturing operations in a virtual environment. This study presents the students' view of the problem and uses the principle of a case study.

I. INTRODUCTION

As is know, the economy development and the constant competitive work for the customer always brings new impuls to production, trade and consumption. Manufacturers are increasingly striving to meet customers, their production and business strategy to meet the needs of a wider consumer cluster. To meet the individual needs of the customer, the new marketing strategy - Mass customization - has been at the forefront since the 1990s. The concept of "mass customization" (MC) was first mentioned in Staven Davis' Future Perfect in 1987. It is defined as a way to produce one type of product based on customer specification and regardless of the economic aspect of production [1]. However, mass customization has been achieved thanks to the publication "Mass Customization: The New Frontier in Business Competition", where Pine (1993) defined it as the ability to design and produce customized products at the same efficiency and speed of production as mass production [2]. The goal is that almost every consumer finds exactly what he needs on the products and services market, without sacrificing the increase in the sales price. Some ways of customization give the consumer the ability to directly influence some of the specifcs of the final products. Otherwise, the range of products is expanding, thus increasing customer satisfaction through a wider choice of different end-products of one kind.

Different ways of customization include [2, 3]:
- creating customizable products and services,
- personalization of services for standardized products and services,
- taking into account individual requirements in the delivery of goods,
- modularization of components to meet individual requirements,
- achieving rapid response in the value chain.

From the point of view of the implementation of the MC into the production process, we can define 4 development stages according to Lampe, which can be seen in Figure 1. Among the most progressive mass customization strategy it is pure customization.
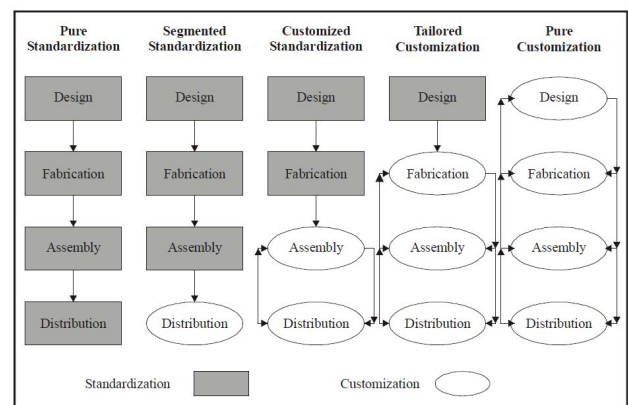
Figure 1 Mass customization strategy according to Lampe [4]

At different phases of the manufacturing process, from design to distribution, more intense and unpredictable situations are caused by greater consumer interaction and external impact, many of which cause considerable financial investment or losses. Therefore, it is now necessary to introduce new technical applications, software and programs that are capable of anticipating adverse impacts in the production process that could disrupt the operation of the

plant and alert control authorities to the red numbers that may occur. On this basis, it is very important for employers to employ competent and educated graduates of higher education institutions who have also gained practical experience with the virtual world of the manufacturing enterprise.

Generally, education of technical and economical subjects is presented in an informative field of educational process. [5]. To engage and teach universities students is becoming more and more complex in today's, modern times. Therefore, modern methods such as internet, simulation, interactive education and case studies are being used in learning. In the education of technical and economical subjects there is a problem with the imagination of the students. A great opportunity to help with education is the use of computer simulations and case studies. By interconnecting them, it is possible to realize that students can imagine the whole process of the actual production process [6]. It turns out that the simulation of manufacturing processes is becoming a new trend, which also points to Industry 4.0. From the amount of information needed for simulation, it is necessary to choose only some of the necessary and necessary simulation. This opens up the possibility of using a case study. This is one of the new trends when a student receives all the input information defined in the wording of the assignment. Just as every person is unique, his solution is also unique. After defining the same problem to different learners of different focus, it was found that different design views were achieved to deal with these assignments, which ultimately had a direct impact on the production costs of the company, the complexity of the production process and the variety of products.

II. RESEARCH MATERIAL AND METHODOLOGY

This paper is focused on the designing of manufacturing systems, which is taught at the Faculty of Manufacturing Technologies with a seat in Presov of the Technical University of Kosice. This study subject is realized in the second study year of the engineering degree, in the academic year 2016/2017 it was attended by approximately 150 internal students within the five accredited study programs:

- Computer aided of manufacturing technologies (CAMT) - The graduates of the study programme are qualified to become manufacturing engineers with complex capabilities of computer skills. Students deal with organizational and technical problems and solve the innovative production processes and systems too. During the study at faculty graduates are in contact with CA systems and CA technologies, which are used by the preparation and managing of production. After the subjects graduation students are able to solve and create special applications according to specific company requirements as well as lead teams. All modification is performing by engineering computer analysis, simulation of production process and design production units. Being equipped with the knowledge of economics and business, they can occupy positions of team leaders in the field of technical preparation of production as well as

managers and private entrepreneurs in the area of computer technology and CA systems application,

- Manufacturing technologies (MT) - The graduates of the study programme are qualified to become manufacturing engineers. They can systematically and comprehensively deal with technological and organizational issues in rationalization, modernization and design of new production processes and systems using CA technologies. Good understanding of economics enables our graduates to solve problems of production and operation management. They can occupy positions of manufacturing engineers, production managers, team leaders in the field of technical preparation of production and production quality control. They have the ability to deal individually or in teams with the issues of production processes and systems technological design based on complex and system relationship of particular technologies, integration requirements, and automation and production processes efficiency. Students are ready to solve the problems of economic, operational and management in the company. Graduates are in the front rank of specialist engage on material, technological and organizational problems of rationalization, modernization and design of new mechanical engineering and electrotechnical production in the companies. All students after a successful graduation are qualified to solve problems of management and mechanical and electrotechnical operation of manufacturing production. All these activities are carried out with the support of CAx technologies, methods of mathematical modelling, simulation methods, logistics and mathematical optimization,

- Manufacturing management (MM) - The graduates are able to independently manage a company in all sectors of production and business in different economic conditions and situations. Among the basic knowledge of the technical and economical subjects belong to preparation of technical documentation. They have understanding of manufacturing technologies, production machinery, materials, production processes, tooling and fixtures and their management. Students can provide the production and technological cycle and manage operating parameters in the system. The graduates are knowledgeable in the newest management methods and are able to react flexibly to market changes, manage tasks in the area of financial management and management of technical and technological development, preparation and implementation of new products and goods. They can estimate future financial outcomes of the company, design working environment, monitor ecology and environmental protection with regard to health and safety at work,

- Monitoring and diagnostics of technical equipment (MADTE) - The graduates possess necessary knowledge and skills of theoretical and application character which enable them to independently solve the tasks aimed at technical equipment, detection, analysis and assessment of operating conditions as well as modeling and simulation of reliability,

maintenance systems design, systems for measuring and evaluating the quality of production, tribological diagnostics, vibrodiagnostics, service of technical equipment. They are equipped with knowledge of production systems modeling, application software for evaluation and prediction of operating conditions and modes of technical equipment, production facilities management, engineering materials and their testing as well as logistics, economic basis, industrial psychology, ethics, ecology, environmental protection, health and safety at work. Students after graduation are able to manage professional teams. According to very good knowledge can solve the problems by production technique application as well as and can monitored and solve the diagnostics of the operating status. Being competent to assess operational states of technical equipment, they can suggest methods, equipment and systems for providing technical and manufacturing operations as well as propose the cost-effective systems for diagnostics, maintenance, service and operation of technical equipment. They can occupy the positions of chief operators, diagnostic and service teams operators as well as become specialists for designing methods and technical systems for the diagnosis, maintenance and servicing of technical equipment. Our graduates are highly qualified specialists when ensuring competitive operation of technical equipment and complex production systems,

- Renewable energy sources (RES) - The graduates have understanding of momentum, mass and heat transfer as well as the theory of constructing devices, machinery and equipment for process engineering. They have knowledge of the theory of mechanical, hydraulic, thermal, diffusion processes and reactors, especially in the field of physical chemistry, processing of solids, powder materials, liquids, gases, and various mixtures of Newtonian and non-Newtonian nature. After graduation can students manage equipment process technology and conceptual designs for the operational functions. Fully equipped with broad theoretical knowledge of individual processes and their contexts, they can participate in research projects in the field of process technology for the implementation of new production technologies with a high degree of creativity and independence. The graduates possess knowledge of a process modeling, mathematical description, methods of measuring static and kinetic characteristics, measurement of process variables and process control technology management using PC, microprocessors, etc. They are trained to apply the newest methods and means to solve complex technical problems in the field of process engineering. Practical abilities and skills of the graduate: to specify, design, operate, manage and evaluate the process according to the general criteria applicable for process engineering; interact with designers within investment activities; cooperate in research and development processes as well as design elements for process engineering; assess the accuracy and appropriateness of the application process and set parameters in process engineering within the production process [7].

The main task of the subject is to teach students to design the production process in the company - a system for producing several outputs on the production line, according to the specifications and the requirements of the consumer. The input data of the case study are defined as [8]:

- the size of the production hall space,
- the number of machines needed in the production process,
- the number of outputs produced,
- technology of individual outputs,
- production times,
- production costs and other monitored economic indicators.

The simulation tool Tecnomatix Plant Simulation (TPS) is used to solve the assignments. This is a technical support from Siemens tool that simulates and optimizes manufacturing systems and processes within a virtual enterprise [9]. The software recognizes and removes problems, unanticipated phenomena within the production process that would otherwise require costly and time-consuming measures to remove and further manufacture. In this respect, it also minimizes the investment costs of production lines without jeopardizing the required performance. Through TPS, we optimize the performance of existing production systems by adopting measures that have been verified in the simulation environment prior to implementation itself in the production process and able to produce future-stage scenarios at the time of planning itself. TPS uses extensive analytical tools such as statistics, charts and diagrams, which are becoming an important basis for long-term and operational decision-making [10, 11].

Tecnomatix Plant Simulation enables to quickly create realistic simulation models of dynamic operations and evaluate the properties and performance of design alternatives before they are implemented in real-world manufacturing processes. TPS used by manufacturing processes modelling make better decisions and can minimize defects in the production process and economic inefficiency.

Tecnomatix Plant Simulation software is available for use in many languages, for example in English, German, Japanese, Hungarian, Russian and Chinese, etc.. The user can create individual dialog boxes using double-byte characters that offer individual parameterization [12]. Tecnomatix Plant Simulation can display production sequences in 2D and 3D mode as can be seen in Figure 2.
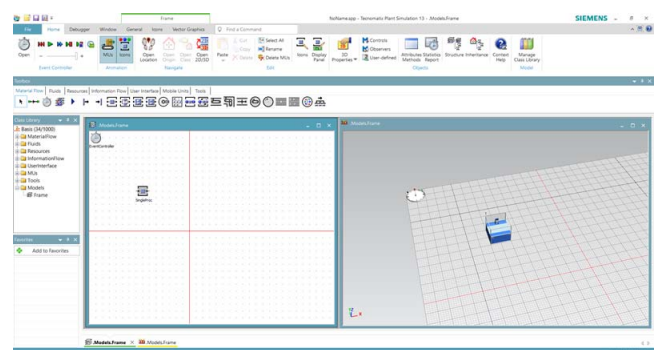
Figure 2 Basic work environment of Tecnomatix Plant Simulation

III. RESULTS AND DISCUSION

Case study input information for students who need to the educational process:

- workspace size - 20 x 15 m
- number of machines - 5 pcs
- number of parts - 5 pcs
- defined cost per machine hour
- defined basic production times
- number of employees - arbitrarily optional
- way of transport – different
- robotic workstation - 1pc
- technological arrangement of machines – optional.

The first step is to define and analyze the base station. Subsequently, an initial analysis of the product dimensions is made, the size of the semi-finished product, the definition of the semi-finished product, the evaluation of the technological process requirements, the method of moving the semi-product/ product between the workplaces, the operational and production times, the analysis of the technological arrangement of the machines, determination of profitability and return [11]. After the manufacturing analysis, the production attachments are modelled. Model of manufacturing lines are shown in the next figures. (Fig.3 a-d)
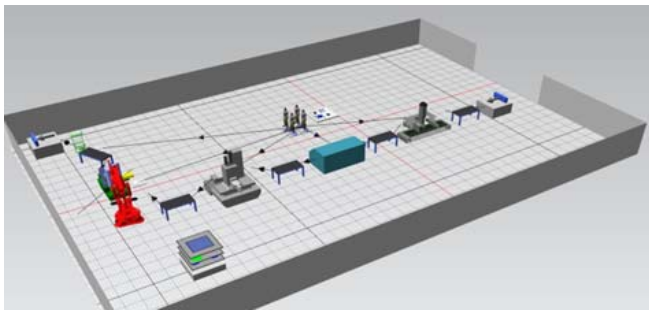
Figure 3 a) Model of manufacturing line – line arrangement of machines

76 % of the students organized the lines according to the order of production operations. They used inter-operational warehouses to remove blocking machines. In simulation, the overall production times were higher.
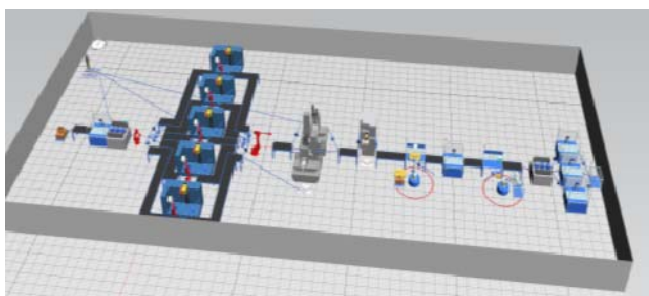
Figure 3 b) Model of manufacturing line – parallel arrangement of machines

In some simulation cases, students attempted to remove blocking by a parallel arrangement of production machines.

For parallel-time operations, a parallel arrangement was used. From a general perspective, this meant higher procurement costs and the employment of several employees. In the case that 2 machines were used by one employee, total labor productivity increased.
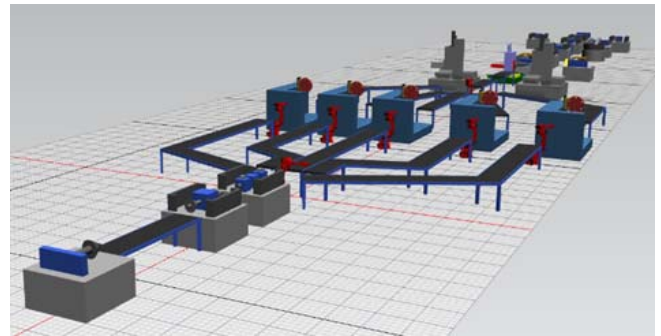
Figure 3 c) Model of manufacturing line – view without building walls

For models that did not have wall maps, students' rating was lowered. The condition defined in the case study was not met.
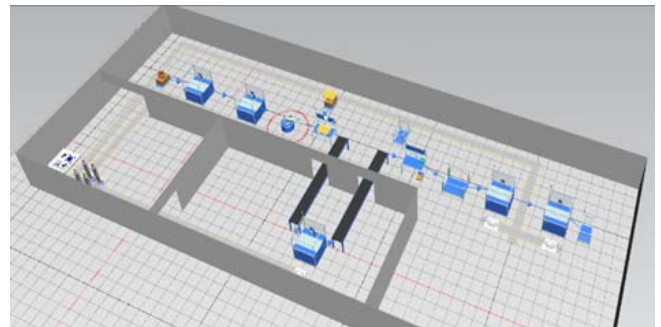
Figure 3 d) Model of manufacturing line – view with building walls

In wall models, students mostly chose the technology of production. Operations with precision technology were placed in other areas as vibration and shock technologies. Technological organization was mostly realized by students focusing on manufacturing technology.

After the basic simulations, various experiments were carried out, in which students tried to reduce the production line utilization. In many cases, they attempted to increase the productivity of production lines by increasing the number of machines. The following table presents the results of the complexity of the manufacturing system proposed by students in the design of manufacturing systems, based on a case study.

TABLE I. COMPARISON OF COMPLEXITY SYSTEM

	0 pc	1 pc	2 pcs	3 pcs	4 pcs	5 pcs	6 and more pcs
Pcs of machines	0 %	0 %	0 %	0,6 %	0,8 %	98,8 %	0 %
Pcs of robots	0,4 %	95 %	4,6 %	0 %	0 %	0 %	0 %
Pcs of employees	0 %	0 %	0 %	0 %	2,3 %	57 %	40,7 %
Pcs of buffers	0 %	0 %	0 %	1,1 %	68,2 %	27,4 %	3,3 %
Pcs of conveyors	0 %	0 %	0 %	4,8 %	11,2 %	21,4 %	62,6 %

In determining the number of machines, the majority of students selected 5 pieces of production equipment. In some cases 3 to 4 pieces were used, which the students justified using multifunctional CNC machines. When determining the number of robot manipulators, in most cases 1 piece was used. Up to 97,7% of the employees were employed by 5 or more employees, with manufacturers and auxiliaries. To remove bottlenecks in production, most students chose at least 4 buffers. In order to achieve smoother production, students have used more conveyors to accelerate production.

The second part of the evaluation consisted of a comparison of the results between the different topics. The selected indicators have been compared in the tables 2 and 3 below.

TABLE II. COMPARISON OF THE AVERAGE RESULT TIMES OF EACH STUDY FIELDS

	CAMT	MT	MM	MADTE	RES
Set-up Time	1,23 %	1,35 %	1,45 %	1,38 %	1,49 %
Working Time	98,2 %	97,85 %	93,75 %	95,46 %	94,35 %
Rotation Time	0,53 %	0,48 %	0,63 %	0,57 %	0,65 %
Waiting Time	45 %	34,7 %	53,87 %	43,6 %	52,13 %
Blocked Time	34,06 %	36,75 %	26,84 %	42,75 %	36,54 %
Powering up/down Time	0 %	0 %	0,12 %	0 %	0,32 %
Stopped Time	0 %	0 %	0 %	0 %	0 %
Empty Time	23,45 %	20,21 %	32,1 %	25,14 %	27,36 %

TABLE III. COMPARISON OF TOTAL PRODUCTION – MANUFACTURING - STORAGE

		CAMT	MT	MM	MADTE	RES
Production	Working	38,34 %	57,63 %	29,24 %	10,33 %	9,12 %
	Waiting	5,25 %	36,52 %	47,10 %	4,43 %	4,45 %
	Sum	43,59 %	94,15 %	76,34 %	14,76 %	13,57 %
Transport	Working	0,42 %	2,93 %	0,02 %	0,12 %	0,08 %
	Waiting	21,74 %	0,08 %	23,64 %	29,98 %	59,70 %
	Sum	22,16 %	3,01 %	23,66 %	30,10 %	59,77 %
Storage	Working	0 %	0 %	0 %	0 %	0 %
	Waiting	34,25 %	2,84 %	0 %	55,14 %	26,66 %
	Sum	34,25 %	2,84 %	0 %	55,14 %	26,66 %

Based on previous comparisons of the total times, total production of manufacturing and storage and total comparison of percentual financial costs, as is presented in Table 4. below.

TABLE IV. COMPARISON OF FINANCIAL COSTS

	CAMT	MT	MM	MADTE	RES
Machine purchase	45,32 %	27,67 %	55,34 %	36,47 %	37,41 %
Personal costs	27,33 %	32,42 %	24,61 %	27,41 %	28,42 %
Energies	15,38 %	17,44 %	13,27 %	19,31 %	18,17 %
Transport	11,97 %	22,47 %	6,78 %	16,81 %	16,00 %

VI. CONCLUSION

Based on the introduction of the case study, we will improve the imagination of students, and from the present it is possible to create several conclusions within the individual accredited study programs:

- CAMT- is technology-oriented and computing-friendly. Their simulations are graphically more sophisticated and, after analyzing the financial indicators, it is obvious that the largest investment would be put into the purchase of machinery and equipment.
- MT - simulations have been geared to minimizing machine waiting time, which suggests that students focus primarily on designing technology and optimizing production times.
- MM - most invest in the purchase of production facilities, focusing on minimizing shipping costs.
- MADTE- most invests in the transportation of individual components. As part of the simulation, they use a larger number of trays, which speeds up the way of transport, but high blocking of machines occurs due to the inappropriate technological process.
- RES – used by simulation, when necessary work is with a larger number of conveyors using by transport. In this case is high blocking of machines.

From the presentation it can be concluded that the use of case studies and simulation through Tecnomatix Plant Simulation in students improves the way of education, opens the possibilities of their imagination and helps in acquiring the overall knowledge of the subject of designing production systems and management economy. As we have seen, the influence of students' focus also reflects on their learning outcomes. Students oriented technically (CAMT and MT) have achieved better results in the optimization of technological processes. On the contrary, economically oriented students (MM) have achieved better results in optimizing production costs. The third group was the students (RES and MADTE) who spent more time in the simulation on the design of the transport and the inter-operational storage.

Presented paper shows the possibilities of using a computer simulation used the principles of a case study. Based on the present paper, it is possible to state that after defining the same parameters and the students have the influence of their study field.

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Improving Student Engagement and Learning Outcomes through the Use of Industry-Sponsored Projects in Human-Computer Interaction Curriculum

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Abstract—Engaging students in higher education can often be a challenge. Traditional curriculum approaches of lectures, homework, and exams are the norm for many university-level courses, especially in the computing and engineering fields of study. This work introduces the use of industry partnerships for class projects to give students exposure to real-world problem solving and solution development. Students work in small groups of 3-5 students (undergraduate and/or graduate) to design, prototype, implement, and evaluate solutions that are later put into production with our industry partners. This approach results in students completing the full development life cycle learned in computer science classes and includes delivery of products that can be used as part of their portfolios. This approach has resulted in improved learning outcomes and higher levels of student engagement in these courses and the industry partners have a product that they can use for their companies. Details are provided that discuss: how to develop industry relationships, designing the course curriculum to support these types of projects, timelines and checkpoints to assess student progress, final presentations, documentation, and product deliverables. There is also a discussion on non-disclosure agreements and what students can use as part of their portfolios and resumes from the course projects. Feedback on the projects from students have been very positive and comments from the student evaluations will be presented in addition to recommendations on possible improvements to the learning process associated with this approach.

Keywords—Human-Computer Interaction, Student Engagement, Industry-Sponsored Projects, Learning Outcomes

I. INTRODUCTION

A significant challenge with teaching any course is increasing student engagement in the topic area and improving learning outcomes. To enable students to transfer knowledge between one specific example provided in the classroom or in a book to a wider application area [1] demonstrates a higher level of learning achieved by the students. College-level courses are often taught as a lecture using PowerPoint presentations to the students and they are often not actively engaged in the material. In highly technical topics, such as those in science, technology, engineering, and mathematics (STEM) fields, maintaining student engagement is difficult for some

students [2], [3]. Project-based and problem-based learning has demonstrated positive effects on student engagement and learning outcomes [4].

One approach that has been used in the classroom is the development of projects and specific problem-solving as part of the curriculum. This has been effective overall, and allows the students to transfer the knowledge they have learned in a more applied manner. The main issue is that this approach usually takes the form of problems that the professor has developed and may not be based on actual real-world problems. This approach is definitely an improvement over non-project courses, but still lacks in the development of skills that would translate directly into future employment opportunities for the students. Employers often criticize that students who come to work immediately following graduation often lack the context and skills necessary for immediate success on the job. They often have a strong theoretical background, but often do not have the ability to transfer the theoretical foundations into applied problems found in the workplace.

To attempt to resolve this concern, introduced industry-based projects have been introduced into split-level Introduction to Human-Computer Interaction and graduate-level Advanced Human-Computer Interaction courses at Mississippi State University. With this approach, partnerships with industry were formed to develop projects together with the instructor that meet the needs of the industry partners and provides the students with hands-on experiences working on real-world problems similar to those they would find in the workplace. The feedback from the students with this approach has been positive. Students have a better understanding and retention of material and have shown improvements over prior classes taught with a project-based approach but without the industry partnerships. I have always taught these courses as project-based courses, but have been teaching them with industry-sponsored projects for the past three years. There is a noticeable difference in student engagement and overall learning outcomes since making the change to industry-sponsored projects.

II. RELATED WORK

The integration of industry-sponsored projects into educational curriculum is not a new concept, but has mostly been included in senior-level two-semester courses as a capstone or as an interdisciplinary curriculum experience for students prior to graduation to prepare them for the workforce [5], [6]. Teaching project-based learning and combining it with design-based learning to meet the needs of industry have also been successfully used in the classroom; however with this approach industry partners were not providing the actual projects for the students to complete [7]. Some projects have been developed by trying to simulate industry standards in the classroom by consulting with industrial partners [8]. There is evidence to support the integration and the mentorship that can occur with using industry partners in classroom and learning environments helps to improve retention, graduation, and employment in STEM career fields [9]. There is strong evidence to support this approach and the following discusses one method for including industry-sponsored projects in the computer science and engineering curriculum.

III. DEVELOPING INDUSTRY RELATIONSHIPS AND NON-DISCLOSURE AGREEMENTS

The development of industry relationships can be daunting if you have not approached a company before. What was surprising to me was that many companies have projects that they just do not have time or resources to complete, and having a student team take on these projects that often help with productivity or some major area of concern and is of great benefit for many companies. This has been the approach taken for Senior Design project courses or capstone courses that are typically two semesters in length and help tie together different concepts from the curriculum in an applied approach. Unfortunately, this approach has not often been used in regular courses, but can be an invaluable approach for teaching and learning.

The first step is making contact with different local or regional companies and offering to provide assistance by letting the company know this would be at low or no-cost to them. Inquiring if there are any technical problems that they would like to solve, in this case, through a web or mobile application to provide assistance to the company. In my case, we provided mobile applications for a top 100 international logistics company and for an international automobile manufacturer.

The companies both stated that it would have taken a year or more to develop the prototypes the students were able to create in a semester's effort. This provided benefits to the companies and for the students. It is a win-win situation for all involved. The companies could take the completed software and applications and in some case directly implement them into their business plan, and in other cases, they used the software as a starting point to implement their own process and protocols to develop a commercial version. The companies like that the students have a fresh perspective and are open-minded in their approach to problem-solving and it breaks away from the company mindset for operationalizing the applications.

Most companies will want to have some type of non-disclosure agreement (NDA) in place to protect their businesses. Usually, this means not using the actual company name or discussing the details of the work being performed with people outside of the projects. This can be done individually between the students and the company or it can fall under a university-level NDA. That will need to be discussed with the company prior to the start of the projects. This is a detail that does need to be resolved and may be intimidating to faculty wanting to have these types of projects, but it is usually not a major issue, but will need to be discussed with the university legal team prior to starting to determine the best way to handle this issue.

IV. DESIGNING COURSE CURRICULUM

The use of industry-sponsored projects are similar to any course that contains projects or specific problem-solving activities. The key to success is well-defined projects, multiple checkpoints with feedback, and making sure that the faculty member and/or teaching assistants are available to answer questions quickly when students have concerns. It is amazing how much can be accomplished in the course of a semester if the projects are well defined, explained at the start of the semester, and excellent feedback provided.

For the human-computer interaction courses, the companies would work with the instructor to define multiple projects that included the development of either a web application or a mobile application or in some cases both, with an initial set of broadly defined requirements. It is typical for them to describe between 3-5 different projects depending on the class size and often multiple teams will complete the same project and a prize is awarded at the end of the semester for the best team for each project. For the Introduction to Human-Computer Interaction, the students would design and implement only the front-end aspects of the interfaces. For the Advanced Human-Computer Interaction course, the students would design and implement the front-end interfaces along with the back-end supporting structure including a database, if needed. It works best to have small teams of 3-5 students, so that work can be evenly distributed among team members. For the Introduction to Human-Computer Interaction, it is an interdisciplinary course that includes computer science, engineering, and social science students; therefore, I make sure the teams have distributed members from the different majors to meet the requirements of the project.

A. Timelines/Schedule

For any project-based course to be successful it requires a well-specified timeline and schedule. I typically try to distribute the schedule the first week of the course stating that changes may occur depending on circumstances that may arise throughout the semester. Overall, the students are required to prepare a project proposal stating, which of the projects they are interested in pursuing and their order of preference.
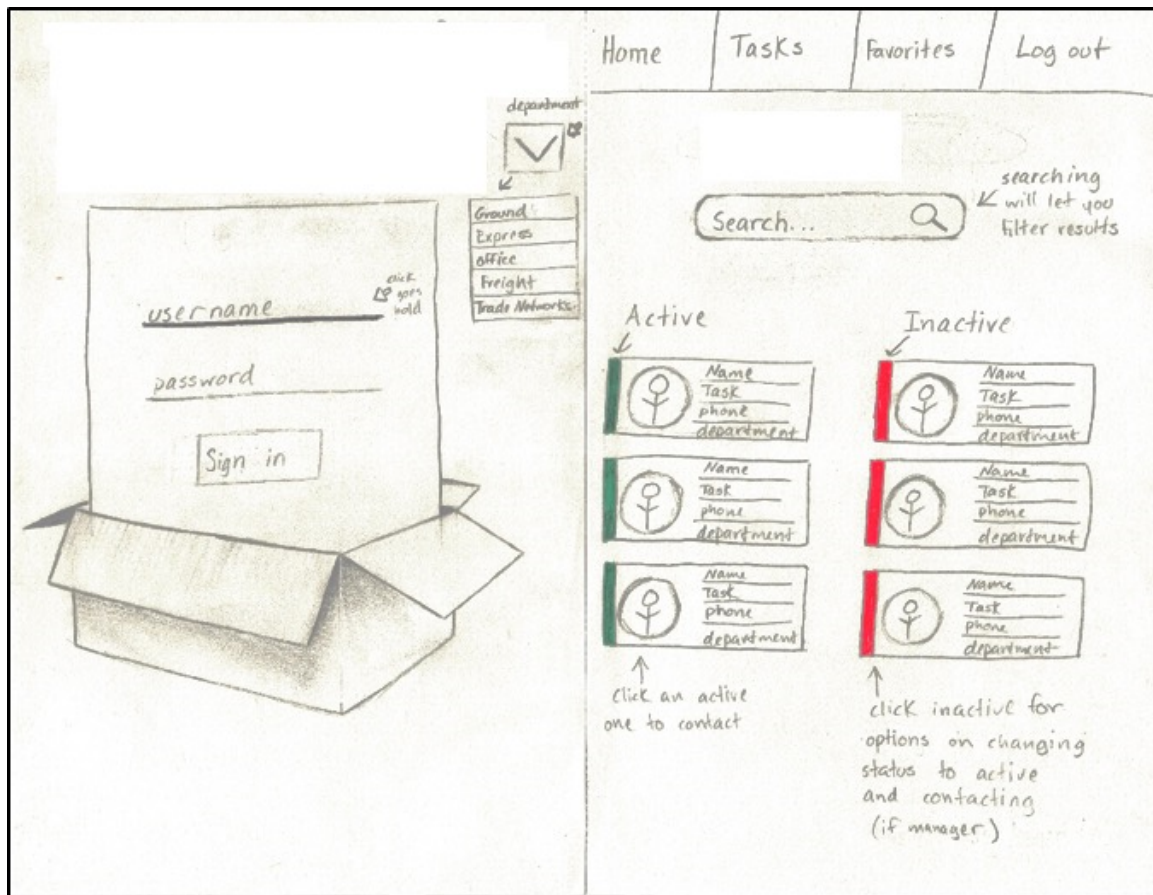
Fig. 1. Preliminary interface design sketch.

Then they provide more details on their approach for the project identified. Next they develop initial prototypes using sketching [10], iterative prototypes using wireframes, and a final implemented design that includes product deliverables (e.g., software, user manual, screenshots, and project/design documentation).

B. Progress Checkpoints

Although everyone has the best intentions, I have found that students seem to perform best when they have structure and multiple progress checkpoints that include feedback from the instructor, classmates, and the industry partners. These checkpoints occur approximately every 3-4 weeks to provide them time to complete the work, but keeps the projects on track. There are different options for providing access to the presentations for the industry partners to provide feedback throughout the projects. In some cases, the industry partners have visited the class during the presentations for each checkpoint, They have also used video conferencing to be able to view the presentations while they are happening and provide feedback at the time of the presentations. Lastly, we have video-recorded the presentations, uploaded the videos to the industry partner, and have them provide written feedback for the students. It is critical that the industry

partners participate in providing feedback, because they are the customer/stakeholders for these projects.

The first checkpoint typically outlines which team members are responsible for which aspects of the project and provides initial sketches using techniques presented in [10]. Each individual student on a team is required to produce 10 brainstorming sketches for the project, and then as a team they sort through the sketches to develop one or two preliminary designs (see Fig. 1).

The second checkpoint, the students take the initial design sketches from the preliminary designs and convert them into wireframe interface images based on feedback from the instructor, classmates, and industry partners, that have a digital look and feel. This is where is starts to look like an actual interface (see Fig. 2). This has the starting components and expresses ideas, but it is not ready for production. These prototypes can be either vertical in which one or two aspects are fully implemented and functional and the other aspects are placeholders, or they can be horizontal prototypes in which all of the aspects have limited functionality but none of the aspects are fully implemented at this stage [11]. This version is typically created using a prototyping software. The instructor provides feedback along with members of the class, and the industry partners. This is important for the learning process

for the students to also learn to be critical of their own and their classmates' designs.
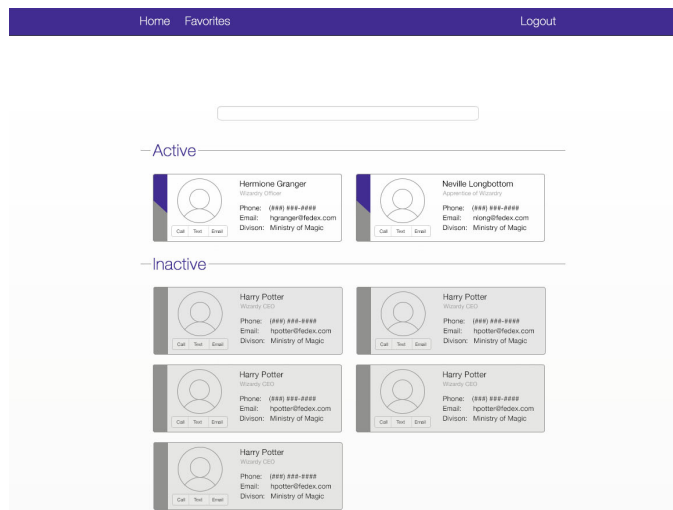
Fig. 2. An example of an initial wireframe interface design.

The third checkpoint, typically occurs following some initial pilot studies with users of the system or with fellow students for testing and evaluation. It is important for students to understand the process and to make sure that stakeholders are providing input and have had some initial use of the interface. In my classes, the students are required to develop a survey, recruit at least 20 participants, conduct a user study that includes the think-aloud technique [11], gather information and feedback from people not familiar with their interface to learn what aspects may not be clear or usable or may create a negative user experience, and attempt to resolve these issues before the final design is completed. This version is more refined and includes more details and functionality based on feedback. It is actually implemented in software and is interactive at this stage in the project (see Fig. 3).
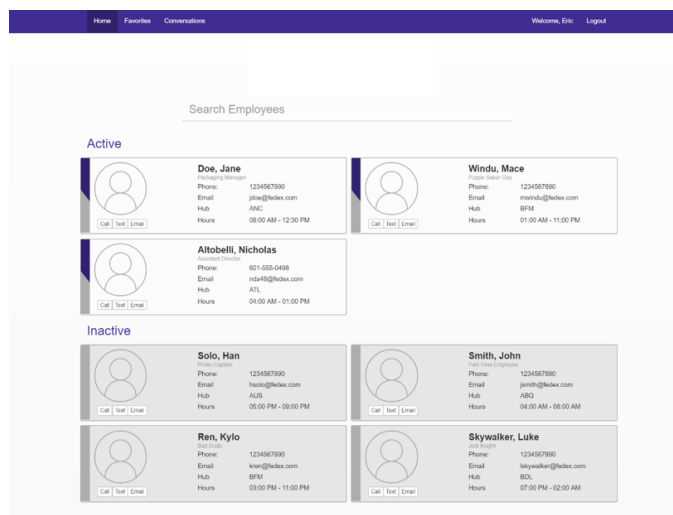
Fig. 3. An example of an implemented prototype interface design.

The last phase of the project is the final presentation to the industry partner(s), instructor, and class (see Fig. 4). Each student in the class is required to provide a written evaluation of each project's interface including their own interface, and this includes: (1) three items they like about the interface, (2) three items that could be improved, and (3) any other comments on the design and interface they may have. They also give each project including their own, a numerical score on a scale of 0-100. Throughout the project at each checkpoint, the students provide self-evaluations and team member evaluations that include: cooperation, communication, items they or a team member struggled with, items that they or a team member excelled in, and other comments. These evaluation materials are available upon request. This reduces the situation in which one or two members of the team may not be doing their share of the work on the project. It holds each team member accountable. A base grade is provided for the overall project and the students' work for that checkpoint, and the students are informed that individual grades may be higher or lower depending on the feedback provided on the self and team member evaluations.

C. Final Presentations

The final presentations are designed to demonstrate the final product or interface and to describe the results of the user studies and how that impacted the final design. The students are required to present the results of their user studies as graphs and/or charts. They also report on team member responsibilities and who completed which parts of the interface, any assumptions that they have made when designing and implementing the interface, provide a justification for any recommended changes that they did not implement as a result of feedback, and discuss any additional items that they performed that went beyond the requirements for the project. An actual demonstration of each project working is performed and screenshots of each interface or application page are included in the presentation as well. Notes are taken during each final presentation so that the students and industry partners can provide a final evaluation of the projects and these are used as part of the process to determine the best team results for each project type. The industry partners typically will bring to the final presentations higher level management and they will make a determination of best project in each project category and best project overall and that is announced to the class. The industry partners often will provide a plaque or some other small prize to reward the winning teams for their efforts and they can include this on their resumes/CVs.

D. Project Deliverables

Each project has deliverables similar to what would be expected when working in industry. The students are expected to follow a software engineering approach and develop an initial requirements document. They should produce a design document that details the changes made over each iteration. They provide all of their software developments including detailed comments and documentation of what the software
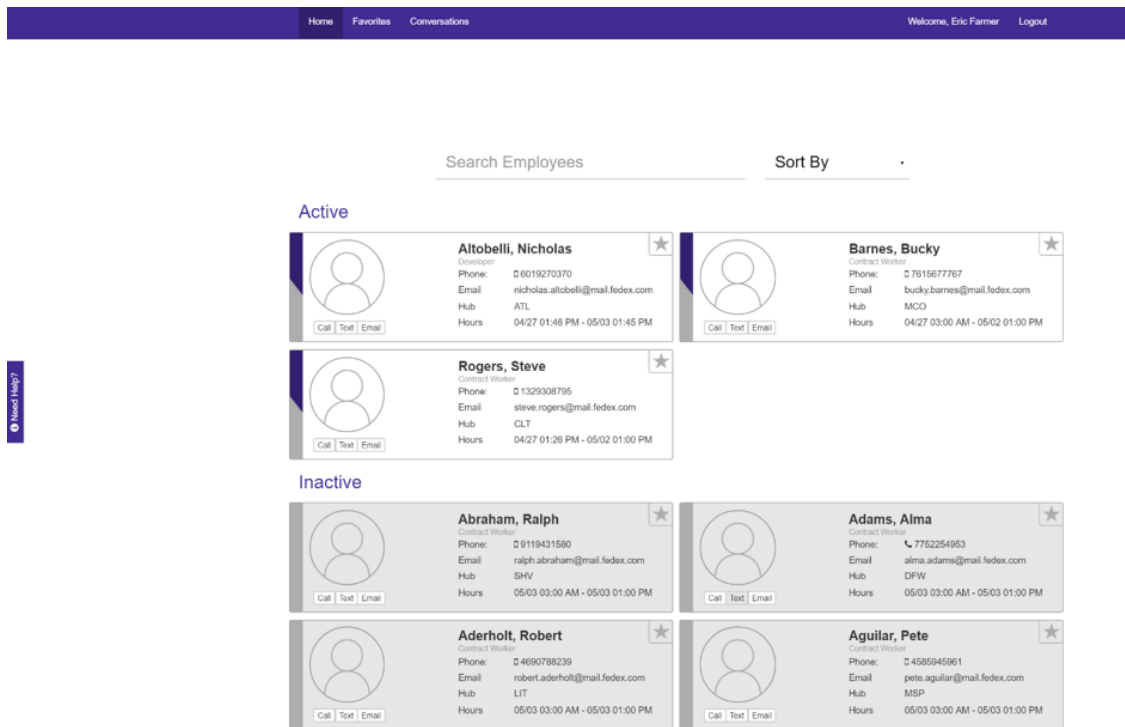
Fig. 4. An example of an implemented final interface.

is expected to provide. The students also include a user manual for the application or software interface they have developed so that novice users can use the software. They are also required to include any 3rd party software and/or libraries they used in the implementation of their projects. They are required to detail what each team member contributed to the project and who was responsible for all aspects of the project. They are to provide their raw data from their data collections including survey results and transcripts of the think-aloud process during the user studies. The think-aloud process, participants of the user studies speak verbally about their thought process, concerns, and what they find beneficial about the interface while they are using it, and for each aspect of the interface or application design. The students also provide summaries of the data collected in the form or charts and/or graphs from the raw data obtained. The last item they include is their presentations from the final class with screenshots of all aspects of the interfaces. For the Advanced Human-Computer Interaction course, they also provide any back-end software and data obtained for use by the industry partner. All of these materials become part of a package that is the final deliverable to the industry partner for them to use as they see fit.

V. STUDENT PORTFOLIOS AND RESUMES

The students can use the results of the project in their portfolios when interviewing for positions and can state in general terms the industry partner for whom they completed the project and must remove any direct identifiers of the company (e.g., top 100 international logistics company, international automobile manufacturer). They are not permitted to publish company details on their personal websites until the project has been put into production. They can present the information in person to different employers as part of the interview process, but the industry partner must remain anonymous, but that will depend on the agreements made between the industry partners and the students and/or the university. The students can also list this on their resumes or curriculum vitae as long as the same restrictions are followed.

This enhances the students' experience and demonstrates capabilities beyond typical theoretical classroom assignments. This type of industry-sponsored project, provides them with the structure and experience of working in industry while still in the classroom and increases their marketability when searching for a position for internships and/or full-time employment following graduation. There have also been situations that have occurred in which the industry partner actually recruited directly from the classes because of being able to observe the students' work ethic and capabilities. This is a significant benefit for the students to have these types of interactions and experiences in the classroom.

VI. CONCLUSIONS AND FUTURE WORK

This approach of using industry-sponsored projects has been very positive for the partners and the students involved in these classes. Student course reviews and comments have been overall positive and they have commented that the project and the experience gained was invaluable and the best part of the course. One student commented *"I really learned a lot in this class, specially because it dealt with how things are dealt with*

and done in the industries." Another student commented in the course evaluation at the end of the semester, *"... I'm also really enjoying the project and like the idea that it is being done with a real company."* The class will not ever please every student, but overall the experience of including an industry-sponsored project was positive for the industry partners and for the students.

A. Conclusions and Recommendations

Project-based and problem-based learning have been demonstrated to be effective in improving student engagement [1]–[4], improves understanding of theoretical concepts through real-world application, and improves overall student learning outcomes. Teaching these courses using industry-sponsored projects compared with instructor designed projects, revealed an improvement in overall test scores. Based on observations, the class discussions were richer and the students were more willing to discuss concepts based on their experiences with these real-world projects. They were able to better apply the concepts presented in lectures through their experiences with the industry-sponsored projects even beyond what was noticed in the instructor-designed projects of prior courses. The students seem to take the projects more seriously because they were accountable not just to the instructor but also to someone who may possibly offer them an internship or employment opportunity. The industry-sponsored project provided the students with material that they could include in their software portfolios and for their resumes and/or CVs.

As a result of teaching this course for several years, there are a few recommendations I would like to provide. First, I would add in more homework assignments to reinforce the material presented in class and that will be needed to complete the projects. One example, was having the students design and develop their own icons for functionality, in this case I had them design icons for a camera for red-eye reduction, crop the image, enhance the image, and rotate the image 90 degrees. This was a popular assignment that was considered beneficial by the students. They were not allowed to use common icons already available. I would highly recommend more small assignments similar to this for reinforcing aspects of the lecture material presented and help the students be better prepared for the project.

Another recommendation would be to perform more in-class evaluations of existing websites and applications, so that the students can improve their ability to evaluate good and bad websites and applications and identify what makes some better than others. This proves to be a challenge for most students to learn to evaluate and critique existing work.

B. Future Work

Future work associated with this approach is to continue to develop relationships with other industry partners and to offer new and exciting projects for the students. This also improves economic development in our state with these types of projects. I have found that many industries have needs that they are not able to meet with their own resources.

This offers them the advantage of meeting their needs at low to no cost to the company and provides an invaluable learning and work experience for students. The more industry connections and relationships that can be developed the better it will be for students and for the courses. At Mississippi State University, this approach has been favorably received not just in the Human-Computer Interaction and Advanced Human-Computer Interaction classes, but also in other areas such as Industrial and Systems Engineering. For this to be successful it requires faculty to be willing to reach out to companies and develop the relationships that allow these types of learning opportunities to be successful.

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Project and Team Based Teaching of System Programming in the Course of Operating Systems

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Abstract—**Higher education in Slovakia faces a number of problems. In this paper, we focus on one of them - an outdated way of practical teaching of computer science students, because of which the students do not understand enough the acquired knowledge and they often fail to apply this acquired theoretical knowledge in practice.**

This article represents the description of our experience with the experiment in which we have introduced modern teaching methods of project and team learning into the Operating Systems course taught at the Technical University in Košice. After the experiment, the results of the students were collected and compared with the results of other students who did not participate in the experiment. These comparisons, along with the feedback from participating students, represent real data that enables the authors to evaluate the relevance of applied innovative teaching methods. We believe, that our solutions can serve as an inspiration for other people in academic circles encountering similar problems as we do.

I. INTRODUCTION

We consider the massification [1], [2] to be the most important problem of universities in Slovakia. The term massification refers to an increase in the number of university students, university graduates and number of private and state colleges. The number of college academics with a high academic degree does not grow linearly with the growing number of students, so colleges feel deficiencies of sufficiently funded people in teaching positions. The lack of knowledgeable staff in connection with the ever-increasing number of students is a great inconvenience. An equally serious, if not a more serious problem is the lack of quality in addition to the enormous quantity of students. The mass of students studying at universities is not always internally motivated to get higher education, and they participate in studies without the willingness to systematically learn.

An unfavorable trend in recent years is that the highest-quality Slovak secondary school students participating in international competitions and projects usually do not decide to continue their studies at Slovak universities. Most often, they are tempted to study in the Czech Republic, but they are also interested in the United Kingdom, Denmark, Austria, Germany, Norway, etc. They often consider studying in Slovakia as a bad choice for their future. They are partly right - in the current composition of colleges at universities (almost 50% of social sciences), there is a risk of low employment of graduates in the labor market. The poor quality of students sometimes causes the difficulty of curriculums to adapt to the average, which is the direction that the school should not decide to take. At the same time, it is another reason why the most talented students do not decide for studies in Slovakia.

It is important to look for modern and innovative ways [3], [4] for students to effectively teach even the most demanding substance, even with regards to massification. At the same time, it is advisable to prepare them for real practice, which is expected from them in future employment - students must be able to use the acquired knowledge in practice and they need to be able to work in working groups solving problems. The Operating Systems course has long been trying to adapt to changing trends, while maintaining the above-standard usability, quality and difficulty of the substance being taught. We use a number of procedures (see chapter IV). This article focuses on an experiment in which we have enriched the teaching process with team and project learning opportunities.

II. PROJECT-BASED LEARNING

Scientific and technological advances at the turn of the 19th and 20th centuries pushed the society forward and gave, among other things, an incentive to innovative ideas to motivate pupils in their school activities in line with social events.

The role of students in the world is changing dynamically and evolving at a very rapid pace. The socio-economic factor is not the only role that plays a part in here, but also global education, thinking, innovative teaching methods that know that information is readily available, and crucially important is the critical work with them. Society moves and world thinking focuses on the individualisation of education, the tendencies of the differentiation of teaching are clear, and it is also a major topic of inclusive education at different levels. Therefore, the articulation of theory and practice within the framework of project teaching is further developed and has a well-established place in schools.

Project-based learning [5] is a pedagogical approach designed to inspire a deep, detailed level of learning using research-based or research-based methods that are supported by topics that are real, interesting, and important for students to learn. It is a complex teaching method that is based on the interconnection of practice (real situations) and theory (knowledge acquired in classical school teaching) in the targeted activity of the pupil on a particular project.

The time periods devoted to the project are meaningful, complementary, and always result in the final product (outcome), compared to conventional teaching, which takes place in isolated blocks that are often incoherent in many respects. Project lessons combine several teaching methods during their realization, and both individual and group work of the students, while actively developing the key competences of individuals. Project learning is not intended to study simple facts. For example: Students may have the task of monitoring water quality in a local river, based on which they get information about the environment of their surroundings and the issues that affect them.

III. TEAM-BASED LEARNING

Traditional teaching is based on the fact that each student acquires knowledge, solves tasks and performs practical exercises. Team (cooperative) learning [6] uses student collaboration to achieve the agreed goals. The fact that an individual achieves the goal only with the help of other members of the group not only makes the process of acquiring new knowledge more efficient but also develops personality and social knowledge Incorporating team learning into the learning process of students is a necessary step for the overall improvement of society.

The team teaching method does not only involve teams of students, but also their teachers. Therefore, the prerequisite for effective team teaching is the co-operation of several teachers working with students divided into groups. A team of teachers collectively plans and evaluates their teaching activity.

A well-functioning team of pedagogues is a prerequisite for the creation of organized student groups.

The co-operation of students in groups gives them more complex knowledge, improves their ability to cooperate, communicate, resolve conflicts and plan their work properly. Team learning is based on the principles of group interactions, their interdependence and equality, the personal responsibility of individuals, and the use of group knowledge. In order for this process to be successful, a teacher should be able:

- to select appropriate curriculum and assignments for individual groups,
- know how to guide student teams and set them goals,
- to review and agree on the procedures by which student teams advance in understanding the learning materials,
- to strengthen teamwork and also the teamwork between teams of students,
- to support the personal responsibility of group members, and always to take into account that teams are made up of individuals - an individual approach is also important in team teaching.

The number of groups and the number of students in each group is tailored to the demands of the learning curriculum and the capacity of the learning space. The optimal number of students in a group is 2 to 5. Working in pairs should not be frequent as full interdependence develops. If pairing is necessary, it is appropriate to change the pair of learners in the learning process or to create new, at least three-member groups in a more demanding learning phase.

The assessment of the students depends on the evaluation of the group, but it is also influenced by the contribution of individual students in the overall work result. The disadvantage of such an approach is that more assertive and strenuous students get to the forefront. An advantage (in addition to the obvious learning of effective collaboration) is the multiplication of student performance - weaker students learn from more skillful, more skilled learn to better understand the substance they are taking.

IV. OPERATING SYSTEMS

The Operations Systems (OS) course [7] is taught at the Technical University in the second semester of the bachelor study. It is compulsory for students of Informatics but it is optional for students of Economic Informatics. The lectures are provided by associate professor Ján Genči, the exercises are evenly distributed among the authors of this article. The aim of the lectures is to explain to the students the basic principles of OS, seminars on the contrary enable them to acquire practical skills in system programming. The experiment we want to describe is exclusively about OS seminars.

On seminars, students are taught to use the selected UNIX kernel service suite. It is not possible for students to present a complex set of kernel services (there are several hundreds of them), so exercises aim at understanding the possibilities of system programming and its use. Students have available literature - manual pages that contain documentation of all

kernel services if they want to work with a larger set of services than is necessary to successfully complete the exercise. Basic core services with which students work are described in the Sofia textbook [8] that we have created for the courses needs. Sofia contains not only the description of individual services, but also concrete examples of their use along with source codes. This support material is divided into smaller units in the form of PDF files that cover individual topics of system programming, gradually presented on exercises.

A. Organization of OS seminars

Students have one lecture (3x45 minutes) and one seminar (2x45 minutes) per week. Materials are divided into individual weeks, so each seminar is thematic. To achieve this, we use the LMS Moodle system [9], where students have a lot of study materials appropriately broken down into individual weeks. The exercises are organized as follows:

- 1st week: Introduction, structure and course conditions - students are given access to the LMS Moodle system, where 3 documents are presented, the content of which is explained in detail to students:
  - Syllabus of the course,
  - Instructions for seminars and conditions for granting credits,
  - Recommended course of study.
- 2nd - 5th week:: Work on assignments Copymaster and Scripting I , where the topics of the seminars are:
  - working with files,
  - working with directories and other file-handling services,
  - control of devices,
  - working with regular expressions.
- 6th week: Seminar exam I. - verifies the knowledge of students gained on seminars 2 - 5,
- 7th - 11th week: Work on assignments Processes and Scripting II, where the topics of the exercises are:
  - pipes and signals,
  - shared memory,
  - synchronisation and semaphores,
  - network communication,
  - scripting in bash.
- 12th week: Seminar exam II. - verifies the knowledge of the students gained on exercises 7 - 11,
- 13th week: Acceptance of assignments, correction of tests, granting of credits to students.

Each activity that students perform is rated. Students can earn up to 60 points for the OS exam, with a maximum of 40 points for the seminars. However, activities during the seminars are divided into 100 points, which means that the number of points earned by the students must be multiplied by a coefficient of 0.4 before closing the credit. The breakdown of points for activities undertaken by students the seminars is as follows:

- Seminar exam I. - 20 points,
- Seminar exam II. - 20 points,
- Copymaster assignment - 20 points (15 entry points + 5 points documentation),
- Scripting I and Scripting II assignments - together 15 points (without documentation),
- IPC assignment - 20 points (15 entry points + 5 points documentation),
- 5 points in the competence of the trainer (continuous checking, overall activity, ...).

In addition to these points, students can earn bonus points for voluntary activity outside the exercise. This step has ensured that students are motivated to devote time to learning during leisure time. Self-study of students is a prerequisite for successful completion of the subject by students. At the same time, the lecturers allowed to dedicate almost all the space of seminars to solve the problems encountered by the students, instead of only vaguely describing the curriculum. Bonus points can be earned by students for the following activities:

- continuous tests - 0.5 points for each preparatory test from weeks 1 to 4 carried out until the date of Assignment I and for each preparatory test from weeks 5 to 10) carried out by the term of Assignment II. Each test is evaluated by a scale of 0-100, a score above 70% rated as 0.5 points. Students can get a maximum of 4.5 points by running a continuous test,
- homeworks - up to 2 points, for each series of homeworks from weeks 2 to 4 submitted to the term of Seminar exam I and for each series of homeworks from weeks 5 to 10 handed over to the term of Seminar exam II. The number of points is proportional to the quantity and quality of the solved examples. Students can get up to 16 points by completing homework.

B. OS assignments

We attempted to apply the principles of team - project teaching to the assignments of the OS, which was ensured by the work of the students on several projects in several students teams.

The assignments do not have the same difficulty, the simplest is Scripting, the IPC is the most demanding. Therefore, we have appropriately spaced the seminars so that more time is devoted to difficult tasks. The difficulty of individual assignments also influenced the number of students in teams - for scripting students were working individually, for Copymaster in pairs, and for IPC in a team of three students. By this measure, we have avoided problems that would arise if students were working in the same groups for all the assignments. Working on projects in non-changing groups causes the students to be too reliant, and the failure of a part of the team causes the functioning parts of the team to experience problems throughout the OS course. On the contrary, alternating the composition and the number of team members allows skilled students who encounter non-cooperating colleagues in the development of a project to change and successfully get credits. At the same time, weaker students are motivated to work actively on projects because they can not rely on a

stable team of "friends" who will also make their share of assignment work. In order to maximize the elimination of non-working students who wish to "take advantage" their more skilled colleagues, the Scripting assignment was incorporated into the teaching process as a separate work of individuals.

1) Copymaster assignment: Students worked on the Copymaster assignment from the 2nd to the 5th week of the semester. The knowledge gained during the assignments was tested during the 6nd week on the Seminar Exam I. Copymaster is a project where students create a program that copies the content of the input file to the output file. It must have the following syntax:

copymaster [options] infile outfile

Students in the assignment also implement 17 options that modify the behavior of Copymaster. For example, the -ap append option adds the contents of the infile file to the end of the file outfile, - f (fast) is a "fast" copy when the entire contents of the infile file is copied to outffile, -s (slow) is "slow" copy, -t size (truncate) sets the size of the infile file to size ¡size¿ etc. Individual options can be combined, if semantics allow it. The functionality of the Copymaster options is designed to allow students to understand and use a large number of UNIX system kernel services to work with files and directories, thus to learn how to use the principles of system programming.

The work of students on the Copymaster project has been controlled. In order to be able to control their submission process, each week they submitted the newly created parts of the program to the git repository at git.kpi.fei.tuke.sk. The distributed git management system is suited for teamwork on projects, allowing each developer a local copy of the entire project development history. Even with more complicated projects and larger teams, there is no risk of overwriting unwanted files, it is always possible to find out who is the author of the individual files, find older versions of the developed application, and effectively merge the software developer's work into a comprehensive program. Each student team has set up its own git project in which the dates of student activity, the extent of their activities, and the authorship of each team member were clearly seen on the parts of the project. Teachers have access to student repositories, so they could track the work of all students, increasing the overall objectivity of the evaluation.

The final assignment was uploaded by the students to the automated system for evaluation. An e-mail was sent to students, that represented the report of the assignment. They could correct some bugs after reviewing their implementation shortcomings. The assignment was also handed in person, with the documentation provided. The documentation also had to contain percentage information on how the students themselves assess their share of work in the team. Based on the ongoing work of the students captured on the git, the automated evaluation of the assignment and the oral defense of each member of the team, the student was awarded a rating for the Copymaster assignment.

2) Scripting I and Scripting II assignments: The aim of the bash scripting assignment is to introduce students into basic text procesing toolchain available in Unix/Linux environment and basic Bash shell syntax.

The assignment is split into five exercises. The first three exercises - Scripting I assignment, focus on usage of grep (or egrep) utility, starting with basic commands requiring students to correctly use escape characters, then searching expressions with diacritics, and finally the third exercise requires students to design regular expressions matching patterns such as emails, time and date formats.

Scripting II assignment has two parts - the exercise four and five. The exercise four requires students to create pipelines of Unix/Linux utility calls ("oneliners") to filter, sort, change, and rearrange contents of text files. The task of the fifth exercise is to write more complex bash script. Students can hand in their work multiple times, and daily receive reports about correctness of their solutions. Each exercise (regular expression, oneliner, script) is processed using dataset provided by students and non-public dataset. In case of incorrect solution, student receives snippet of output data showing difference between reference and handed in solution.

3) IPC assignment: Inter process communication assignment introduces students into basic system calls for process management and inter-process communication. The goal of the assignment is to create application demonstrating various inter-process communication mechanisms provided in Unix-like operating system.

The application consists of nine concurrent processes where each process passes data to the process following in a communication chain. Executables for three of these processes are provided to students with description of communication interface, while each of these programs has to communicate with another through a program provided by the student.

The assignment is validated by executing student's application with non-public pseudorandom input dataset and comparing required and produced output of the last executable in the communication chain. Students can submit their solutions multiple times and review validation results through a web interface. The interface also provides download of standard and error outputs of executed student programs, which allows students to identify potential problems in their implementation.

V. EVALUATION

In 2015, students were working on the seminars of the Operating Systems course on two assignments, namely the IPC and the Scripting assignments, while the Scripting was completed by each student himself and three-member teams were working on the IPC. Operating system kernel services, such as file and directory handling services were not tested in any way. To solve the IPC assignment, it is necessary to be able to use the kernel services in addition to the other and we had the impression that the students did not understand enough this part of the course .

Another fact that we noticed during the 2015 lessons was that the work in one team demotivated some students because

they worked with non-cooperating colleagues. As a way to solve these problems and even more strikingly apply team and project learning, we've decided to include a new assignment Copymaster, on which they must work on with a new team. To illustrate our results, we chose to use graphs that were based on the analysis of the student's learning outcomes during 2015 and 2016. We analyzed the students' results in the Copymaster team assignment at Seminar Exam I and we also analyzed student success in the context of the entire credit period , respectively. seminars.

From the overall student achievement chart in 2015 (Picture 1), one can read the fact that the highest frequency of the obtained points was in the range 21-23, which represents the lower limit for successfuly complete the seminars. The number of students who earned 0 to 20 points during the seminars and those who earned 24 to 40 points was comparable. The overall success rate was therefore 53%. 47% of students who studied the subject in the academic year 2015 did not receive enough points to be able to attempt the Final Exam.

Fig. 1. Overall success of students 2015

From the overall student achievement chart in 2016 (Picture2), in which we incorporated the teamwork for the Copymaster project, is evident that the number of students gaining a score of 21-28 has increased considerably, thus reducing the number of students who gained insufficient points from the range of 0 to 20. We also consider the fact that in this year none of the students got the final 13 to 20 points. The overall student achievement during the semester was 81.61%, which represents a significant improvement in the study results.
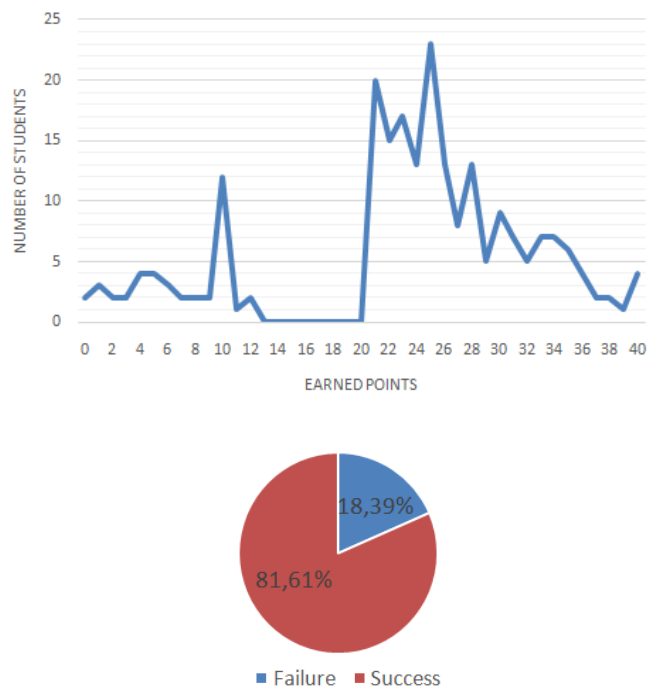
Fig. 2. Overall success of students 2016

In 2015 (Picture 3), a student could earn a maximum of 15 points for Seminar Exam I. From the graph representing the success of students in Seminar Exam I for 2015, the highest number of students earned a score of 7 to 11 points, which we consider to be a positive result. However, up to 17 students did not receive a single point for Seminar Exam I.
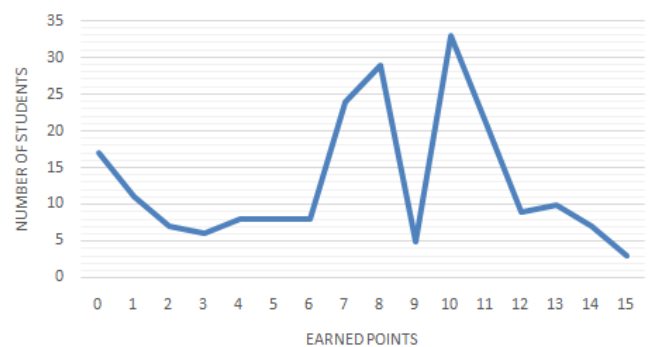
Fig. 3. Overall success of students in Seminar exam I. 2015

In 2016 (Picture 4), the student could earn a maximum of 20 points for the Seminar Exam I. From the chart representing student success in Seminar Exam I for 2015 it follows that the highest number of students has earned points ranging from 9 to 18 points. Students' results are comparatively better in this case than in 2015. Only three students have received 0 points for Seminar Exam I.

From the graph (Picture 5) representing the success of students who worked on the Copymaster project, we can
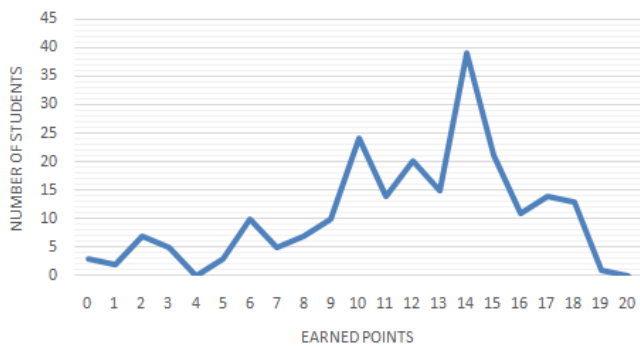
Fig. 4. Overall success of students in Seminar exam I. 2016

conclude that the highest number of students has reached points ranging from 9 to 18, which is a comparable result with the success of Seminar Exam I in 2016. The maximum achievable score for this work was 20 points. We assume that the positive result of the students in this work came up for the use of team and project work.

Fig. 5. Overall success of students in Copymaster

At the end of the semester, our team created a student questionnaire that we sent through the Internet to students who completed the Operating Systems course in 2016. The Graf Response to team work (Picture 6) represents the result of our poll among the students. The overwhelming majority of students expressed their positive opinion on this issue and were glad to have the experience of working in teams. For many students it was the first experience with this form of work. Only 12.5% of the students said they did not like the work in the team, respectively, they would prefer to work independently at the seminars on the course of Operating Systems.

VI. Conclusion

Teachers teaching the course of OS have been trying for many years to dynamically adapt to the ever-changing trends in teaching. This adaptation is not self-serving - an outdated university system in Slovakia produces a small number of real-time future employees. While teaching the students, we try to
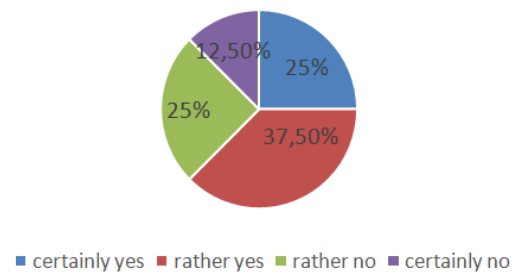
Fig. 6. Response to team work

preserve the high quality of the course being studied, focus on its application in the professional future of students, and at the same time eliminate the devastating consequences of the mastery of university studies as far as possible.

We consider it essential to motivate students to systematically study throughout the semester. After several attempts to implement various teaching methods in the education process to support students in systematic work, we observed their best results using team and project teaching. The use of the methods themselves was effective, but the really significant improvement in student results only occurred when we successfully combined project and team work. The OS students worked on more projects (2015 - 2 projects, 2016 - 3 projects) in several teams, with the composition of the teams not constant. This change does not seem to be significant at first glance, but in 2016 the subject successfully ended by 28.61% more students than in 2015.

The tremendous success we have recorded motivates us to continue our efforts to innovate ineffective traditional teaching methods. We continue to look for new opportunities to enable students to acquire real knowledge, working with them with productive dialogue. We adapt to their needs and demands because we believe that the student is the most important element in the learning chain. At the same time, we think that our experiments can be an interesting inspiration for other college educators.

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Applications for Interactive Whiteboards in Computer Science Courses

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Abstract—**One of the necessary parts of every classroom is blackboard. Many of the were replaced with interactive whiteboards in last years. They are often regarded as one of the most revolutionary instructional technologies. Provided software, which should help to discover the potential of the interactive blackboard, can be restrictive in many cases. This article presents easy way, how to create own interactive applications based on HTML5 technologies.**

I. INTRODUCTION

Involving some kind of interactivity in learning is not new idea. Teachers and lecturers do it all the time. They are still trying to find new ways, how to provide the knowledge to students in more attractive way to impress and motivate them. Not always they need to use the latest technologies or trends, sometimes it is sufficient, if they change the traditional way of lecturing and impress students with common activity, where they can present their opinion or creativity.

During the last years many schools in Slovak republic were equipped with many new IT tools. This was done through several projects handled by the *Ministry of education, science, research and sport of the Slovak republic*[1]. Those tools can help teachers and lecturers to make lectures much more attractive. Nevertheless the role of the student can be still in the form of passive observer.

One of the tool, which was supplied to the schools, is *interactive whiteboard*. Many researchers expressed about their benefits and attractiveness, such as [1], [2] and [3]. The name itself contains word *interactive*. This should mean, that the learning process will be enriched with the interactivity. Special software is usually bundled with the interactive whiteboard. This software should help the teachers in creation of interactive learning materials. When the software is used, the teacher and the learner can become active part of the learning process and they are able to tune it to their own needs.

The supplied software is limited in it's functionality. Only limited types of interactive activities and applications are provided. Those types are not suitable for every type of course, such as computer science courses, which have specific requirements. The applications, such as "fill the correct word to the sentence" are just not very useful.

To find useful and inspirational examples of how to use interactive whiteboards in the computer science courses is not easy. Some examples can be found in [4] or in [5]. This article is focused on creation of own applications for interactive whiteboards, which are created with open source tools and technologies. The presented examples can be used as an inspirations of what different kind of applications can be created. The main inspiration for this contribution is course *CS50*[2], which represents the introductory programming course at *Harvard University*.

At the *Department of computers and informatics* at *Technical university of Košice*, we evolve the idea of usage of interactive whiteboards with interactive applications from 2014 in several computer science courses. In this article will be also summarized our best experiences and practices. The result applications and the experiments were published in the bachelor thesis [6] and published in the conference proceedings [7].

II. SUITABLE APPLICATIONS

Lets define some rules at the beginning, which must be followed by suitable applications for interactive whiteboard. Based on our experiences we identified two main rules:

1. the usage of keyboard in such application must be as low as possible, and
2. the application must be in some way interactive.

First rule describes the whiteboard as a tool, which can be used autonomously. If the presented application requires heavy usage of keyboard, there is something wrong in it's design, because instead of interaction with the whiteboard, there are plenty interactions with the keyboard of connected computer. The on-screen keyboard in this way is not solution (the idea of using interactive whiteboard as an integrated development environment or as a text processor is completely wrong). But there should exist some exceptions, when some small input is required by application.

The second rule is crucial. Interactivity means, that for some kind of input (touching the whiteboard), there must be provided some output (application reaction). There can be found also some anti-patterns for this rule, such as changing the slides of presentation by touching the board, or processing file operations by dragging and dropping them on the screen. You don't really need interactive whiteboard for this.

Interactive whiteboards are equipped with software, which provides some example applications. Many of them reminds puzzles, which can be found in magazines. This kind of applications works very well in elementary schools and can work also in some courses in high schools such as language courses. In following section will be introduced tools, which can be used for introductory programming courses.

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[1] https://www.minedu.sk/about-the-ministry/

[2] https://cs50.harvard.edu

III. SCRATCH, SNAP AND BLOCKLY

During the initial investigation, when we started to search for existing applications which are somehow related to interactive whiteboards and programming science, we found *Scratch* very soon. *Scratch3* is a free programming language and online community where you can create your own interactive stories, games, and animations. The programs are created with the graphical colored blocks, which reminds pieces of puzzle. These blocks are used as replacement for programming language keywords or statements. Each one of them represents specific statement. *Scratch* is representative of *visual programming languages*.

To create a program in *Scratch* means to connect these blocks together by dragging and dropping them, so they will create an algorithm. When the program is started, the blocks are interpreted and executed. Example of such program is on figure 1.
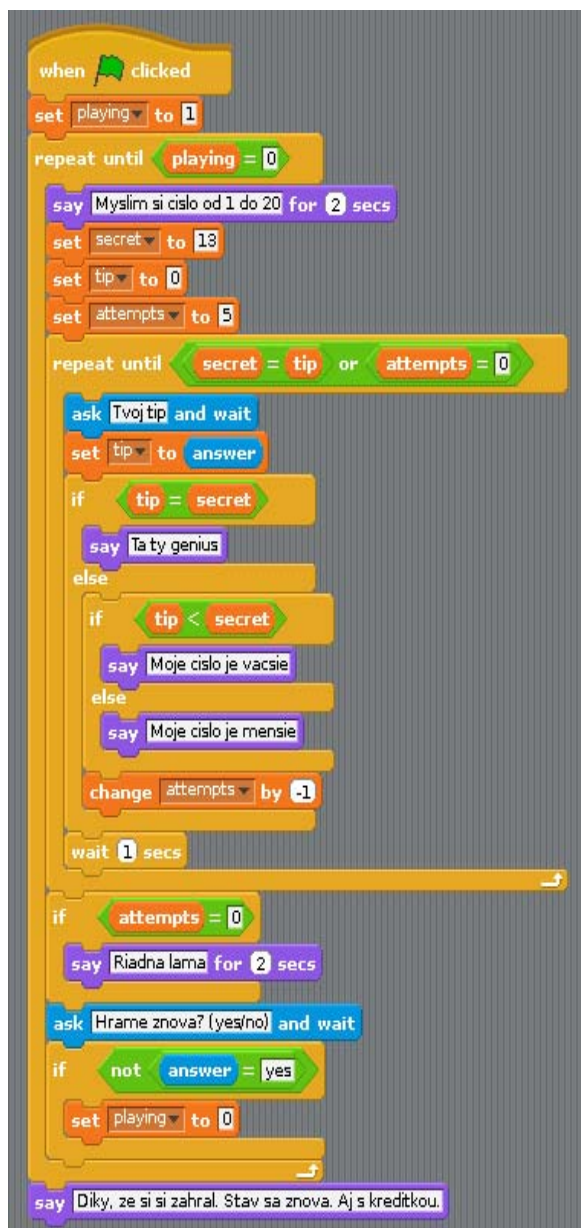
Figure 1.   Implementation of *Guess the number game* in *Scratch*

Scratch is originally intended for people in the age from 8 to 16 years, but because of it's features, it can be used by people of all ages.

If we confront *Scratch* against the rules defined in previous section, *Scratch* violates the first rule. The keyboard must be used when naming variables, assigning the values, defining expressions. But it is still less than in traditional programming languages, where every statement must be written.

Scratch is is also popular in Slovakia. It is used in many high schools and also in some universities as a tool in introductory programming courses. Several books related to *Scratch* were published in last years. Some of them are just translations, such as [8] and [9]. In last years we can also see many activities of the initiative *Learn2Code*[4], which organizes summer camps for kids, supports high schools in usage of this tool and published also own book.

Current version of *Scratch 2.0* requires the user to have Flash installed in his browser. The upcoming version 3.0 will be based on *HTML5* technologies, so it will be Flash free application.

There are already some alternatives to the *Flash* already, such as *Snap!*[5] and *Blockly*[6]. Both are build with *HTML5* technologies. But *Blockly* uses completely different approach than *Snap!* - it is library to create visual and interactive applications, which run in web browser. *Blockly* is heavily used for example in applications, which are provided by *Hour of Code*[7] to attract young coders. This library is great for creating applications for use with interactive whiteboard in web browser only.

There exists also another kind of tools, but the need for keyboard is much higher than in *Scratch*. Those tools involve tools for UML modeling, where you need to write the name of drawn entities, their attributes and relations and also tools such as *Node-RED*[8], which is another representative of visual programming languages or visual programming tools. It is labeled as *flow-based programming tool for IoT*, but in dependence on use, from time to time you have to write source code directly in *JavaScript*.

IV. SUITABLE TECHNOLOGIES FOR CREATING INTERACTIVE WHITEBOARD APPLICATIONS

Every lecturer, which provides some programming course, has different habits. Some of them brings their own laptop, where they have prepared their lecture with programming environment for live coding. It is hard to rely, that all necessary applications will be installed on the computer, from which the presentation will be provided. Some of them don't do live programming during the lecture – they just talk about it, so they only bring the presentation on USB key.

Before we select the appropriate technology for creating interactive whiteboard applications, based on the lecturer's stereotypes we can specify some selection criteria:

1. The selected technology should be **multiplatform**. It's common nowadays to work

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4   https://www.learn2code.sk/
5   http://snap.berkeley.edu/
6   https://developers.google.com/blockly/
7   https://hourofcode.com
8   https://nodered.org/

in different operating systems. So if lecturer uses OS Linux for preparation of his lectures, some of the tools will don't have to run on different platforms.

2. Applications should be implemented with the technology and language, which is **not closely tied with the platform**. This criterion is closely related with previous one, but it can be related also with specific part of operating system, such is file system.

3. The interactive applications should **not be desktop applications**. Such applications are closely tied with specific technology and application itself will contain plenty of accompanying code (e.g creation of the windows, handling of closing window, exiting application, …) The problem can be also maintenance of the application, when the version *X* of the used technology could not be backward compatible with the newer version or the version, which is used on presentation computer.

4. The **learning curve** of selected technologies **should be sharp** enough. We can suppose, that lecturers of programming courses are familiar with programming, not all of them are familiar with any technology or language.

If we start to apply these criteria to the today's languages and technologies, we can discard also the most popular languages such as *Java* or *.NET* platform. On the contrary, as a suitable technology that fulfills the stated criteria, appears *HTML5*. The only conditions, which must be met, when we want to run application written in *HTML5*, is to have web browser available with enabled *JavaScript*. Another advantage is, that for the development of such applications we need just text editor and web browser.

V. CREATING AN APPLICATIONS

The *JavaScript* as a language is quite raw. So we were looking for some extension, which will help us to develop interactive applications much faster and easier. Among the huge number of existing libraries we use *jQuery*[9].

To impress students, we started to use *HTML5* technologies also for lecture slides. There exists also plenty solutions, which can be used for presentations. For our purposes we use library *reveal.js*[10]. The advantage of such approach is, that the interactive applications become part of the slides. As a lecturer I don't need to run anything else, when I want to run interactive application – I just proceed to the specific slide, where the application is located.

In the following text will be introduced some of the created applications for interactive presentations. The applications will be categorized by the course, where they were used.

A. Courses Programming and Basics of algorithmization and programming

Course *Programming* was first, where we started to create applications for interactive whiteboards. At the beginning it was about implementation of applications

9   https://jquery.com
10   http://lab.hakim.se/reveal.js

from the mentioned course *CS50* as an inspiration and choosing the right technologies.

First applications were illustrations of the searching algorithm. In general the application is presented as a game. One student will come to the whiteboard, where several cards are located and his/her task is to find number 7. In first case there are no more information provided, but in the second case, the student knows, the numbers are in sorted order. So he can start searching by the method of splitting the interval.

From that time we were looking for other possibilities in this course. So when we are talking about time
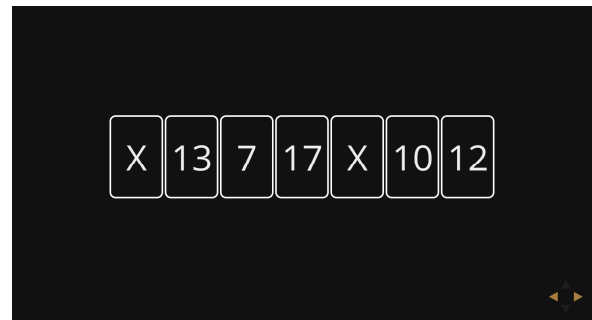
Figure 2.   Example application - Find number 7

representation, we have a slide, which content can be used in the source code directly. The slide represents time and date structure, which contains current data updated every second. Or when we talk about overflow issue, we have application, which acts as a car odometer to illustrate the situation.

These two mentioned applications are not interactive at all, but they act more like an animations. This is example of another usage of *HTML5* technologies.

Another type of application is used during the lecture about *Regular expressions*. For this purpose we created own application, which can be used during the lectures to validate the written regular expression against the input text.

This type of application violates the rule about the use of keyboard. During the lecture is this application used only by lecturer, so he stays with the presentation and don't need to switch to any other browser window or any other tool, where he can test the regular expression.
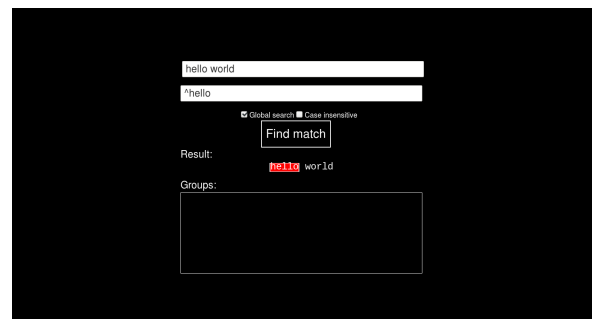
Figure 3.   Example application – Regular expressions validator

One of the inspiration was also to use directly one of the programming games by *Hour of Code* in our introductory programming course. As you can see in

figure 4, the environment is very similar to the *Scratch*. The application is also built with *HTML5* technologies. The activity itself was fun – we invite two students to help us to solve two levels of the game by "writing" the algorithm. It motivates us to create our own *HTML5* implementation of *Karel the Robot*, which we use a lot in the early classes of our introductory programming course.
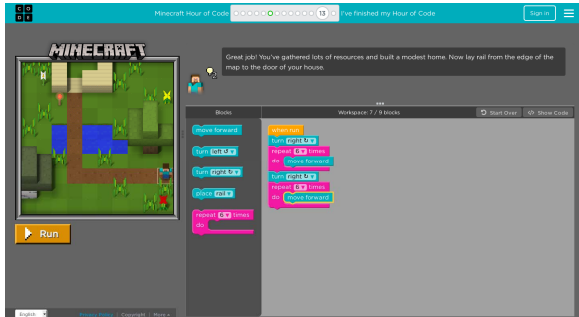
Figure 4.   Hour of Code - Minecraft

B.   Course Application development for smart devices

Focus of this course is to development of *Android* applications. But the usage of interactive whiteboard is in showing the prototypes of applications going to be developed. Instead of hard descriptions it is easy to show their (almost) fully working *HTML5* implementations directly in the lecture slides.

First type of application is implementation of simple *Torch*. Application contains one button and one image button and when user clicks to one of them, the label of the button changes and image changes also. In the real application also the flash light will start to shine. The prototype of *Torch* application is located on figure 5.
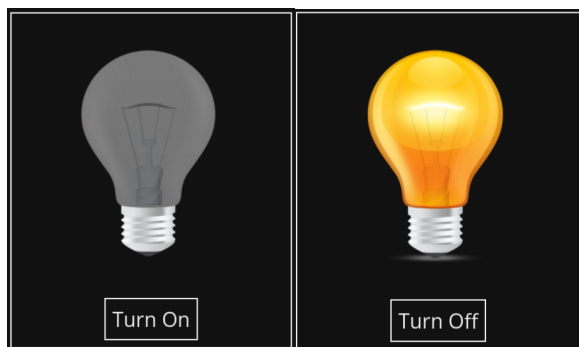
Figure 5.   Example application – Turned off and Turned on Torch

Another application, which was developed during the course is *Mr. Il'ko*. This application is simple weather
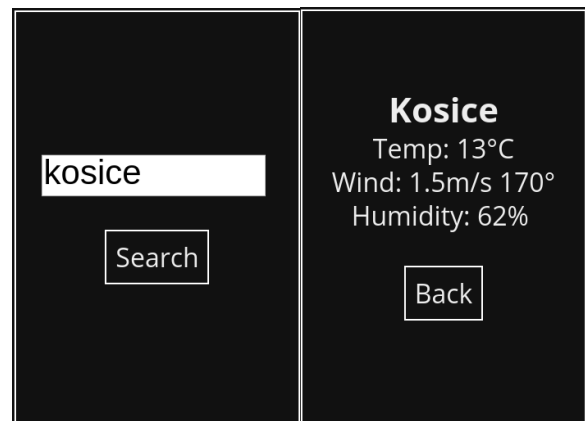
Figure 6.   Example application – Weather forecast with Mr. Il'ko

forecast application, which uses the real data from the server openweathermap.org. When user wants to know current weather forecast, he enters the city, application contacts the remote site and renders the returned data.

This type of application demonstrates the benefit of used technologies. To obtain the information about current weather forecast, application needs to contact the external service over HTTP protocol. Because JavaScript is the language of HTML5, it has built in support for synchronous and asynchronous communication over HTTP protocol. Screenshot of this application is on figure 6.

This type of application also violates the rule about the use of keyboard. To avoid this issue, default text (city) can be entered during application development.

C.   Game development

Last example is course dedicated to design of computer games. During the first lecture a lecturer tried to play a game with student. For the game they need to use a dice. So simple application which represents the dice was created. The screenshot of this application is locate on figure 7.

Figure 7.   Example application – Dice

VI.   DIFFERENT TYPES OF APPLICATIONS

As was presented in the previous section, there can be created several types of applications. Their goal remains same – to provide knowledge in more attractive way and interesting way. Based on the given examples , we can divide them into several categories:

1. **animations** – The application does not provide any interactivity at all, but it is used as illustration for better explanation of the problem.

2. **games** – Usually the student is invited to use the application. Application contains some winning condition and student has to play the game to accomplish it.

3. **application prototypes** – Used as example of application going to be developed during the lecture or case study.

4. **tools** – This kind of applications have specific purpose and can be used as standalone applications.

VII.   CONCLUSION AND FUTURE WORK

Creating an applications with the *HTML5* technologies for the interactive whiteboard is very easy. There exists plenty of tutorials and books related to these technologies, because they are common mainly in web development.

Lectures, where these applications were used and where we invite some of the students to come and play, were always much more fun than traditional lectures. We provided a questionnaire to the students, where they presented their opinion [x]. Also many of our colleagues were interested, when we presented some of the applications to them.

The created applications are not very large, when measuring number of lines of source code. Another benefit is, they don't need to be necessary part of the presentation. It is possible to link the presentation to the application, which is located somewhere on the internet. With such approach it is easy to ensure maintenance of applications, so the presentation will always contain the latest version of the application without any manual updating. With this in mind it is very easy to create a "gallery" of applications suitable for whiteboards such as *TeXample.net[11]*.

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[11]   http://www.texample.net

In general, the interactive whiteboard is just a tool. And it is up to the lecturer, which way it will be used. He can have an interactive whiteboard available in the class and all of the interactive applications too, but the lecture can be still boring. And on the other side, the lecture should not contain any computers at all, and it can be attractive, interesting and creative such as *Walter Lewin* is able to do. The purpose of this article was to provide inspirations and ides, how easy it is to attract students during the lectures with own applications for interactive whiteboards.

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Analysis of Factors Influencing the Motivation of Generations Y and Z to Perform in the Educational Process

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Abstract - **The main objective of the article is to identify and analyse the dominant factors influencing the motivation to perform during a university study in Y and Z generation groups. The selected research sample were the first-year students of the first grade of their study (Bc.) who represented the generation Z and the first-year students of the second grade of study (Eng.) who represented the generation Y. Several factors have been identified in the pre-survey that affects motivation to performance during the learning process within the two generational groups. In the research process, there were used three psychodiagnostic standardized questionnaires (NEO Questionnaire, respectively two of the five items: conscientiousness and neuroticism, Motivation of Performance from D-M-V Questionnaire and the HO-PO-MO Questionnaire, namely its part Motivation to Performance – MO). The NEO questionnaire shows that neuroticism and the scale of performance braking from the D-M-V Questionnaire is much higher for the first-year students (Generation Group Z) than for fourth-year students (Generation Group Y). In overall, Y and Z generating groups have poorer results at a high score of neuroticism and, on the contrary, too low values at high scores for conscientiousness.**

Key words - **personality characteristics of the student, Y and Z generation, motivation to performance, motivation factors, educational process, statistical analysis**

I. INTRODUCTION

Nowadays, it is very important to explore motivation, not only in the workplace but also in the educational sphere. To create motivational programmes is a difficult and expensive process for any type of the organization [17]. The term motivation represents a hidden activity of inner driving force in the human psyche for the action. The inner stimulus is the motive, which can be defined as "a rational impulse that make the human behaviour psychologically meaningful; therefore, it is the purpose of a human behaviour" [13]. Motivation has a dominant position in the educational process in educational establishments. As the authors declare, they consider the student motivation as an important factor to ensure effective learning. The basic classification of motivation is: "Motivation resources and problems determine students' internal, external, and negative motivation" [17]. The internal motivation means the situation that the student learns because he or she is interested in a topic, issue, and other activities. The student actively and independently works without paying pledges or guarantees praise or under threat of penalty. External motivation is connected with students who learn primarily because they want do get some external reward or in order to avoid punishment for failure to perform the task [5].

From the interviews with teachers coming from elementary or secondary school, as well as college and university, the authors of the paper can sum up that the students are not interested in learning and their performance motivation, but mainly the learning outcomes are getting worse. Similarly, the results of the National Institute of Certified Measurements of Education have shown worsening results in various standardized tests within the Y and Z generation groups [10].

A. Definition of key concepts

Personality is the overall organization of mental life. It encompasses all of the individual mental functions: perception as a mental process does not exist in itself, but there is an individual (the person) who perceives. Also there is no thinking, attention, will, or feeling and emotion on its own. Personality is an integrated summary of the inner features and traits of a person through which all external influences are broken. It is also a set of features that characterize the individuality of each person. Personality is primarily composed of the character, temperament, qualities and abilities of the personality [2]. The individual (from the Latin individual = indivisible, indissoluble) is understood as the whole organism and the unity of all biological, psychological, physiological and social conditioned psychological properties [4].

Rehakova (2006) states that there are four generations in the working environment and each of them is something specific. The author further explains why children today are different than they were twenty

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years ago. „*Generational groups share cultural, political and economic experiences and have a similar view of the world and values. These facts are the reason why today's children are different than children twenty years ago and young adults are currently entering a work process different than those over twenty years ago*" [12]. Rehakova (2006) identifies five types of generational groups: veterans, post-war generation, generation X, generation Y and generation Z. Generation groups are accustomly divided by the period in which their members were born: the veterans (born between 1939 and 1947), the post-war generation, the so-called baby boomers (1948-1963), generation X (1964-1978), generation Y (1978-1991) and generation Z (1992-2010). „*Every generation has grown in different periods, have different values and communicate in a different style. However, it is possible that they should proceed without conflicts* [12]. *Veterans and the baby boomers often think that any type of work for society is beneficial and therefore they do everything their supervisor tells them. On the contrary, Generation X and the Millennium strive to find a greater balance between work and lifestyle. Therefore, the older generation thinks of the younger, they are unfair to the company and do not have a strong work ethic*" [12].

Motivation is the space between the requirements imposed by the school on the student and the prerequisites for mastering the requirements that the student has [9]. Motivation affects the performance of students in schools and institutional facilities. Lack of motivation for learning causes students to fail to meet school requirements and vice versa. High motivation can help overcome deficiencies in certain individual assumptions and abilities of students. Similar or identical motives can cause different behaviour. Each kind of motivation raises different human behaviours which have different consequences. With the same assumptions (abilities) of the students it is possible to achieve different results just thanks to motivation. For this reason, motivation has a dominant position in the educational process [7]. According to the Kačániova's classification (1992) there can be three basic groups of needs identified in the school environment: (1) cognitive needs; (2) social needs and (3) performance needs.

Cognitive needs can be characterized as needs that contribute to the development of an individual by compelling him or her to achieve ever higher and higher level of knowledge. From the pedagogical and psychological point of view, the need for knowledge involves the process of new knowledge and experience acquiring, their development searching information and solving problems [7].

Social needs arise in the direct interaction of the student and his/her surroundings, such as family, school, friends, out-of-school environment and others. In connection with the learning process, the social needs include: the need of positive relationships (affiliation), having specific social role, group position,

prestige and recognition of team or society. In the school environment social needs are developed through rewards and punishments [6].

To **performance needs**, primarily is assigned the individual's effort to push himself, his "SELF". Through performance needs, the need for autonomy and competence (the need "to understand something", to be someone who "knows something") is being formed. In general, it is possible to state that it is the motivational tendency to "achieve success" [6, 7]. One of the primary tasks of the pedagogue is to develop performance needs in accordance with the student's skills and abilities [7].

II. METHODS

The following part of the article contains the definition of a research problem, the description of the pre-survey and its results, the research objectives, the research questions and the hypotheses. However, the methods of data collection are specified together with evaluation methods.

A. Research issue

In the last three decades, there has been a complex problem with declining the students' motivation and the associated worsening of academic results. This problem concerns primary schools, secondary schools but mainly colleges and universities. Many pedagogues, especially those who have been teaching for longer time period, have been experiencing worsening of academic results and declining of students' motivation for study. The National Institute of Certified Measurement Education (NUCEM) annually performs inter-national standardized tests where the Slovak students achieve significantly lower scores than other participating countries. According to the school psychologists, the main reason for described state is the constantly declining motivation to study.

B. Pre-research of motivational factors affecting students

The first step of the pre-research was to summarize the factors that can influence the motivation of students and their academic results in the tests. Based on [7] and her theory of needs influencing the motivation in the educational process, the authors summarized 17 factors, which students had to mark based on the five-steps Likert scale, from totally disagreeing to wholly agreeing. Prior to the distribution, the reliability of the data collection tool was determined, which has reached the **Cronbach coefficient $\alpha = 0.732$**. This level of coefficient is sufficient for the scientific purposes. The selected group of students was from the study branches Industrial Management and Personnel Work in Industrial Enterprise in the second year of the 1st grade (Bc.) form of study. The students received the questionnaires during the exercises from the subject Personnel Management. Together, 40 questionnaires were distributed, of which 39 were returned. Overall, the authors of the paper can state that the distributed

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questionnaire return was 97.50 %. The collected questionnaires were evaluated on the basis of the abundance of responses of the surveyed students. Based on the evaluation of collected data, the authors of the paper have identified six influencing factors that affect students. These factors are: (1) ongoing student assessment, (number of transferred points), (2) exam time (day of the week, morning hours, afternoon hours, evening hours), (3) form of exam (test, open questions, examples, oral answer), (4) the conduction of exercises during the semester (the approach and expertise of the pedagogue), (5) the atmosphere on the exam (relaxed, tense), (6) the clarity and availability of the study materials (lectures in AIS, scripts).

C. Objectives of research, research questions and hypotheses

The primary objective of the research is to identify and analyse the motivational factors and personality characteristics of the generation group Y and Z. To achieve the main goal of the study, it was necessary to implement a number of partial objectives, namely: designing a pre-survey questionnaire and its subsequent distribution; identification of personality variables affecting the motivation of generational groups Y and Z; statistical evaluation of formulated research questions and the research hypotheses and interpreting the current state on the basis of the data obtained.

The research questions were formulated and conditions on the research objectives of the article. Based on established research questions, the authors formulated research hypotheses that were verified by means of a questionnaire survey and via subsequent statistical evaluation.

1. Research question: What score do survey respondents achieve within the selected characteristics of BIG FIVE model in NEO questionnaire? Are there any statistically significant differences between the personality characteristics measured by the NEO questionnaire in the generation group Y and the generation group Z?

2. Research question: What score do survey respondents achieve within each item of D-M-V questionnaire of Motivation to Performance?

3. Research question: What score are the survey respondents achieving within Motivational Resources - MO from a comprehensive HO-PO-MO questionnaire?

H1: There is a statistical relationship between high scores measured in MV - Motivation to Performance from the D-M-V questionnaire and a composite score of all statements - factors that may affect students' performances.

H2: There is a statistically significant relationship between the values measured by the MV - Motivation to Performance scale from the D-M-V questionnaire and the values measured by the Consciousness item from the NEO questionnaire.

H3: There is a statistically significant relationship between the values measured by the AB scale - Anxiety that Inhibits the Performance from the D-M-V questionnaire and the values measured by Neuroticism item from the NEO questionnaire.

D. Research file and data collection tools

The research sample was the students of the Slovak University of Technology in Bratislava, namely the Faculty of Materials Science and Technology in Trnava. For a higher sample representatively in terms of the selection framework, the authors of the article decided to include the students of the first year of the first grade (Bc.) form of study (generation group Z) and the students of the first year of second grade (MSc.) form of study (generation group Y).

The research sample of respondents was selected based on unlikely quota selection. In total, 100 questionnaires were distributed, of which 96 have returned, but only 93 questionnaires were filled in correctly. The quota selection was to ensure the same or similar distribution of one indicator in the group. This indicator was the number of students of the first year in the first grade (Bc.) form of study (generation group Z) and the first year in the second grade (MSc.) form of study (generation group Y), where 50 and 50 questionnaires were distributed into each generation group.

In the research process, the authors of the paper have used three research tools (psychodiagnostic standardized questionnaires):

NEO Questionnaire - a five-factor personal questionnaire, respectively two of the five items (conscientiousness and neuroticism), Questionnaire Motivation of Performance D-M-V (all of its items) and the HO-PO-MO Questionnaire, namely its part Motivation to Performance – MO. In addition, the factors mentioned in the pre-survey questionnaire of factors influencing the student motivation during exams, plus general questions that were built up and that are necessary to meet the research goals set up.

III. RESULTS OF THE RESEARCH

In the following section, the authors of the paper focus on the overall evaluation of the collected data. The first part deals with the evaluation of the individual research questions and in the second part the authors evaluate the individual research hypotheses. The results of the research were compiled by the statistical program SPSS (Statistical Package for Social Sciences) and MS Excel. There, were it was necessary, the authors of the article used the parametric and nonparametric statistical tests to determine the relevant conclusions that gave a picture of the motivation and personality characteristics of the generation groups Y and Z.

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A. Evaluation of the research questions

Evaluation of the 1st research question: The first research question consists of two parts. The first part of the question seeks a response to the composition of the frequencies of respondents who were ranked in three groups according to the achieved score (high, middle and low) in the selected personality characteristics of the NEO questionnaire (neuroticism and conscience). Analytical results can be seen in Fig. 1: Absolute frequency of results in the NEO questionnaire.
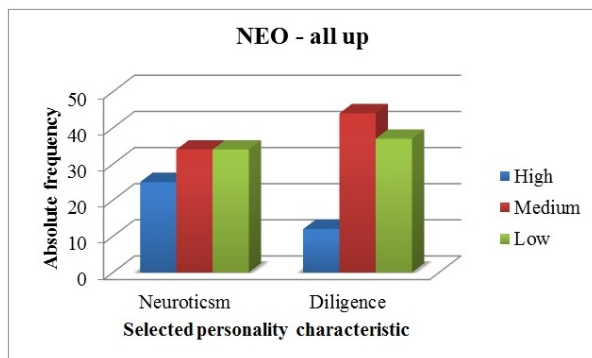
Figure 1. NEO Questionnaire - Score Achieved

In Fig. 1, it is possible to see the frequencies of the gross score obtained for the first graders (Generation Group Z) and fourth graders (Generation Group Y) together in selected personality characteristics from the NEO questionnaire. In neuroticism, it was found that the high score reached 27 % of respondents, with a medium score of 37 % and a low score of 36 % of respondents. With diligence, the students in each category achieved a value of 13 % low score, 47 % medium score and 40 % high score. Here it is evident that the students have a great disparity between high and low scores in personality characteristics. Low diligence indicates that generational groups Y and Z are not entirely consistent in fulfilling their duties in the educational process.

The second part of the first research question asks whether there are statistically significant differences in the measured values of the selected personality characteristics of the NEO questionnaire between the students of the generation group Z and the generation group Y. Thus, in the exploration of the first research question, the authors of the paper approach the parametric Student t-test for independent choices. The result of the t-test shows a statistically significant difference between the group of first graders and fourth graders in the subgroup of neuroticism ($t = 2.708$, sig = 0.008). The value of the practical significance estimated by Cohen's d parameter is d = 0.578 can be considered as the mean measure of the effect [15]. For the diligence subscale, a significant difference between groups was not shown ($t = -0.795$; sig = 0.429). On the basis of a complementary analysis in MS Excel, it is possible to declare that the first graders (generation group Z) show much higher values in the high score

scale for the item neuroticism, unlike the group of fourth graders (generation group Y). In Tab. 1: Students' t-test finding differences between first and fourth graders, it is evident that the values show statistically significant differences between groups of respondents.

TABLE I.
STUDENTS T-TEST DIFFERENCES BETWEEN NEO
QUESTIONNAIRE

Selected personality characteristics		Levente's test for scattering equality		Students' t-test		
		F	Sig.	t	df	Sig. 2
NEO - neuroticsm	The same deviations are assumed	4.081	0.046	2.687	91	0.009
	The same differences are not assumed	-	-	2.708	88.248	0.008
NEO - diligence	The same deviations are assumed	0.001	0.977	-0.795	91	0.429
	The same differences are not assumed	-	-	-0.796	90.896	0.428

Evaluation of the 2nd research question: The second research expects a response to the composition of the respondents amount who were placed in three groups according to the score (high, medium and low) in the D-M-V questionnaire. The analysis results can be seen in Fig. 2: The Absolute Frequency of the D-M-V Questionnaire and it shows the total number of the respondents according to the assigned score.
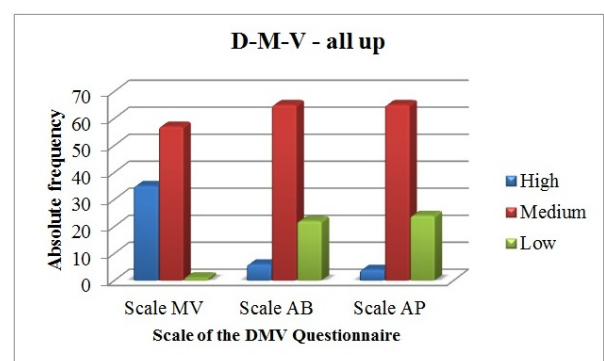
Figure 2. D-M-V Questionnaire - Score Achieved

In the Fig. 2, is the frequency according to the scores of the first and fourth graders (Z and Y generation) together in all the D-M-V scales of the questionnaire. In the MV scale - performance motivation, the results showed that a high score was achieved by 38 % of the respondents, a medium score achieved 61 % of respondents, and a low score achieved 1 % of the respondents. On the contrary, there are almost 40 % of students with high performance motivation values. The following values were recorded for AB - performance-slowing anxiety: a high score of 6 % of respondents, a medium score of 70 % of respondents and a low score of 24 % of respondents. The authors of the paper evaluate the findings positively, as the students have very low values in risk high scores. The last scale is the AP scale and it is also called the performance-supporting anxiety scale. The following scores were

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measured: a high score of 4 %, a medium score of 70 %, and a low score of 26 % of the respondents.

Evaluation of the 3rd research question: The third research question looks for an answer to the composition of the number of respondents who were ranked in three groups according to the score obtained (high, medium and low) in each item of MO questionnaire from the HO-PO-MO file. The results of the analysis are expressed in the Tab. 2.

Table II.
ABSOLUTE FREQUENCY OF THE QUESTIONNAIRE

HO-PO-MO measured values fourth graders			
Scale / Score	High	Medium	Low
a) Interesting work	37	39	17
b) Joy from work results	15	60	18
c) Exciting situations	3	34	56
d) Free working regime	3	37	53
e) Amount of salary	25	40	28
f) Promotion possibility	2	46	45
g) competition in group	5	20	68
h) benefit to the company	2	40	51
i) recognition from colleagues	2	28	63
j) Recognition by the manager	8	51	34

The analysis proved that the most motivating means for first and fourth year students are: interesting work, joy from work results and the salary.

B. Evaluation of research hypotheses

For the evaluation of individual correlations, the authors of the paper have chosen the parametric statistical Pearson correlation test (r) and the nonparametric statistical Spearman correlation test (rs).

H1: The result of the Pearson Correlation Test proves that there is a statistically significant relationship between the measured high score on the MV scale - performance motivation and composite scores in all the statements - factors. This variable correlates at sig. = 0.005 with the Pearson correlation coefficient r = 0.446. Significance has reached the required level (sig. <0.05), so it is not possible to reject this hypothesis and confirm that there is a low relationship between the monitored variables.

H2: The result of the Pearson correlation test proves that there is a relationship between the MV scale - motivation to performance from the D-M-V questionnaire and the diligence item from the NEO questionnaire. The above variables correlate after eliminating AB - anxiety slowing performance, which was removed because it is a partial correlation at sig. = 0.001 with the Pearson correlation coefficient r = 0.594, so the authors of the paper accept this hypothesis and there is a very strong dependence between the variables examined.

H3: The result of the Pearson correlation test proves that there is a relationship between the AB - anxiety slowing performance from the D-M-V questionnaire

and the neuroticism item from the NEO questionnaire. These variables correlate at sig. = 0.001 with the Pearson correlation coefficient r = 0.644. Therefore, the authors of the paper do not reject the hypothesis and there is a very strong dependence between the measured values of the AB scale from the D-M-V questionnaire and the NEO neurotic questionnaire item.

IV. FINAL ASSESSMENT

Based on the pre-survey and its evaluation, the authors of the paper came to the conclusions necessary to compile the research questionnaire itself. The distribution of the research questionnaires to the groups of students was followed by the evaluation of all the questionnaires. The authors of the paper converted an output table with data from MS into the SPSS statistical program in which the data were evaluated on the basis of statistical theory and correctly selected statistical methods.

To determine the reliability of a pre-survey questionnaire, the Cronbach alpha coefficient was calculated and reached 0.732, indicating that the assembled factors can be used in further investigations. Of the 17 factors based on the three tasks done by 39 respondents, there were 6 factors selected: (1) Height / number transferred points - student assessment, (2) exam time (day of the week, morning hours, afternoon hours, evening hours), (3) the form of the exam (test, open questions, examples, oral exam), (4) the way of conducting exercises during the semester (pedagogue's approach and expertise), (5) the atmosphere on the test itself (relaxed, tensed), (6) clarity and availability of study materials (lectures in AiS, scripts).

In MS Excel, the authors of the paper have created the tables with aim to create frequency histograms of the respondent's responses. At the same time it was the answer to the first part of all three research questions.

As far as statistically significant differences in personality characteristics, the Student's t-test was done. From this is evident the result that in the neuroticism scale, the differences between the values measured in the first graders (Z group) and the fourth graders (Y generation) were statistically significant. Another point of analysis was the evaluation of research hypotheses. For this analysis was chosen either the parametric Pearson correlation test (r) or the nonparametric Spearman correlation test (rs) depending on the character distribution. The evaluation of the hypotheses brought the authors of the paper to a positive result, all the hypotheses were confirmed. Therefore, there exist statistically significant relationships between the selected variables.

One of the goals of the work was to bring a clear overview of the state of motivation from the point of view the generation group Y and Z. Based on the pre-research, it is possible to declare that before and during the test the students are influenced by a set of the following factors: (height / number of transferred points, exam time, exam type, the way exercises are led

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during the semester, atmosphere on the test itself, clarity and availability of study materials). From the NEO questionnaire, neuroticism and the scale of D-M-V questionnaire slowing performance are much higher for the first-year students (Generation Group Z) than for fourth-year students (Generation Group Y). Overall, it can be summarised that generation groups Y and Z have worse results with a high score of neuroticism and, on the contrary, too low values for a high score for diligence. Another finding is that the incentives that mostly affect the students are interesting work, joy of the work done and the salary. However, in near future it is worth to examine also motivational factors that will help to achieve better results in the whole educational process.

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Virtual Reality for Education and Workforce Training

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Abstract—The advent of inexpensive consumer virtual reality display technology has made new possibilities for delivering education and training in immersive and engaging ways widely available. In the past, technical challenges and prohibitive cost have impeded progress of virtual reality in education. Educational institutions and industries are now moving rapidly to adopt virtual reality as a key training tool. Virtual learning environments have been very successful in generating positive learning outcomes in a variety of domains. The powerful sense of presence and effective immersion created by virtual reality applications promise to provide on-site training in a safe and controlled environment. Virtual learning environments can provide trainees with access to cost-prohibitive equipment in impossible locations. It can provide a space for students to explore problem spaces and test solutions without risk. Despite these successes, questions remain regarding the capabilities and limitations of current technology, particularly regarding the effectiveness of knowledge and skill acquisition in virtual reality. The process for developing effective educational training virtual environments begins with understanding the learning objectives, re-creation of the real-world task(s), and assessing user performance and learning. Each stage of the process presents unique challenges and opportunities.

Keywords—Virtual Reality, Augmented Reality, Training Tool, Workforce Training

I. Introduction

Providing effective training for future workers can present significant challenges. Hands-on real-world training requires access to real equipment or physical mock-ups. If training occurs 'on the job', there is an increased risk of loss of productivity, damage to material, and injury. Training may be performed away from the actual job site and require dedicated space that may not accurately represent the actual worksite [1]. Real-world training requires logistical support to set up training sites and coordinate training times. Training may require teams of personnel dedicated to re-creating training scenarios (e.g., medical and first responder training [2], [3]). Low frequency events may be difficult or impossible to recreate in the real-world. For example, workers need training in how to respond to mechanical failures, fire or medical emergency, power outages, etc. These cases require specific responses that workers may only rarely have the opportunity to practice and, when it is possible, the training may be superficial in nature leading to possible errors in the event of an actual incident. Similarly, some training may only be available at specific times of the year. For example, workers may need training in how to handle snow and ice conditions. Many jobs require workers to operate in dangerous conditions (e.g., military, law enforcement, firefighting) that are difficult or impossible to recreate in the real-world. In some cases, it may actually be impossible to perform training. The work may involve work spaces or tasks that are still being designed or environments that cannot be recreated (e.g., space). Real-world training also may not provide support for adequate metrics. It may not be possible to objectively monitor worker performance, stress, and workload to determine when a worker is fully prepared to perform the work in the real-world.

Virtual reality may provide solutions to many of these challenges for training. Virtual reality has key strengths that help to address many of the issues identified and its application to education and training has been demonstrated in many domains.

II. Virtual Reality Applications

Virtual reality has been used to provide training for first responders [2] and has been investigated as a training tool for CBRN response training [3]. Virtual reality training systems have been developed for teaching aircraft cabin safety procedures [4] and for improving communication skills [5]. Virtual environments have been successfully used to provide individuals with spatial knowledge that transfers from the virtual environment to the real-world [6]. There are numerous industrial and medical virtual reality training applications (e.g., laparoscopic surgery [1], automotive manufacturing [7], working with robots [8], using CNC machines [9] [10], and tool use [11].

Some of the largest companies in the United States (e.g, Walmart [12]) are now adopting virtual reality as a training tool. As virtual reality is more broadly adopted for education and training, understanding the true strengths and weaknesses associated with the technology and properly designing and validating training tools is critical to ensuring the effectiveness of virtual reality training tools.

Fig. 1. Virtual Reality Head-mounted Displays: Oculus Rift, Samsung Gear VR, and HTC Vive

III. CAPABILITIES OF VIRTUAL REALITY

Virtual reality has a number of strengths that support its use as a training tool. First, virtual reality can be very accessible. Prior to the Oculus Rift and HTC Vive platforms, immersive head-mounted displays could be cost prohibitive. However, the current immersive virtual reality solutions are more affordable with many individuals owning a virtual reality ready mobile platform. Virtual reality training tools can also be designed to have limited or no physical prototypes [13] [14]. Of those that do have physical interfaces, it is possible to use a hybrid of physical and virtual objects [14] or combine non-immersive virtual reality with physical mock-ups of interfaces (e.g., [15]). With haptic-capable interfaces, an immersive environment can support complex interactions with no physical components [16]. Virtual reality training tools are also far easier to modify to train for variants of models (e.g., multi-model assembly) or for new versions of equipment [13]. Virtual reality training can also be used with limited supervision [9] allowing trainees to access training at their convenience without requiring a trainer to provide constant supervision.

Another key strength for virtual reality is the ability to create a strong sense of presence in the user. Users in immersive virtual reality can become fully engaged in the virtual environment so that they effectively forget about the real world and believe that they are present in the training environment where they can act as they do in the real world. For example, participants in our virtual reality studies will walk around a virtual table and, in fact, some will find it difficult to force themselves to walk through the space the table occupies. Also, participants in virtual reality have been observed setting their

controllers down on a virtual table and accidentally letting them fall to the ground in the real world. For a generation of technologically-minded students, virtual reality presents a new way to engage students in learning [17]. Virtual reality has been shown to result in higher levels of engagement in learning compared to traditional teaching methods [18].

The virtual environment can allow a user to explore and experiment with an environment that in the real world might be dangerous. Because the virtual environment and the resources in the environment are not real, the user can use materials in a way that might be wasteful in real world training. The virtual environment is also a safe environment. The user can learn through experience and perform actions that might be costly or embarrassing without concern [9].

While the costs of mistakes in virtual reality are low compared to the potential physical costs in the real world, it is much easier to provide objective measurements of performance, and immediate feedback on the results of performance, in virtual reality compared to the real world [11].

IV. ADVENT OF LOW-COST SOLUTIONS FOR VIRTUAL REALITY

Despite the potential and the significant amount of research investigating virtual reality applications for education and training, the technology has had limited use until recently. Modern consumer hardware and software has made low latency, high resolution, and low cost systems available not only to consumers focused on gaming but also to schools and corporate training teams. Virtual reality hardware platforms are now widely available in two general categories: tethered

PC or gaming console head-mounted displays and mobile smartphone-based head-mounted displays.

A. Consumer Head-Mounted Displays

The tethered PC and gaming console head-mounted displays are most similar to the immersive virtual reality displays familiar to researchers. Currently, there are four major efforts (Sony PlayStation VR, HTC Vive, Oculus Rift, Microsoft's Mixed Reality family of head-mounted displays) and several smaller efforts to bring head-mounted display virtual reality technology to the mass market. All of these efforts are similar. The head-mounted displays are directly connected to a PC and provide high resolution, high frame rate, attractive environments, and support for many options for interaction. Despite these advantages, these systems are less accessible than mobile virtual reality systems largely because they require significant computational power, are tethered to limited area, and are expensive.

B. Mobile Systems

The mobile virtual reality systems use an individual's smartphone to provide a display and the basic sensor suite for tracking head orientation. The head-mounted display is primarily a housing for the smartphone and a pair of lenses. The Samsung Gear VR (see Figure 1) and Google Daydream are more comfortable and more immersive solutions while inexpensive solutions such as the Google Cardboard promise to make virtual reality applications available to anyone with a smartphone. The benefits of a mobile platform are that they are wireless, portable, and the smartphones are ubiquitous. However, because they use smartphones as the computing platform, mobile solutions typically have less processing power, lower fidelity environments, and are limited by battery life. In addition, current mobile solutions have limited support for advanced modes of interaction.

Recently, hardware companies have announced standalone virtual reality headsets that promise to attempt to bridge the gap between tethered PC headsets and smartphone-based headsets [19]. It remains to be seen what advantages the standalone systems will have over smartphone solutions and whether the cost will be sufficiently low to make it an attractive option for education and training.

V. Building Virtual Reality Training Tools

Improvements in hardware and software have made virtual reality more broadly accessible. However, all virtual reality experiences are not equal and there remain challenges in building effective virtual training tools. The primary objective of a virtual reality training tool is to facilitate the transfer of knowledge and skill from the virtual environment to the real world. It is important to note that a related objective is to avoid transfer of inappropriate or incorrect knowledge or skills from the virtual environment. The secondary objective is to maximize presence and realism to the level necessary to support the primary objective.

The goal for the virtual environment is to create the workspace and the functions necessary to perform the task of interest in an interactive environment. [13] presents a general process: import CAD into virtual reality, program the interactions, add interfaces, and test to verify that the desired knowledge and skills successfully transfer. In addition to these steps, a training tool should begin with a careful examination of the task. This can be performed with a formal task analysis [14] or consultation with subject matter experts to determine the specifics of what must be re-created in the virtual environment.

Simulator sickness is a common issue with virtual reality. It is common to have drop out rates of 10% to 20% and we have observed drop out rates as high as 50% in older participant groups. See [14] for a thorough discussion of simulator sickness and strategies for mitigating the effects.

A. Identify Learning Objectives

In the following sections, application of the general development process will be applied to two virtual reality training tools. The goal is to provide brief examples of application and describe differences in how the tools will be developed based on the learning objectives and the details of the tasks of interest.

1) Industrial Workspace Training Tool: The goal for the workspace training tool is to expose new low-skilled workers to the fundamental knowledge and procedures necessary to perform the task. Virtual reality is a good candidate for the task because of difficulties associated with training: First, the work area is a critical work unit at the manufacturing facility and is rarely available solely for training activity. Second, when the work area is available, a combination of personal protective equipment requirements and limited space in the work area makes it very difficult for a trainer and a trainee to work together in the space. A virtual reality training tool will allow the trainee to learn the fundamental skills - what the basic function of the job is, how to wear the personal protective equipment, how to identify and use the tools - in a separate location until the trainee demonstrates basic knowledge as measured by the virtual reality training tool.

2) Tool Use and Safety Training Tool: The objective for the tool use and safety virtual environment is to provide low-skilled novice workers with a safe space to be exposed to and to experiment with a variety of tools. For each tool, the goal is to identify the tool, demonstrate proper use of the tool, identify recommended or required personal protective equipment to be worn when using the tool, and teach the trainee to identify wear and tear or damage to the tool that may make it unsafe to use. This task is a good candidate for virtual reality training because the virtual environment can provide access to dozens of tools in a limited space where it is safe to learn about the tools without risk of injury or embarrassment to the trainee.

B. Implementation: Environments and Behaviors

Every element of the training environment must be digitally created. Elements in the virtual learning environment can be

categorized into three types: contextual, fundamental, and interactive elements [14]. Contextual elements help to orient the user to the general idea of the scene. For example, in the tool use and safety training tool, the context could be a workshop or a garage. For the industrial workspace, our context is already defined explicitly by the task of interest. Fundamental elements provide the structural elements of a scene. In the workshop, tables, cabinets, lighting fixtures, etc. are fundamental parts of the scene but may not support interactions. The interactive elements are those parts of the scene that are the focus of the training and will either be directly or indirectly interacted with. In the tool use and safety training, this would include the tools and any work material (direct interaction) as well as storage areas and safety signage (indirect interaction) that make up the training experience. Figure 2 shows the contextual environment and some of the interactive tools in our tool use and safety training environment.

Generating the geometry and audio content for the virtual environment requires a significant portion of the time and cost associated with developing a virtual reality training tool. There are many methods for generating geometry for the training environment. In training environments, a popular method is to use CAD models of work spaces and tools when they are available [13]. CAD models are good-to-excellent representations of the real-world objects of interest. CAD models may not include surface texturing or coloring and often include technical details that may not be necessary for the virtual environment. Often CAD models will require modification when importing into the virtual environment.

When CAD models are not available, digital artists can create the geometry necessary to recreate the real world environment in the virtual environment. For common objects, models of objects can be easily acquired from online asset stores. It can be a challenge to create a consistent look-and-feel when using art purchased online. In our tool use and safety training environment, we use art assets from a single artist to help ensure consistency in the environment. For projects that will require specialized models, working with one or more

artists to generate the entire environment will help ensure that the quality of the art assets is consistent.

Photogrammetry is a technique that uses photographs to create a map, measurement, or, in our case, a 3D model of the object or environment. By taking multiple photographs with different views of the object of interest and establishing corresponding locations in the two images, it is possible to produce 3-dimensional coordinates for points of interest in the image. With sufficient photographs, a 3D model of the object can be created. There are commercially available photogrammetry software packages including RealityCapture [21], Agisoft Photoscan [22], and others. Some software packages support combination of laser scan data with photographs to improve the quality of the output [21]. While direct capture of objects and environments results in detailed and impressive virtual environments, the output often includes gaps and flaws in the representation that, given the high fidelity nature of the data, requires talented artists to refine for use in applications. In addition, direct capture can easily generate complex models with millions of vertices that present computational challenges, particularly for mobile VR development. In our industrial workspace training tool, we are using photgrammetry to create a very realistic representation of the work environment (see Figure 3).

In addition to the visual elements, audio elements also play a key role in establishing realism, supporting immersion, and creating a sense of presence in the virtual environment. As with visual elements, the realism of audio elements can range from abstract representations of sounds to realistic recreations using real-world recordings. The realism of the audio elements should match the realism of the visual elements.

Fig. 3. Screenshots of 3D model of industrial workspace generated using photogrammetry

C. Interaction and Feedback

Programming the behaviors that provide the interactivity with the environment is as critical as importing the geometry that makes up the scene. Interactions include basic physics, collision detections, interaction with simulated system interfaces, and user interfaces [13]. How the users interact with the environment will dictate what and how they can learn [6]. The specific goals of the training will dictate the types of interactions necessary to meet the required level of fidelity. In the tool use and safety training tool, it is critical that the users are able to pick up the tools, manipulate them, and, as much as possible, explore a full range of physical interactions

Fig. 2. Screenshot of workshop environment and models for tool use and safety training. Models from [20]

with the tools. In the industrial workspace training tool, the objective is to provide a general introduction to the task and interaction with the tools could be reduced to simplified point-and-click actions that would still allow the user to learn the tools and procedures related to the task without requiring complex physics modeling and haptic feedback support.

Interactions should be natural, easy to use, and easy to learn [13] [14] [9]. In addition to ensuring usability, the more sensory channels that are used to inform the user (balanced against the possibility of information overload) will improve learning in the environment [11]. Multi-sensory feedback will facilitate task performance and learning [14] [11] [13]. Visual feedback in both of our training environments will include visual aids (highlights, signs, and other augmented cues) that are expected to improve performance, usability, and training outcomes. Audio sensory information plays a significant role in both of our target tasks and the use of power tools.

Haptic feedback can allow users to 'feel' virtual objects in the virtual environment. This can include interaction with virtual objects that are recreations of real-world objects used in training as well as interaction with user interface objects. When interacting with virtual objects, haptic feedback helps to recreate the real-world sensations associated with touching and interacting with the object improving realism of the simulation [13]. Force feedback effects can be created through the use of vibrating motors, instrumented gloves, hybrid prototyping [14] [13] [11], and physical surfaces [14]. For example, in the tool use and safety environment, haptic feedback can provide sensory inputs that support user's ability to touch and manipulate the tools much as they would in the real world. Without haptic feedback, the user must rely on primarily visual cues for manipulating the tools.

D. Measuring User Performance and Experience

A common method for assessing user task performance is to measure the time required to complete the assigned task. The unit of measurement could be an individual action (possibly better characterized as a reaction or response time measurement) or a measurement for completion of a simple task or even a collection of tasks. In virtual reality, timing of task performance can often be easily implemented by logging all of the user's interactions with the virtual environment. In our virtual environments, we log controller inputs, controller and head position and orientation, interactions with objects including user interface elements. In addition, we record the position, orientation, and actions of other agents in the environment. For example, in our industrial workspace training tool, new materials arrive at the workspace from an external source. In our virtual environment, we create new materials and push them into the workspace to recreate a co-worker moving materials from their space into the trainee's workspace. We record the creation and all movements of the material as part of our data logging system. This allows us to later analyze actions of the trainee in response to the actions of objects outside of their direct control. In this particular instance, we use the arrival of new materials to create a time pressure on the trainee to complete their current assignment.

Another common metric for assessing a trainee's task performance is to evaluate their accuracy. In our industrial workspace training tool, accuracy is assessed based on the percentage of the material that was processed using the tools available to the trainee. Based on the task, we could evaluate the trainee's performance by evaluating the specific tools used for specific phases of the task and sections of the material. This kind of tracking of a trainee's performance both at the simplified and the detailed level would be very difficult to execute in the real-world.

In our tool use and safety training tool, accuracy is measured based on proper tool selection, proper personal protective equipment selection, inspection of the tool (recognizing or failing to recognize that a tool was damaged), and proper application of the tool to the problem. Proper application of the tool requires specific analyses for each task-tool combination and evaluates the position/orientation/movement of the tool relative to the task elements. Again, while many of our metrics are pass/fail in this tool, the virtual environment is able to continuously monitor every interaction the user has with the tools. The virtual reality tool does not require a trainer to spend one-on-one time with the trainee and the virtual reality tool never gets frustrated with the user.

Completion time and accuracy can be easily recorded in a virtual environment at a level of detail and objectivity that is very difficult to achieve in the real-world. The virtual reality tool supports exploration and experimentation while providing endlessly patient feedback based on real-time analysis of the data.

Subjective analysis of the virtual reality tool and the work task are also valuable tools in assessing the quality of the training and the difficulty of the work task. A virtual training tool should be assessed for usability and for user experience. For usability, a simple assessment using a questionnaire such as the System Usability Scale [23] can provide insight into how users perceive the usability of the training tool. The SUS is a 10-item Likert questionnaire that assesses user perception of system in terms of ease of use and ease of learning. For user experience, virtual reality has two key components. On the positive side is presence. The Presence Questionnaire [PQ] [24] includes 32 seven-point scale items and includes subscales related to sense of control, haptic and auditory aspects, and more. On the negative side is simulator sickness. In virtual reality applications, it is practically inevitable that some users will report feeling nauseous [14]. There are many factors that affect sickness in virtual reality and steps can be taken to try to minimize the effects on users. The Simulator Sickness Questionnaire (SSQ) provides a method for assessing the effects of simulator sickness on users and we regularly assess our users using the SSQ during studies using virtual reality [25].

Mental and physical workload may affect task performance, learning, and even sickness in virtual reality [11]. The NASA-TLX questionnaire assesses mental demand, physical demand,

temporal demand, performance, effort, and frustration [26]. The survey is completed after experiencing virtual training or participating in a study using virtual reality. The scores are used to assess user perception of workload.

Motivation and engagement influence effectiveness of learning [18]. [18] adapted a questionnaire for evaluation of motivation during virtual reality training including scales for immersion, control, challenge, purpose, and interest. This evaluation can provide insight into how a virtual training tool is engaging and motivating users and help to identify areas for improvement.

E. Validation

The overall objective of virtual reality training is to facilitate the transfer of knowledge and skill from the virtual reality to the real world. We will verify that the virtual reality training tools are accurate and effective in two ways: First, we will ask subject matter experts to review the virtual environment and the training content to determine the construct validity of the training [13]. Is the simulation accurate? Is the virtual environment exposing users to the knowledge and skills that the tool was intended for. Following expert review, we will expose novice trainees to the virtual environments, collect data on their performance, then transfer them to the real world task and compare real world performance to other trainees that receive only the traditional training.

VI. Conclusions

As a training tool, virtual reality is experiencing a period of explosive growth and development due, in part, to the advent of low-cost and easy to use immersive head-mounted displays and peripheral technology. The effectiveness of virtual reality training has been demonstrated in many different domains from surgical training to manufacturing and assembly. There is a growing body of research examining in detail the factors that influence the effectiveness of virtual reality training and identifying methods for building and evaluating virtual training tools. We have briefly reviewed some of the results of this research and described application to two candidate tasks for virtual reality training. We are leveraging the lessons learned and considering the specific context and objectives for each project. Our future efforts will be to complete the implementation of the virtual environments, validate the effectiveness of the results, and review and revise the design in an ongoing iterative process.

Acknowledgment

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Effective Collaborative Environment with Live Broadcasts using Slovak National Telepresence Infrastructure

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Abstract—This paper introduces deployment, operation and technological challenges of project named National telepresence infrastructure to support research, development and technology transfer in Slovakia (NTI), which was managed by Slovak Centre of Scientific and Technical Information. NTI is effective collaborative environment with not only videoconferencing ability but it dispone also live broadcast functions, recording to multimedia archive or automatic conference booking system. Overall infrastructure consists of core layouts, web platform and over two hundred collaborative endpoints, which will be described in solution design. After one and half year of pilot operation the NTI shows trends of usage among research, development and innovation institutions. The paper shows also examples of real usage of live broadcasts ability of NTI.

I. INTRODUCTION

As the predecessor of National Telepresence Infrastructure (NTI) project, the smaller network of videoconference systems was deployed [1][2]. With the experience in the field of sophisticated streaming technology [3] and web-based videoconferencing systems [4] the idea of interconnecting collaboration environment with live streaming components was born.

As part of the pilot operation of the NTI, it has been shown that access to efficient high-tech collaboration infrastructure is now a necessary for all successful scientific, research and innovation locations around the world. Such infrastructure can become key element to supporting science, research, innovation and technology transfer. At the same time, collaboration infrastructures are now perceived as a basic strategic not only for the education sector but also for the innovative industrial sector, which is interested in the corresponding integration with other platforms.

It is clear that for institutions active in the field of research and development, operative and effective access to the latest knowledge in the field, combined with cooperation with both domestic and international institutions, is one of the key factors of successful operation.

II. SOLUTION DESIGN

A. Collaborative Endpoints

Hardware endpoints of National Telepresence Infrastructure were deployed in various types of rooms, offices or lecture halls (Fig. 1). Depending of dimensions of installation room and expected amount of room participants there were considered 6 types of collaborative nodes: TP100+, TP100, TP20 TP10, TP06 and TP02 [5].
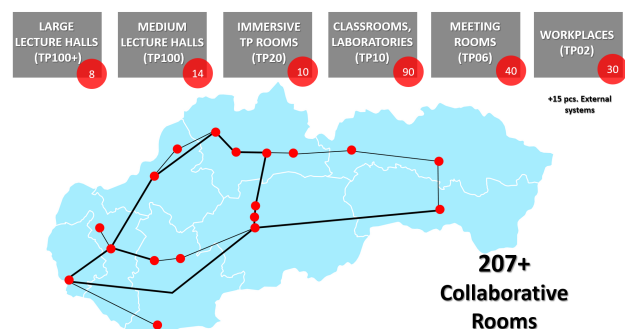
Figure 1.   Visualization of National Telepresence Infrastructure in Slovakia between EDU institutions

Large lecture halls (TP100+) at selected public universities were deployed by two videoconference system Cisco SX80 with 6 cameras. Overall solution designed for more than 100 participants in hall with 2 projectors, 4 LCD's, 5 speakers and 2 microphones is controlled by central room controller based on AMX.

Medium lecture halls (TP100) designed up to 100 participants at universities and research institutions were deployed by one videoconference system Cisco SX80 with 3 cameras. There is also AMX based central room controller, which controlling beside videoconferencing also projection, streaming and audio components.

Immersive Telepresence Rooms (TP20) were designed for up to 20 participants and consist of three 70-inch display device Cisco IX5200 with three auto-tracking cameras and two designated tables with integrated audio components.

Classrooms and laboratories for up to 10 participants (TP10) were deployed with Huawei RP200 collaboration codec with dual 55-inch screen, dual auto-tracking camera and dual microphone.

Smaller meeting rooms (TP06) for up to 6 people were deployed with single 60-inch display device Cisco MX300 with one camera and microphone.

There were also deployed the smallest devices Cisco DX80 for workplaces with single 23-inch screen and integrated camera.

B. NTI Core Platform

The central element of the entire system is the Cisco Unified Communications Manager (CUCM) component, which primarily ensures centralized registration and communication of each system component. Immersive video conferencing systems are registered directly to CUCM (Fig. 2). In addition there was also implemented a MPLS design verification for NTI [6].
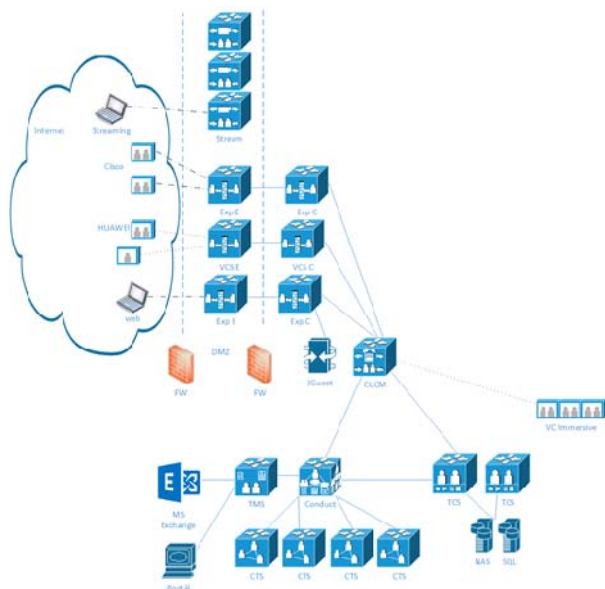
Figure 2. Scheme of NTI Core components with interconnection to external elements

An Expressway Component is used to safely register videoconference systems from Internet and in locations available only through NAT. One dedicated Expressway instance is used here to communicate with external users who do not have any videoconference hardware. In combination with Jabber Guest, it connects external users through a web browser.

The VCS (Video Communications Server) component is used to register Huawei video conferencing devices. VCS is practically an Expressway appliance with a different licensing and an extended set of features.

Several components of Cisco Conductor (CC) and Cisco TelePresence Server (CTS) components are used to connect multiple calls to multi-point conferencing. This is a more sophisticated replacement of the earlier used classical MCUs. An intelligent conductor allocates resources to individual videoconference endpoints to achieve efficient use of load distribution and the required redundancy.

Recording of ongoing video calls is provided by TelePresence Content Server (TCS) components. In this case, there are two servers to achieve the required capacity. Cluster uses an external SQL Server and NAS server to store recorded calls. An advantage is durability to the failure of one of the recording servers and increased storage capacity.

Storage of NTI is based on Huawei OceaStor storage system with SAS and SSD disks with cumulative raid capacity of 408TB.

The TelePresence Management Suite (TMS) provides videoconferencing planning and reservation of capacity for planned conferences. These components are integrated into the NTI Web Platform to increase user-friendliness.

C. NTI Web Platform

Important part of National Telepresence Infrastructure is NTI Web Platform (www.nti.sk), which consists of 3 interconnected web portals: NTI News, NTI Calendar and NTI Archive. Overall web platform has shared authentication with different user roles and administration roles.

NTI News is the landing page with global view on ongoing videoconferences, promoted broadcasts and promoted news and recordings. It also contains NTI endpoints list, devices handbooks, and essential information about NTI project and helpdesk section with live chat.

The NTI Calendar (Fig. 3) serves to reserve planned videoconferences and live broadcasts to the parties involved. The portal is directly linked to the overall NTI infrastructure, which provides secure services such as automatic initialization of videoconference at the specific time, automatic live broadcasting from supported NTI endpoint and promotion of videos to the NTI Archive [7].

Once a new booking is created, all participant receives an email with videoconference details along with an ICS file, which allow to interconnection with calendar systems (Outlook, Google Calendar).
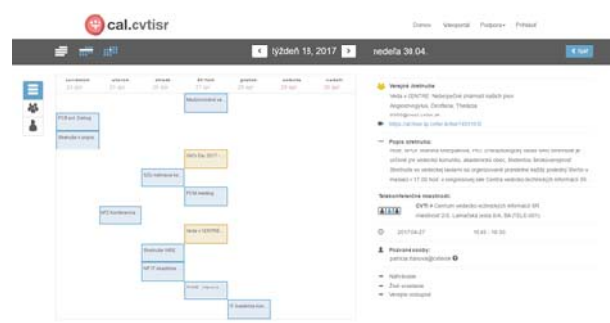
Figure 3. NTI Calendar for videoconference and live broadcast reservation

The NTI Archive portal contains video on demand section of public recordings, live streaming section and section for administration of recordings and broadcasts with statistics.

From the viewpoint of the end-user, the NTI Archive portal (Fig. 4) allows not only to watch recordings and broadcasts that have been created using national

telepresence infrastructure, but also it allows to monitoring, rating, commenting, sharing or embedding.
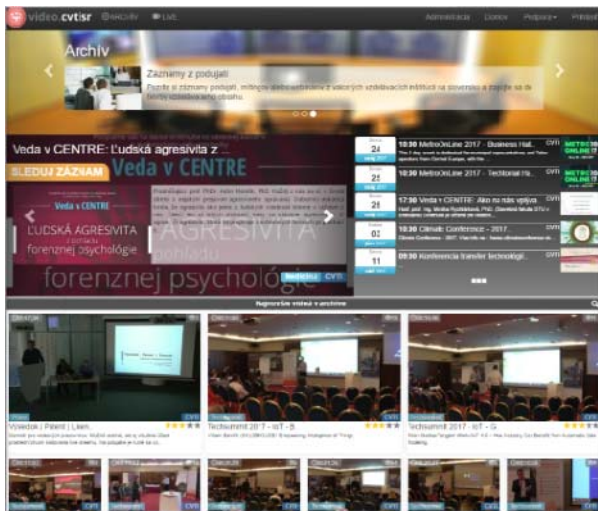
Figure 4.   NTI Archive for publishing videoconference recordings and live broadcasts

In principle, the management section of NTI Archive (Fig. 5) showing the recordings of videoconferences or broadcasts from lecture rooms booked by users via NTI Calendar. Recording in the NTI Archive administrative interface will appear after the booked videoconferencing is completed and the output video will be processed automatically after encoding processes. Owner of recording can publish it, assign it to an institution, categories, change its description, edit it online using a video editor or use other advanced management options. Live broadcasts booked through the NTI Calendar portal appears in NTI Archive at the time of start of the broadcast and also allow advanced management of display and categorization properties.

Some advanced administration features associated with assigning recordings to another user, changing the start or end time of an ongoing event, or changing the room associated with the recording, etc. , are managed via super admin interface for Central Management Office of National Telepresence Infrastructure (CMO NTI).
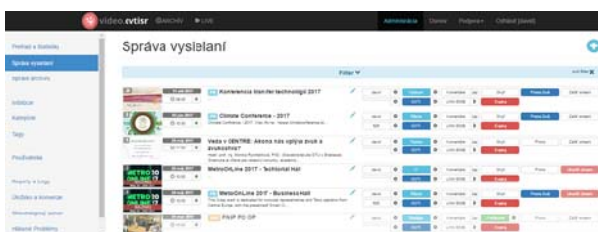
Figure 5.   Management section of NTI portal for administration live broadcasts

D.   *Live Streaming Platform*

Live streaming ability from larger NTI rooms (TP100 and TP100+) is operated via streaming encoder controlled by room controller software (Fig. 6). Streaming encoder is sending the H.264 RTMP stream to Wowza streaming engine with the video and audio from videoconference

codec via capture card. Live streaming operated from exponed room with NTI mobile streaming studio works on the same way of sending RTMP stream via FFMPEG based encoder to Wowza streaming engine.

Streaming server consists of three instances of Wowza streaming engine (WSE), which is shared also for VOD distribution. WSE is also modified for automatically creating recordings on distributed storage. Incoming streams from encoders are via WSE transited to RTMP, HLS and DASH stream.
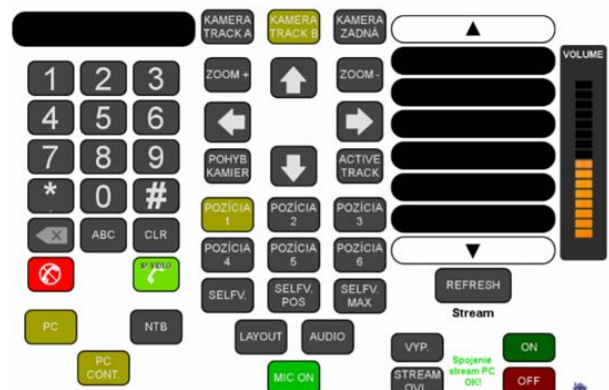
Figure 6.   AMX based controller interface on tablets in NTI TP100/TP100+ rooms

Web based live streaming player was integrated in live broadcast section of NTI portal (Fig. 7). Web player is designed for playing live broadcast in three ways – RTMP for flash-enabled browsers, DASH for non-flash browsers or HLS (HTTP) for mobile devices.
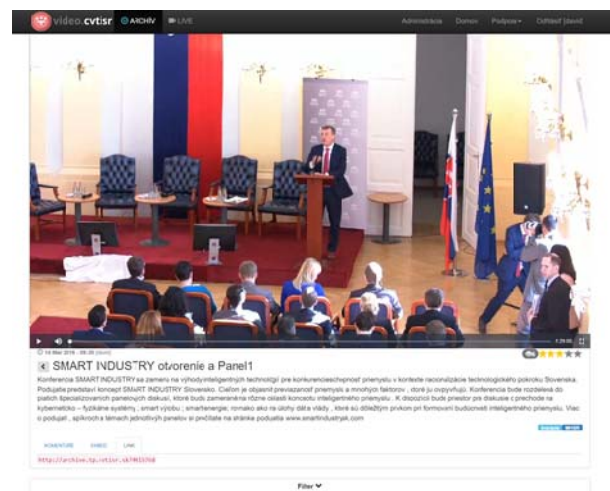
Figure 7.   NTI portal interface for live broadcasts watching

E.   *Connecting NTI with mobile devices*

Connecting to planned videoconferences or connected directly to NTI endpoint from external device such as PC or mobile phone was ensured by using SIP calling ability from multiplatform application of Cisco Spark.

Specific case of collaboration with H.323 protocol videoconferencing with NTI TP10 endpoints (deployed

from Huawei components) for mobile clients was ensured by using application TE Mobile for direct IP H.323 calls.

There were also approaches to deploy WebRTC based videoconference running directly in web browser without third party plugins [8][9].
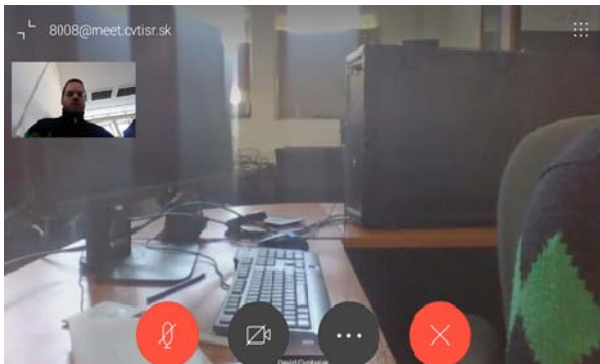
Figure 8. Videocall between Android smart-phone with Cisco Spark application and NTI Endpoint.

III. REAL USAGE EXPERIENCES

A. General usage of NTI

In one and half year of pilot operation of National Telepresence Infrastructure there were in summary 23 496 videoconferences SIP calls with 47 285 participated sites. Total duration of these videoconference calls was over 6790 hours. It was created 1985 videoconference and broadcast recordings with total duration of 1137 hours. Public recordings are available via web-based NTI archive with cumulative amount of 20 206 viewers.

Amount of realized videoconferences via protocol SIP in form of point-to-point calls during the monitoring period of January 2016 to April 2017 is depicted on Fig. 9.

Amount of realized videoconferences via protocol SIP in form of multipoint calls during the monitoring period of January 2016 to April 2017 is depicted on Fig. 10.

The statistics of usage NTI endpoints for videoconferencing was influenced by duration of summer and winter semester and holidays between them.
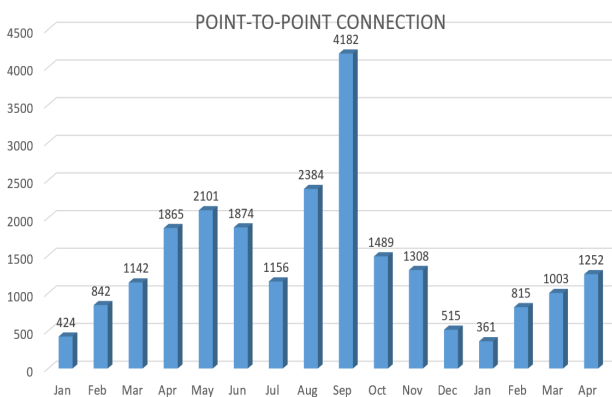
Figure 9. Increasing and decreasing usage graph of point-to-point videoconference calls via NTI
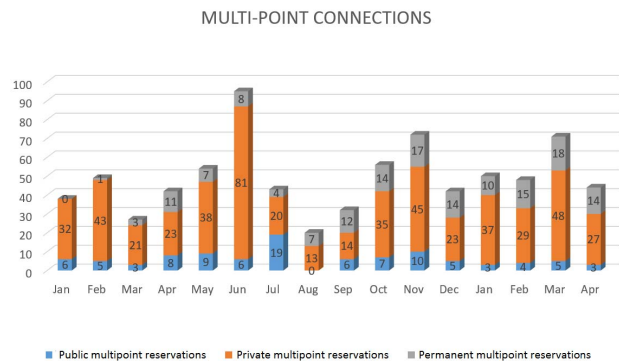
Figure 10. Increasing and decreasing usage graph of multipoint videoconference calls via NTI

One of the increasing forms of usage NTI endpoints is organizing defense of theses via videoconference with collaboration. For example, National Telepresence Infrastructure was used for realization of PhD minimal thesis defense with student located in Victoria University of Wellington, New Zealand and committee located on Technical University of Košice, Slovakia. The connection was seamless despite the great distance between universities, and the defense could run in full comfort.

Majority of realized videoconferences were private with specific definition of connected sites and recordings from these conferences were delivered only for organizers. Despite that, there was many of public videoconference with public multipoint address inviting the people from professional community to join during the conference. Some of videoconferences demanded a more secure connection, for example realization of secured videoconference from international science videoconference between Police Academy of Slovak Republic, University of Defense of Czech Republic and National Security Authority of Slovak Republic.

B. Alternative ways of usage NTI endpoints

Beside SIP videoconferencing NTI endpoints are supporting also a H323 videoconferencing. With this IP based point-to-point method, the two devices connecting directly over IP addresses without bridging the NTI Core, and therefore such activity hasn`t been monitored remotely. However, the number of H.323 calls is not negligible, and there is a huge amount external H.323 systems (f.e. Polycom), which make a significant contribution of infrastructures of foreign scientific research institutions.

Statistics do not interfere with the use of systems for local presentation on videoconferencing endpoints - the realization of lectures through an NTI device displaying a presentation locally in a room on a display or projector without a videoconferencing call. Such a method of use hasn`t been remotely monitored. However, videoconferencing systems are also being used extensively on many sites for such purposes to present content on projector connected to a collaborative device (university lecture rooms equipped with TP100 or TP100+ systems are using for that purpose in number of tens of hours a week).

C. Expieriences of handling Live Broadcasts

During the period of pilot operation there were realized over 175 live broadcasts with total duration of 743 hours. These broadcasts were published on NTI web portal with total amount of 26 178 viewers. The largest NTI rooms (TP100 and TP100+) equipped with live streaming encoder allow to realize live streaming to the web with couple of clicks on the controlling tablet. But majority of realized live broadcasts were located in externals venues without installed NTI devices. This is the reason why NTI deployed a mobile streaming studio, which consists of various live streaming mix components, videoconference components, encoders, cameras and sound equipment.

There were realized tens of interesting broadcasts on exponed venues. As one of example which could be mentioned is live broadcast combined with videoconference of gynecological surgery between hospital located in city of Prešov and congress hall located in High Tatras (Fig.11 and Fig. 12). Overall setup allowed chief surgeon to lead surgery remotely via videoconference without delay. Both sides received a fullHD live view from laparoscopy and cameras with audio from wireless headsets.

Figure 11. Using the mobile broadcast and videoconference studio connected to laparoscopy during the surgery in hospital

Figure 12. Providing the broadcast via NTI from live surgery to congress hall in High Tatras

Another great example of realization of live broadcast with NTI platform was the live streaming of one of the largest scientific conferences in Slovakia held during the Slovak Presidency of the Council of the EU. For example, live streaming with projection from 6 congress rooms simultaneously on REinEU 2016 conference. With NTI

there were streamed conferences (Fig. 13) like TechSummit 2016 and 2017, SET plan 2016, Climate Conference 2017, MetroOnLine 2016 and 2017, SSH 2016 or monthly based live broadcast activity – Science in the Center by SCSTI. Great success was the live broadcast of round table discussion "Legal Aspects of Abandonment of Amnesty" with over 8 000 live viewers, which proofed operational capacity of streaming servers (13% of performance was used with 8000 viewers).

Figure 13. Mobile streaming studio installed on one of the conference during Slovak Presidency of the Council of the EU.

In difference with videoconferencing there is no many possibilities to automatization process of producing live broadcasts without human technical intervention. Each live broadcast from exponed venue realized with NTI use to have different setup. In these setups, every component – streaming encoders, video mixers, video and audio components are connected to existing projection screens, audio speakers or network infrastructure with specific policy.

IV. CONCLUSION

As part of the NTI project, an infrastructure has been created to provide pilot services for high-quality video conferencing meetings with high efficiency, as well as the implementation of on-line broadcasts for the broad community.

Using the NTI infrastructure to deliver on-line broadcasts has attracted the public interest, which is a significant factor in increasing interest in research and development activities, increasing the professional level of the young generation and raising its interest in science and research itself.

The implemented NTI project has shown that a communications-collaborative infrastructure with centralized management and well-managed operational support can ensure effective communication of research teams not only in domestic but also international collaborations.

For the coming years, there is an expected increase in the number of videoconferencing connections, the number of live broadcasts and an increase in the number of participants in these events. To increasing interest in NTI it helps not only to popularizing the project, but also additional training and seminars for end users and administrators. To illustrate cost savings, it is interesting to reflect the use of NTI on the saved travel costs for participants of videoconferencing calls and live viewers.

In that point of view the NTI could save millions euros for next decade.

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Estimation of Human Body Height from Uncalibrated Image

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Abstract— In this paper the method for extraction of selected human body features, particularly dimensional units, is presented. The key parameters we focus on are the total human body height, arm length, leg length, shoulders distance and head height. Prototype software solution utilizes Histogram of Oriented Gradients (HOG) and Haar classifiers algorithms. The analysis of existing object detection approaches in the image is carried out. Following this analysis, the suitable approach is selected, while bearing in mind the software prototype requirements. Further, the methods for extraction of human body parameters are presented and specific details of implementation are described. Prototype of the application enables specification of selected human body features having the output values close to the real dimensions of human body.

Keywords- Detection, Haar Classifiers, Histogram of Oriented Gradients, Human Body.

I. INTRODUCTION

Computer vision is one of the most popular science disciplines, whose outputs are being utilized in a daily life. Many practical applications based on this science discipline emerged over the years. Big challenge in computer vision is object and person detection and subsequent processing of this acquired information.

Detection process directly related to human beings is person detection. On top of the detection, the human face recognition is used in many areas, e.g. in banking for user authentication, in security forces during the search for suspects etc. This very connection with the human body offers many applications that may be used in work with the image information. Input for these applications include eye color, sex, age, mood or total height.

The main objective of this paper is the extraction of human height and other related parameters such as head height or arm length from the static still image. Application of specific detection algorithms is not sufficient per se, for that reason it is also vital to know the certain properties of human body. Relations between specific human body parts are to be described in the following sections.

II. ANALITICAL CONSIDERATIONS

Technologies and techniques essential to the project are described in this section. We also present the information on human body proportions and relation between dimension to the other.

A. Histogram of Oriented Gradients

Histogram of oriented gradients is one of the techniques selected for the utilization in this project. HOG is described and specified in detail by Navneet Dalal and Bill Triggs in their work Histogram of Oriented Gradients for Human Detection [1]. Authors managed to design an algorithm for person detection with excellent results. Oriented gradients method is based on the calculation of the normalized local histograms, i.e. image oriented gradients.

The main idea is that the appearance and shape of the local objects can be characterized by the distribution of local gradient intensity or edge orientation. In practice this means, that image window is divided into small cells. For each of these cells, the local one-dimensional histogram of directional gradients or oriented edges over all pixels is collected. Individual cell histograms are connected to the overlapping blocks allowing to avoid the lighting and shadowing effect in image. These connected blocks, which are normalized, are called descriptors of the histogram of oriented gradients (HOG). To identify person or another object the classifiers are used. They are determined by support vector machines (SVM).

SVM classifier [2] decides, based on prior training, if the input image contains person or not. Training is realized on the vector bases, which are created from detection window with person and from detection windows without person.

B. Haar Clasifiers

Another essential algorithm in object detection to be used is designed by P. Viola and M. Jones, and presented in their research [3]. Object detection using Haar classifiers belongs to the machine learning approaches, when cascade function is created based on huge number of positive and negative images, which are used for training data. From these images are extracted features. For the extraction process the Haar features are utilized and these may be edge, line or four rectangles. For the final classifier definition, these features are used together with training set of positive and negative images.

Viola and Jones came up with cascade classifiers concept. This concept increases the overall detection speed. The principle of this method is to apply group of the features to image, in contrast with all the features. In case, that the first features group fails, it does not

continue, since the remaining features are not expected. In opposite case, the second group is applied and the process continues. After successful application of all groups it can be said that the area represents the object of interest, e.g. human face.

C. Human Body Proportions

Each human body is different, yet as presented in [4][5], there is a certain relation between head height and total human height. Proportions in human body follow certain rules:

- eight times the head height represents approximately the total height,
- double the head height represents shoulders distance,
- treble the head height represents the arm length,
- quadruple of head height represents leg length.

Another relation that can be used for person height specification is the distance of fingertips on both hands in pulldown position. This theory was introduced by Da Vinci in his writings [6], who stated that human height represents exactly this very distance.

III. Solution Proposal: Specification of Real Dimensions

Collection of the real human body proportions is one of the most essential parts of the entire solution, since the extraction of body parameters requires the real and exact data. As presented in [7], there is a relation between human body dimensional units and mathematical apparatus.

The goal of this project is to acquire the parameters from the still image without prior knowing the data. For this reason, the better solution is to use the relation between human head and other body parts.

Several control measurements with various persons have to be carried out in order to collect the real data. In this way the relation of human head to the total height is to be proven and the final software solution is to provide the best and the most realistic results in consideration of available technical and software equipment.

The relation for extraction of the parameters in the application is to be based on collected data. The software application will process the static image with the entire bodies present. The requirement is to extract the real height of person, head height, arm length, leg length and shoulders distance.

Human head can be used as primary element for the extraction of dimensions of specific body parts. Head itself contains the parts that serve as reference points, since we will work with static image and some reference real size or distance is required to estimate the real dimensions. Correct distance is the key parameter in determining the real head height. Human head consists of nose, mouth, ears – however the only usable are eyes. These are present in every face and their distance represent approximately the value of 65 millimeters for

every person. Distance is measured from the middle of the eyes.

A. Detection of Human Body and Head

Detection process is to be realized in two ways – automatic and semi-automatic. This very approach is suitable, since no detection algorithm can guarantee full accuracy with human body nor can mark the points of interest in every case.

Histogram of Oriented Gradients and Haar classifiers are used as the suitable detection algorithms. HOG will serve for detection of the whole person in the image, yet it does not represent the key algorithm for solution itself. HOG uses SVM, which creates the classifier based on training set of data.

In our case, positive images with person and negative images with other objects than person. Using this classifier, HOG is able to recognize human body and highlight it. The most essential algorithm we are about to use are Haar classifiers.

Haar classifiers allow representation of the individual parts of body. This part is required for the functionality of the whole solution. The utilization of this algorithm is to run in several steps and will find several points of interest. The first step is to show the whole input image and mark the top part of human body. It means part from shoulders to the top of the head. Second step represents utilization of Haar algorithm to enclosed area, which was found in the previous search.

In this research, the human head will be detected. Head will be used as principal component in the whole solution. In the last step, the eyes are to be detected, detection is to be carried out in area that was detected in the previous step.

IV. Experimental Implementation

Application prototype is implemented in Java programming language using OpenCV library, which provides suitable methods for actual implementation and manipulation with the image. Final software application is depicted in the Fig. 1. Its functionality is divided to the two way of detection: automatic and semi-automatic. In case of automatic detection, the application detects the person once the input image is loaded, i.e. detection of head and eyes.

Subsequently, based on this detection the head height is computed following the relation (1),

$$head\ height = \frac{(y^2 - y^1)*6,5}{x^2 - x^1} \tag{1}$$

the individual parameters are shown in the Fig. 2.

Once this value is determined, the other parameters of human body are computed according to the following rules:

- 8 * head height = whole person height,

- 4 * head height = leg length,
- 3 * head height = arm length,
- 2 * head height = shoulders distance.

In case of semi-automatic detection, which is used if detection algorithm does not detect eyes, the user marks points that represent the eyes. The calculation is then the same as for automatic detection.

In addition to the detection and specifying of selected parameters of the human body, it is also possible to mark skeleton model of human body to visualize different human body parts.
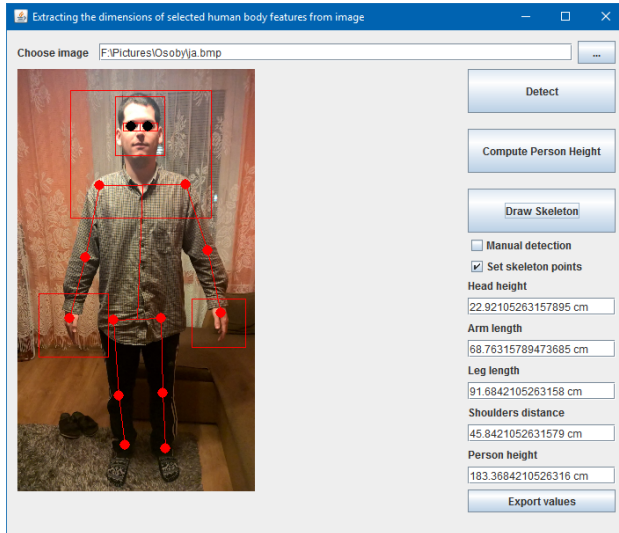
Fig. 1. Screenshot of program prototype with detected person
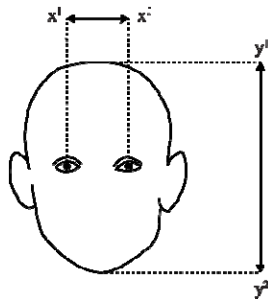
Fig. 2. Calculation of head height

V. EVALUATION

The final software program prototype is designed and implemented to provide as accurate results as possible and operates reliably considering the limiting factors.

As these factors we consider the input static image and weaker set of training images. In order to train Haar cascade classifier the set of two hundred positive and two hundred of negative images was used. Software solution and related detection process was tested on several devices.

Further debugging and enhancement made utilization more effective, and case of a computer system with hardware resources – Intel Core i5 4200M 2,50 GHz processor and 6 GB RAM was utilization as follows:

- CPU consumed in range 40 to 50 %,
- RAM consumed - 40 %.

Detection success in each of three body parts, head, eyes and torso was 65 % on thirty tested inputs. Head and torso were detected on every input.

Measurement depends on the previous detection. For automatic or semi-automatic detection were measured values as shown in Table 1. Please note that the data in the table represent only partial extraction of results, the overall over 50 subjects (see Fig. 3) were measured and subsequently tested using proposed solution.

		arm length [mm]	leg length [mm]	head height [mm]	shoulders distance [mm]	total height [mm]
1	real	783.00	976.00	244.00	453.00	1950.00
	measured	738.95	985.26	246.32	492.63	1970.53
2	real	758.00	928.00	232.00	464.00	1850.00
	measured	687.63	916.84	229.21	458.42	1833.68
3	real	666.00	890.00	221.00	438.00	1760.00
	measured	652.50	870.00	217.50	435.00	1740.00
4	real	642.00	868.00	212.00	427.00	1680.00
	measured	624.00	832.00	208.00	416.00	1664.00
5	real	749.00	924.00	229.00	468.00	1830.00
	measured	697.89	930.53	232.63	465.26	1861.05
6	real	650.00	880.00	350.00	440.00	1860.00
	measured	702.00	936.00	234.00	468.00	1872.00
7	real	620.00	910.00	300.00	460.00	1870.00
	measured	712.50	950.00	237.50	475.00	1900.00
8	real	610.00	840.00	300.00	480.00	1870.00
	measured	717.15	949.00	237.25	474.50	1898.00
9	real	640.00	880.00	280.00	560.00	1850.00
	measured	682.50	910.00	227.50	455.00	1820.00
10	real	670.00	950.00	340.00	380.00	1930.00
	measured	731.25	975.00	243.75	487.50	1950.00
11	real	650.00	103.00	300.00	400.00	1880.00
	measured	705.71	970.67	235.24	470.48	1881.90
12	real	590.00	880.00	250.00	460.00	1790.00
	measured	675.00	900.00	225.00	450.00	1800.00
13	real	680.00	770.00	290.00	520.00	1820.00
	measured	682.50	910.00	227.50	455.00	1820.00

Table 1. Overview of real and measured values
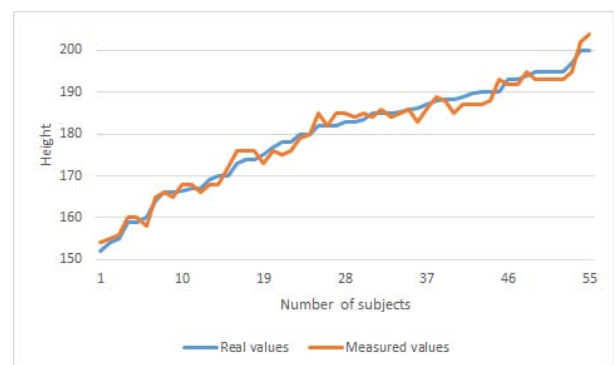
Fig. 3. Height of the persons: Real vs. measured values

VI. CONCLUSION

In this paper, the approach on computation of values from selected parts of human body from static image was described.

Extraction process is based on the existing relations in human body. Application prototype is able to detect the head of the person, by which other parts of the body are calculated. Measured values differ from real values while having the maximum error of 10 percent. This is considered as a good output bearing in mind the input is static uncalibrated image.

The overall solution is to be used as the part of a complex system for the enhancement of person recognition in the image in university premises, as assistive value for recognition of personnel. Another utilization is in the field of anthropometry for the extraction of anthropometric values. This includes collection of anthropometric data and effort to extract anthropometric data from the uncalibrated images.

In the future research software solution is to be enhanced for new functionalities regarding the detection processes and recognition of specific person. Pose estimation and subsequent mapping of 3D human body model are expected to enhance the overall outputs of human body dimensional units.

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IT Academy project: An opportunity for the IT industry in Slovakia

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Abstract — **National project "IT Academy – education for 21st century" supports the development of IT industry through the changes in educational system at primary schools, secondary schools, and universities. Proposed innovations enhance the quality of education in IT, mathematics, science, and related technology areas that have as the main focus ICT. Further, they improve the motivation of pupils and students to study informatics and ICT, and help to develop scientific abilities of both, pupils, and students. Following the requirements of IT sector, in the 5 to 8 years the project aims to adjust educational system to educate 1000 new specialists, as compared to the current state. Project activities are designed for min. 24 000 pupils of primary school, min. 9 000 pupils of secondary schools, min. 3 000 students of universities and min. 1 800 teachers of primary and secondary schools from all over the Slovakia, except for Bratislava self-governing region.**

IT Academy as a sustainable system for education and training of specialists, recognizing the demands of IT industry, is based on market and IT sector requirements. It incorporates also the partnerships of all subjects within Slovakia that co-create the system itself – i.e. IT companies, universities, secondary school, primary school, self-government, and other subjects. Partnership with IT Academy is established in form of contract or memorandum of cooperation, giving the entity status of "IT Academy partner".

I. INTRODUCTION

Over the last few years the labor market in the IT industry has grown significantly across both Europe and the Slovak republic. Large investments in this area were given mainly to the East Slovak region (T-Systems, Ness, Siemens, IBM, GlobalLogic, RWE IT, etc.). The education system falls behind the current and long-terms needs of IT companies, as proven by various expert analyzes. Several conclusions from selected studies are presented next.

A. Youth employment in the ICT sector [1]

ICT industry, as a hi-tech sector, has high innovation potential. It is a key part of the knowledge economy for other sectors of the national economy such as "smart" energy; intelligent transport systems; integrated production, modern financial services; modern and efficient healthcare; protection and accessibility of cultural heritage or modern and efficient public administration

(eGovernment). The ICT sector generated more than half of the new jobs in European union (EU) in 2010-2013 and the European Commission (EC) expects that the ICT sector will be missing 700 000 jobs by 2018.

IT Association Slovakia (ITAS) expects an increase of 10 000 jobs in Slovakia over the course of 3-5 years, however Slovak secondary schools and universities do not cover the market demands of ICT experts. Hence, there is a requirement to increase the qualification potential of university graduates for the demands of IT professions. Specific ICT training should be provided to persons that are in search of employment. Above stated implies that the number and quality of Education Programs related to changing labor market demands should be increased.

B. Importance of ICT sector for Slovak republic [2] and Sector analysis of ICT [3]

Demand to increase the number of employees in IT sector is imminent. Increase of ICT deployment in economy was recorded (it may lead to increase of the efficiency of development, production, and distribution). For this reasons the development of computer literacy is required, since there is a demand to increase the competitiveness and development of the IT sector. ICT technologies should be as well deployed in government (i.e. eGovernment).

Scientific research compared the profile of Pavol Jozef Šafárik University in Košice (UPJŠ) graduates with the labor market demands [4]. Following the outputs of the study, 52 employers identified the following requirements:

- the need for higher level IT skills and practical knowledge and abilities,
- the need to prepare youth to handle information systems and technologies (e.g. SAP, C++, JavaScript, C#, ACCP, CISCO certification),
- increase the professional experience in cooperation with IT companies,
- direct contact between pupils, students, and IT companies (in form of internships, practice etc.),
- support education of SAP system for university students.

National project *Universities as motors of development of knowledge society*, carried out its activity *Assessment of effectiveness of universities study programs (2014)*. As a result, the higher education institutions should, based on the input from the employers:

- labor market demands in the content of study programs must be considered,
- teachers have to be prepared for current trends and innovations,
- cooperation of schools with companies should be improved,
- forms and methods of teaching should be changed,
- soft skills of students must be improved.

In cooperation with universities and public administration, the causes of the deficit of qualified IT specialists were identified. "Národná koalícia pre digitálne povolania" was established in accordance with the pan-European initiative Grand Coalition for Digital Jobs. Same as in other European countries, the Coalition wants to aid in solving the problems with shortage of IT specialists; help with training programs for IT departments; help in increase of digital literacy and help to motivate young people to tackle IT issues.

Support for Digital Coalition activities, in the form of specific responsibilities, was declared by Digital Leader of Slovak republic the Minister of Education, Minister of Economy, Minister of Labor and Social Affairs as well as other representatives of the academic community and ICT industry, including specific commitments.

The main aims and activities of the Digital coalition are:

1. motivate young people to study technical and ICT disciplines, both at secondary and higher education,
2. increase the quality of pedagogical staff and thus improve the quality of study of these programs,
3. improve the pedagogical process through the modern pedagogical aids and ICT,
4. introduce the industrial and internationally recognized certifications to schools and thus enable employers to better target persons that are in search of employment,
5. enhance cooperation in work environment and education through the partnership of ICT companies with schools,
6. launch projects for retraining of unallocated graduates from other departments and specializations related to in technical area and ICT.

The IT Academy - education for 21st century is compliant with virtually all of the above stated objectives and activities and ITAS is directly involved in solving of the project tasks.

The project support the development of the IT sector through changes in the educational system at primary, secondary school and universities. This development is to be carried out by increasing the quality of education focused on IT, mathematics and technical areas that are in scope of ICT, also the develompent is aimed to enhance scientific compentences of pupils and students. The aim of the project is creation of model for education and training of young people to meet the actual demands of knowledge society and labor market. The education system will be designed to generate new specialists following the IT sector demands. It is based on the formation of so-called the pyramid of pupils and students (min. 24 000 at primary schools, 9 000 at secondary schools, 3 000 at universities). Pupils or students will be oriented and motivated to study natural and technical sciences, having as the focus informatics and ICT since the very first grade

of primary schools. The project is to involve elementary schools (min. 300), secondary school (min. 200) and universities (min. 5) from all the regions of Slovakia, except for Bratislava region. The project acitivties include: innovation of science and technology education at elementary and secondary schools with a focus on informatics and ICT; innovative preparation of university students for employment in the IT sector; education of teachers of informatics, mathematics, natural sciences and technical subjects of primary and secondary schools; motivation of pupils and students for ICT, mathematics, science and technology, developing the standards of digital literacy; development of personality and communication competencies according to ECDL and ECo-C® international standards, and development of partnerships and network of schools and IT companies.

The outputs of the project will be innovated study programs at universities, secondary schools and primary schools; then the content and methodology for teaching of informatics classes; popularization and out-of-school educational activities; partnerships between schools and IT companies; pupils/students of elementary, secondary schools and higher education institutions will be oriented to study ICT; another output will be trained primary and primary school teachers (at least 2100) and last but not least development of IT ScienceLab technology labs.

Other parts of this paper will cover in detail the described activities and outputs of the project.

II. INNOVATIONS OF FORMAL EDUCATION

Innovation of learning as a part of School Education Programs is aimed to update the content, methods and forms of teaching mathematics, informatics, science subjects and professional subjects towards a consistent and meaningful implementation of ICT tools for education. Created innovative methodologies mainly focus on the development of exploratory (research) abilities of students at primary and secondary schools. A model of a special class that focuses on informatics, especially in grammar schools is created. Its part includes the formation of eight new courses for these classes. Two new motivational subjects will be created: *Informatics in Natural Sciences and Mathematics* and *Internet of Things*. These subjects should guide pupils of secondary schools pursue university study of computer science programs and ease search of employment in IT sector. Part of activities cover formal and informal teacher training, courses, IT camps, seminars, competitions, and other extracurricular activities aimed to motivate primary and secondary school pupils to study computer science, ICT, natural and technical sciences, develop digital literacy, help in development of personality, and enhance communication competencies. The activity is carried out in close cooperation with IT companies based on the partnership with schools.

A. Innovating education of science and technology at elementary, secondary schools focused on IT and ICT

The mail goal is to develop digital literacy in the context of mathematical, informational, natural, and technical education of pupils at elementary and secondary school. Changes will be monitored through the conceptual activities or tests, while comparing input and output results, and results after 6 months since the

implementation of innovative lessons. This is based on state of the art researches in the field of assessment of pupils' exploration (or research) abilities. Outputs of these researches indicate weak development of these abilities at, both primary and secondary school. We expect that the systematic and coordinated use of innovative teaching methods based on the application of exploration (research) approaches to learning will have a positive impact on the development of pupils' exploration (research) capabilities. The basic tools to measure the level of development of exploration (research) capabilities will be pre- and post-tests, formative assessment tools and questionnaires.

The following three tasks were set to achieve the defined goal, i.e. innovation of science and technology education at primary and secondary schools:

The first task: The content, scope, methods, and forms in teaching process of mathematics, informatics, science subjects and vocational subjects will be innovated and updated. Thus, creating consistent but meaningful implementation of ICT tools for education (primary and secondary schools).

- Content and scope of the update is proposed based on the analysis of the current state of mathematics, informatics and science subjects at elementary and secondary schools within the framework of the School Education Program (in Slovak *Školský vzdelávací program, ŠkVP*).

- Hourly subsidies (e.g. division of the lesson, increase of the hourly subsidy for subjects) will be updated based on the current demands and possibilities. This covers Educational program subjects, specifically mathematics, informatics, and natural sciences.

The content, methods, and approaches to teaching of mathematics, informatics and of science related subjects will be innovated based on the State and School Educational Programs at elementary and secondary schools. This bears in mind the rational implementation of ICT tools and takes into account research approaches in education. The starting points for the innovation of the content, methods and forms of teaching mathematics and natural sciences are the outputs of successfully completed and deployed national and international projects (MVP, ĎVUI, VEMIV, ESTABLISH, SAILS). Some are currently successfully implemented (and contractually guaranteed by Ministry of Education, Science, Research, and Sport of the Slovak Republic) projects that enable cooperation with industrial sphere, such as e.g. Cisco Networking Academic Program (this is the most important functional model of private and public cooperation in vocational education in the Slovak Republic). Existing learning materials are utilized and are adapted or adjusted to meet the project objectives.

Educational materials utilized in teaching of subjects related to natural sciences aim to support primarily the experiments and modeling, as the basic methods of exploration (understanding) of natural sciences through the available hardware and software (e.g. computer data measurement and processing, video analysis and mathematical modeling on a computer). Educational materials are based on current trends in education that highlight the demand to deploy scientific and research methods with aid of ICT tools.

The second task: Models of class at secondary schools with advanced teaching of natural sciences and

mathematics is created, using digital technologies. Also, a special class focused on informatics is created at grammar schools.

In secondary schools with extended teaching of natural sciences and mathematics and with the use of digital technologies the following applies: At least one lesson per week, in at least two subjects (Mat, Chem, Bio, Phys, Geo) will be divided. The *Informatics in Natural Sciences and Mathematics* as a subject will be deployed to the Education Program (see part 3 of this section) to the 3rd year with a range of 2 hours a week. The informatics is extended by at least one hour a week, mathematics 3 hours a week and teaching of at least two subjects (Chem, Bio, Phys, Geo) by 4 hours a week, the content will be extended to include new topics.

In secondary schools with extended teaching of informatics the following applies: At least one hour a week, in to at least one of the subjects (Mat, Chem, Bio, Phys, Geo) will be divided. The School Education Program will include the subject of *Informatics in Natural Sciences and Mathematics* in 3rd year of study, having scope of 2 hours per week and the teaching of informatics will be expanded by at least 6 hours a week, while its content will be expanded by at least 3 subjects from 8 new IT subjects, and teaching of mathematics by 3 hours per week, extended to include new topics.

Model designs of innovated School Education Program for primary and secondary schools take into account the class focus and the hourly subsidy of mathematics, computer sciences and natural sciences subjects. Above mentioned designs will be experimentally verified:

- The pupils of elementary and secondary schools should be acquainted with the real possibilities of deploying IT to practice and the possibilities of its study at universities while emphasizing easier employment future. This is to be done in cooperation with IT companies.

- Model of class focused on IT will be created for a given type of school. Within this model the new subjects are prepared and added to school Education Programs in cooperation with schools and IT experts:
  o Troubleshooting and Programming (2 hours a week).
  o Programming of Mobile Devices (1 hour a week).
  o Computer Systems and Networks (2 hours a week).
  o Information Security (1 hour a week).
  o Databases (1 hour a week).
  o Object-based Approach to Troubleshooting (2 hours a week).
  o Creating and Presenting the Data (2 hours a week).
  o Programming the Websites (2 hours a week).

- Methodology that will involve IT specialists in education will be developed, e.g. in form of lectures or discussions, at the premises of secondary schools, regarding the activities of the company and current modern technologies. Thus, motivating the pupils to study the informatics.

- Methodology for realization of excursions in IT companies for selected groups of pupils in cooperation with IT companies is to be developed.

The third task: Models for two new motivational subjects will be designed. The first for grammar schools,

to show the utilization of IT in natural sciences and mathematics with a focus on the inner relationships between informatics and mathematics and science subjects, in cooperation with IT companies through IT experts. The second for secondary vocational schools as well as for grammar schools to acquire practical experience and skills with the implementation of the concept of the Internet of Things (or Internet of Everything), also in cooperation with IT experts.

- Model of a new subject *Informatics in Natural Sciences and Mathematics* should be created for a given type of school focusing on the interdisciplinary relationships between informatics and mathematics and natural sciences with a duration of 2 hours per week. Suitable topics with that cover multiple subjects (or courses) will be selected (e.g. imaging methods in medicine - biology and physics, Forensic science - physics, chemistry, biology, energy around us - physics, chemistry, biology, geography , Biofluorescence - biology, physics, global environmental pollution problems - physics, chemistry, biology, geography, geophysical phenomena in the atmosphere - geography, physics, use of modeling to solve problems from real life - biology, physics, mathematics).

- Model of a new innovative motivational subject for a secondary school subject will be created, having duration of 2 hours per week for the given type of school. Complete subject content is to be prepared and, following the analysis of the existing materials, in cooperation with representatives of IT companies, the appropriate cross-cutting topics that integrate several subjects will be selected. A modular system is used to organize the learning process so that the motivational and creative factor of the subject is at the forefront. The aim of the subject is to get acquainted with the concept of the Internet of Things (or Internet of Everything). Students will gain a broad-based overview of Internet architecture, its functional building blocks, sensors, action members, software programming and integration with the physical world, local network processing, secure and efficient data transfer over various network protocols, data storage and processing in the cloud, data management, as well as business ideas in the area. The student will learn to creatively design skillful systems from one end to the other for Internet things. And will learn to connect the physical world to the software world through the rapid prototyping method.

B. *Innovation of education at universities*

Educational models, offered by universities will bring maximum benefit to students, the private and public sectors as well as the whole of society. However, only provided that they are focused not only on the up-to-date but mainly on the future perspective of the entire knowledge-based society. Universities are involved in the development of new technologies and trends through their research, and their role is to incorporate such knowledge into the learning process. Through the innovation of their Education Programs, they give their graduates the opportunity to focus on emerging trends and technologies, to participate in their co-development and to be as relevant as possible on the labor market.

The traditional form of education at universities, where the techniques and methods are realized as part of practical exercises that were covered mostly through theoretical lectures is inappropriate in today's rapidly changing IT world, especially for the following reasons:

- It is difficult and more or less impossible to incorporate wide range of technologies that use the most innovative companies and into a small number of subjects focused on general principles, methods, and technologies of the specific field.

- On the other hand, subjects narrowly focused on some, selected technologies narrow the horizons of graduates of universities, who should have a wider view of the main areas and directions of IT. From the experience, we can see that if the graduate learns to work with some technology, he or she also tries to use it in situations where it is more appropriate to use other techniques (Man with a hammer syndrome).

- Exercises just mechanically practice the standard tasks that are rare in practice or are not required in companies.

Students receive mostly "lexical" knowledge during such lessons, their creativity is insufficiently developed, and there is a decline in interest in a given area of informatics.

In the preparatory phase, we identified several factors that should be taken into account when planning the lesson:

- Lessons should also, to some extent, reflect the needs of the "market". It should be focused on practical issues that are currently addressed in innovative global and regional IT companies.

- Students should be given sufficient insight into the subject area and should be able to recognize appropriate as well as not quite appropriate ways to solve specific practical tasks.

- The tasks that will be used in the educational process should be sufficiently motivating and should develop creative thinking.

The three above identified factors describe the so-called problem-driven learning (PDL), which is a way of learning with logical continuity between all participants in the educational process (student, teacher, and market). This continuity depends on a particular problem or task.

The core of educational process is a given problem or a task to be solved. This task should be specified in cooperation with the teacher and the representatives of the companies, taking into account the current and future needs of the market. The problem should be up to date, interesting and non-trivial, making it suitable for the learning process, while at the same time allowing professional grow as a student as well as a teacher. The main role of teacher in this process is to guide students in finding a solution, which requires practical knowledge and an overview of the different approaches and technologies used in the context of the given task. On the other hand, companies also act as consultants to provide students and educators with the necessary help in the context of domain expertise. Students should use all the available resources that teachers and consultants (businesses) allocate to solve the problem.

PDL teaching approach requires teacher to have some flexibility and ability to identify and schedule appropriate

tasks to manage education process. Active support is expected from the participating companies through consultations with students and educators. Students should be able to work in groups where, among other things, soft skills are needed for effective teamwork. During consultation with business representatives, they also get important contacts that can help to develop their professional careers. Note that this form of teaching reflects on all three above identified factors.

In order to achieve the specific objectives of the activity that is focused on building a modern and creative educational environment, we plan to divide the individual tasks within the activity into the following parts:

- Establishment and operation of the Competence Center for Education - Academy: Enterprise-information systems, Data science, Internet of Things, Networking Academy with the participation of all project partners.

- Participation of university teachers at conferences, courses and trainings, consultancy with representatives of IT companies.

- Innovation of training programs and creation of the "IT for practice" program.

III. EDUCATING TEACHERS OF INFORMATICS, MATHEMATICS, SCIENCE AND TECHNOLOGICAL SUBJECTS AT PRIMARY AND SECONDARY SCHOOLS

The success of the full implementation regarding the innovation at schools depends to a large extent on the preparedness and knowledge of the teaching staff, its systematic influence on the pupil and the responsibility of the school management for the proper graduate profile.

In Slovakia, we have a legally adapted credit system for lifelong learning of pedagogical staff. Education of teachers has its own specifics, especially when it comes to innovation of the content but especially in case of learning methods and objectives. Teacher needs to be inspired with the idea of prepared innovations, i.e. internally identified and ready to participate in own work in order to achieve given goals. As a part of the innovation of the content in teacher's education it is necessary for teacher to get familiar with the activities carried out by pupil, as an implementer. This is the very reason to prepare updated and innovative continuous education for teachers of mathematics, informatics, science and technical subjects. Overall, 23 new programs of updated continuous learning and 4 programs of innovative continuing education will be created. The nature of the educational programs is clearly defined. The methodology of reversed teaching, cooperative teaching and distance learning is strongly utilized. Use of innovative methods during the training of the teacher will allow their better adoption and creation of prerequisites for their implementation in practice. Emphasis is placed on the formal assessment of acquired competencies, i.e. immediate feedback, its evaluation, and subsequent adaptation to the learning process. The goal is to achieve conceptual understanding of the problem by teachers and their participation in the creation of assessment tools, innovations of methodologies and collection of pupils' outputs. Outcomes for the broader scholastic community will represent the concepts of the innovative education focused on IT.

Specific attention is put to the subject of informatics. Informatics has gradually expanded from secondary schools to second and first levels of primary school in various forms of compulsory and optional subjects and courses. This subject is very often taught by IT amateurs or computer enthusiasts who are not qualified and often lack the required and appropriate expertise. For this reason, we will continue to support the study program called *Expanded study of Informatics* (in Slovak *Rozširujúce štúdium informatiky*). This is important step in providing the opportunity for these teachers to get quality and modern IT education and achieve professional and didactic level of qualified IT teachers, who can initiate and manage a modern constructive cognitive process in which pupils develop their digital literacy, as well as independent, critical, and responsible decision-making, creativity, and other higher cognitive functions. Graduate of course will in many cases act as an innovator, being able to engage in new forms of teaching and teaching of other colleagues, and will also be able to help in the development of information literacy at school.

In society, we have long-term evidence of the growing non-formal learning that helps to acquire knowledge and skills. It will be necessary to incorporate this into the training of teachers who will then be able to utilize initial knowledge of pupils, their internal motivation and also eliminate the often-emerging misconceptions. Not only popularizing lectures but also excursions and internships of IT teachers will serve for this very purpose. As a part of these excursions, teachers will be able to find out how businesses and processes in IT companies work in practice, gain the practical experience and skills directly from practice and broaden own horizons. These activities aim to motivate teachers to innovate their lessons to inspire more students to study computer science and to reveal the connection between the theory and practice.

Regarding the non-formal education, the special attention to should be given to school headmasters. It is primary due to their responsibility for the graduate's profile and the direction of the school. Informed and supported headmaster feels confident in argumentation towards the teachers regarding the innovations and in luring pupils to study IT.

Education of the primary and secondary school teachers is divided to:

- Formal education
  o Up-to-date education of teachers of informatics, mathematics, natural sciences at elementary and secondary schools.
  o Innovative education for teachers of secondary schools (informatics class).
  o Extensive study of informatics for elementary and secondary school teachers.
- Non-formal education
  o Education of elementary and secondary schools' headmasters to transform the school to provide education for the information society.
  o Open hours for primary and secondary school teachers.
  o Popularizing lectures for elementary and secondary school teachers.
  o Excursions in IT companies for elementary and secondary school teachers.

- o Internships in IT companies for secondary school IT teachers.
- o National and international conferences for teachers of informatics, mathematics, natural sciences at elementary and secondary schools.

IV. MOTIVATION OF PUPILS AND STUDENTS TO STUDY INFORMATICS, ICT, MATHEMATICS, NATURAL AND TECHNICAL SCIENCES

The study of informatics, mathematics, natural sciences, and engineering is a long-distance course. It takes many years to create a solid understanding of science disciplines, contemporary mathematics, computer science and technical sciences. Child has to be accepted by its surroundings to keep the enthusiasm for natural sciences, mathematics, informatics and technical sciences. Another problem is decreased interest of girls to study and pursue in areas requiring mathematical, informational, technical and, finally, science education. It is through our primary activities that we aim to solve these problems. When it comes to motivation of female population, we plan to build on the successful project "You in IT (in Slovak *Aj Ty v IT*)" and work closely with the members of this project. In addition to activities that are already running for some time, we want to bring new formats such as "Science in the City", "IT Tea Room" and "IT Conference in Practice". Formation of additional activities of different formats, adapting to situation, is of course possible. In addition to experts from universities, the experts from IT companies participate in the implementation of popularization activities in individual regions, and also contribute to their goals. Many of those involved in these kinds of activities pursue study of natural sciences, mathematics or informatics at universities after graduation. Later, they become top scientists and experts not only in their fields of expertise.

Popularization activities help to meet given goals, these include:

- mathematical and informatics competitions focusing on the development of algorithmic thinking and problem-solving strategies,
- popularization activities in the fields of informatics, mathematics, natural and technical sciences in the form of workshops, lectures, and seminars,
- activities in utilization of ICT and informatics in the natural sciences,
- camps that focus on activities that lead to development of pupils' talents towards the study of informatics, mathematics, natural and technical sciences,
- activities that promote the importance (for girls) to study informatics in the form of workshops and lectures.

Partial activities will help to present other project activities and promote their importance as a part of the motivation and popularization to study informatics, mathematics, natural and technical sciences.

V. STANDARDS OF DIGITAL LITERACY, PERSONAL DEVELOPMENT AND COMMUNICATION

International surveys in the European Union report a large discrepancy between the digital capabilities of the population as declared based on the self-assessment and the same digital capabilities as tested in the real-world environment. A great difference was found between abilities of so-called digital "lifestyle" skills (such as movie or music downloads, chatting, electronic communication) and "business" digital competences that are needed for labor-related activities (such as processing the text or tables, etc.). While "lifestyle" digital capabilities are in a broad population at a good level, "business" digital capabilities are of rather bad quality. As a surprise may be considered the fact that in the survey young people shown worse results compared to older ones.

The demands placed on an individual in today's labor market are and will become increasingly challenging. In addition to digital competences and economics, the possibility to develop personality and ability of communication (so-called soft skills) is becoming more important. The structure of a modern society requires the ability to rely on one's own personality. Growth of persuasiveness and the subsequent progress in career, especially in employee relationships, may be achieved through the effective communication.

We want to participate in the development of standards, in preparation and testing of digital literacy of target groups following the international standard ECDL, and also on testing of the personality development and communication competencies of the target groups following the international standard ECo-C®.

Development of standards of digital literacy, personality development and communication competencies is one of the requirements of practice. The acquired knowledge and skills have practical use in education in preparation for future vocation. In the case of teachers, these skills have a direct impact on mastering the basic and advanced skills for work with computer applications, which can be subsequently used in preparation of lessons, e.g. in preparing the young generation for practice with respect to personality growth, or other digital and communication competencies.

VI. FORMATION OF PARTNERSHIPS AND NETWORK CONSISTED OF PRIMARY, SECONDARY SCHOOL, UNIVERSITIES AND IT COMPANIES

IT Academy represents a sustainable system of education and training of specialists, while having as a focus the demands of the IT industry. It established on the demands of the labor market and on the requirements of the IT sector. It incorporates the relations of all entities in the Slovak republic that it is composed of, these are: IT companies, secondary schools, elementary schools, universities, local government, and other subjects. The partnership with the IT Academy is concluded on a contractual basis in the form of a co-operation agreement or memorandum, and thus the entity acquires the status of "IT Academy Partner".

Types and content IT Academy partnership:

- University as an IT Academy partner.
- Secondary school as an IT Academy partner.
- Primary school as an IT Academy partner.
- IT company as an IT Academy partner.
- Other entity as an IT Academy partner.

Partnership agreement defines the specific content and extent of cooperation between primary and secondary schools and universities that acquire the status of "IT Academy Partner". As required, it is continuously specified for each school (academic) year. Memorandums bind companies to help meet the goals of IT Academy in terms of its status.

Other entities can also become the IT Academy partners, since the ICT and digital skills are also needed for other professions (e.g. self-governing bodies, personnel agencies, etc.). Partnership with IT Academy is mainly implemented in the form of a cooperation agreement in which the partners are bounded to fulfill the content of the partner activities at the specified levels.

VII. CONCLUSION

IT Academy is a pilot project with great potential to change the education system in Slovakia from the primary up to the university education. Motivation of target groups (being pupils and students) to pursue technical sciences, natural sciences, mathematics, and informatics is impossible without the help and direct participation of the IT sector in the implementation of the project. The success of the project is dependent on the adoption of philosophy and project ideas by participating subjects. Outputs from the first year of the project implementation allow to express confidence that the goals and expected outcomes are real and feasible.

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Content Security Policy (CSP) as countermeasure to Cross Site Scripting (XSS) attacks

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Abstract—**This article presents one of several HTTP Security Headers – Content Security Policy (CSP) header, nowadays preferred countermeasure to Cross Site Scripting (XSS) attacks. It is emphasized that implementation of CSP header is relatively simple method how to improve security level of communication among people and devices over Internet. In the environment where secure web services are vital – web applications and Internet of Things (IoT) networks, this way it is possible to strictly define communication parties and assets used in web services. Simple and effective reporting is native part of the CSP design, what means administrators can be notified about running attacks almost instantly. It is demonstrated on practical examples what benefits of CSP implementation can bring to communication and how easy is to propagate CSP header to web browser.**

I. INTRODUCTION

Secure communication is always current topic and new security challenges are discovered every day. Securing communication between web server and web browser is not totally brand-new area, but there are appearing new security tools – HTTP Security Headers, which have identified new techniques in securing communication between the above mentioned parties.

Communication among people and devices over HTTPS protocol is widely accepted today, but allowing communication only among approved domains or subdomains is relatively new security request. Thanks to web applications and IoT networks, it is becoming important to implement countermeasures to Cross Site Scripting (XSS) attacks. Hardening communication over HTTPS protocol and allowing communication only among allowed domains and subdomains, brings requested results.

Despite the fact HTTPS protocol is relatively secure, it is necessary to think about possible threats in HTML source code resulting to inappropriate use of URIs. For example, it is possible to overlook HTTP protocol used instead of HTTPS even in well-managed code. Second example are dynamically generated HTML pages, where everybody from the Internet can inject links to the 3rd party malicious targets and these malicious assets can lead to unpredictable web application or web service behaviour.

Implementation of Content Security Policy (CSP) as HTTP Security Header is the main topic of this article. CSP is one of several HTTP Response Headers used in last time for advanced protection of communication over HTTP and HTTPS protocols. It brings higher level of security in communication between web server and web browser, and among devices communicating in IoT networks.

CSP header is not mandatory today, but it is recommended for environments, where communicating parties (people and devices) want to be sure they use assets (source code and services) only among approved domains and subdomains.

Nowadays, everybody can evaluate security level of web service thanks to publicly available testing tools like those available at www.securityheaders.io developed by Scott Helme. It is possible to scan web servers and evaluate them on scale from A+ to F [1].

Used methodology is not exact or scientific, but it offers overview on security level web servers can gain. In time of writing this article (October 2017), above mentioned web site published grand total statistics about grades, which have gained domains, subdomains (or fully qualified domains), tested by Internet volunteers for themselves.

From approximately 7 million realized tests, there were published pairs – grade and totals, which have led to the following grand total statistics.

Approximately 24% of web sites (or fully qualified domains) is in very good condition, with score A+ or A. Another 20% of web sites is in average conditions, with score on scale from B to D. In the first case the reason is that administrators already explored new security threats and possible workarounds. In the second case, the reason could be fact, that new HTTP Response Headers (known as HTTP Security Headers) are not so widely adopted yet and it is usually possible to identify only some of them in production environment (configuration).

Unfortunately, approximately 56% of web sites is in poor or even very bad conditions, because according to test results, they have gained score E or F.

Overlooking the fact this statistic is only informational and not scientifically exact, it highlights the necessity of adopting HTTP Security Headers in communication over Internet realized by HTTP or HTTPS protocols.

II. CONTENT SECURITY POLICY

Content Security Policy (CSP) as another kind of HTTP Security Header has purpose, like in case of HTTP Strict Transport Policy, to deliver from web server to web browser security policy in form of HTTP Response Header. In this policy are included assets – sources of content that the web browser may load. It is effective countermeasure to Cross Site Scripting (XSS) attacks and this mechanism is widely accepted among the top web

browsers, like: Chrome, Firefox, Opera, Safari, Internet Explorer and Edge. Unfortunately, support of SCP headers vary among them and among browser versions too [2].

A. Is Content Security Policy necessary?

Web browsers not only load HTML code alone, but they load assets mentioned in code, like stylesheets, java scripts, fonts, image, etc., because they were instructed to do so by source code of web page. Web browsers do not have any method to identify, whether they may or may not load those assets. An attacker can place a special snippet of code on web page to instruct browsers download 3rd party malicious code. In traditional way, web browsers have no reason not to trust the assets from malicious domains or subdomains a not to load it.

This is where Content Security Policy comes in and offers elegant solution to this security issue – called Cross Site Scripting (XSS) attack.

B. Approving secure sources

CSP header defines allowed sources for web page content that web browser can load. By identifying approved sources that web browser use for page rendering, it is possible to protect web browser from a range of security issues.

CSP Response Header is pretty simple method how to give permission to web browser to load for example script only from domain self. This is illustrated in form of HTTP Response (CSP) header on Fig. 1.

> Content-Security-Policy: script-src 'self'

Figure 1. Example of CSP header [2]

Using before mentioned example of an attacker with malicious code from 3rd party domain, now the web browser prevents to load java script from domain or subdomain different from that for which CSP header was specified.

Like in case of HSTS header, CSP header consists of name-value pair, where name is "Content-Security-Policy" or "Content-Security-Policy-Report-Only" and value is a string of directives, separated by semicolon. For example, Fig. 1 specified directive called "script-src", where approved sources are defined as "self". Keyword "self" specify whole domain and make policy easier to read as it grows. It is even faster to write CSP using "self" keyword, in comparison with using "https://domain.tld" string everywhere. It there is an attempt to load code from, for example www.attackers.com, web browser will now not load the script from this domain.

C. What can be protected

CSP defines a wide range of directives that can be used to enforce policy across all circumstances. Brief information about widely available CSP headers can be found at The Open Web Application Security Project [3] and detailed descriptions of directives are written by W3C Consortium [4].

Despite the fact implementation of directives in web browsers vary [2], in literature there are usually mentioned the following directives:

- **default-src**: defines loading policy for all resource type in case of a resource type dedicated directive is not defined (fallback),
- **script-src**: defines which java scripts the protected resource can execute,
- **object-src**: defines from where the protected resource can load plugins,
- **style-src**: defines which styles (shylesheets, or CSS) the web browser applies to the protected resource,
- **img-src**: defines from where the protected resource can load images,
- **media-src**: defines from where the protected resource can load video and audio,
- **frame-src**: defines from where the protected resource can embed frames,
- **font-src**: defines from where the protected resource can load fonts,
- **connect-src**: defines which URIs the protected resource can load using script interfaces,
- **form-action**: defines which URIs can be used as the action of HTML form elements,
- **sandbox**: specifies an HTML sandbox policy that the user agent applies to the protected resource,
- **script-nonce**: defines script execution by requiring the presence of the specified nonce on script elements,
- **plugin-types**: defines the set of plugins that can be invoked by the protected resource by limiting the types of resources that can be embedded,
- **reflected-xss**: instructs a web browser to activate or deactivate any heuristics used to filter or block reflected cross-site scripting attacks, equivalent to the effects of the non-standard X-XSS-Protection header,
- **report-uri**: specifies a URI to which the user agent sends reports about policy violation.

Precise definitions of CSP headers in time of writing this article (October 2017) is available in form of Editor's Draft by W3C Consortium [4].

D. Creating a CSP header

Process of specification of SCP header could be as specific as it meets requirements. The following example policies illustrate what is possible, but none of them is mandatory.

- Example 1: Allowing any assets to be loaded over HTTPS protocol from any domain, is illustrated on Fig. 2.

> Content-Security-Policy: default-src https:

Figure 2. CSP header example #1

- Example 2: Allowing any assets to be loaded from any domain on specific domain using any scheme or port, is illustrated on Fig 3.

Content-Security-Policy: default-src domain.tld

Figure 3.   CSP header example #2

- Example 3: Allowing only assets to be loaded from specific domain over https on any port, is illustrated on Fig. 4.

Content-Security-Policy: default-src https://domain.tld:*

Figure 4.   CSP header example #3

It was proofed by author's praxis, that the most common starting point for creating schema is the example on Fig. 5.

Content-Security-Policy: default-src https://domain.tld

Figure 5.   Starting point for creating SCP schema

Above mentioned schema can also use the following keywords [2] [4]:

- none – blocks the use of this type of resource,
- self – matches the current domain, but not subdomains,
- unsafe-inline – allows the use of inline java scripts and stylesheets,
- unsafe-eval – allows the use of mechanisms like eval().

In a process of creating CSP schema it mandatory to use the following rules:

1. Wildcards character * can be used for the scheme as port and left most part of a domain.
2. It is not allowed to specify directive twice, because the second will be ignored.
3. There is not inheritance from the default source directive.

For testing purposes, it was used author's personal web site available at https://www.dolnak.eu, where were used the most common 3rd party services used today, like services from Google, Cloudflare, jQuery, Bootstrap, etc.

```
▼ General
    Request URL: https://www.dolnak.eu/
    Request Method: GET
    Status Code: ● 200
▼ Response Headers
    content-security-policy: default-src 'self'; script-src 'self' htt
    ps://www.google-analytics.com https://code.jquery.com https://
    cdnjs.cloudflare.com https://maxcdn.bootstrapcdn.com; style-sr
    c 'self' 'unsafe-inline' https://maxcdn.bootstrapcdn.com; img-
    src 'self' data: https://www.google-analytics.com https://map
    s.googleapis.com; report-uri https://a34838f3192a6d321f99638e3
    8131735.report-uri.io/r/default/csp/enforce;
```

Figure 6.   CSP header implemented on author's personal web page

The same configuration options for Apache httpd server are presented in more readable form on the Fig. 7. In the code snippet are used SCP directives:

- Default Source
- Script Source
- Style Source
- Image Source
- Report URI.

```
<IfModule mod_headers.c>

  Header always set Content-Security-Policy "
          default-src 'self'; \
          script-src 'self'
                  https://www.google-analytics.com \
                  https://code.jquery.com
                  https://cdnjs.cloudflare.com \
                  https://maxcdn.bootstrapcdn.com; \
          style-src 'self' 'unsafe-inline'
                  https://maxcdn.bootstrapcdn.com; \
          img-src 'self' data:
                  https://www.google-analytics.com \
                  https://maps.googleapis.com; \
          report-uri https://.report-uri.io/r/default/csp/enforce;"

</IfModule>
```

Figure 7.   SCP configuration snippet for Apache httpd

E.   Testing a CSP header

After creation of first CSP header version, it is recommended to start in "Report Only" mode, illustrated on Fig. 8.

```
<IfModule mod_headers.c>

  Header always set Content-Security-Policy-Report-Only "default-src 'self'"

</IfModule>
```

Figure 8.   Report-Only version of SCP header

This "mode" actually means there are two version of SCP header, with and without 'Report-Only' supplement. Because different web browsers understand to CSP header parameter differently, "Report Only" mode offers possibility to test the policy among the most common web browsers used for specific domain (website) [2].

This usually means the browser receive and act upon the policy according the internal rules, but instead of enforcing the policy, it will give a feedback on what the effects of the policy would have been.

This way it is possible to tune policy without the risk of blocking some assets like java scripts, stylesheets or even some domains and subdomains.

There is also possibility to send from web server to web browser both headers – with and without "Report-Only", what is usable in situation where "Report-Only" header is optimal and can be used as production ready – without "Report-Only" supplement.

Second option is to use production ready header and still use testing header in order to enforce policy and test new parameters at the same time. For this purpose is very helpful report directive.

F. Reporting policy violation

Identifying links in HTML code to disallowed asset or attack due to found XSS attack vector is not possible without appropriate reporting. Without reporting, there is no straightforward way how to identify policy violation. For information what is happening on web server accessed by web browser, it is necessary to use "report-uri" directive.

This directive specifies at which location the web browser should send JSON formatted report in the event of CSP policy violation. Example of JSON report is illustrated on Fig. 9 without deeper explanation. In author's opinion, repot format is self-explanatory.

```
{
    "csp-report": {
        "document-uri": "https://www.dolnak.eu/",
        "violated-directive": "img-src",
        "effective-directive": "img-src",
        "original-policy": "default-src 'self'; report-uri https://.report-uri.io/r/
default/csp/reportOnly;",
        "disposition": "report",
        "blocked-uri": "https://img.routerboard.com//mimg/785_m.png",
        "line-number": 81,
        "source-file": "https://www.dolnak.eu/",
        "status-code": 0,
        "script-sample": ""
    }
}
```

Figure 9. JSON formatted report

Today, because of transformation of web sites from HTTP to HTTPS protocol, there are situations where some asssets are to be downloading via HTTP protocol and if it is not allowed by CSP policy, report directive helps to send message about it to specific location.

G. CSP builder and reporting service

As in the case of HTTP Security Header testing, there is free and publicly available CSP builder and reporting service (Fig. 10) created by Scott Helme and available at: https://report-uri.io/ [5] [6].

It is really "Real time security reporting tool", as it calls itself, and it helps to implement and monitor implementation of several HTTP Security Headers.

Figure 10. Report-uri.io web site logo

CONCLUSION

This article presented introduction to Content Security Policy header, a new security technology used in web and IoT environment for improving security level of communication over Internet among people and devices. It was illustrated how simple is to adopt Content Security Policy and make communication among people and device over Internet even more secure.

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Implementation of Referrer Policy in order to control HTTP Referer header privacy

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Abstract—**This article presents another from several available HTTP Security Headers – Referrer Policy. Nowadays, this policy (HTTP header) brings new possibility how to control information flow about origin from where the communication come to a destination web site. Thanks to this functionality, it is possible to show or hide navigating information, what can be precisely managed by web site's administrator. In the environment like the Internet, it is necessary to keep user's privacy at appropriate security level and not to allow everyone to track every user's step. In web server configuration it is simple to define policy for whole domain, subdomain and even for every web page individually, while this policy is directly propagated and used by web browser.**

I. INTRODUCTION

Keeping user's data and user's navigation (browsing) data private is current topic in different spheres of communication security, but it is brand new topic in case of Referer value used in communication over HTTP and HTTPS protocols.

Fortunately, there appeared new security tools – HTTP Security Headers, which identified new security technique in protecting data privacy in communication between web servers through web browser.

Never ending hardening of communication over HTTP and HTTPS protocols brings requested results again. Implementation of Referrer Policy as HTTP Security Header is that results and the main topic of this article at the same time. Referrer Policy is one of several HTTP Security Headers used in last time for advance protection of private data transferred between web servers via web browser in the form of Referer Request header, illustrated in Fig. 1.

▼ Request Headers
    :authority: www.dolnak.eu
    :method: GET
    :path: /kontakt/
    :scheme: https
    referer: https://www.dolnak.eu/
    upgrade-insecure-requests: 1

Figure 1.   Example of Referer header made in Google Chrome Developer Tools

Referrer Policy is not strictly required, but it is recommended to use it even in default configuration, thanks to what it can be maximally helpful in protecting browsing data.

There are different testing tools available today for evaluating HTTP Security Headers, but my preferable tool is available at www.securityheaders.io developed by Scott Helme. It is possible to scan web servers for compliance with today security standards and to get grades on scale from A+ to F [1].

From approximately 7 million of realized tests in time of writing this article (October 2017), it was created grand total statics with the following results.

Approximately 24% of web sites (or fully qualified domains) is in very good condition, with score A+ or A. Another 20% of web sites is in average conditions, with score on scale from B to D. In the first case the reason is that administrators already explored new security threats and possible workarounds. In the second case, the reason could be fact, that new HTTP Response Headers (known as HTTP Security Headers) are not so widely adopted yet and it is usually possible to identify only some of them in production environment (configuration).

Unfortunately, approximately 56% of web sites is in poor or even very bad conditions, because according to test results, they have gained score E or F.

It is important to note that this is only informational source of data and the results have not been compiled scientifically exact.

Above mentioned grand total statistics is illustrated on Fig. 1.
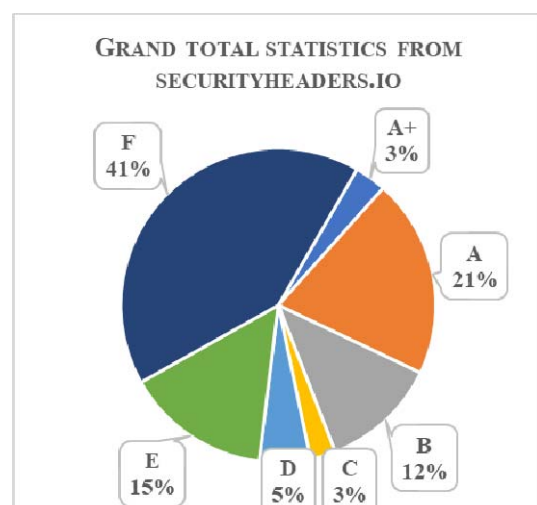
Figure 2.   Grand total statistics from SecurityHeaders.io about using HTTP Security Headers [1]

II. REFERRER POLICY HEADER

Referrer Policy allows to control Referer value in outgoing HTTP/S requests. Referer value is defined as the origin the user came from to a new website. This value is mostly used today by web search engines like Google, for visitor analysis and identification, where site's traffic is originating from.

It is very practical to know, from where are the visitors coming from – for example, from organic search offered by Google search engine, from competitor's website or directly, from domain name entered in web browser address bar. Knowing details about inbound traffic is helpful, but from time to time, it is good to control the amount of information present in Referrer header and so publicly available.

The reason is actually pretty straightforward, new destination site owners are able to identify the origin of communication – HTTP or HTTPS protocol, domain or subdomain name, or even full URL (Uniform Resource Locator) path, from where the traffic is coming.

Last detailed official specification of Referrer Policy was published in January 2017 by W3C Consortium [2] and very beneficial is also Mozilla Developer Network (MDN) documentation [3].

There is one curiosity, "Referer" is a misspelling of the world "referrer" and it appears in HTTP and HTTPS headers send between web server and web browser in incorrect form too. Fortunately, "Referrer-Policy" does not share this error. It is also possible to see this error in Fig. 1. and Fig. 2.

▼ General
    Request URL: https://www.dolnak.eu/
    Request Method: GET
    Status Code: ● 304
    Remote Address: 37.9.175.19:443
    Referrer Policy: no-referrer-when-downgrade

▼ Response Headers
    referrer-policy: no-referrer-when-downgrade
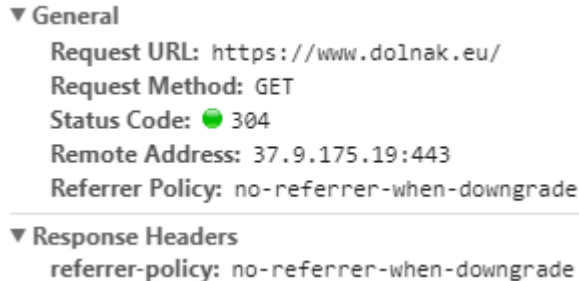
Figure 3. Referrer Policy as HTTP Response Header
made in Google Chrome Developer Tools

The Referrer Policy is enforced by issuing HTTP Response Header and can contain only one of the following directives according to specification [2] [3] [4]:

- "" (empty string),
- no-referrer,
- no-referrer-when-downgrade (default),
- same-origin,
- origin,
- strict-origin,
- origin-when-cross-origin,
- strict-origin-when-cross-origin,
- unsafe-url.

A. Definitions of directives

In the following lines are detailly defined only the most interesting of above mentioned directives. These definitions are used for Referrer Policy technique explanation and do not try to be full description at all. For exact definition, author of this article recommends to visit continuously upgraded specification from W3C Consortium [2].

Empty string – means that web server does not want to specify Referrer Policy using this technique (HTTP Security Header) and web browser should use fallback technique defined at different location (mostly HTML <meta>, <a> or <link> element). Referrer Policy is even possible to set by Content Security Policy, what is not so common in comparison with alternative using HTML elements [5]. Fig. 4 illustrates alternative how to implement Referrer Policy via HTML <meta> element.

```
<meta name="referrer" content="never">
```

Figure 4. <meta> element used for enforcing Referrer Policy [6]

No-referrer – means that web server should instruct web browser to never send the referrer header with requests made from domain. It also includes links to pages on the same domain [4]. Typical configuration of this directive is illustrated in Fig. 5.

```
<IfModule mod_headers.c>

  Header always set Referrer-Policy "no-referrer"

</IfModule>
```

Figure 5. No-referrer directive configured in Apache httpd

The following Fig. 6 illustrate Referer value send by web browser to the destination according to this Referrer Policy and Source of communication.

Source	Destination	Referer
http://example.com	http://example.com	NULL
https://example.com	https://example.com	NULL
http://example.com	https://example.com	NULL
https://example.com	http://example.com	NULL

Figure 6. Impact of "no-referrer" directive
on Referer Header propagation

No-referrer-when-downgrade – is default directive. In this case, web browser does not send during navigation from HTTPS to HTTP, but send full URL during navigation from HTTP to any destination. There is no difference between source and destination in case of this scheme [4]. Typical configuration is illustrated in Fig. 7. And final behaviour is illustrated in Fig. 8.

Referrer-Policy "no-referrer-when-downgrade"

Figure 7.   Configuration of "no-referrer-when-downgrade" directive

Source	Destination	Referer
http://example.com/path1	http://example.com/path2	http://example.com/path1
https://example.com/path1	https://example.com/path2	https://example.com/path1
http://example.com/path1	https://example.com/path2	http://example.com/path1
https://example.com/path1	http://example.com/path2	NULL

Figure 8.   Impact of "no-referrer-when-downgrade" directive on Referer Header propagation

Same-origin – means that web browser set the Referer header only on requests to the same origin. In case of different destination, no reference will be sent [4]. Typical configuration is illustrated in Fig. 9.

Referrer-Policy "same-origin"

Figure 9.   Configuration of "same-origin" directive

Origin – the web browser will always send the Referer header to the origin from which the request was made. It will be stripped any path (URL) information from the referrer information [4]. Typical configuration is illustrated in Fig. 10.

Referrer-Policy "origin"

Figure 10. Configuration of "origin" directive

Strict-origin – this is similar to "origin" directive, but it will not allow the secure origin to be sent on HTTP request, only HTTPS [4]. Typical configuration is illustrated in Fig. 11.

Referrer-Policy "strict-origin"

Figure 11. Configuration of "strict-origin" directive

Origin-when-cross-origin – the browser will send the full URL to requests to the same origin, but only send the origin when requests are cross-origin [4]. Typical configuration is illustrated in Fig. 12.

Referrer-Policy "origin-when-cross-origin"

Figure 12. Configuration of "origin-when-cross-origin" directive

Strict-origin-when-cross-origin – is similar to "origin-when-cross-origin" directive mentioned above, but it will not allow any information to be sent when web browser is navigation from HTTPS to HTTP protocol [4]. Typical configuration is illustrated in Fig. 13.

Referrer-Policy "strict-origin-when-cross-origin"

Figure 13. Configuration of "strict-origin-when-cross-origin" directive

Unsafe-url – the browser will always send the full URL with any request to any origin [4]. Typical configuration is illustrated in Fig. 14.

Referrer-Policy "unsafe-url"

Figure 14. Configuration of "unsafe-url" directive

B. Implementation guidelines

On the first view, selecting proper Referrer Policy is not so straightforward and it always depends on specific requirements. It is recommended to never use "**unsafe-url**" directive, because I this case, web browser always send the full URL of origin as reaction to every navigation request.

Fortunately, for decision making process, which Referrer Policy to select and implement, were published the following guidelines.

Actually, "**origin**", "**origin-when-cross-origin**" are not recommend and it is preferred to use "**strict-origin**" and "**strict-origin-when-cross-origin**" instead.

Because the goal is to control HTTP Referer header privacy, it actually means to minimize information leakage to destination. To eliminate issues coming from HTTP and HTTPS protocol, it is preferred and even made default "**no-referrer-when-downgrade**" directive.

C. Browser Compatibility

In order to practically use benefits of this security technique, it is important to have appropriate support among top web browsers used today, like: Chrome, Firefox, Opera, Safari, Internet Explorer and Edge. Unfortunately, support of Referrer Policy header vary among them and among browser versions rapidly [4].

In Fig. 15 and in Fig. 16 is illustrated support of this technology in time of writing this article (October 2017).

Feature	Chrome	Firefox	Edge	Internet Explorer	Opera	Safari
Basic Support	56.0	50.0	(No)	(No)	(No)	(No)
same-origin	(No)[1]	52.0	(No)	(No)	(No)	(No)
strict-origin	(No)[1]	52.0	(No)	(No)	(No)	(No)
strict-origin-when-cross-origin	(No)[1]	52.0	(No)	(No)	(No)	(No)

Figure 15. Referrer Policy compatibility on desktop browsers

Feature	Android	Chrome for Android	Edge mobile	Firefox for Android	IE mobile	Opera Android	iOS Safari
Basic Support	56.0	(No)	(No)	50.0	(No)	(No)	(No)
same-origin	(No)	(No)	(No)	52.0	(No)	(No)	(No)
strict-origin	(No)	(No)	(No)	52.0	(No)	(No)	(No)
strict-origin-when-cross-origin	(No)	(No)	(No)	52.0	(No)	(No)	(No)

Figure 16. Referrer Policy compatibility on mobile browsers

It worth for mention, that it could also be interesting to watch how big impact more strict implementation of Referrer Policy could have even on indexing of websites in search engines, like Google.

CONCLUSION

This article presented Referrer Policy, a new security technology used in web environment for protecting user's privacy in communication over Internet among web servers and web browser. It was illustrated how straightforward is to adopt Referrer Policy and make communication among network devices over Internet even more secure.

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Introduction to HTTP Security Headers and implementation of HTTP Strict Transport Security (HSTS) header for HTTPS enforcing

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Abstract—**This article presents introduction to HTTP Security Headers – new security topic in communication over Internet. It is emphasized that HTTPS protocol and SSL/TLS certificates alone do not offer sufficient level of security for communication among people and devices. In the world of web applications and Internet of Things (IoT), it is vital to bring communication security at higher level, what could be realised via few simple steps. HTTP Response Headers used for different purposes in the past are now the effective way how to propagate security policies from servers to clients (from web servers to web browsers). First improvement is enforcing HTTPS protocol for communication everywhere it is possible and promote this protocol as first and only option for secure connection over the Internet. It is emphasized that HTTP protocol for communication is not suitable anymore.**

I. INTRODUCTION

Improving security of the Internet communication is the long-term topic and engineers stand in front of new security issues almost evertime. Securing communication over HTTP protocol is another current challenge, because of high protocol popularity. Another reason is also the fact this protocol is used in everyday activities by people and devices without so necessary security considerations. With the rapid development of web sites, web applications and devices communicating in Internet of Things (IoT), people and devices use main benefit of HTTP – simplicity and wide software implementation availability. This comes with various negative aspects, like issues in secure communication, what is sometimes left unresolved by responsible persons. Hardening via HTTP Response Headers and specifically HTTP Security Headers is the main topic of this article. Despite the fact, that somebody could come with argument that HTTPS is actually secure and it does not need another security enhancement, the opposite is true.

For example, HTTP Strict Transport Security header is one among firsts HTTP Response Headers used in last period for advanced protection. It brings new kind of protection in communication between web server and web browser, and among devices communicating in IoT networks.

None of above mentioned HTTP Security Headers is mandatory today, and it is possibility to provide web services for people and devices even without them. On the other side, from security perspective, in well-managed environment, there should be implemented some or even all of them.

The reason is again the same, situation in this environment (where HTTP is used every day as main communication protocol) is not black and white, so there is not HTTP protocol on the one side and HTTPS on the other side. For most cases, communication process is initiated as HTTP connection (at least on the first time) and after that it smoothly flows into HTTPS communication. Between these two opposites is everyday reality and necessity at the same time, how to make this communication more secure. Exactly these mechanisms – new HTTP Response Headers, also known as HTTP Security Headers, lead to a new quality – secure HTTPS communication only.

Fortunately, everybody can evaluate security level of services using HTTP or HTTPS protocol. Thanks to publicly available testing services like those available at www.securityheaders.io by Scott Helme, it is possible to scan server side of web services and evaluate them (not exactly) like in a school on scale from A+ to F [1].

Despite the fact this evaluation is not exact or even scientific, it offers highlight which security level can your web services gain. In time of writing this article (October 2017), above mentioned web site published grand total statistics about grades, which have gained domains, subdomains (or fully qualified domains), tested by Internet volunteers for themselves.

From approximately 7 million realized tests, there were published pairs – grade and totals, which have led to the following grand total statistics illustrated on Fig. 1.
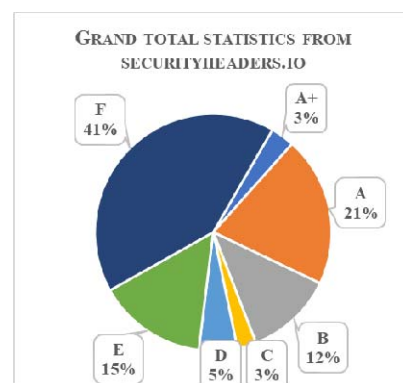
Figure 1.   Grand total statistics from SecurityHeaders.io about using HTTP Security Headers [1]

It is interesting, that approximately 24% of web sites (or fully qualified domains) is in very good condition, with score A+ or A. Another 20% of web sites is in average conditions, with score in scale from B to D. In our opinion, in the first case the reason is that administrators already explored new security threats and possible workarounds. In the second case, the reason could be fact, that new HTTP Response Headers (known as HTTP Security Headers) are not so widely adopted yet and it is usually possible to identify only some of them in production environment (configuration).

Unfortunately, approximately 56% of web sites is in poor or even very bad conditions, because according to test results, they have gained score E or F.

Overlooking the fact this statistic is only informational and not scientifically exact, it highlights the necessity of adopting HTTP Security Headers in communication over Internet realized by HTTP and HTTPS protocols.

A. HTTP protocol

HTTP protocol is a stateless protocol, what implicate that at protocol level, there is no option how to record what happened in communication in the past. The HTTP purpose was different in time of origin in comparison with present requirements – use sessions to maintain state in communication and even persuade clients to specific security behaviour.

This can lead to debate how web servers and web browsers could communicate securely.

For this purpose, HTTP Response Headers are one of the options. These headers are name-value pairs of strings send by server to browser as reply to browser's request. In the past, they were generally used to transfer technical instructions, how client should process data and today, they can be used in case of security for transmitting security policy. Bypassing security policy to clients ensure a much secure browsing experience and reduce possibility for 3rd party involved in communication.

B. The most common HTTP Security (Response) Headers

Today, the most common HTTP Response Headers used for security purpose are:

- Strict Transport Security,
- Content Security Policy,
- Public Key Pins,
- Referrer Policy.

In addition to these, there are also usually mentioned Response Headers:

- Server
- X-Frame Options,
- X-Content Type Options,
- X-Xss Protection,
- Expect CT,
- Expect Staple.

Presence and correct configuration on web server all of these HTTP Security Headers is possible to test by above mentioned tool by Scott Helme, available at www.securityheaders.io [1].

II. HTTP STRICT TRANSPORT SECURITY (HSTS)

HTTP Strict Transport Security is according to definition mentioned in abstract of RFC 6797 from November 2012 "mechanism enabling web sites to declare themselves accessible only via secure connection and/or for users to be able to direct their user agent(s) to interact with given sites only over secure connections" [2]. This is mostly declared by web servers via HTTP Response Header field.

In other words, HTTP Strict Transport Security is a policy to mostly enforce use of Transport Layer Security (TLS) in web browsers (agent(s)). It allows effective implementation of TLS by ensuring that all communication is realized over secure channel. Another positive effect is mitigation of the Man in the Middle (MiTM) attacks, where TLS can be stripped out of communication and leaving browser to risk [3].

HSTS mitigate this risk (threat) by enforcing the use of TLS by the browser, which prevent the browser navigate to the site using HTTP protocol.

A. Implementing HSTS

HSTS implementation is declared by issuing HSTS policy, what is practically realized as addition of the HTTP Response Header named "Strict-Transport-Security". In traditional pair name-value schema, "Strict-Transport-Security" is the name and value could be various parameters, separated by semicolon [3].

First parameter "max-age" is mandatory and can be any value from 0 upwards. It represents the time in seconds during browser treats domain or subdomain as HSTS host. Value 0 has a special meaning for browser – it means that browser must remove all policies for specified domain or subdomain.

Second parameter "includeSubDomains" is optional. It represents that browser should treat all subdomains of specific domain as HSTS hosts too.

On Fig. 2 is presented shortened example of HTTP Response Headers, where HSTS header is important only, This figure was made in Google Chrome Developer Tools for our testing domain, one of author's personal web site available at www.dolnak.eu.

▼ General
    Request URL: https://www.dolnak.eu/
    Request Method: GET
    Status Code: ● 200

▼ Response Headers
    status: 200
    strict-transport-security: max-age=31536000; includeSubDomains
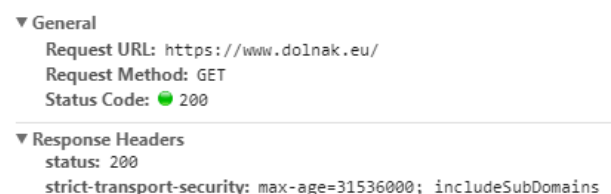
Figure 2. Example of HSTS header
created in Google Chrome Developer Tools

Very important is fact, that HSTS header should be send to browser only over HTTPS protocol, and client should always ignore it, if it was sent over HTTP protocol. Primary reason for this behaviour is that attacker running MiTM attack could strip out this header and causing undesirable results for browser [3]. Details could be now omitted, but are described in References.

Actually, there is only one opportunity for attacker – to intercept first communication between browser and server

or wait, until HSTS policy expires. Details of communication process are illustrated on Fig. 3.
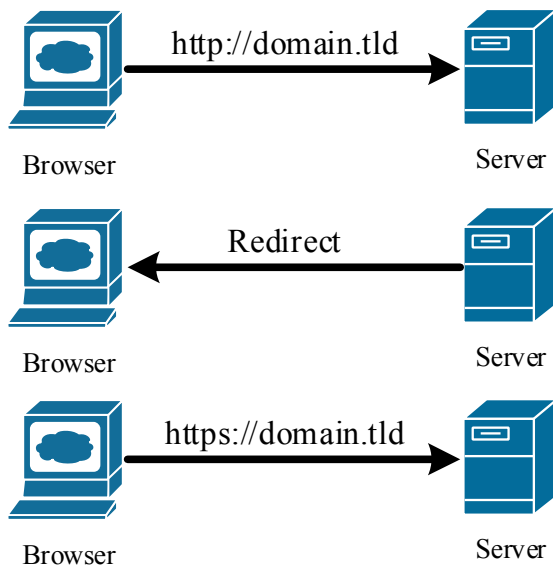
Figure 3. Communication between browser and server leads from using HTTP to HTTPS protocol via redirecting

After the browser accepts HSTS policy, it will consider a server to be a valid HSTS host and for the duration of policy (max-age) it stores that policy internally. During that time, client will transform insecure URI to HSTS host (for domain and even for subdomains) into secure URI (from http:// to https://) before it sends requests and terminate any secured connection in case of errors or warnings. Even if HTTP protocol is explicitly defined, the client always use HTTPS protocol. Terminating the connection when there is any uncertainty is the best possible level of protection to the client. Details of communication process are illustrated on Fig. 4.
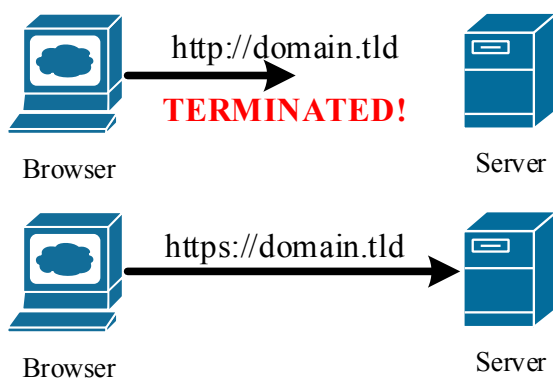
Figure 4. Communication via HTTP is terminated at browser and HTTPS is used instead

B. Configuring HSTS

Presence and valid configuration of HSTS header can be checked by before mentioned tool available at www.securityheaders.io. On the Fig. 5 is illustrated example of configuration used in Apache httpd server. Despite the fact it is necessary to add only 3 lines into main configuration file, it is still possible to find vitally important domains with already implemented SSL/TLS domain certificates and without implementation of HSTS header.

```
#1 <IfModule mod_headers.c>
#2  Header always set Strict-Transport-Security \
    "max-age=31536000; includeSubDomains" env=HTTPS
#3 </IfModule>
```

Figure 5. HSTS header configuration in Apache httpd

III. HSTS PRELOAD

HSTS is simple HTTP Response Header that can be issued by domain or subdomain owner to tell browser that it should use HTTPS protocol for communication. But the problem is that browser have to visit domain's website using HTTP first in order to get HSTS header.

Actually, this is not brand new problem and it is also known from Secure Shell (SSH) communication for the first time. This issue is called TOFU, what means "Trust On First Use" problem [4].

This problem could be simply described as: when browser has never been on specific domain's website, it won't know about HSTS policy. This problem is possible to solve by HSTS Preloading – specific domain can be put on special list built into browser and that domain can be marked as HTTPS only. This way even browsers which have never visited domain's website before, will know they have to use HTTPS protocol only for communication, even for the first time.
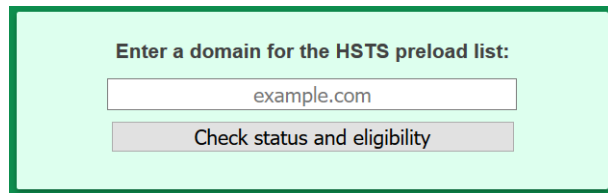
The process of putting domain on HSTS preload list starts with adding **third parameter to HSTS policy called "preload"**. Fig. 6 presents full example of HSTS policy with preload enabled.

```
#1 <IfModule mod_headers.c>
#2  Header always set Strict-Transport-Security \
    "max-age=31536000; includeSubDomains; preload" env=HTTPS
#3 </IfModule>
```

Figure 6. HSTS header configuration in Apache httpd with preload parameter

This parameter, sometimes called token, indicate domain owner's decision to be included on HSTS preload list. The decision to be on the list should be made carefully, because in case the domain's website will be unavailable over HTTPS protocol, the domain will be unavailable at all (even if domain's website offers communication over HTTP protocol).

After careful decision to be placed on HSTS preload list, request have to be submitted via https://hstspreload.org website. Illustration of checking status and eligibility is on Fig. 7.
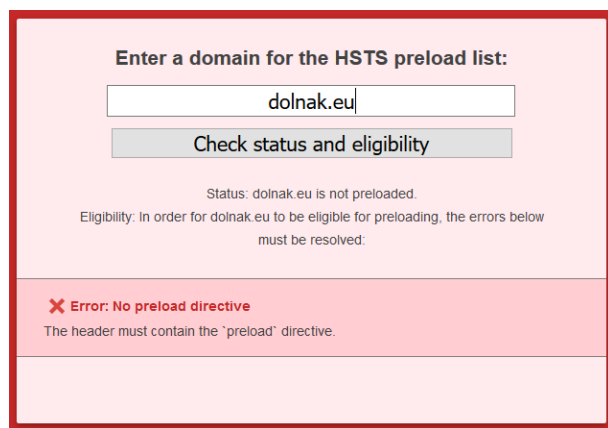
Figure 7.   Checking status and eligibility of domain for HSTS preload list at https://hstspreload.org web site

After correct fulfil the registration form, domain is pending in the HSTS preload list [5]. Illustration of submitting domain to the HSTS preload list is on Fig. 8 and Fig. 9.

Figure 8.   Error in checking of status and eligibility of domain for HSTS preload list

Propagation of the HSTS preload list to web browsers is not realized immediately, but sometimes even after few weeks in new browser versions and the list is hard coded into source code. The list is shared today among the top web browsers, like: Chrome, Firefox, Opera, Safari, Internet Explorer and Edge [4].

There is recommendation, that "preload" directive should not be included in web server configuration by default. Domain owners are warned to include this directive in web server configuration without consideration of the benefits and disadvantages.

Figure 9.   Submitting domain to the HSTS preload list

There are mentioned examples, where domain owners tried to remove domain from HSTS preload list, but removal tends to be slow and complicated. Administrators should know about long-term consequences of preloading before they turn it on for a given domain. [5]

CONCLUSION

This article presented introduction to HTTP Security Headers and specifically HSTS header - new security technologies used in web and IoT environment for improving security level of communication over Internet among people and devices. It was illustrated how simple is to adopt Security Headers and make HTTPS protocol and SSL/TLS domain certificates even more beneficial.

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[5]   *HSTS preload list web site.* October, 2017. Available at: https://hstspreload.org/

Information-presentation educational path for students´self-study of engineering graphics

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Abstract—**The article discusses the information-presentation educational path for students' self-directed engineering-graphical training, which is implemented at M.T. Kalashnikov Izhevsk State Technical University (ISTU) Izhevsk, Russia, and applicably at the Slovak University of Technology, Faculty of Materials Science and Technology in Trnava, Slovakia. The method of expert team evaluation, one of the major ones in qualimetry, was used at all stages of self-directed learning management. The method reveals the components of engineering-graphical competence, establishes the criteria and markers for determining the level of its development, and performs expert evaluation of student tasks and estimation procedures. The paper also describes the criteria and assessment procedures for determining the level of students' engineering-graphical competence: phenomenological, analytic-synthetic, creativity and activity-based levels. It has been found that the revitalization of students' self-directed learning increases their level of engineering-graphical competence development due to professional education and individualization.**

I. INTRODUCTION

Current development trends in computer-aided education provide the teachers with the opportunity to implement significant changes into the training process. They provide not only the possibilities to design text pages but also to design the presentations in multimedia application forms. Such innovations allow absorbing the teaching material faster and more effectively than utilizing only classical teaching approaches.

One of the main quality characteristics of technical university bachelor's professional performance is the level of one's graphic literacy. Therefore, with competency-based approach being implemented in higher education and significantly increasing the importance of student self-directed engineering graphics training, the problem of its revitalization and raising its efficiency in bachelor training arises.

The proposed method of training has the potential to transform the learning experience. By supporting active and interactive learning, it means that learning can become more student-centered.

In corresponding subjects they can find necessary and useful material they have to study, process and send to their teachers. The University is committed to empowering the students as learners in self-study activities, helping them thus to learn effectively with technology and develop their e-skills enabling them to work and participate in a technology-rich society.

II. PURPOSE OF THE STUDY

In order to solve this problem, individual educational paths for Instrument Engineering students' self-directed learning were developed in M.T. Kalashnikov Izhevsk State Technical University, (ISTU) Russia [1, 2, 3, 4] and applicably at the Slovak University of Technology, Faculty of Materials Science and Technology in Trnava, Slovakia. One of such paths is information-presentation path aimed at developing the skills to navigate through information flows, master new technologies and self-study.

Thanks to solid information and communication technologies equipment, both teachers and students can make an effective use of presentations, animations, videos, pictures, scans, notes, commentaries and communicate with each other easily. Furthermore, this type of education possibilities are time consumption friendly, and reflect also recent needs such as costs lowering (in the possibility of delivering the training to significantly larger groups of recipients). In addition, the trainings can be tailored to the specific needs of a group and the approach more personalised and flexible, and the discussion forums can provide both teachers and students with a necessary feedback, and what is more, they also support recent educational trends such as learner autonomy and self-access.

III. METHODS AND CONTENT OF STUDY

Within this educational path students perform different individual tasks corresponding to their training level: for example, drawing an original 3D detail or assembly unit. The learners demonstrate their skills to build a solid 3D model and construct an associative drawing based on this model while presenting the results of their work.

When collecting the content for their self-directed learning, students study thoroughly the materials from scientific-practical conferences, read professional literature, use electronic libraries and virtual laboratories, scientific, educational, and other necessary relevant web resources.

The standard form of presenting the results of self-studying is students' self-presentation. The goal of self-presentation is to not only demonstrate your knowledge, but also to provide listeners with information needed, give one's viewpoint with supporting evidence. In order to acquire self-presentation skills, it is necessary to:

✓ study general and specific principles of composing a presentation, including the latest trends;

✓ understand the algorithm for collecting the presentation content;

✓ navigate through the means and techniques of effective presentation;

✓ know the main advantages and difficulties of public speaking;

✓ employ elements of non-verbal communication;

✓ test their ability to work in team;

✓ prove their stress resistance and willingness to learn;

✓ experience latest corporate and conferencing culture trends;

✓ apply principles of political correctness;

✓ increase their learner autonomy and self-access;

✓ and thus improve their communication and presentation competences within their engineering study programs.

The topics of several reports prepared by the students as self-presentations in 2010-2014 were as follows: «Innovations in instrument engineering», «Research and development in instrument engineering in Udmurtia», «Personalia in instrument engineering».

One of the most difficult and engaging tasks is building a virtual 3D assembly unit in graphical editor «KOMPAS 3D». The assembly is designed with using 2D drawings and related 3D models of the details from this assembly unit as well as a 2D assembly drawing and electronic specification.

When performing this task, one must use control commands, coordinate types and systems in three-dimensional space and manage precise relocations with the object snap. Then all details are relocated one by one. In visualization mode photorealistic image of an object can be viewed from any angle.

After that all step-by-step actions are documented by students in a form of self-presentation using a wide spectrum of digital technologies: text editors, image processing applications and spreadsheets. A prepared slide show is accompanied by a report which must be engaging, easy-to-understand for the audience and logically structured.

Practice shows that information communication technologies facilitate a unique information environment in a training group, intensify communication and complement direct interaction between the subjects of educational process with latest equipment.

It must be emphasized that self-presentation is also a way to personally connect with an audience, when the use of personal tone transforms the talk into the process of interaction with listeners. Acquiring self-presentation skills, therefore, is a way to self-development.

The training in these skills has been successfully integrated into education at ISTU Izhevsk, Russia as well as at STU MTF Trnava, Slovak Republic for its effectiveness, authenticity, learner-centeredness, student professional development, focus on language discourse level, employment of integrated language skills, and possibility to combine individual talents and knowledge acquired in specific subjects studied within the chosen study program.

Such training involves multi-skill activities, challenging students to work together within a team with developed dynamics, and reasonable time management. The implementation of information and communication technologies is a prerequisite for the completion of the assignments; students are challenged to use the resources on web, including mutual cooperation of students involved.

The basic requirements to task performance and engineering-graphical competencies developed are comprehensibly shown in Table 1.

TABLE I.
BASIC REQUIREMENTS TO TASK PERFORMANCE WITHIN INFORMATION-PRESENTATION EDUCATIONAL PATH

Item No.	Basic requirements	Developed competencies
1.	Determining the goals and tasks for the work; making up a work plan; collection and analysis of the information needed	The skill to analyze the material on the chosen topic The skill to navigate across information space and latest information technologies
2.	Full coverage of the work topic, systematization, validity, consistence of information presented	The skill to structure, systematize information from different sources: electronic textbooks, multimedia guides, web resource The knowledge of information web resources
3.	Compliance with copyright when developing the content for work	The knowledge of citing and references documentation rules
4.	The presence of original multimedia components to supplement the content and help in perceiving complex questions	The ability to use computer technologies and software for searching, storing, processing and communicating information The skill to model and build a form of product using information and communication technologies
5.	Quality of presentation structure: slides must have the same style, contain the necessary text material, graphic imaging, slide show and appropriate animation effects	The skill to use special software for presentation preparation The skill to plan and arrange visual aids for the public performance

		The ability to self-aware and the ability of self-development
6.	The depth of the content on the chosen topic and its comprehensibility for students	The skill to demonstrate one's knowledge and provide listeners with information needed; present one's viewpoint with supporting evidence The skill to respond to questions in a competent manner

The results of tasks performed are documented in portfolios. In this case the portfolio is a set of student's graphical work, documents, resumes, presentations, reports and articles.

The portfolio consists of basic and variative parts. Basic part comprises a set of basic component tasks including following documents: calculation-graphical assignments; activity book with descriptive geometry tasks performed; the results of latest control papers and tests. Variative part of student´s portfolio based on information-presentation path comprises the most successful presentations, reports, and practice-oriented developments.

All types of individual work within information-presentation path are evaluated through 100-point rating system which is clearly illustrated in Table 2 [2, 5].

TABLE II.
DISTRIBUTION OF POINTS ACROSS THE TYPES OF INDIVIDUAL WORK

Type of individual work	Score	Minimum/maximum score
Report and presentation	20	12/20
Design of a detail and assembly unit drawing in 2D/3D space and giving a presentation based on it	80	48/80
Total:	100	60/100

The final management procedure within information-presentation path is a conference held in Engineering Graphics department.

Students' total scores are registered in a technological map consisting of evaluation criteria based on the method of team expert appraisal: full coverage of the work topic, presentation quality, its graphical design and reasonableness of answers to the questions.

The level of student's engineering-graphical competence development (Ks), i.e. how well one performs certain operations and acquires necessary skills of engineering graphics activity, is determined by using the formula as followed

$$K_s = \frac{\sum_{i=1}^{n} T_{ci}}{T}$$

where Tci is a number of engineering-graphical competence components the possessing of which was demonstrated by a student when one performed the task; T is a total number of engineering-graphical competence components established by using the method of team expert appraisal in the thesaurus of given educational path [6].

Table 3 shows the evaluation results of students' engineering-graphical competence development level during the final management procedure within information-presentation path in 2013.

IV. MULTIMEDIA IMPLEMENTATION TO LEARNING

One of important tasks of present educational-learning process is using new modern learning forms and methods especially implementing new information and multimedia technologies to learning process.

Modern information tool – multimedia computer that came to traditional learning system can be excellent aid in hands of sore teacher with necessary theoretic and practical knowledge and can increase professionalism of his work. By adequate use it enables to students much new knowledge, enables better work with learned issues and removes the teacher's routine.

The attitude of teacher to preparing and making multimedia learning belongs to critical elements.

Multimedia application combines text and animation video, audio, graphics, schemes and test elements. Education form is chosen on the base of many criteria as, potential students' profiles (accomplishments, attitude to computers, studying environment), type of educated subject matter (theory, practical activity, and work order) or technologic possibilities (computers, networks, internet connection). Prepared learning material assures feedback from students by test questions, options from possibilities or solution designs. Students are active in learning.

CD ROM, local PC discs, computer room, Intranet, Internet or combined methods belong to basic distribution methods. CD ROM and local discs preserve large amount of data but the actualization of learning material is disadvantage. Trend is distribution of learning to Intranet or Internet. These means bring unified standards, environment and security, possibility of regional expandability and instant distribution of final product to student. Combined methods connect advantages of saving data on CD ROM or user disc with Intranet/Internet advantages.

Modern programs for computer aided learning are not electronic duplicate of the original learning material. It is a new kind of material that fully uses advantages of multimedia technologies and enables to prepare interesting graphic and animated materials that bypass boring textbooks.

Certainly, technical and user readiness of teachers and students is inevitable condition. It is important to assure preparation of students and teachers to use information technologies to gain, create, transfer, process and save information and its use in praxis.

V. UTILIZATION OF TECHNOLOGIES AT THE UNIVERSITIES

The current curricula comprise an enormous amount of knowledge to be taught, and therefore it is very difficult for teachers to make teaching attractive, find space for creative activities, learner centeredness, team work, problem solving activities, etc. to deduce own conclusions, as in [13].

The practice in present education shows that there is a gap between ICT development and educational process stages. With regard to own empirical experience and publications commenting on ICT in education, we can state that education falls behind in this preparation.

The current situation in the education cannot be changed just by the new technology or by free access to the Internet. Further steps are necessary to take:
- ✓ technology should carry an appropriate message,
- ✓ teachers should use the technology purposefully.

Therefore it is important to prepare future teachers for changes in goals, contents, and methods so that they can face the educational process of the third millennium.

ICT utilization in teaching opens different dimensions both for students and teachers. The process of informatization allowed for the origin of new multimedia services and applications bringing thus many benefits such as:
- ✓ new opportunities for people's creativity implementation larger,
- ✓ better support of education and lifelong learning,
- ✓ wider selection of services – improvement of life quality,
- ✓ remarkable ability to adopt changes in the structure of offers or demands,
- ✓ etc.

Needless to mention that the society with developed ICT infrastructure can:
- ✓ allow "home office" work,
- ✓ make information sources widely available to public,
- ✓ provide physically challenged people with enhanced possibilities,
- ✓ make full time or distant education more interactive.

Implementation of ICT into educational process is inevitable. ICT should become a tool of everyday life for both students and teachers in at universities as well as in terms of lifelong learning. Therefore, it is necessary to support the development of computer literacy and ensure thus teachers´ IT skills on higher level on all educational stages so that we can approximate to the European standard in ICT application in education.

The current society is called the knowledge-based society. The ICT development and their overall implementation have started changes in all spheres of human life: in knowledge, social interaction, economics, companies and plants control, politics, media, education, health, free time activities, and entertainment.

VI. UTILIZATION OF SIMULATIONS AND VIRTUAL ENVIRONMENT

The process of teaching at technical universities calls for implementation not only theoretical knowledge but also for obtaining practical experience. Nevertheless, at many schools and universities the equipment is insufficient. The solution to the situation can be represented by a virtual laboratory. For instance, in our case it is the teaching of programming an industrial robot. So building a simplified virtual robotic model identical in its interface with the real industrial robot can provide the teacher and students with the same principle. It can replicate the behavior, and provide comparable outcomes, as in [14].

The utilization of a virtual robotic model leads to effectiveness from various aspects, e.g.:
- ✓ Environmental. The advantage of the virtual technology application means that it is not necessary to produce the real model, nor it is necessary to create the real workplace. This means that utilization of the virtual models is environment friendly.
- ✓ Economic. In the optimization of a virtual technology are the investment and operation costs which can influence the decision making in purchasing a new technology.
- ✓ Ergonomic. At present, the possibilities of virtual technologies are sometimes neglected. Nevertheless, the benefits including the working environment are unbeatable, as in [15].

Currently, the issue of utilizing virtual models prior to real ones is vital also for top European companies including, e.g. renowned car factories due to the following advantages:
- ✓ decreasing the risk in complicated and dangerous robot manipulations,
- ✓ providing more transparency in robot control,
- ✓ no travelling to the place of manipulation,
- ✓ creating fully functional application that amends manual control in virtual form,
- ✓ making various simplifications in the robot control,
- ✓ providing constant availability,
- ✓ providing the possibility of creating thee components to expand the workplace peripheries,
- ✓ generating various statistic results processed from any time interval,
- ✓ providing the possibility of periphery corrections and manipulations,
- ✓ setting of work in various working modes,
- ✓ exchanging the knowledge acquired between workers,
- ✓ creating of own programming interface, as in [16,17].

The figures used in the contribution are the proposals elaborated within the study at the lessons of Automation at the Slovak University of Technology, Faculty of Materials Science and Technology.

VII. RESULTS OF STUDY

As can be noticed, the results obtained correlate with the results of students' ranking score which is shown in the following Figure 1.
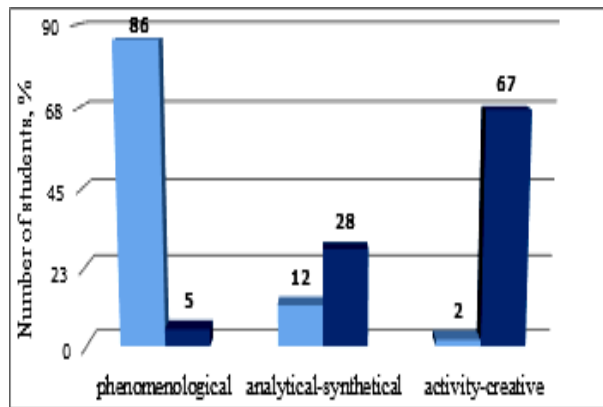
Figure 1. Magnetization as a function of applied field. Note how the caption is centered in the column

The description of engineering-graphical competence levels which were established by using the aforementioned method of team expert appraisal is given in the following Table 4.

The diagrams of self-directed learning results demonstrate an upward trend in engineering-graphical competence development of bachelor students: 60% of learners had their engineering-graphical competence developed at activity-creative level.

TABLE III.
ENGINEERING-GRAPHICAL COMPETENCE LEVEL WITHIN INFORMATION-PRESENTATION

Key actions of the participants in task performance	Level of students' engineering-graphical competence development (%)								
	1	2	3	4	5	6	7	8	9
study and analysis of information needed									
presence of original multimedia components									
structure of presentation									
design of graphics in CAD									
modeling, building a form of products with information technologies	90	82	90	73	64	73	82	90	64
presenting one's viewpoint with supporting evidence									
design of graphical images according to GOST									
using animation effects, slide show									

TABLE IV.
DESCRIPTION OF ENGINEERING-GRAPHICAL COMPETENCE LEVELS WITHIN INFORMATION-PRESENTATION PATH

	Engineering-graphical competence development levels		
	phenomenological	*analytical-synthetical*	*activity-creative*
Information-presentation path	Student is able to extract information needed from professional online literature, electronic libraries and virtual laboratories: scientific, educational, and other necessary and relevant online resources on engineering graphics; the student is also able to demonstrate one's knowledge by means of the self-presentation	Student is able to build original 3D details and demonstrate their work by means of self-presentation showing thus the acquired knowledge of design techniques based on the analysis of product design and the use of GOST Unified system for design documentation	Student is able to build a virtual model of assembly unit using information and communication technologies, demonstrating thus their step-by-step actions using the self-presentation with a wide spectrum of digital tools and technologies

It must be emphasized that the evaluation criteria of engineering-graphical competence development level are given to students at the stage of choosing their educational paths. It allows to exercise timely self-management of their work.

Students' conscious choice of an individual educational path with timely correcting help of a teacher increases the motivation for self-directed learning and enhances thus its quality. The method of team expert appraisal provides a more reasonable approach not only to the content of students' educational self-study paths, but also to the adequate choice of criteria for its quality evaluation.

VIII. CONCLUSION

The university workplaces are involved in multiple projects, many of them being international, or they deal with research. Nevertheless, the results of researchers cannot be sometimes implemented due to demanding costs, technicalities or safety. The possibilities of ICT supported by multimedia are a unique tool to carry out the task – they can implement the results in a virtual scene.

The advantages of integrating information and communication technologies into teaching process are obvious. They provide both teachers and students with easier comprehension of the study material.

To help STU MTF graduates successfully perform on the global market and in the international research and study environment, their e-learning skills should be developed and practiced during the whole study.

As aforementioned, e-education possibilities are time consumption friendly and reflect current needs (costs lowering) as well as it provides the possibility of delivering the training to significantly larger groups of recipients. And what is more, the trainings can be tailored to the specific needs of a group and the approach customized. In addition, e-learning materials and e-

activities developed by STU MTF teachers support recent educational trends such as learner autonomy and self-access.

Thus, the results of the experiment in applying information-presentation educational path to the educational process in M.T. Kalashnikov Izhevsk State Technical University, (ISTU) Izhevsk, Russia, and applicably at the Slovak University of Technology, Faculty of Materials Science and Technology in Trnava, Slovakia show the efficiency of the bachelor student self-study organization technology proposed which provides students' transition to a higher level of engineering-graphical competence.

The application of information technologies should be a must in the whole educational process regardless the specialization. Particularly the university graduates should be able to utilize the majority of services offered by various information technology applications as well as the ability to understand the principle of its operation should be assumed.

Utilization of information technologies and multimedia implementation can be an excellent aid and a useful tool in hands of a professional teacher, and eliminate boring routine. Obviously, readiness of both teachers and students is an essential prerequisite for professional utilization of developed interactive materials.

To help our graduates successfully perform on the global market and in the international research and study environment, the mentioned skills should be well developed, and hence also practiced [7, 8, 9, 10, 11]. The self-directed learning provides an ideal space to meet these requirements. The teachers use it to stimulate the students' interest in such learning activities, to develop their competences, and to fully utilize the educational environment for self-study at the Faculty, University and wider context.

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Contribution to Cloud Computing Security Architecture

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Abstract — **Cloud computing security is an important problem when deploying its services. Users consider security to be the most important aspect when deciding to utilize a service cloud computing. Architectural views of cloud computing are views of stakeholders that have different roles and thereby responsibilities for implementing security mechanisms. Security belongs to cross-cutting aspects and pass over all layers of architecture. The Reference Architecture of cloud computing according to ITU-T Recommendation X.1601 specifies only basic security mechanisms and does not determine security responsibilities to roles in relevant services. Considerable division of responsibilities is in IaaS - Infrastructure as a Service. Responsibility for the security of some layers of architecture is on the service provider and the service customer as well. The division of responsibilities based on their requirements is solved in the article as the security architecture framework.**

I. INTRODUCTION

Cloud computing is generally a grouping of objects to provide various specific ICT services. We choose here two specifications from many Cloud computing definitions.

1. The NIST Definition of Cloud Computing [1], where „Cloud computing is model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models."

2. ITU-T-REC-Y.3500 Specification [2], that is expressed as follows „Cloud computing is a paradigm for enabling network access to a scalable and elastic pool of shareable physical or virtual resources with self-service provisioning and administration on-demand. The cloud computing paradigm is composed of key characteristics, cloud computing roles and activities, cloud capabilities types and cloud service categories, cloud deployment models and cloud computing cross cutting aspect."

Cloud computing belongs to the "Utility Computing" group. This designation is, according to [3] the following: „Utility computing is one of the most popular IT service models, primarily because of the flexibility and economy it provides. This model is based on that used by conventional utilities such as telephone services, electricity and gas. The principle behind utility computing is simple. The consumer has access to a virtually unlimited supply of computing solutions over the Internet or a virtual private network, which can be sourced and used whenever it's required. The back-end infrastructure and computing resources management and delivery is governed by the provider. "

From mentioned specifications, cloud computing systems are the distributed technology platforms but they also provide a variety of on demand services that are created for organizations, to create different innovation changes. Therefore, successful implementation of cloud computing requires not only understanding of technology, architectural layers and models, but also understanding the economic and business factors and decided, which cloud computing services are needed and useful for a certain enterprise. The cloud's technical architecture and business architecture require mutual communication.

This paper addresses to the security in the implementation of IaaS in a private cloud. The selection for the security aspects is based primarily on the following surveys.

Gartner Company in 2010 carried out a survey of 332 cloud computing users. They asked respondents to evaluate from 13 questions the 3 top drivers and 3 top concerns for the decision to implement the cloud computing solution. It was found in [4] these:

Top drivers:
- Meet security requirements and data location/privacy requirements;
- Ability to grow or shrink usage and pay only for consumption;
- Cost or easy to deploy the cloud service.

Top concerns:
- Security of service;
- Data location, privacy or access concerns;
- Perceived loss of control or choice of technology.

The cloud security processed by Information Security Community on LinkedIn through survey its 300,000 members published in [5], some key findings related to cloud security:
- General security concerns (53%);
- Legal and regulatory compliance concerns (42% up from 29% in last year's survey);
- Data loss and leakage risks (40%).

Newtrix Cloud Security Report 2016 reports in [6] the results from a survey of 660 IT professionals, representing

businesses of varying sizes across industries around the world. Respondents asked to name a maximum five 5 concerns about cloud computing technologies, regardless of the adaptation stage. Such are the results "Security and the privacy of data and systems in the cloud remains a top concern for organizations worldwide (70%), and it continues to rise, as a year before about 60% of respondents were worried about data security. This concern is followed by loss of control over data (53%) and data backup and recovery issues (39%), while last year companies were more concerned about the dependency of the Internet connection."

Cloud Security Alliance in [7] published the State of Cloud Security 2016 based on surveys [8], [9] and [10]. There also states that the main reason why cloud computing is not accepted is security. At the same time, it states that the challenge is to integrate and harmonize the security programs of cloud computing providers and enterprises as users. This challenge is the theme of this paper.

The research problem solved in the article arose from the implementation of cloud computing OpenStack at workplace of the authors. Students use IaaS - Infrastructure as a Service in education in the Applied Network Engineering study program. At the same time the following research questions arouse:

1. What is the responsibility of stakeholders for cloud computing security, in our case students as a customers and an administrator as provider of IaaS?

2. Are the security components of OpenStack cloud computing sufficient for IaaS security requirements of customers and provider? If not, upon on what requirements to implement additional security elements?

II. INFORMATION RESOURCES ANALYSIS

The security of cloud computing systems is elaborated in international standards and is the subject of many reports and scientific articles. The above stated problem and the solution of the first research question we started by studying the security standards of cloud computing systems two international standardization institutions, the International Standardization Organization – ISO and the International Telecommunication Union – ITU.

The ISO 27001, ISO 27002, ISO 27017, ISO 27018 standards are the most important to solutions of the security of cloud computing systems. The ISO 27001 standard generally deals with the management of the ISMS - Information Security Management System. It is a brief description and definition of elements and activities of information security. ISO Standard 27002 complement ISO 27001 in more detail descriptions of security management activities. Both of these standards are the basis for all organizations that want to secure their data but do not cover the cloud computing area. ISO 27017 and 27018 have been published for cloud computing security. They extended of ISO 27002 standard to security elements typical for cloud computing, and ISO 27018 is especially concerned with the protection of personal data stored and processed in the cloud computing.

The security of cloud computing systems is worked in ITU in the Recommendations of ITU-T X.1600-1699. Of which the following are important for our solution. ITU-T X.1601 - Security framework for cloud computing where security threats and challenges in the cloud computing

environment are analyzed and describes security capabilities that could mitigate these threats and address to security challenges. It describes a methodology for creating a cloud computing security framework as well. ITU-T X.1641 provides guidelines for cloud service customer data security in cloud computing. The recommendation assumes that the provider is responsible for data security and identifies security controls for customer data that can be used in different phases of data lifecycle. ITU-T X.1642 generally clarifies the responsibilities between provider and user of cloud services, with the aspect of creating a security clause in the SLA - Service Level Agreement. It also contains the requirements and categories of security metrics for the cloud service provider operational security. Chapter 7.1 has the title part Security of Responsibility between CSP and CSC. It is only a general description, centered on the basic technical elements of cloud computing.

The description and implementation of cloud computing is elaborated in the ITU-T Recommendations Y.3500. ITU-T Y. 3501 provides a cloud computing framework by identifying high-level requirements for cloud computing; ITU-T Y.3502 specifying the Cloud Computing Reference Architecture - CCRA and recommendation ITU-T Y.3513 providing functional requirements and use cases of IaaS as one of the representative cloud service categories.

Based on the results of the standards analysis, we found that the sharing of responsibility for the cloud services security for different stakeholders is not recommended. Next studying we have focused on the literature and the existing solutions. In [11] are stated the responsibilities for operation of cloud computing systems. They are shown in Figure 1 from this source.
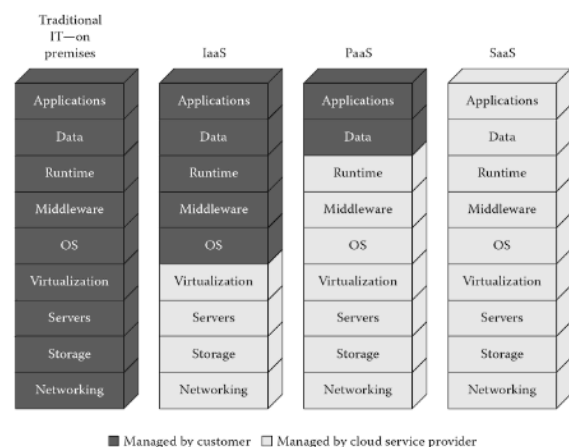
Figure 1. Separation of responsibilities in cloud operation, source [11]

Similar responsibilities are also reported in [12] and in [13]. In [13] is added an access control element that is managed by users across all service models. Next approach is in document [14]. There is stated how Microsoft understand different cloud service models and sharing of responsibilities between providers and customers. The illustration is in Figure 2.

In conclusion of the contribution is mentioned „For IaaS solutions, the elements such as buildings, servers, networking hardware, and the hypervisor should be managed by the platform vendor. The customer is

responsible or has a shared responsibility for securing and managing the operating system, network configuration, applications, identity, clients, and data."

Responsibility	On-Prem	IaaS	PaaS	SaaS
Data classification & accountability				
Client & end-point protection				
Identity & access management				
Application level controls				
Network controls				
Host infrastructure				
Physical security				

Cloud Customer   Cloud Provider

Figure 2. Shaded responsibilities for different cloud service models, source [14]

The information sources analysis does not lead to a exact solution, only the principles, on which responsibility for individual services of the stakeholders concerned, is shared. The stakeholder needs to have defined responsibilities and challenges within the system. These are different in service models and deployment models. Any unclearness in defining responsibility between the user and the provider may result in various conflicts and threats.

III. SOLVING OF RESEARCH PROBLEM

A. Starting Point

Based on an analysis of information sources, we found the principles to address the sharing of security responsibility in cloud computing services. Security will be understood in the next according to [2] as one of the cross-cutting aspects of cloud computing, along with auditability, availability, governance, interoperability, maintenance and versioning, portability, performance, protection of PII (Personal Identifiable Information), regulatory, resiliency, reversibility, service level and service level agreement. Cross-cutting aspects are characteristics or competencies that can affect multiple roles, activities, and elements in such a way that they cannot be uniquely assigned to individual roles or elements. And thus become shared issues across the roles, activities and elements cloud computing systems.

In the solution, we will consider only the aspect of security and its influence on roles, activities and security features. We will consider two roles as the architectural views of the service - provider and user. Based on their

security requirements, we create the architectural framework of the security of all service models.

Security is a broad concept that can be understood in many contexts. The solution will be based on the definition given in the document [2]. There is expressed as "Ranges from physical security to application security, and includes requirements such as authentication, authorization, availability, confidentiality, identity management, integrity, non-repudiation, audit, security monitoring, incident response, and security policy management". Important information in this cloud security specification are security requirements.

B. Stakeholders requirements

For a general specification of requirements, we used the description of the threats and challenges for the roles Cloud Service Customers (CSCs) and Cloud Service Providers (CSPs) from the recommendation ITU-T X.160, [15].

We have divided the requirements of the user from the security point of view as follows:

- Securing access to the service. It is the user's interest to make the service available to selected entities. Since the service is provided through remote access, an insecure connection is one of the potential threats.

- Data security. The user has interest in modify and use the own data only he and selected subjects and that this data does not obtain other unauthorized users.

- Confidentiality and privacy. Sensitive data in cloud computing must remain confidential. When processing such user information by the provider, there is a possibility of disrupt their confidentiality. This requirement can also be understood as a subset of data security interest.

- Data control. The user wants to have a certain level of control over cloud-based data. If a user migrates his system to the provider's cloud, he submit to the provider a part of the competences. This may be a threat to the user's data because the provider also control the data, the repositories and backups.

- Availability of service. It is the user's interest to use the service most of his time, especially when the user uses it for very important applications, calculations, operations.

- Software integrity preservation. The user's software should be retain without any changes, unless the user wants differently.

- Responsibility sharing. The user needs to have defined responsibilities and challenges within the system. These are different for service models and deployment models. Any unclearness in defining responsibility between the user and the provider may result in various conflicts and threats.

- Interoperability. In case of user dissatisfaction with the provider, the user wants to have the chance to switch to another provider. This can be a security risk for user, especially if the provider no response to security gaps.

- Trust towards provider. The user should trust the provider that cloud computing system is properly secured by him. Sometimes it is difficult for the

user to estimate the level of confidence by the provider especially if there is no means to obtain information about the provider's level of protection.

The interests of the service provider are:

- Administrator access securing. Providers have interest that administrator tasks are operate only by authorized persons. Cloud computing services contain interfaces and other software components that are the target of many attacks when an attacker works off oneself as a client's administrator and attacking the provider.

- Internal threats eliminating. The provider, within own organization, should avoid threats that may be caused by employees. Internal threats can be caused by two types of employees. In the first case, that are the employees of the provider who create this threat accidently, in the second case it may be intentional.

- Responsibility sharing. Unclearly defined responsibilities between stakeholders regarding data, access control, or infrastructure maintenance may lead to later disagreements.

- Security of sharing environment. Many users use the same cloud computing services simultaneously. These can be virtual devices, data, or network traffic. Any such unauthorized access may disrupt the aspects of the CIA triad.

- Migration and integration. System migration to the cloud means the transfer of large amounts of data and significant configuration changes (network, security policy). Poor integration can have a huge impact on security, so the provider should ensure simple migration.

- Integrity of security mechanisms. Due to the decentralized architecture of cloud computing infrastructure, uniformity of security mechanisms must be ensured.

- Deployment security - Cloud computing does not have to implement some software components in the development phase but only when they are needed. Such a dynamic system may pose a security risk because it has certain security assessments in the development stage and after the development stage a new security risks may appear after adding other components.

- Business continuity. Service availability is required to ensure the business continuity of the provider. By service unavailability due to DoS or delay, the provider may ensue financial damage.

- Trust towards supplier. Hardware or software components to be procured from a trusted vendor. Otherwise, it is possible that it was supply with a malicious code or other security gap.

- Software independence. To ensure software independence, if a security gap in one software is detecting, another software component do not defend of the actualization.

- Jurisdictional conflicts. Data can be transferred between data centers located in different countries or areas where different laws apply, such for example processing personal identification data.

The general interests of the stakeholders identified above are mapped into the cloud computing technology

elements shown in Fig. 1. The results of its relationships are shown in Table 1.

TABLE 1.
RELATIONSHIP OF STAKEHOLDER'S INTERESTS AND TECHNOLOGICAL ELEMENTS OF CLOUD COMPUTING

Stakeholders interests	Technical elements of cloud computing system	Customers	Providers
Securing access to the service	Networking/Virtualization /Applications	X	-
Data security	Networking/Storage Applications	X	X
Confidentiality and privacy	Networking /Storage /Applications	X	X
Data control	Servers/ Servers	X	-
Availability of service	Networking / Servers	X	-
Software integrity preservation	Servers / Storage / Virtualization /Applications	X	-
Responsibility sharing	-	X	X
Interoperability	Applications	X	X
Trust towards Provider	-	X	-
Administrator access securing	Networking / Servers / Virtualization	-	X
Internal threats eliminating	Servers	-	X
Security of sharing environment	Virtualization	X	X
Migration and integration	-	X	X
Integrity of security mechanisms	Networking / Servers / Storage / Virtualization /OS	X	X
Deployment security	Virtualization/OS/Middle ware/Environment/ Applications	X	X
Business continuity	Networking / Servers	-	X
Trust towards supplier	-	-	X
Software independence	OS/Middleware/Environm ent/ Applications	X	X
Jurisdictional conflicts	Servers/Storage	X	X

Note: Stakeholders, which identifies and determines its requirements and interests, may not always be responsible for the implementation of the security mechanisms.

C. Security Framework for Cloud Computing

The requirements of stakeholders for service security go through all the cloud computing technology elements. According to the ITU recommendation [2], security is a cross-cutting aspect that affects multiple roles, activities and elements. And IaaS has two stakeholders or two roles - a user and a service provider. The solution requires creating a security architecture framework. When designing an architectural security framework, we followed the principles for designing a multi-layered

general system model. Each layer provides precisely defined related functions. The number of layers is proposed so that different functions not to be in the same layers. However, the number of layers should also be small enough to make the architecture clear. Based on these principles, we assigned to the technical elements of the cloud computing system, shown in Fig. 1, according to the specify requirements into four layers. The layers have the name according to the [16].

The resource layer is where the resources reside. This includes equipment typically used in a data center such as servers, networking switches and routers, storage devices, and also the corresponding non-cloud-specific software that runs on the servers and other equipment such as host operating systems, hypervisors, device drivers and generic systems management software. The resource layer also represents and houses the cloud transport network functionality which is required to provide underlying network connectivity between the cloud service provider and the users, as well as within the cloud service provider and between peer cloud service providers.

The service layer contains the implementation of the services provided by a cloud service provider. The service layer contains and controls the software components that implement the services (but not the underlying hypervisors, host operating systems, device drivers, etc.), and arranges to offer the cloud services to users via the access layer

The access layer is responsible for presenting cloud service capabilities over one or more access mechanisms –

for example, as a set of web pages accessed via a browser, or as a set of web services which can be accessed programmatically, on secure communication. Another responsibility of the access layer is to apply appropriate security functionality to the access to cloud service capabilities. The access layer is responsible for authenticating the request through the use of user credentials and for validating the authorization of the user to use particular capabilities. The access layer is also responsible for handling encryption and checking for request integrity, where required.

The user layer is the user interface through which a cloud service customer interacts with cloud service provider and with cloud services, performs customer related administrative activities, and monitors cloud services. It can also offer the output of cloud services to another resource layer instance.

We have mapped the requirements of stakeholders into the layers of the security architecture framework, and at the same time we defined the responsibilities of stakeholders to carry out them. The proposed security architecture framework is in Table 2. Although our interest was sharing of a security responsibilities in IaaS, we have added for comparing a sharing of security responsibilities in PaaS - Platform as a service and SaaS - Software as service.

TABLE 2 SECURITY ARCHITECTURE FRAMEWORK FOR CLOUD COMPUTING

Architectural layers	Stakeholders requirement	Stakeholders responsibilities					
		Customer			Provider		
		IaaS	PaaS	SaaS	IaaS	PaaS	**SaaS**
Resource layer	Data security	-	-	-	X	X	X
	Confidentiality and privacy	-	-	-	X	X	X
	Data control	-	-	-	X	X	X
	Availability of service	-	-	-	X	X	X
Resource layer	Software integrity preservation	-	-	-	X	X	X
	Administrator access securing	-	-	-	X	X	X
	Internal threats eliminating	-	-	-	X	X	X
	Integrity of security mechanisms	-	-	-	X	X	X
	Business continuity	-	-	-	X	X	X
	Jurisdictional conflicts	-	-	-	X	X	X
Service layer	Software integrity preservation	X	-	-	X	X	X
	Administrator access securing	-	-	-	X	X	X
	Security of sharing environment	X	-	-	X	X	X
	Integrity of security mechanisms	X	-	-	X	X	X
	Deployment security	-	-	-	X	X	X
Access layer	Securing access to the service	-	-	-	X	X	X
	Data security	X	-	-	X	X	X
	Confidentiality and privacy	X	-	-	X	X	X
	Availability of service	-	-	-	X	X	X
	Integrity of security mechanism	X	-	-	X	X	X
	Business continuity	-	-	-	X	X	X
User layer	Securing access to the service	X	X	-	-	X	X
	Data security	X	X	-	-	-	X
	Confidentiality and privacy	X	X	-	-	-	X
	Interoperability	X	X	-	-	X	X
	Deployment security	X	X	-	-	X	X
	Software independence	X	X	-	-	X	X

The security architecture framework is only the partial answer to the first research question. It does not provide information on which mechanisms or elements will meet these requirements. Here arise the problem formulated in the second research question. If we know stakeholders

requirements and responsibility, do we know implemented correspondent security mechanism and elements?

Nevertheless, cloud computing companies declare that they provide a secure cloud computing system according to the relevant recommendations. Security management in cloud computing systems is in a common recommendation of ITU-T X.1631 and ISO / IEC 27017 [17]. This Recommendation and International Standard provides control and implementation guidance for both cloud service providers and cloud service customers, but do not answer to our research question.

IV. CONCLUSION

Compliance of recommendations connected to the cloud computing security and Service level agreement will ensure to meet regulatory and business requirements. This situation is replaced in many publications to the idea leading to Threat Intelligence. For example, in [18] states that the current state of cyber security architecture, engineering and operational practice is primarily implemented through compliance with directives, regulation of various security policies or frameworks. Three primary gaps in this current state limit its effectiveness:

1. The behaviors, culture and the excessive amount of resources allocated to implementing and adhering to compliance requirements.

2. The lack of formalized threat modelling and analysis practices that scale vertically and horizontally

3. The lack of institutionalized integration between the architecture/engineering functions and the operational/analyst functions.

Therefore, our further research direction leads us to discover the vulnerabilities of the communication systems, in response to the analyses incidents. The implemented cloud computing system OpenStack will serve for practical implementation.

V. CONTINUITY OF THE RESEARCH

The continuity of the research is based on the architectural security framework shown in Table 2. We will start with the security requirements of the IaaS provider for cloud computing Open-Stack implemented at the workplace of the authors. We will come out from the general requirements under the architectural framework of security described in the contribution. The implemented cloud computing OpenStack has already embedded some security mechanisms. Neutron has implemented firewall, IDS and IPS; Swift is object-oriented and can manage data integrity and replication; Keystone has implemented identification and authentication systems. The security features of the embedded security elements provide only some of the requirements specified in the security architectural framework. Determination of the next features will lead to security gaps, to solution of them we will use the Threat Driven Approach Architecture. This will be integrated approach between implementation existing security element procedures and the architectural approach based on attack and vulnerability analyses.

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From school-company collaboration on educating students to a structured career development system

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Abstract—**In this contribution we look at our experiences as a large regional ICT company with educational initiatives for various target groups. In the introduction we present an analysis of acquired ICT skills within the company and their mapping onto various clusters of commercial activities in ICT. Next, we consider a broader context of available target groups and their preferences of methods, collaboration styles and expected career steps. In today's fast evolving ICT sector the range of target groups relevant for an ICT company grows and more of them are important when planning and realizing their business growth scenarios. In the next section we present specific examples of the above-mentioned activities and justify the need of creating a portfolio of educational, supportive and marketing "events" to boost interest in ICT career. The core of our paper is a new model of long-term co-operation between a company and a young person (student or pupil) that draws upon the philosophy of customer relationship management (CRM). We argue that systematic, long-term co-operation with a job candidates is critical for digital business success and it will require suitable portfolio of "tools" that includes various activities, educational and marketing events across multiple phases of the career preparation lifecycle.**

I. INTRODUCTION

T-Systems Slovakia is the largest ICT company in Slovakia focusing on outsourcing and provisioning of ICT services. During 12 years of its presence in Slovakia it has grown to current 4 000 specialists – to a great extent this strong growth can be attributed to a broad range of educational activities both within the company and in co-operation with the regional schools and universities.

Although the company is formally classified in the ICT segment, its portfolio is broader. This implies a range of business domains and a range of skills is needed in the company. Thus, our co-operation with local schools and universities has to reflect this range of requirements. In order to obtain a picture of how to focus our attention we performed segmentation analysis across local institutions and business domains served (e.g., software development, ICT infrastructure, service management, and like). In the analysis we used 9 different business areas and considered 12 types of educational institutions of our employees. Despite business diversity, we observed essentially 3 main clusters of what students of respective institutions prefer and what particular career they typically choose – basic ICT services (infrastructure/applications) vs. high-value services (application development, design) vs. non-ICT ones (project or service management).

As shown in Figure 1, there is a clear difference in the academic background fitting two rather distinct ICT areas. Compare this to Figure 2, where a third main cluster is

shown covering non-ICT part of business portfolio, here represented by service management. As visible, academic background a job entrant is not sufficient to decide, which career is most fitting for any given student. In other words, it is rather difficult to obtain crisply segmented labour market. As a consequence, the company cannot send one specific message to any single university or school. On the contrary, our recruitment is by default broader and we need to send multiple messages – make offers of multiple potential careers – to each local educational institution.

Whilst it is necessary to mix career messages, it is not possible to treat students or graduates of any institutions as a sufficiently clear target. In practice we need to find means how to approach *individual* students and how to *tailor* a career exploration and later development path to their particular position. Considering that T-Systems Slovakia concluded with a contract as many as 1 560 positions during 2016, thereof 610 with external candidates, there is a clear need of a systemic, structured and scalable system for managing career paths.

We have taken inspiration in a standard customer relationship management (CRM) philosophy, whereby a seller is tracking his or her leads with the potential customers, and adjusted it to career exploration. In this
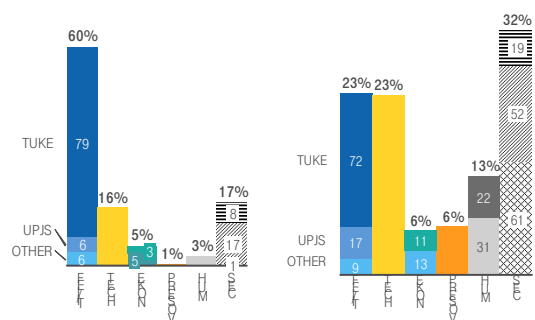
Figure 1. High-value ICT career cluster (app dev, left) compared to basic ICT services cluster (app operation, right)
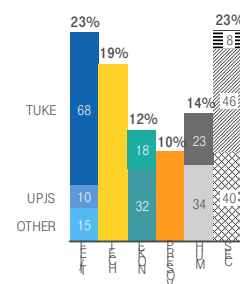
Figure 2. Non-ICT career cluster (service mgmt. as a sample)

context, our company takes the role of 'a seller', the product on offer being ultimately the specific job position, but in a broader sense of word, any educational or developmental activity we are offering alone or in a co-operation with an educational institution. 'The customer' role would be taken by a student responding to one or more of our 'product offers'.

II. UNDERSTANDING LOCAL LABOUR MARKET

In the previous section we motivated our need to work with individuals rather than coherent groups – when it came to identifying suitable talents and skills, and thus making the most fitting offer for career development.

Another complication has arisen from our experience that such individual interaction needs begin earlier than in the final years of a university study (which is a typical target audience for many recruitment activities). In order to identify what different target segments do care about, what preferences they exhibit in terms of collaboration methods, learning methods and methods of mutual interaction. First, we analyzed broader target groups and decided to group them by age into three categories to keep the overall complexity of analysis reasonable:

- lower secondary school level (cca 14–16 yo)
- upper secondary school level (cca 17–19 yo)
- university bachelor level (cca 20–23 yo)

For each category we identified main characteristics – based on international research but also local observations. As can be seen in Table 1, in the broad-cut categories, the lower secondary group is rather closed in terms of engaging with a company with an objective of a concrete career path development. On the other end of spectrum, bachelors at universities proved to be more or less certain about their career trajectories – if influence, then mostly by specific benefits. The middle group, however, seems to be very interesting one for further analysis – mainly because it is relatively open to career path shaping (incl. university choice) and far less researched from the career viewpoint compared to university students or graduates.

Probably, the key aspect that makes the upper secondary level interesting is their preference to try out choices. They are less likely to reject an idea just because

their friends have different opinions and also less rigid in sticking to their previous or earlier decisions. What makes it harder for this category to work with – and presumably, why companies typically do not engage with this category very intensively, is their lack of accepting rules, orders, prescribed scenarios… the research is emphasizing their preference of making *choices*, and at the same time there is a strong willingness to *follow the role models* [5].

It is precisely these two characteristics that, in our opinion, make this group a relevant and potentially very responsive target for career planning. Let us, however, look deeper into how this category is stratified and how the knowledge of the strata may help a company to develop strategy for better engagement of young talents.

III. TYPOLOGY OF POTENTIALS FROM CAREER DEVELOPMENT PERSPECTIVE

Within the upper secondary level we carried out analysis in our team comprising of managers, employees and two graduates from a local secondary school. At the end we identified 5 types of potential candidates for more intensive interaction. Perhaps not fully surprisingly for educational practitioners, the main discriminating factor was the student's interest in extracurricular activities and how they prefer to use their available time. There are, of course, many other factors that can stratify any single class of young people at secondary school – social status, family academic background, prestige of their school, city, etc. However, we found out that the interest in the extracurricular activities and events is pretty much a good estimator of how likely the students will develop their talents, and how likely they are to work on their careers.

Let us look at the stratified group of upper secondary students and highlight some of their characteristics that are particularly relevant from a career viewpoint:

1. *"I don't care about anything"*

   This group is very hard to approach, needs a lot of pushing, reward, repetition.

   - Challenge: find something that excites them
   - Driver: no value in additional, new knowledge
   - Evidence: personal, strong experience
   - Potential: hidden, unused

Table 1. Identification of driving factors and preferences for interaction in three target categories

	LOWER SECONDARY	UPPER SECONDARY	UNI BACHELOR
VALUES	- Feel independent - Closer to friends than family - Need to "change the world" - Following new trends and "cool" people - Social media is the no.1 source of news - Don't know what job they want in the future	- Revolutionaries, still feeling independent - Focus on getting onto Uni - Know their skills, know the career direction - Little influenced by parents - Making first career plans - Thinking of career prospect and benefits	- Partial economic independence from family - Mature decision making - Greater responsibility - Focus on studies - Plans & expectations from future careers - Already employees, or at least actively seeking jobs
PREFERENCES	- Life is about gaming - Social media is the key - Following the friends - Not very open to any offer of engagement that is not approved by friends	- Life is about right skills, capabilities & choices - Performance matters - Following the role models - Open to offer within their ideal job context	- Life is about opportunities (& decisions) - Travel/exploration is cool - Following the benefit (from a job, career, company) - Open to offer within or outside their target field

2. *"I go in depth, in detail"*

This group is very one-sided, they develop the skill, area they are already good at.

- Challenge: broaden their horizons
- Driver: becoming best, star in their field
- Evidence: appreciation of expert peers
- Potential: co-operation beyond their field

3. *"I consider myself an artist, a creator"*

This group is open-minded, with broad interests, but can be very self-righteous.

- Challenge: get into details, get more information
- Driver: need to create, produce, see outcome
- Evidence: tangible, presentable 'thing'
- Potential: harnessing out-of-box thinking

4. *"I want to focus (on me)"*

This group participates in many events, but mostly pushed/pulled by others; diligent generalists.

- Challenge: narrow their scope of activities
- Driver: reliability, good planning skills
- Evidence: appreciation by school, teacher
- Potential: stepping out from the shadows

5. *"I am an active explorer of options"*

This group typically suffers by lack of time, due to (too) many side activities and interests.

- Challenge: manage the scope of interests
- Driver: active creation, contribution
- Evidence: good means useful to others
- Potential: gaining insight into topics

As one can see in a brief summary of observations from our ethnographic study with the local upper secondary students, there is quite a diversity in how they are likely to react to anything related to career development or to being approached by companies as potential talents [3,4]. Let us therefore explore how the discovered features inform the strategies for working with students as potential talents and potential job candidates in one specific company.

IV. TALENT RELATIONSHIP SCENARIOS

The million dollar question is relatively simple – *how to approach such diverse groups of potential talent*? Well, taking the different observations we summarized in sections II and III, we can break down the question into five main challenges, as shown in Table 2.

From the topics mentioned in Table 2, CH-3 and CH-4 appear frequently in numerous research findings, particularly those discussing the Generation Z and Millennials – strong focus on emotion, on the fact that relationship at work is much more than just a working relationship. However, let us for the purpose of this paper focus more on the other three challenges – *creating a pull factor* (motivator), *tracking and developing interests*, and *engaging parents* in the career development plans.

A. Interactive & Gaming Factor

Before we touch on some details, let us emphasize we are after *longer-term relationship* here – as opposed to simply attracting a young person to an odd event or two.

Second, we are after actually *identifying talents* in a large pool of youngsters in local school, where "talent" can be taken very pragmatically as somebody who is likely to develop such skills, competences and attitudes that bring him or her closer to a regular job in the near- or mid-term future. From this perspective, talent is someone with whom a long-term relationship makes sense also if take in account the limiting factor of resources the company is willing to invest in (see also [1,3,6]).

From the HR perspective the challenge is to become more than just another company for the targeted young people. We need to create an idea around the company, around its brand, around its presence in the region. At the same time, we need to make this idea sufficiently interesting, sufficiently entertaining to keep momentum.

One example of an event we created for such a purpose is our "Magenta Game" – deliberately not referring to our company name or underlying technologies. Magenta is the emotion behind the brand, the distinctive colour one can easily associate with our company locally, nationally, but also internationally. Magenta Game was created as an unusual way to capture imagination of potentials students, first with economics background, later adapted to ICT, project management and other domains. The idea is simple – come as a team, work as a team on real-world cases, discuss, defend your ideas, and aim to sell your idea to the jury. The general feeling is more of a pub quiz laced with a talent show, rather than formal testing and skill assessment. Because of this, the game is seen worthwhile even if one does not win – the students are willing to attach value not only to the obvious outcome (winning) but simply to participation. It is "cool" enough to be seen in the game and use it as an informal showcase of one's capabilities, learned skills or knowledge.

Another example, where our company managed to create a strong interactive feeling, is our Hackathon series. Admittedly, the event is linked to a formal curriculum, but its main pull factor is in the teams, their striving to create something new within given time limits. The pull factor is also created through a careful use of role models (actual employees) who act during the event as guides and advisors to the potential talents. Similarly as with the Magenta Game, the value is not only in winning, but in taking part – the appreciation comes not only from jury but also from peers, from other teams…

In both examples, we are able to capture all five types of student mentioned in section III. They work for artists (type 3), but also for explorers (type 5) and performers (type 4). The easygoing nature of otherwise deeply educational events makes them relevant also the hard-to-approach type 1.

Table 2. Key challenges in approaching potential talents

IDENTIFIER	LOWER SECONDARY
CH-1	Actively learn and track interests of our target potentials…
CH-2	Create something to act as a motivator…
CH-3	Convince them it is "cool" to hang around with T-Systems…
CH-4	Become more than just a company, just an institution for them…
CH-5	Convince the parents that such interaction can be valuable for them and children…

B. Tracking the interests and achievements

In addition to two examples briefly introduced in the previous section, we compiled in T-Systems Slovakia an initial portfolio of events and initiatives that are available to a pool of potential talents. While each event has its primary target audience, they are, in principle, reusable components that can be combined as and when needed to attract a particular target group.

In such context it becomes important to create means to obtain and build in feedback. When we speak of feedback we do not mean the usual "how satisfied are you with…" questions. The feedback from the perspective of long-term career development arises from understanding what students are choosing which events. Are they returning to us for additional events after participating in some of the more general "learn about us" events (such as e.g., open days or coder fests)? Are the students from the desired talent groups responding to our advanced offers? Are we linking, daisy-chaining the events in a way that makes sense to the desired target groups (and their parents)?

Pushing it further – if most of our events carry an element of gaming, competition, outcome appreciation, is it possible to see how an individual gamer (student) progressed through the portfolio of event s/he has chosen? Is there observable an improvement in competence or skill? How far or close is s/he to achieve the desired thresholds we typically apply to our own employees?

We believe it is not only possible, but there is a good practice available in the sales world. Taking the concept of CRM and applying to the talents, permits us to aim at something we tentatively call Talent Relationship Management or TRM.

V. TALENT RELATIONSHIP MANAGEMENT (TRM)

We introduced TRM as variation of common CRM philosophy – and we deliberately use term "philosophy" instead of "tool", as we believe it is more a way of thinking about relations than a tool to manage them. According to [XXX] CRM is a customer-focused business approach designed to effectively create *experiences* that attract, acquire, and/or retain customers. To realize the benefits of CRM companies usually implement a range of interactive processes and technologies that support interaction with their respective customers throughout as many *channels* as desirable [2].

CRM systems are usually software applications used to automate and manage communications with prospective and current students, employees, alumni, donors, etc. Customer information, such as lead's/customer's name, gender, educational background, telephone, email, marketing materials, social media and any other relevant information across different channels is compiled into a single database enabling easier information access, allowing to personalize and customize messages and the channels used to deliver the message to the student in a timely manner. Every interaction with the "customer" is tracked by the CRM, all in one place [6].

Besides faster service and workflow automation, one of the most prominent capabilities of a CRM tool is tracking – albeit often at a relatively coarse level, such as looking at which website a potential student has from, which advert brought a potential customer to the educational institution or course web site [6].
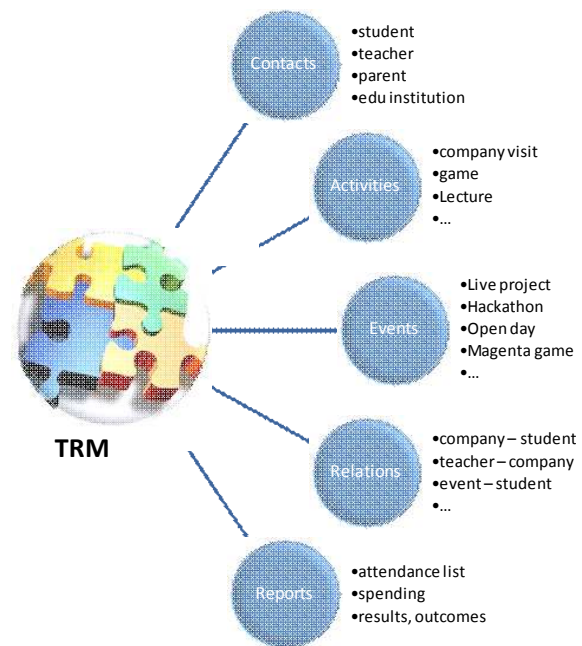
Figure 4. Initial element features of a TRM system

Like in CRM, the TRM concept can be structured alongside similar key dimensions:

- *Talent potentials* … this is primarily about the belief that our potential talents (in CRM equivalent to customers) are indeed valuable asset, whereby the long-term prosperity of the company depends on productive relationship with them.
- *Processes & events* … this is primarily about enabling the structure of the activities and initiatives so that they support the culture of talent seeking, talent and career development.
- *Technologies & tools* … this is primarily about creating supporting mechanisms, ideally automated and integrated into other (HR) processes and tools that will help the company to capitalize on the above-mentioned culture and philosophy

Research shows that CRM is not a novelty in education management. For example, CRM can be used to improve student retention, to manage student recruitment or to support alumni activities [1,2,3,6]. We have implemented the TRM (our take-on on CRM approach) around the features as shown in the model in Fig.4. To this model we translated our existing, as well as considered activities that aim at introducing our company to a target audience, develop personality, develop technical or transferrable competence, offer relaxation, etc. An immediate benefit of structuring our portfolio according to TRM model as shown in Fig.4 was the definition, description of further particulars that existed for one activity but were missing in another. Also, some elements inherited some features from their "parent" categories.

Scope of this paper does not permit details for the entire portfolio of educational, developmental and marketing activities of T-Systems Slovakia. However, let us offer a sample of two specific activities that can be seen as some sort of headliners our company is proud of. Table 3 shows a partial description of two elements in our portfolio – IT Academy and Hackathon.

A. Worked example of applying TRM in practice

In a similar style, as shown in Table 3, we were able to describe an initial set of 20 specific TRM elements. Once in, we utilized the feature titled "*Dependence*" to chain together elements that can complement or mutually support each other. For example, while the *Hackathon* concept is always some sort of competition, work on own project, building an own team, there are actually possible differences in its implementation depending on how we constrain our target audience.

In one scenario we combined the *Hackathon* element with the *Business in a nutshell* series of short, focused lectures and training sessions at university, and followed by the *Career Day* element to obtain Magenta Hackathon even aiming at master-level students of local university and introduction of software development careers to them. In another scenario, the same *Hackathon* element was combined with the *Volunteer for ICT* element aiming at secondary level students and followed by an *Excursion* to a specific team in T-Systems Slovakia to create an interesting opportunity for younger talents who got a taste of a cool event, became part of a cool crowd, and (we hope) strengthened their motivation to dive deeper into ICT skills development – e.g., via one of our summer academies.

B. Relection on benefits of the TRM model

This approach of Lego-style building of educational, developmental and marketing events from some reusable components indeed speeds up the ideation of events. In our scenario, based on the initial portfolio elements, their analysis and elaboration, two of the authors managed to rapidly develop three alternative scenarios for running Hackathon concept in 2017. Moreover, this has been done in an end-to-end style, i.e., the presentation of the three scenarios made it from the initial discussion with "product owner" to the board of our company and approval of funding within 2 weeks. Compare this to a more typical period of 6-8 weeks for developing, agreeing and fine tuning hackathon ideas in the previous years…

However, we observed not only benefits related to speed and rapid prototyping – both of these are extremely

valuable in the current competitive environment, nonetheless. Another important benefit was an increase in quality of the scenario and thus proposal for funding. Drawing upon in-advance estimated, expected benefits, constraints and assumptions of specific portfolio elements, we were able to create a more holistic perspective onto topic. In the early versions we covered the difficult notion of formulating explicit value for the company as well as value proposition for the potential participant. We were able to show more explicitly the prerequisites and follow-up activities to ensure we get from an event maximum possible value.

Thus, getting it all right in one (or fewer than usual) iteration is also an extremely valuable competitive advantage. This saving in iterations enabled us to spend more time on actually tuning the marketing message, marketing mix, spend more time on finding the right production partners, etc. And this, in the long run, has led to a more favourable return on investment, more efficient and effective use of available funding. Less money spent on conceptual ideation and more on actual value tuning, value delivery assurance…

VI. NEXT STEPS AND PLANS

Currently we are extending our TRM portfolio and improving the description of the existing as well as new elements that would eventually feed our TRM model. The main challenge for the upcoming period is to turn the pilot implementation into a fully-fledged TRM tool or platform, that would enable not only capturing and structuring data about the individual elements, but will actually deliver on the promise of *tracking* how different groups of potential talent (as briefly described in sections II and III) uses and responds to the individual elements, to their chains and combination, and also how they progress from simpler initial interactions towards deeper, more intensive ones.

As described in section I, the main motivation of our company is to increase the likelihood a talent from the age group of secondary students takes up a career path and career development choice that bring him or her closer to a career in a high-value ICT segment or perhaps in one of the higher-value non-ICT job families.

Table 3. Sample elements from our TRM portfolio described according to TRM model (cf. Fig.4)

CONCEPT	SUMMER ACADEMY	HACKATHON
LIFECYCLE PHASE	▪ Acquisition of basic ICT knowledge ▪ Development of basic, applied skills	▪ Practicing in-depth ICT specialist skills
CATEGORY	▪ Semi-formal education ▪ Workshop	▪ Public event ▪ Game/competition
TIME DEMAND	▪ 40–80 hodín, v priebehu 1–2 mesiacov	▪ 24–48 hours, continuously
TARGET	▪ 19 – 25 yo ▪ Non-ICT student/graduate	▪ Young ICT specialists from market ▪ Ambitious ICT students/graduates
DEPENDENCE	▪ Series of predefined events ▪ Causality given by topic	▪ No explicit dependence ▪ Optionally drawing upon introductory events
OUTPUT (MEASURABLE)	▪ Professionally qualified job candidate ▪ 30% candidates needed to interview to fill in any level 2 job position	▪ New CV acquired by company for hiring, recruitment approach ▪ Retention of identified talent CV-s
OUTCOME (VALUE FOR FIRM)	▪ Maintenance of up-to-date skill level of current and future employees (in depth + in breadth)	▪ New potential job candidate ▪ New, cool image of company
USER BENEFIT	▪ New skill acquisition and practicing ▪ Obtain a competitive advantage in labour market ▪ Positive feeling from the company brand	▪ New job opportunity (option) ▪ Work on own ICT project ▪ Meeting like-minded people, potential partners for joint ICT start-ups, teams, etc.
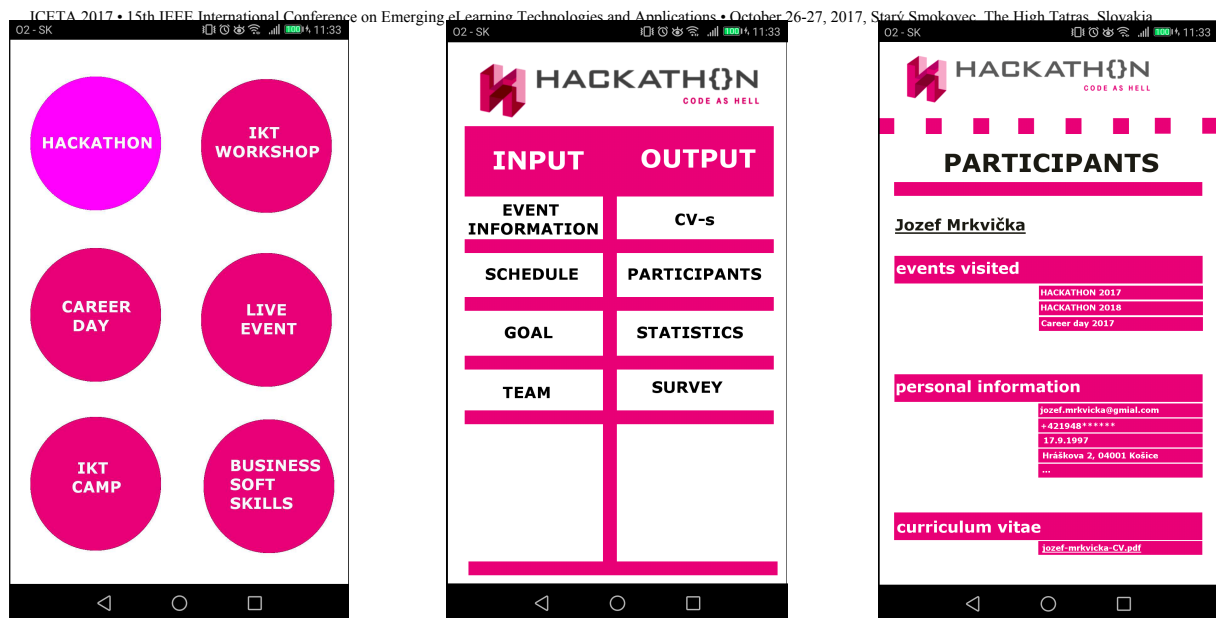
Figure 5.   Early sketch of an TRM front-end on smartphone: left – overview of events available to a particular participant at particular time; middle – an analytic overview of a specific event from an organizer/owner perspective; and right – detailed information about a specific event participant accessible during an event via smart tags, NFC or QR and linked to third-party information and insights onto the student.

Another challenge is to work together with the Kosice Self-governing region on linking our TRM model to the Reqruit concept the regional government wants to apply to the students of their schools. Cross-linking the public system aiming more at tracking the academic progress of a student during their studies with more personal, individual-oriented TRM system we have introduced in this contribution would create a true win-win-win situation. The students will gain access not only to academic but also vocational activities, beyond basic education. The region will be able to discern schools and their educational quality based on how the individual students fare vis-à-vis practice, local companies. And, of course, for our company, this would be an invaluable data warehouse to perform analytics and knowledge mining on, in order to predict, estimate who would better fit a specific job, project or career opportunity.

Last, but not least, one of our next steps relates to the factor mentioned in section II in the context of millenials preferring gaming and through-digital-tools interaction with the world around them and with their peers. In our context it means going for a smartphone app, which is envisioned to act as a talent's passport to gain access to events, to track their endeavours and achievements, to link to their peers, discover new opportunities, offer their skills and more. Whilst the application prototype is still a good way ahead of us, we are already rapidly prototyping and putting together sketches of what it may do and what it may offer to their owner.

VII.   CONCLUSIONS

In this paper we built a *bridge* from our rich history of collaborative initiatives in the domain of supporting education, skill development and awareness of ICT sector together with local educational institutions towards a structured approach to managing talents. We called this approach TRM – Talent Relationship Management – to pay homage to the philosophy of CRM.

Unlike most existing applications of CRM to educational domain, our approach differs: a) in the fact it is not primarily designed to support one educational institution and its drive to attract students, and b) in the fact that it prioritizes the benefit for the consumer (learn, find the right, personalized opportunity) ahead of the benefit of the TRM owner (identify, motivate, recruit new talent before our competitors do).

Although the concept of TRM is rather fresh, we believe this approach offers a good potential in the competitive labour market, to which a new generation of young talents is arriving, as we also analysed and cross-linked in the first half of this contribution.

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Gloffer – Searching implementation in sales portals and marketing strategies creation

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Abstract-**This article describes students work on a project called Gloffer. It combines knowledge from economy, marketing and information technologies. The primary goal of this article is to discuss problematics of searching in sales portals, full-text and also parametric. Here are described ways, how to optimize searching based on available relevant data. In the second part, marketing strategies for Gloffer are discussed and subsequently implemented in the portal environment. Various approaches to brand promotion and presentation, as well as products and services are described. Here is a description of the way, how students are involved in analyses and the subsequent realization of the student's proposed search procedures and related marketing communications of the Gloffer sales and demand portal.**

I. INTRODUCTION

This article describes the collaboration of students from VŠB Technical University in Ostrava on the analysis, realization and implementation of searching system within sales and demand portal Gloffer (available at https://www.gloffer.com). Here are discussed actual topics related to the search for relevant information, over extensive catalog of products in a multilingual environment. There are described issues and related questions of fulltext, parametric and then approximate search.

In the next part are discussed the ways of cooperation between students of the Faculty of Economics and Faculty of Electrical Engineering and Informatics, who deal together problem of low-cost marketing in the area of electronic commerce and then they apply and evaluate their experiments within the Gloffer portal. Here are described the target groups that the marketing communication should address and influence. Processes combining modern methods of marketing and information technologies, analysis of the competitive environment and description of the basic strategy in marketing communication within the Gloffer portal are discussed and tested. Students define their own experiments that are undergoing an assessment of the impact and financial complexity of implementation. If the experiment is easy realised and can be useful, it is passed to the next round of evaluations and, if it is successful, it is implemented in practice.

The advantage for students is possibility to work on a real project, which is commissioned by a real commercial company. Students have space to understand business processes in the field of information technology and marketing, and then they can practically try to solve problems. The cooperation between the university and the commercial sector is very positive. Students can choose semester projects, bachelor and diploma theses and scientific and publishing activities. It is beneficial that the space for cooperation on this project is not only for students of doctoral studies, but also for students of master and bachelor study programs.

At the end of this article, the possibility of further cooperation and thematic areas in the future is outlined.

II. SEARCHING WITHIN GLOFFER PORTAL

Information portals are nowadays very popular. Their typical representatives in the area of electronic commerce are price comparators, auction system, discount portals, shopping market and others. In comparison to classical e-shops that have smaller product databases with thousands of items in terms of data processing. Large portals work with millions of cataloged products and services. E-shops usually tend to focus on a few product areas that are able to describe very well, parameterize and catalog. Thus, sorting and searching methods are clearly defined here and are rather aimed at and evaluating the properties of each of the same product types that have these characteristics listed [1].

Extensive portals combine a wide range of products and services so it is difficult to determine which product the user is interested in, based only on common queries, especially in full-text search. It is necessary to take into account the individual phrases queried, the search context, the previous activity of the seeker on the portal, as well as other users' queries. In the case of parametric queries, we deal with the fact, if the person understands exactly the meaning of the individual properties, if he wants to search with an exact list of items or range questions, and lastly through an approximate search, where it is necessary to define user preferences and classify the similarity of individual products.

Within the Gloffer portal, authors work with the all three search areas. Due to the used technologies and many variants of query phrases and search results required, many experiments have to be carried out, which evaluate the speed of achievement of the result and its relevance and time variation.

Here looks like ideal possibility collaboration of students with the commercial sector, where students do not deal with fictitious or uninteresting data sources, but they work with real data about existing products. In addition, students can put themselves into the role of the interviewer, who searches for data and can accurately assess the relevance of the results obtained.

A. Full-text searching

A full-text search system is known from many portals. A simple field where a word or audio through a microphone (and its subsequent conversion to a written text) forms a query that is sent for processing. We can add an extension to say, whether we are searching in the concrete category, within the products of the selected brand, or the vendor. In addition, for transnational projects that reflect the multilingual content of the database, we solve if users can formulate their requirements in different languages. This complex search problem should be divided into sub-tasks, which usually have several subclasses of problems and can also be solved in different ways. The resulting compiler must minimize the difficulty of building the desired result, both in terms of time (number of comparison operations) and spatial complexity (amount of required memory) [2].

Usually, speed is at the expense of accuracy, so we get less relevant information, and if technologies with the multiple fragments and data replicas are used, we may experience an unpleasant situation, where we get different results on identical queries. The more we begin to refine the search by doing more steps in the field of pre-search queries, polling itself and subsequent postproduction, sorting according to additional parameters, such as price, availability, alphabet, etc., must be done. The results are more accurate, but their processing is much more demanding. Now the problem of caching that saves search results comes into play. These are then repeatedly used if the same or different user types an identical query.

The next step in optimizing is to identify different search phrases that have the same result over different phrases. For them, it's a good idea to build a synonym dictionary to reduce the number of search queries. It is necessary to define the validity of the cached data, which can be affected by the time, the frequency of the query or the change of the source content. Here it is necessary to ensure, that in the case of a change in the source data, the item has been deleted from the cache so that the entire search query is retrieved the next time, when it is searched [3].

An important step in this process is the choice of a cache strategy. Usually, a so-called "lax" method is considered, when the data is searched until the moment, when the user requires them, which may cause a significant slowdown or even unavailability of the search service at extreme peak times. In this case, you need to define a set of frequently-asked phrases, usually also trendy products that are searched by users. Here we can pre-process the search result for these phrases at lower traffic times.

Another important factor is the frequency of changes to the source database. It is necessary to define the degree of accuracy and relevance of the data provided and the speed of reaction to change. Taking into account the fact, if after updating the data of each vendor (e-shop), we are updating the search indexes and consequently the search results this is extremely demanding. Therefore, it is appropriate to define intervals, either in terms of time or on the basis of the number of changes made in the source data, after which the original caching values are updated or deleted.

As can be seen from the procedure described, there are a number of strategies and optimizations that work on this process. Just working with students' "young brains" can find a better way to get more relevant and faster results. It is possible that unconventional approaches by young scientists, who are not always burdened with established procedures can deliver better results. Overall, this approach is very positive for students, where they can compete not only within the university but also across them.

B. System of whisperers (auto-completer)

The next step is to work on a whisper system to help users enter the correct value in fulltext search, or when entering parameters with high frequencies of individual properties. Consider a situation, where we want to enter the exact name of a product, brand (manufacturer), or properties that have thousands of acceptable values (for example, book authors, musicians, movie actors, etc.).

Nowadays it is used system called "whisper system", which adds the rest according the fragment of the text. Whisperers are usually divided into two types, where they search for a given phrase from the beginning, or this phrase can be contained anywhere "in the middle" within the parameter. Additionally, it is possible to define different sets of, over which it searches. In the search result, we can show relevant products, brands (manufacturers), categories,

In case of whisperers, the usually it is not used the classical full-text, which combines synonyms and other syntactic and semantic rules of a concrete language, but rather a search method under the string. If we search for fragments from the beginning, this process is effectively optimized and indexed, and for text searches inside the text, this situation is much more complicated. It is also necessary to optimize the system of inserting values into whisper windows, since each value change results means the recalculation of the resulting values (new polling). It is advisable to optimize on the side of front-end, where the search entry can be sent to the server for processing after some time, after a change, after a period of inactivity, but not immediately after changing each individual character.

Here also exists many variants and ways of working with data and here is a space for caching intermediate results of the searching.

C. Precise parametric searching

Parametric searching appears rather simple. The user defines a filter in which he sets the exact match of the required parameters. Alternatively, it defines multiple allowable values for one parameter. This process is

relatively simple and the search efficiency is affected by the server's technical parameters (operating memory, disk access speed) and the storage method chosen rather than the complexity of search logic. Complications occur, when we provide users with information about the number of relevant records, both in cases of extension (adding) records and reducing them (refining parameters and thus limiting selection). Here, it is necessary to recalculate the remaining values, and generate aggregate results, which give information about how many objects they add or withdraw to the final selection. These calculations are relatively complicated and calculation varies with the number and order of the selected parameters.

A possible simplification is to provide the calculation as the only information, it means how many items will be selected totally for this filter. The last reduction in performance is the possibility that the resulting number cannot be published at all, but here we can get into an unfortunate situation, when, after choosing an inappropriate combination, the user does not pick up any relevant object and learns it after sending the query.

Student work in this area is mostly based on content analysis, where users prefer different properties for different categories of products and services according which they search. The properties are then generally divided into primary and secondary. Depending on the primary properties, it is possible to search and sort. Secondary properties represent only additional descriptive information. In addition, properties may be divided into common (for example price, availability, name) and specific, when for example, a particular product model has a feature, which other products may not have at all.

In addition, the properties can be divided from the main, important and complementary. The main characteristics of the products divide them in the concrete segment of the market, for example in the case of cars, it means their model and brand, mileage, fuel, year of manufacture, etc. Among the other main features, we can add gearbox type, wheel drive, air conditioning, etc. As supplementary properties we can understand special types of equipment. Here a human factor is entering into the game, which decides which attributes will be classified.

Students can combine different setup methods and evaluate relevancy for users. They also have space for caching of search results and their reusability [4].

D. Combination of parametric and full-text searching

An interesting possibility is a combination of full-text search, including the definition of relevant parameters. This combination requires advanced search and sorting technologies.

These types of filtering are also suitable for a refined selection of products in a concrete category, as users, for example, want to find a suitable TV from a specific manufacturer with specific parameters. This predefined filter can be stored in Gloffer. The search result can be pre-processed and updated regularly. Finally, it is then offered to users, making it easier to pre-fill the search values.

This whole process is once again suitable for students, who can analyse user requirements in the first instance, both in terms of the categories they visit and also the products and services they are looking for. Predefined filters can be presented to users in different combinations,

based on their content, the experience of other users, the time of year, and other circumstances, such as what the user has previously visited, or which products they have previously purchased.

It is obvious that there are a lot of combinations that can be tested by students in the Gloffer project.

E. Approximate searching based on similarity

The catalogs based on parameters are as perfect as their content is perfect. It often happens that content providers do not fill all the features, or they are able to adapt the products and services provided to the request of a user.

Taking into account only the exact match in the search, the user selects only the specific objects, which the filter will provide. As well as in the real world, a user may want a product that does not exist in a defined combination of parameters, but can accept products with similar properties.

The process of defining such parametric queries is twofold. The user can choose the product that best suits his needs, and then add new parameters, modify existing or so-called discovery searches by accepting multiple properties of the admissible values for one property, or completely eliminating the filter property, thereby expanding the set of potentially acceptable objects. An example is a situation where a user wants to buy a new notebook, requiring a larger hard disc beside the existing one, and accepts this model from more different manufacturers. This procedure is complicated but still works with the same model of object storage and its properties.

Another, probably, the most sophisticated way is the one, when the user defines his ideal product, which does not exist, and then assumes that he wants this product or the better one? Of course, there must already be added what are its preferential criteria and what does the "better" product mean? If it is a product with lower price, better parameters, extra service, etc. from the point of view of the database a very complicated problem arises, which requires that the quality scale of the individual properties be defined. This process is extremely demanding, as it is difficult to judge for many parameters, which property is better than another. For example, with a computer processor that itself has many partial properties, it is very subjective to say that this processor is better than another in terms of price, consumption, power in games, stability for server solutions, etc. This very complex task would be to previously described filters, should be able to dynamically complement the properties about which Gloffer thinks that are suitable for the user, based on predefined scales. So we are in the field of expert systems, which are an interesting area for the research and application of modern technologies.

F. Multi-objective, cumulative searching

Also an interesting area of research is the so-called multiple filter cumulative search. This is the case, where a user expects a combination of multiple input queries within one search result. This may be the case for real estate, where a user accepts buying a house in more locations, but requires different properties in each of them. The same may apply to cars where a user chooses to buy multiple brands and each has different parameters and preferences.

Here, it is necessary to set up a clear and simple way of searching, with the possibility to save partial intermediate results and their final combination into a whole, which can then be appropriately sorted.

Again there is space for analysis of user preferences and admissible combinations.

G. Outages and catastrophic scenarios

Because sales portals are conceived in the area of internet as 24/7 services, and their solution consists of several technologies (database, cache, full-text index, querying queue messaging system), which can be scaled to increase performance into multiple instances. It is necessary to analyse and plan the methods of updating data, storing and re-usability of search results, etc. The whole process includes a description of crisis situations, a failure of individual services and a system of substitutability of these services. This procedure solves, for example, a situation where a full-text or database failure occurs and is temporarily replaced by another technology. Outages may be planned (maintenance, migration) or emergency when an unplanned shutdown of a machine occurs. The entire process of deploying and scaling the individual technologies is closely linked to server virtualization and container services (dockers) [5].

III. SEARCHING OPTIMALIZATION BASED ON AVAILABLE RELEVANT INFORMATION

From the perspective of search optimization, many factors need to be taken into account. It is not only about the phrases entered into a full-text and input filters, but also user preferences, long-term and short-term traffic statistics, trends and business logic that may temporarily prefer a brand or a new product that does not have historical statistics. as a novelty we want to favour into the search results. Students have here again the opportunity to optimize search results and test different strategies for selecting and presenting the search result. For testing these services, Gloffer has integrated a user satisfaction measurement system, where users can tell, if the concrete search result is relevant to them or not. [6]

A. Marketing preferences

Marketing preferences include highlighting a concrete brand or product. This may be a paid service or a temporary benefit of a new product without historical statistics. Marketing preferences need to be categorized and scaled and then saved on the specific objects, brands, vendors, or categories and added to the full-text search system, where they affect the relevance of the searched records.

B. Subjective measurable values

Subjective values include user profile settings, tracking of popular products, companies, categories, etc. It also includes black-list settings, where the user registers products, companies and categories that they reject or has bad experience with. Ideally, these subjective values are taken into account in search results.

Additionally, users with the same shopping behaviour can be identified, those who visit the same or similar products and categories, work with the system at the same time, or have the same popularity preferences, or have

bought (demand) the same products. Here, after applying anonymization and aggregation, these statistics can be applied to the current user.

C. Internal objective measurable values

The most important internal statistics include the user behaviour protocol. So, for logged-in users, you can see which products and services, categories, brands, businesses they visit, from which vendors they buy, and what they ask for searches.

It is necessary to realize that all these statistics represent historical events and values that describe what happened, not what can happen. For example, when the first child is born, certain preferences in search and demand will change. Again, here is a space for modelling customer behaviour, the problem of this type of adaptation is that it is a maximum degree of personalization, and search results are then only relevant to the current user, what means increasing the difficulty of the system.

D. Group aggregative statistics

As we follow individual preferences and behaviours of people, we can include the experience and behaviour of multiple users in the search result. It is appropriate to define user classes with multiple subtypes, assign the current user to this class and edit the search parameters accordingly. While this approach is not as accurate as the previously described option, there is a space for reusability of search results, because if the same question is asked by a representative of a concrete group, its result may be used with the same query of another member.

E. External objective measurable values

There are a big number of anonymized statistics in sales portals. They are mostly unregistered users who work with the system. Although it is possible to identify them partially (inaccurately) by the IP address from which the query was asked or by using a cookie record in the Internet browser. However, this information may not be accurate. Additionally, it is rather complicated to track user behaviour accurately in web presentations and mobile applications, and it is a good idea to combine data with resources from external applications such as Google Analytics. Data may be incomplete, given that users can use the blocking tools. The resulting data supplement information, where the users came from or where they continued.

F. Long-term and short-term statistics

Another relevant area is long-term and short-term statistics. It is necessary to monitor how, for example, the product (category, brand) is visited and demanded, in the last week, month, quarter and a whole year. Traffic trends can be tracked, whether the product is visited more or less and if it is seasonal goods. Also if this are products that have a business model based on development versions (for example, mobile phones, where a new model comes every year, the old one is discounted until the sale phase).

Short-term trends may be affected by advertising campaigns, long-term statistics may present historical values that are not valid at the current search time, and this may result in a distortion of search. For example, a new mobile phone model does not have long-term statistics,

but may be more demanded than an old model that is no longer interested.

It is clear that there is again a great scope for research, with conclusions in the form of rules and preferential variables may greatly improve search results.

IV. MARKETING AND INFORMATION TECHNOLOGY

An important part of the Gloffer project represents marketing communication. It is obvious that in order for the project to be successful, people must use it. Nowadays, the internet is literally flooded with a number of different, more or less, high-quality applications that typically direct to concrete segments rather than global solutions.

In this area, the Gloffer project is exceptional, as it combines not only the reach of more market segments with transnational scope (language versions, currency conversion, etc.). There is a great space for marketing communication as part of the presentation of the brand and also of the individual products and services. The condition is the implementation of low-cost marketing. It is necessary to test the individual approaches, to evaluate them and based on these results, to repeat the successful marketing communication. Students have the opportunity to present their projects and in case of potential, they can realised them to a real experiment.

A. Brand marketing on the internet

The first phase of marketing communication is brand awareness. The goal is to make the online shoppers (not only) in the Czech Republic aware of the existence of the Gloffer portal and gradually identify its advantages and shortcomings with today's solutions.

It is necessary to present Gloffer as an open platform that is constantly evolving and is ready to solve basic user problems in finding the ideal product or service.

B. Service marketing

In the next phase of communication, it is necessary to present the services offered by Gloffer. In particular, it means saving time, searching and collecting, and comparing products and services, then presenting direct communication between the customer and the company which portal links together and it try to make selling process more effective.

C. Product marketing

There is also a segment of product marketing that presents the individual segments covered by a project. In the first phase there is an area of products that are represented by e-shops. They can be further divided into product categories where different ways of communication are needed as these products are purchased by different consumers with different demographics, education, and preferential values.

Future expansion plans are planned into other segments, which are classic demand systems in the area of services, as well as the presentation of offers and demands of clients for example the sale of cars and real estates. Now, the portal concept is based on a price comparator with a fast demand for a defined (catalog) product. Consequently, it is possible to expand the

demand area to demand models with approximate similarities, or complex demands that associate multiple objects from one or more companies. It is desirable to present a presentation portal that will offer the specific benefits of individual manufacturers and suppliers. Additionally, portal can be complemented by discount portals and action offerings, auction systems and rental systems. Later, the project may be a provider of direct sales, which is a relatively demanding legislative logistical process and its real launch requires complex preparation.

V. TARGET GROUPS OF MARKETING COMMUNICATION

Within the Gloffer portal, it is necessary to build three directions of marketing communication. It is necessary to address supplier companies that should provide interesting content and be the source of funding for the Gloffer project in the future. The next important group consists of customers, who actively use the portal, search for relevant products and create demand and last group consists of investors. In this case, it is necessary to present the quality and potential of Gloffer [7].

The model of marketing and business communication is defined in five steps: Introduce, persuade, sell, recommend, repeat.

The stage of the introducing represents the dissemination of the basic awareness of the portal. It is necessary to present the brand and explain the basic model of the system use. It is necessary to map the user experience and the procedures used. Because the project represents another type of buying behaviour, a new user needs to learn this behaviour first [8].

The second step means persuading that overrides critical views and doubts. It compares solutions with other business models and highlights their advantages and disadvantages. It is necessary to communicate the different situations that lead to the purchase where it is much easier to describe the advantages of shopping where there is a typical longer period of information gathering and decision making. On the contrary, it is rather complicated to change the shopping model for products that need to be acquired quickly due to urgent need, malfunction etc.

The sale itself is conducted through a demand process, where the portal represents the area of demand, obtaining relevant offers, comparing them and then evaluating and closing a deal with one or more suppliers.

The process of the recommendation is carried out in the form of positive comments and ratings of realized business cases. Moreover, of course, if the customer is satisfied, it is very important to build a long-term partnership and motivate them to make repeated purchases [9], [10].

A. Companies – products suppliers, providers of services

Companies (suppliers) must understand the benefits and benefits of this solution within the marketing campaign. It is necessary to minimize their work in the process of

presenting the offered products and services and minimize their time when searching and creating offers for user demand. It is necessary to confront procedures with competitors and to highlight benefits. As companies welcome every good source of promotion, they provide content with many listings and business reviews, this part of marketing communication is well-behaved and feasible.

B. Customers – users of goods comparators and demand systems

The more challenging is the acquisition of new customers, who have to accept a new purchase model (by demand). In order for the customer system to be acceptable, it must offer the relevant benefits. Many customers are also not prepared that someone takes care about them and are not always willing to meet their demand-driven obligations. In the first phase, it is necessary to provide tangible benefits that the customer can use immediately. It can be the clarity, reliability, simplicity, clarity and trend of the services provided.

C. Investors

The last interest group in the area of communication consists of the investors. Here, it is necessary to demonstrate the potential of the whole project and the ability of the team to solve the problem. The entry of a strategic investor is then directed to the area of intensification of current development and marketing, and so-called smart money (knowledge and resources) that would help expand and reach other potential customers and suppliers.

VI. CONCLUSION

As can be seen from this article, the Gloffer project is a very robust platform that offers many possibilities how to use it. Obviously, cooperation with the academic sphere can offer a number of benefits and ideas. It provides students with the opportunity to implement their own ideas and to verify them in practice. It is also interesting to cooperate between economically and computer-focused students, understanding each other how technology should work and what added value they should bring to customers. The project is mainly appreciated by students

and is presented as part of the university's promotional activities.

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Speech Interface Dialog with Smart Glasses

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Abstract—This paper describes design of elderly-user-friendly multi-mode user interface with different modules. Use of eye glasses is common among senior citizens, and it inspired us to implement interface modules on it. Indicator-based Glasses contains the Eye Blinking Detection module integrated with visual cues indicators as system feedback. The multi-mode interface provides five interaction channels by proposing audio input/output modules and Android application on smartphone device. The VoiceXML Dialog Manager implementation (VoiceON) is described and proposed for speech enabled computer initiated dialogues. Senior citizens suffering from mild and moderate dementia are the primary target group of the proposed system. The human factors of the multi-mode interface will be tested in experiment with senior citizens, and different scenarios will be evaluated.

Keywords—Indicator-based Glasses, Automatic Speech Recognition, Dialog Management

I. INTRODUCTION

Kortum [1] studied nontraditional user interaction techniques, and discussed usability improvement in auditory interface, voice dialogue, audio display, interactive voice response (IVR) when they are integrated as a module in multi-interface system. Considering this motivation, Kortum [1] stated that there are two types of multi-interface interaction systems. Multi-mode interface includes two or more interaction techniques, which are designed to perform and accomplish same unique task. The user freely can select the preferred method of interaction technique based on the context. On the other hand, multi-modal interface includes two or more interaction techniques, which are combined to perform and accomplish only one specific task. So, the user has to perform different interaction methods to perform the task. In most cases, the multi-modal interface is designed to resolve the ambiguity problems in the interaction process. [1]

Multi-mode interactions are significantly common among the service providers, when they allow users to access and modify data by the preferred interaction method such mobile user interface, voice interactive response or web browsing. Zhang et al. [2] designed a gaze and speech multi-modal interface to select objects with different colors in environment. Speech and gaze recognizer report accuracy scores, and integrated module resolves inaccuracy problem which may caused by gaze deviation or noisy environment. [2]

Although nontraditional, multi-mode and multi-modal interfaces are different from traditional graphical user interface, they must conform to basic interaction principals such as ISO 9241:11 to provide effective and efficient interfaces to satisfy user expectation. Early testing and experiment with target user group measure usability factors such as effectiveness, efficiency, satisfaction level and error tolerance. [1]

In this study, we explain design of context-sensitive multi-mode user interface with more than one interaction techniques. Touch screen input and output, voice interactive response and blinking detection system are the interaction modules in the proposed system.

Significant achievement in the development of voice-based interfaces through automatic speech recognition (ASR), natural language process and text to speech (TTS) in the recent years open the door to develop more intuitive IVR system. Open source and commercial products are currently available to be used as above-mentioned modules of context-aware IVR system. Cloud-based commercial apps are described in [3].

Prylipko et al. [4] explained the architecture of Zanzibar OpenIVR which includes speech application server utilized with Voice-XML interpreter (JVoiceXML), speech recognition engine (CMU Sphinx 4) and text to speech engine (FreeTTS). The prototype used dialogue management with mixed imitative dialogue strategy. The mixed strategy allows the system to ask for missing information from the user, while still following the form items in VoiceXML. Prylipko et al. [4] also tabulated different characteristics of available platforms for spoken dialogue system. The comparison focuses on use of modular component, VoiceXML dialogue and being open source. [4]

Cohen et al. [5] provided guideline to design Voice User Interaction (VUI) by including prompts, system message, grammars and dialog logic. The dialog logic provides the system action procedure in response to user's actions. Furthermore, Schnelle [6] involved context information to support workflow engine while designing audio-based interface. The context information is collected from the environment such as location and current task in hand. Since the prototype was developed on 2007, limitation on mobile and wearable devices forced the designer to consider a separate desktop server to integrate the tasks for workflow engine, VoiceXML interpreter, ASR, TTS and dialogue manager; while the auditory messages

and commands were streamed to/from end user client. [5, 6]

Although context-aware VUI can be developed to provide human-like conversation and mature man-machine interaction to obtain information from user, in most cases the nature of the tasks defines suitable interaction technique especially if the user suffers from memory decline or physical disability. In some cases, mobile graphical interface can catalyze the interaction while IVR, VUI and auditory display fail to fulfill user expectation. In fact, user perception of human-to-human conversation lead to the high user expectation of VUI system, while the system fail to properly proceed with unpredictable user input, and it is considered as one of the major drawback in VUI systems. Sorri et al. [7] conducted experiment with elderly users with dementia to evaluate usability performance of three different type of user interaction technique as output channel. Auditory display, visual-based information and tactile messages were compared each other to get navigation instruction while performing a simple navigation task. Considering nature of the navigation task, the result indicate that the mixed auditory display and visual cue provide the most efficient interaction to accomplish the tasks. [1, 7]

Our previous study includes design of visual cue navigation instruction system for elderly users and bike riders. The interface provide navigation cues and voice commands through led-based glasses. Figure 1 shows the prototype and example visual cue commands, which can be adjusted based on ambient light, and user preferences. It is suitable for bikers since their hands are not free to interact with hand-held devices. We conducted experiment with young bikers and elderly users to evaluate usability of the prototype in navigation tasks. In case of elderly users, most of the participant suffered from mild or mediate dementia, but they accomplished their navigation task by assistance of visual cues and voice command.

Two unresolved issues are revealed during the interview sessions. First, users expect the glasses to help them with some other tasks in daily activities such as shopping, calling and organizing calendar. Second, they expect the system to preserve their dignity and privacy in public places by providing unobtrusive interaction. Loud voice interaction through VUI is an example that violates the privacy of the users. Furthermore, the speech-enabled system which is designed for elderly users should be customized to be used in public places. [8]

Above-mentioned argument accentuates simple problem of speech/voice dialogue system, which is preserving dignity and privacy of the users in public environment. This is the primary motivation behind this study and it derives us to design a conceptual context-aware multi-mode interaction system that resolves the problem, and bring efficiency and performance to the system together with dignity and privacy to the user.

Eye blinking detection is considered as an unobtrusive input channel to fetch information from users. Many research prototypes and techniques are designed to detect blinking eye action in the recent years. In most cases, a camera with image processing solution is setup such as Pupil Lab eye tracker. Infrared proximity sensor is also popular implementation, which is used in Google Glasses. Biopotential measurement
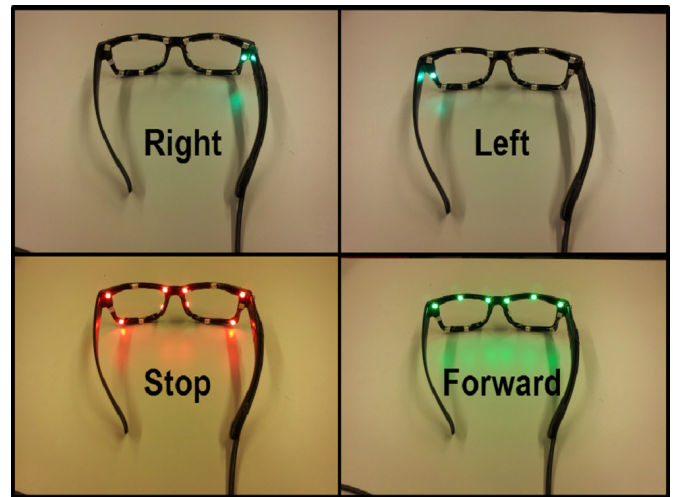
Fig. 1. Indicator based glasses is designed to provide near eye visual cue to assist users in navigation tasks. Android application set brightness, color, blinking frequency and combination of LED indicators.

such as electrooculography (EOG) sensor implementations or EEG [9] are considered as unobtrusive implementation of eye blink detection in eye glasses. Since use of eye glasses is common among the senior citizens, implanting eye blink detection system in eye glasses is the most suitable approach to design elderly-user-friendly interaction. [10, 11, 12, 13, 14, 15]

Zajicek [16] studied speech enable user interface for senior citizens which is known as VoiceXML-based Voice Activated Booking System (VABS). The user interface designed to fetch information from the web regarding bus timetable, council collection, doctor appointments. Furthermore, Zajicek [16] argued that the user interface should follow three design principles, which are:

1) The output message should be short but understandable.
2) User should be able to reduce number of choices as desired.
3) Confirmatory message should be considered in different steps of dialogue communication.

The study concludes with six specific pattern forms of messages, which are menu choice message, confirmatory message, default input message, context sensitive help message, talk through message, explanation message, partitioned input message and error recovery loop. [16]

Elderly user group is the primary subjects in web browsing experiment with VABS. Considering the result of the experiment, our proposed prototype inherits pattern forms classification from characteristics of VABS. Another reason to apply design principals in our multi-mode user interface is the similarity of tasks and possible scenario that our prototype should be able to handle. The user interface should handle the daily tasks of senior citizens efficiently and provide smooth transition between modules. The tasks includes reading and modifying shopping list, appointments and calendar events; reading news; providing navigation instruction and managing the phone calls and text messages. Furthermore, nature of

dialogue-based interface facilitates answering short health, cognitive or nutrition state examination. [16]

II. ARCHITECTURE

Common use of eye glasses among the senior citizens has derived us to implant interaction modules on wearable glasses. Furthermore, it supports our research motivation which is designing unobtrusive interaction mechanism in public environment. Android application running on a hand-held device works as local processor, and it communicates with headset Bluetooth (voice user interface) and Bluetooth transmitter (eye blink detection). Android application provides graphical user interface and synchronize dialogue sequence for eye blink detection and voice user interface modules. The local processor parses dialogue and communicates with remote processor. Sensory ambient data such as GPS location data are sent to remote processor, and then relevant dialogue is generated and sent back to local processor to initiate the interaction with user. Abstract architecture of the system to provide and parse dialogue document is shown in Figure 2.
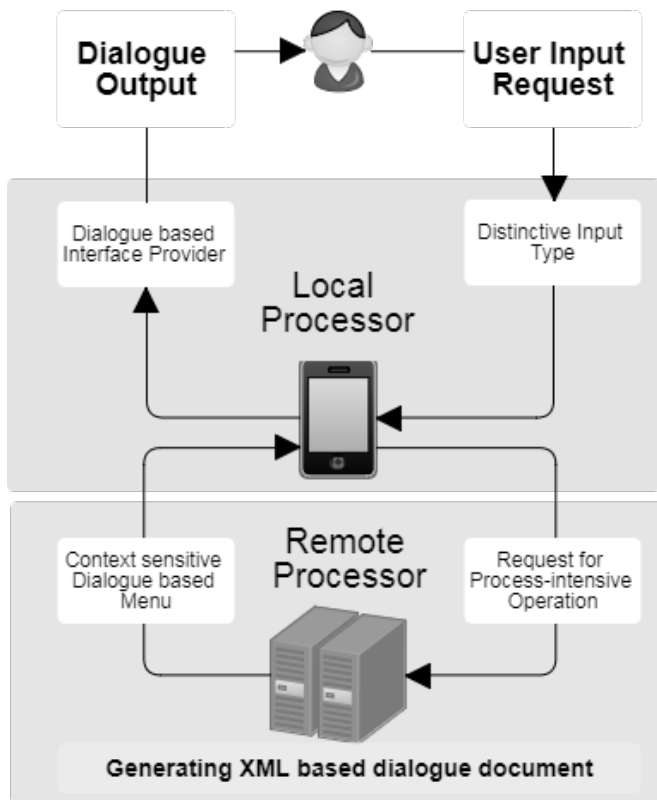
Fig. 2. Abstract architecture of the system.

Voice user interface allows user to interact in convenient approach while hands are involved in other tasks. The speaker and microphone components of Bluetooth headset device are implanted on the side arms of glasses frame to compose hardware input and output channel of voice user interface. Android application activates the interface and speech dialogues are streamed between two endpoints. However, to preserve dignity

and privacy of the user in public places , the interaction can be extended to blink detection module for input commands.

The proximity QRD1114 sensor, integrated with infrared LED and phototransistor, is the main hardware component of eye blink detection module. It detects reflected infrared signal from blinking eye and informs Android application through low energy Bluetooth transmitter. The proximity sensor is implanted on the corner lens frame of the glasses to avoid blocking user's field of vision. A rechargeable Li-ion battery supplies the electricity power for Bluetooth transmitter, proximity infrared sensor and Bluetooth headset.

The above-mentioned system architecture provides hardware platform for multiple input/output channels between user and system (3). This study argues the process of generating the dialogues documents, and different types of dialogues (message/command) that can be handled by three modules through five channels.
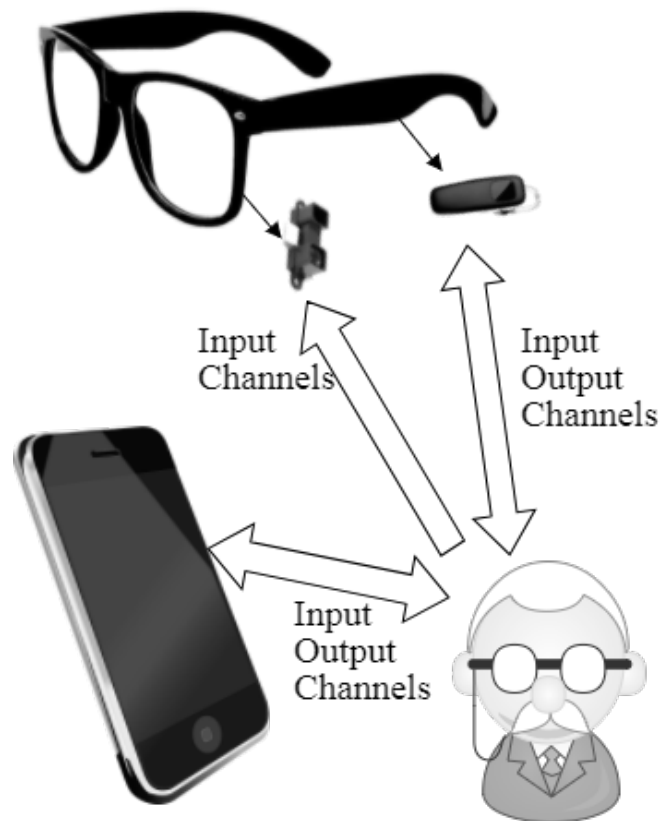
Fig. 3. There are five channels of communication between users and multi-mode interface: Input and output channels for mobile graphical interface; input and output channels for speech enabled interface; input channel for eye blink detection.

The interaction between user and system is triggered by user request message which presented by voice user and graphical interface. The user request command is sent to the remote server to generate required dialogue. This process is performed through partitioning the dialogue and providing menu choice message.The remote server includes a machine learning engine

to consider user request command, time, location and ambient sensory data as features to learn user behaviour to generate the Voice-XML document and initiate the dialogue. For example, based on user request commands, the dialogue can be generated to manage the shopping list or set an appointment in the calendar.

Voice dialogue management is performed by VoiceON dialogue manager [17], which interprets VoiceXML language. Using of VoiceXML-based solution is well suitable for intended application, because of well defined dialogue flow. Moreover, VoiceXML language has proper readability (see Fig.6), which supports fast development of new services and also automatic generation of VoiceXML code by machine learning algorithms. The architecture of the manager is shown in Fig.4. VoiceOn consists of two main parts - Dialogue manager server and the wrapper module (see Fig.5). This arrangement enables extensive use of dialogue manager for various dialogue systems, because only wrapper module need to be changed. Wrapper translates messages between VoiceON manager and a platform, which contains other modules of communication system as are automatic speech recognition, text-to-speech synthesis [18] and others. The VoiceON system offers two wrappers - one for DARPA Galaxy architecture [19] and one for Aldebaran NAO robot [20].

Fig. 5. Architecture of the voice dialog system

```
<?xml version="1.0" encoding="UTF-8"?>
<vxml version="1.0" lang="English" application="applications/ARD.vxml">
<var name="Name"/>
<form id="steptwo">
  <field name="YourName">
<nomatch>
      <prompt bargein="false">Sorry, I don't have your name in my database. </prompt>
  <goto next="#help"/>
    </nomatch>
    <grammar src="lang_resources/grammars/names_eng.xml"
type="application/grammar+xml"/>
    <prompt bargein="false"> Hi. I am your assistant. What is your name? </prompt>
    <filled>
<prompt bargein="false"> Hello <value expr="YourName"/>. </prompt>
<assign name="Name" expr="YourName"/>
<goto next="#help"/>
    </filled>
  </field>
</form>
  <form id="help">
    <noinput>
      <prompt> Could you repeat your answer? </prompt>
      <reprompt/>
    </noinput>
```

Fig. 6. VoiceXML code example

Fig. 4. TUKE VoiceON Dialog manager architecture

VoiceON dialogue manager is written in C++ and supports also subset of elements from W3C SRGS and SISR recommendations, which enable to write complex XML speech grammars with semantic interpretation tags.

The next figure (Fig.5) shows the architecture of designed voice dialogue system, where the glasses are used as input-output interface device. Behind this front-end, voice dialogue system consists of three basic modules - automatic speech recognition (ASR), Text-to-Speech (TTS) and VoiceON dialogue manager.

In order to allow users to select method of interactions based on the context, different type of input/output and types of messages and commands should be defined. Menu choice dialogue provides several items for selection. There are many studies arguing number of possible items to remember in voice dialogue system. Based on capability of user's short term and working memory, prior study suggest 6 to 7 items for young users and up to 3 items for senior citizens, while the first and last items have higher possibility to be remembered. Providing less items means more interactions, navigation and depth are needed to reach the final goal. However, previous studies consider short messages approach with more in-depth navigation as more efficient approach with elderly users. [16]

Confirmatory dialogue is used to assure user's selection or input interaction. All three input channels can handle confirmatory interaction. It provides user with only two alternative of confirm and rejection.

Default input message is considered as subset of menu

choice message, and it is generated by machine learning engine based on user's behaviour and sensory data to include most fitted item in the menu choice message. If the user fails to interact with the system, the default input message is selected by the system for proceeding to the next task. The main drawback of default input message is the threat of unsatisfactory message which needs frequent users interaction over the time for training the machine algorithm.

Explanation message is provided by specific command and it presents user with extra information related to current task and dialogue. It is triggered by an arbitrary speech command or button in the graphical interface. Explanation message is useful when the system fails to provide an intuitive approach of interaction. Zajicek [16] discussed necessity of context sensitive help message which is a human to human communication, and talk through message which is continuous provision of task instruction to the users. However, we consider them as subset of explanation message, as human assistance can be activated as a extension of explanation message and need for continuous task instruction is highly dependant on the performance of working memory.

Recovering from speech input error required strategy to avoid user frustration, and still focus to the task accomplishment. Partitioned input message is designed to systematically categorized possible inputs from user, similar to a decision tree model. It is triggered by providing menu choice and confirmatory messages in the error recovery loop when the system fails to recognize input speech.

Designing the speech enabled system for elderly facilitates interaction of the user while the system recognizes user input from a set of valid expressions. On the other hand, it brings high risk of usability issue if speech recognition fails. Error recovery process keeps the user on the right track by partitioning valid statements and providing menu choice and confirmatory messages. Using partitioned input message results the trade-off which increase the length of the interaction by providing more dialogues, while it reduce the risk of errors.

User request message, menu choice message, confirmatory message and explanation message are presented to user by audio display and graphical interface in parallel. On the other hand, menu choice command and confirmatory commands can be given by eye blink detection module in addition to other two modules. The Table.I demonstrates modules that are involved in different type of dialogue forms.

TABLE I
MODULES TO PRESENT MESSAGES AND CAPTURE USER'S COMMANDS.

	eye blink detection	voice user interface	graphical interface
user request message		X	X
user request command		X	X
menu choice message		X	X
menu choice command	X	X	X
confirmatory message		X	X
confirmatory command	X	X	X
explanation message		X	X

III. CONCLUSION AND FUTURE WORK

The proposed interaction mechanism is designed to bring two advantages of fault tolerance and unobtrusiveness to the existing speech enabled interaction, and it provides an elderly-user-friendly system.

First, it outlines the procedure of handling speech recognition error, and provision of partitioned message to the user.

Second, it enables context sensitive and convenient interaction which not only customizes the dialogue content, but also provides users with multiple parallel interaction modules to accomplish same task based on the context.

Using dialogue based multi-mode interaction system brings trade off between task complexity and above-mentioned advantages. Furthermore, the main target group of the study is elderly users suffering from mild and moderate dementia, and the system is not expected to handle complex tasks. The proposed solution should be able handle simple tasks such as navigation or managing appointments, shopping list and calls. Furthermore, it provides suitable platform to conduct short examination regarding health, cognitive or nutrition state.

There are several issues relating to internal validity threats in this study. Different technology aspects are involved in the research which should be addressed during the improvement phase. Generating well-partitioned dialogue document needs assessing iterative experimentation and implementing customized practice of design. Inclusion of emotion detection module [21] could improve the system user friendliness.

VoiceXML documents are traditionally used in Dual Tone Multi Frequency (DTMF) to provide telephony services for customers. Since DTMF system are designed for regular users, time interval between choices in the menu forms are not considered as usability concern. Error recovery loop provides strategy to make transition between message types. However, repeating number of message should also be investigated before transition in processing user request command, menu choice command and confirmatory command. Time interval and repeating number of messages are metrics which should be studied in the experimentation phase.

Experimentation phase should be conducted in three blocks to evaluate usability of the system with combination modules of blink detection system, speech enabled module and graphical interface in hand-held mobile device.

Prior studies argued that context related questions must be short and expect short answers. Qualitative studies should be conducted to measure satisfaction level of elderly users with different type of messages considering length and clarity of the messages.

The experiment should be conducted in three different phase with primary subject group. In the first phase, users need to accomplish the task with graphical interface only.

The second phase allows subjects to use speech messages and commands.

In the last phase, users have alternative to interact with all modules of Eye Blink Detection, Voice User Interface and Graphical User Interface based on preference.

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Project and Team Based Teaching of System Programming in the course of Operating Systems

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Abstract—Higher education in Slovakia faces a number of problems. In this paper, we focus on one of them - an outdated way of practical teaching of computer science students, because of which the students do not understand enough the acquired knowledge and they often fail to apply this acquired theoretical knowledge in practice.

This article represents the description of our experience with the experiment in which we have introduced modern teaching methods of project and team learning into the Operating Systems course taught at the Technical University in Košice. After the experiment, the results of the students were collected and compared with the results of other students who did not participate in the experiment. These comparisons, along with the feedback from participating students, represent real data that enables the authors to evaluate the relevance of applied innovative teaching methods. We believe, that our solutions can serve as an inspiration for other people in academic circles encountering similar problems as we do.

I. INTRODUCTION

We consider the massification [1], [2] to be the most important problem of universities in Slovakia. The term massification refers to an increase in the number of university students, university graduates and number of private and state colleges. The number of college academics with a high academic degree does not grow linearly with the growing number of students, so colleges feel deficiencies of sufficiently funded people in teaching positions. The lack of knowledge-able staff in connection with the ever-increasing number of students is a great inconvenience. An equally serious, if not a more serious problem is the lack of quality in addition to the enormous quantity of students. The mass of students studying at universities is not always internally motivated to get higher education, and they participate in studies without the willingness to systematically learn.

An unfavorable trend in recent years is that the highest-quality Slovak secondary school students participating in international competitions and projects usually do not decide to continue their studies at Slovak universities. Most often, they are tempted to study in the Czech Republic, but they are also interested in the United Kingdom, Denmark, Austria, Germany, Norway, etc. They often consider studying in Slovakia as a bad choice for their future. They are partly right - in the current composition of colleges at universities (almost 50% of social sciences), there is a risk of low employment of graduates in the labor market. The poor quality of students sometimes causes the difficulty of curriculums to adapt to the average, which is the direction that the school should not decide to take. At the same time, it is another reason why the most talented students do not decide for studies in Slovakia.

It is important to look for modern and innovative ways [3], [4] for students to effectively teach even the most demanding substance, even with regards to massification. At the same time, it is advisable to prepare them for real practice, which is expected from them in future employment - students must be able to use the acquired knowledge in practice and they need to be able to work in working groups solving problems. The Operating Systems course has long been trying to adapt to changing trends, while maintaining the above-standard usability, quality and difficulty of the substance being taught. We use a number of procedures (see chapter IV). This article focuses on an experiment in which we have enriched the teaching process with team and project learning opportunities.

II. PROJECT-BASED LEARNING

Scientific and technological advances at the turn of the 19th and 20th centuries pushed the society forward and gave, among other things, an incentive to innovative ideas to motivate pupils in their school activities in line with social events.

The role of students in the world is changing dynamically and evolving at a very rapid pace. The socio-economic factor is not the only role that plays a part in here, but also global education, thinking, innovative teaching methods that know that information is readily available, and crucially important is the critical work with them. Society moves and world thinking focuses on the individualisation of education, the tendencies of the differentiation of teaching are clear, and it is also a major topic of inclusive education at different levels. Therefore, the articulation of theory and practice within the framework of project teaching is further developed and has a well-established place in schools.

Project-based learning [5] is a pedagogical approach designed to inspire a deep, detailed level of learning using research-based or research-based methods that are supported by topics that are real, interesting, and important for students to learn. It is a complex teaching method that is based on the interconnection of practice (real situations) and theory (knowledge acquired in classical school teaching) in the targeted activity of the pupil on a particular project.

The time periods devoted to the project are meaningful, complementary, and always result in the final product (outcome), compared to conventional teaching, which takes place in isolated blocks that are often incoherent in many respects. Project lessons combine several teaching methods during their realization, and both individual and group work of the students, while actively developing the key competences of individuals. Project learning is not intended to study simple facts. For example: Students may have the task of monitoring water quality in a local river, based on which they get information about the environment of their surroundings and the issues that affect them.

III. Team-based learning

Traditional teaching is based on the fact that each student acquires knowledge, solves tasks and performs practical exercises. Team (cooperative) learning [6] uses student collaboration to achieve the agreed goals. The fact that an individual achieves the goal only with the help of other members of the group not only makes the process of acquiring new knowledge more efficient but also develops personality and social knowledge Incorporating team learning into the learning process of students is a necessary step for the overall improvement of society.

The team teaching method does not only involve teams of students, but also their teachers. Therefore, the prerequisite for effective team teaching is the co-operation of several teachers working with students divided into groups. A team of teachers collectively plans and evaluates their teaching activity. A well-functioning team of pedagogues is a prerequisite for the creation of organized student groups.

The co-operation of students in groups gives them more complex knowledge, improves their ability to cooperate, communicate, resolve conflicts and plan their work properly. Team learning is based on the principles of group interactions, their interdependence and equality, the personal responsibility of individuals, and the use of group knowledge. In order for this process to be successful, a teacher should be able:

- to select appropriate curriculum and assignments for individual groups,
- know how to guide student teams and set them goals,
- to review and agree on the procedures by which student teams advance in understanding the learning materials,
- to strengthen teamwork and also the teamwork between teams of students,
- to support the personal responsibility of group members, and always to take into account that teams are made up

of individuals - an individual approach is also important in team teaching.

The number of groups and the number of students in each group is tailored to the demands of the learning curriculum and the capacity of the learning space. The optimal number of students in a group is 2 to 5. Working in pairs should not be frequent as full interdependence develops. If pairing is necessary, it is appropriate to change the pair of learners in the learning process or to create new, at least three-member groups in a more demanding learning phase.

The assessment of the students depends on the evaluation of the group, but it is also influenced by the contribution of individual students in the overall work result. The disadvantage of such an approach is that more assertive and strenuous students get to the forefront. An advantage (in addition to the obvious learning of effective collaboration) is the multiplication of student performance - weaker students learn from more skillful, more skilled learn to better understand the substance they are taking.

IV. Operating Systems

The Operations Systems (OS) course [7] is taught at the Technical University in the second semester of the bachelor study. It is compulsory for students of Informatics but it is optional for students of Economic Informatics. The lectures are provided by associate professor Ján Genči, the exercises are evenly distributed among the authors of this article. The aim of the lectures is to explain to the students the basic principles of OS, seminars on the contrary enable them to acquire practical skills in system programming. The experiment we want to describe is exclusively about OS seminars.

On seminars, students are taught to use the selected UNIX kernel service suite. It is not possible for students to present a complex set of kernel services (there are several hundreds of them), so exercises aim at understanding the possibilities of system programming and its use. Students have available literature - manual pages that contain documentation of all kernel services if they want to work with a larger set of services than is necessary to successfully complete the exercise. Basic core services with which students work are described in the Sofia textbook [8] that we have created for the courses needs. Sofia contains not only the description of individual services, but also concrete examples of their use along with source codes. This support material is divided into smaller units in the form of PDF files that cover individual topics of system programming, gradually presented on exercises.

A. Organization of OS seminars

Students have one lecture (3x45 minutes) and one seminar (2x45 minutes) per week. Materials are divided into individual weeks, so each seminar is thematic. To achieve this, we use the LMS Moodle system [9], where students have a lot of study materials appropriately broken down into individual weeks. The exercises are organized as follows:

- 1st week: Introduction, structure and course conditions - students are given access to the LMS Moodle system,

where 3 documents are presented, the content of which is explained in detail to students:

– Syllabus of the course,
– Instructions for seminars and conditions for granting credits,
– Recommended course of study.

- 2nd - 5th week:: Work on assignments Copymaster and Scripting I , where the topics of the seminars are:

  – working with files,
  – working with directories and other file-handling services,
  – control of devices,
  – working with regular expressions.

- 6th week: Seminar exam I. - verifies the knowledge of students gained on seminars 2 - 5,
- 7th - 11th week: Work on assignments Processes and Scripting II, where the topics of the exercises are:

  – pipes and signals,
  – shared memory,
  – synchronisation and semaphores,
  – network communication,
  – scripting in bash.

- 12th week: Seminar exam II. - verifies the knowledge of the students gained on exercises 7 - 11,
- 13th week: Acceptance of assignments, correction of tests, granting of credits to students.

Each activity that students perform is rated. Students can earn up to 60 points for the OS exam, with a maximum of 40 points for the seminars. However, activities during the seminars are divided into 100 points, which means that the number of points earned by the students must be multiplied by a coefficient of 0.4 before closing the credit. The breakdown of points for activities undertaken by students the seminars is as follows:

- Seminar exam I. - 20 points,
- Seminar exam II. - 20 points,
- Copymaster assignment - 20 points (15 entry points + 5 points documentation),
- Scripting I and Scripting II assignments - together 15 points (without documentation),
- IPC assignment - 20 points (15 entry points + 5 points documentation),
- 5 points in the competence of the trainer (continuous checking, overall activity, ...).

In addition to these points, students can earn bonus points for voluntary activity outside the exercise. This step has ensured that students are motivated to devote time to learning during leisure time. Self-study of students is a prerequisite for successful completion of the subject by students. At the same time, the lecturers allowed to dedicate almost all the space of seminars to solve the problems encountered by the students, instead of only vaguely describing the curriculum. Bonus points can be earned by students for the following activities:

- continuous tests - 0.5 points for each preparatory test from weeks 1 to 4 carried out until the date of Assignment I and for each preparatory test from weeks 5 to 10) carried out by the term of Assignment II. Each test is evaluated by a scale of 0-100, a score above 70% rated as 0.5 points. Students can get a maximum of 4.5 points by running a continuous test,
- homeworks - up to 2 points, for each series of homeworks from weeks 2 to 4 submitted to the term of Seminar exam I and for each series of homeworks from weeks 5 to 10 handed over to the term of Seminar exam II. The number of points is proportional to the quantity and quality of the solved examples. Students can get up to 16 points by completing homework.

B. OS assignments

We attempted to apply the principles of team - project teaching to the assignments of the OS, which was ensured by the work of the students on several projects in several teams.

The assignments do not have the same difficulty, the simplest is Scripting, the IPC is the most demanding. Therefore, we have appropriately spaced the seminars so that more time is devoted to difficult tasks. The difficulty of individual assignments also influenced the number of students in teams - for scripting students were working individually, for Copymaster in pairs, and for IPC in a team of three students. By this measure, we have avoided problems that would arise if students were working in the same groups for all the assignments. Working on projects in non-changing groups causes the students to be too reliant, and the failure of a part of the team causes the functioning parts of the team to experience problems throughout the OS course. On the contrary, alternating the composition and the number of team members allows skilled students who encounter non-cooperating colleagues in the development of a project to change and successfully get credits. At the same time, weaker students are motivated to work actively on projects because they can not rely on a stable team of "friends" who will also make their share of assignment work. In order to maximize the elimination of non-working students who wish to "take advantage" their more skilled colleagues, the Scripting assignment was incorporated into the teaching process as a separate work of individuals.

1) Copymaster assignment: Students worked on the Copymaster assignment from the 2nd to the 5th week of the semester. The knowledge gained during the assignments was tested during the 6nd week on the Seminar Exam I. Copymaster is a project where students create a program that copies the content of the input file to the output file. It must have the following syntax:

copymaster [options] infile outfile

Students in the assignment also implement 17 options that modify the behavior of Copymaster. For example, the -ap append option adds the contents of the infile file to the end of the file outfile, - f (fast) is a "fast" copy when the entire contents of the infile file is copied to outffile, -s (slow) is "slow" copy, -t size (truncate) sets the size of the infile

file to size ¡size¿ etc. Individual options can be combined, if semantics allow it. The functionality of the Copymaster options is designed to allow students to understand and use a large number of UNIX system kernel services to work with files and directories, thus to learn how to use the principles of system programming.

The work of students on the Copymaster project has been controlled. In order to be able to control their submission process, each week they submitted the newly created parts of the program to the git repository at git.kpi.fei.tuke.sk. The distributed git management system is suited for teamwork on projects, allowing each developer a local copy of the entire project development history. Even with more complicated projects and larger teams, there is no risk of overwriting unwanted files, it is always possible to find out who is the author of the individual files, find older versions of the developed application, and effectively merge the software developer's work into a comprehensive program. Each student team has set up its own git project in which the dates of student activity, the extent of their activities, and the authorship of each team member were clearly seen on the parts of the project. Teachers have access to student repositories, so they could track the work of all students, increasing the overall objectivity of the evaluation.

The final assignment was uploaded by the students to the automated system for evaluation. An e-mail was sent to students, that represented the report of the assignment. They could correct some bugs after reviewing their implementation shortcomings. The assignment was also handed in person, with the documentation provided. The documentation also had to contain percentage information on how the students themselves assess their share of work in the team. Based on the ongoing work of the students captured on the git, the automated evaluation of the assignment and the oral defense of each member of the team, the student was awarded a rating for the Copymaster assignment.

2) Scripting I and Scripting II assignments: The aim of the bash scripting assignment is to introduce students into basic text procesing toolchain available in Unix/Linux environment and basic Bash shell syntax.

The assignment is split into five exercises. The first three exercises - Scripting I assignment, focus on usage of grep (or egrep) utility, starting with basic commands requiring students to correctly use escape characters, then searching expressions with diacritics, and finally the third exercise requires students to design regular expressions matching patterns such as emails, time and date formats.

Scripting II assignment has two parts - the exercise four and five. The exercise four requires students to create pipelines of Unix/Linux utility calls ("oneliners") to filter, sort, change, and rearrange contents of text files. The task of the fifth exercise is to write more complex bash script. Students can hand in their work multiple times, and daily receive reports about correctness of their solutions. Each exercise (regular expression, oneliner, script) is processed using dataset provided by students and non-public dataset. In case of incorrect solution,

student receives snippet of output data showing difference between reference and handed in solution.

3) IPC assignment: Inter process communication assignment introduces students into basic system calls for process management and inter-process communication. The goal of the assignment is to create application demonstrating various inter-process communication mechanisms provided in Unix-like operating system.

The application consists of nine concurrent processes where each process passes data to the process following in a communication chain. Executables for three of these processes are provided to students with description of communication interface, while each of these programs has to communicate with another through a program provided by the student.

The assignment is validated by executing student's application with non-public pseudorandom input dataset and comparing required and produced output of the last executable in the communication chain. Students can submit their solutions multiple times and review validation results through a web interface. The interface also provides download of standard and error outputs of executed student programs, which allows students to identify potential problems in their implementation.

V. Evaluation

In 2015, students were working on the seminars of the Operating Systems course on two assignments, namely the IPC and the Scripting assignments, while the Scripting was completed by each student himself and three-member teams were working on the IPC. Operating system kernel services, such as file and directory handling services were not tested in any way. To solve the IPC assignment, it is necessary to be able to use the kernel services in addition to the other and we had the impression that the students did not understand enough this part of the course .

Another fact that we noticed during the 2015 lessons was that the work in one team demotivated some students because they worked with non-cooperating colleagues. As a way to solve these problems and even more strikingly apply team and project learning, we've decided to include a new assignment Copymaster, on which they must work on with a new team. To illustrate our results, we chose to use graphs that were based on the analysis of the student's learning outcomes during 2015 and 2016. We analyzed the students' results in the Copymaster team assignment at Seminar Exam I and we also analyzed student success in the context of the entire credit period , respectively. seminars.

From the overall student achievement chart in 2015 (Picture 1), one can read the fact that the highest frequency of the obtained points was in the range 21-23, which represents the lower limit for successfuly complete the seminars. The number of students who earned 0 to 20 points during the seminars and those who earned 24 to 40 points was comparable. The overall success rate was therefore 53%. 47% of students who studied the subject in the academic year 2015 did not receive enough points to be able to attempt the Final Exam.

Fig. 2. Overall success of students 2016

did not receive a single point for Seminar Exam I.

Fig. 1. Overall success of students 2015

Fig. 3. Overall success of students in Seminar exam I. 2015

From the overall student achievement chart in 2016 (Picture2), in which we incorporated the teamwork for the Copymaster project, is evident that the number of students gaining a score of 21-28 has increased considerably, thus reducing the number of students who gained insufficient points from the range of 0 to 20. We also consider the fact that in this year none of the students got the final 13 to 20 points. The overall student achievement during the semester was 81.61%, which represents a significant improvement in the study results.

In 2016 (Picture 4), the student could earn a maximum of 20 points for the Seminar Exam I. From the chart representing student success in Seminar Exam I for 2015 it follows that the highest number of students has earned points ranging from 9 to 18 points. Students' results are comparatively better in this case than in 2015. Only three students have received 0 points for Seminar Exam I.

Fig. 4. Overall success of students in Seminar exam I. 2016

In 2015 (Picture 3), a student could earn a maximum of 15 points for Seminar Exam I. From the graph representing the success of students in Seminar Exam I for 2015, the highest number of students earned a score of 7 to 11 points, which we consider to be a positive result. However, up to 17 students

From the graph (Picture 5) representing the success of students who worked on the Copymaster project, we can conclude that the highest number of students has reached points ranging from 9 to 18, which is a comparable result with the success of Seminar Exam I in 2016. The maximum achievable score for this work was 20 points. We assume that

the positive result of the students in this work came up for the use of team and project work.

Fig. 5. Overall success of students in Copymaster

At the end of the semester, our team created a student questionnaire that we sent through the Internet to students who completed the Operating Systems course in 2016. The Graf Response to team work (Picture 6) represents the result of our poll among the students. The overwhelming majority of students expressed their positive opinion on this issue and were glad to have the experience of working in teams. For many students it was the first experience with this form of work. Only 12.5% of the students said they did not like the work in the team, respectively, they would prefer to work independently at the seminars on the course of Operating Systems.

Fig. 6. Response to team work

VI. Conclusion

Teachers teaching the course of OS have been trying for many years to dynamically adapt to the ever-changing trends in teaching. This adaptation is not self-serving - an outdated university system in Slovakia produces a small number of real-time future employees. While teaching the students, we try to preserve the high quality of the course being studied, focus on its application in the professional future of students, and at the same time eliminate the devastating consequences of the mastery of university studies as far as possible.

We consider it essential to motivate students to systematically study throughout the semester. After several attempts to

implement various teaching methods in the education process to support students in systematic work, we observed their best results using team and project teaching. The use of the methods themselves was effective, but the really significant improvement in student results only occurred when we successfully combined project and team work. The OS students worked on more projects (2015 - 2 projects, 2016 - 3 projects) in several teams, with the composition of the teams not constant. This change does not seem to be significant at first glance, but in 2016 the subject successfully ended by 28.61% more students than in 2015.

The tremendous success we have recorded motivates us to continue our efforts to innovate ineffective traditional teaching methods. We continue to look for new opportunities to enable students to acquire real knowledge, working with them with productive dialogue. We adapt to their needs and demands because we believe that the student is the most important element in the learning chain. At the same time, we think that our experiments can be an interesting inspiration for other college educators.

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Systolic-based 2D convolver for CNN in FPGA

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Abstract— **Convolution is a primary mathematical operation used in many signal processing and analysis algorithms. High dependence of the complex systems on the correct operation of the convolver demands its continual improvements mostly related to the decrease of resource consumption. The paper proposes a model of 2D convolution massively used in the algorithms of image processing. The paper provides a detailed description of the model structure with focus on the implementation aspect. The model is particularly applied to the convolutional layer of Convolutional Neural Network, currently the most known image-based deep learning method. The key difference of the proposed model compared with other common implementations lies in the placement of line buffers. The correctness of the model design is validated through the simulation discussed at the end of paper.**

Keywords- 2d convolution, FPGA, CNN, systolic array.

I. Introduction

Convolution is a primary mathematical operation used in many signal processing and analysis algorithms, e.g. FIR and IIR filters. Therefore, there will be always need for an improvement of the convolution implementation in order to meet increasing requirements on the consumed resources of hardware platforms - **memory**, **processing units**, and **time**.

An example of massive convolution application is the Convolutional Neural Network (CNN), in particular its convolutional layers. CNN is a type of deep neural network applied to image processing and thus it processes a huge amount of data. Furthermore, the method requires the algorithm implementation to run in real-time and often on embedded devices that achieve very restricted resources. Therefore, the optimal algorithm implementation for platforms like FPGA is crucial for the overall performance of the system.

The paper presents a particular model of 2D convolution with focus on the effectiveness of computation. The second section introduces the mathematical expression of 2D convolution, a way of its decomposition into a group of general one-dimensional convolutions and our selected approach. The third and fourth sections provide a detailed description of the proposed model structure composed of two parts – data path and control path. The processing of both parts and related timing control are described in the fifth section. The last two sections contain the discussion about the correctness of the proposed model, its contribution, limits and future improvements.

II. 2D Convolution and its decomposition

The key operation of the convolutional layer in the CNN model is the 2D convolution. This operation is a variant of convolution that increases the dimension of data from a vector to a matrix while it preserves the basic mathematical way of output computation - **the weighted sum**. 2D convolution is applied in areas that process multivariate data, such as image processing. Because we selected the **pipelining** as a primary processing approach related to systolic arrays, we expect pixels to flow through the system one-by-one in a stream. The streaming approach allows us to avoid data preprocessing related to the data rearrangement in memory, which would increase the latency. However, the vector-based form does not fit data structure required for the 2D convolution. Thus, the system requires modifications in comparison with the traditional 1D convolution design.

There are various approaches presented in [1]–[5] that deal with 2D convolution from the point of implementation optimization regarding the consumed resources. The common idea of streaming data through the system of processing elements is same for all models described in mentioned papers, but they differ in the structure and interconnection of elementary processing units.

According to (1), which defines 2D convolution, we can split the computation of the final output into several steps, where each step returns only the partial result corresponding to one line of the weights matrix - kernel illustrated in Fig. 1 and presented as inner sum in (1). This view enables us to decompose the operation into several 1D vector-based convolutions and apply common practical solutions. Before we describe the structure and behavior of our proposed architecture, we state the assumptions about the format of inputs and outputs of the system. These assumptions specify the overall design of the 2D convolver.

$$y(i,j) = \sum_{m=0}^{K-1} \sum_{l=0}^{K-1} x(i+m, j+l) \times w(m, l) \qquad (1)$$

A. Input conditions of the proposed model

We assume that the input feature map is a squared image with the same width and height and this shape is a constant known in advance. Therefore, we describe the input image size only via one parameter *N*. The same
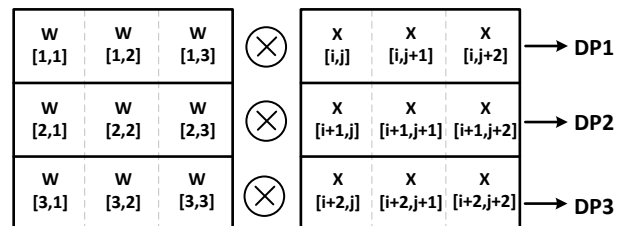
Figure 1. Visual form of 2D convolution

assumption is made about the shape of kernels defined via the parameter K.

The other set of parameters defines the dimension of inputs, weights and outputs. Because we use fixed-point arithmetic, we set the integer and fraction width for all these operands after consideration of their expected ranges and the whole computational model. Thus, we perform correct arithmetic computations and subsequent numeric adjustments, such as rounding and truncation.

The changes of these parameters lead to the modification of the original model and its components. On the other side, these changes are straightforward due to the chosen design of **systolic arrays**. Usually they require only the insertion of additional elements while preserving the model core. For that reason, all examples displayed in figures assume $K=3$ as the elementary case. This elementary case provides the simplicity and clear understandability while it preserves the main principle.

B. Architectural approach – Systolic array

Systolic arrays represent an architectural approach that enables a massive parallel computing and internal pipelined processing. Both benefits lead to the increase of the performance. This design form is applicable to the problems that exhibit simplicity and regularity hidden in repeated computational patterns. The modular design consists of a set of basic cells - **processing elements (PE)** - arranged in a systematic configuration, such as chain, matrix, or tree. PE units are interconnected through a simple regular network of links. The network controls the correct flow of data through the system of PE units and so it ensures the synchronization. Because the modular design provides scalability and flexibility, the model created for the solution of a particular problem is also usable for a set of bigger problems. They require only minimal modifications without the need to start from scratch. The systolic array pays off when applied to the computation-bound problems because its structure maximizes usage of inputs required for many computational operations.

The principle of systolic array provides various models that differ in the way of arrangement and interconnection of PEs. The paper [6] explains the foundations of systolic array with its benefits and presents several examples of models appropriate for a particular task related to FIR filter – the convolution. This digital signal processing task is an example that deals with the combination of two input data flows - the inputs and coefficients. Considering the following implementation dependent on the structure and possibilities of DSP blocks available in FPGA, we chose the design *W2* depicted in the mentioned paper. This model makes the assets of permanent utilization of all computation units, pipelining and continuous output flow without the requirement for the adder tree to merge the products.

However, not all systems can be effectively designed as a systolic array. The suitable system has to meet particular requirements - **multiple usage** of each input signal in various operations, **concurrent computation** that allows parallel and **pipelined processing**, the simple definition of PE, and regular shape of interconnect network. The task of

convolution meets all of these requirements and therefore is an exemplar candidate.

III. THE STRUCTURE OF DATA PATH

The data path of the proposed 2D convolver design consists of two main parts depicted as abstract model in Fig. 2 and as implementation model in Fig. 3. **The first part** computes all required partial sums of products. It performs a classical digital signal processing (DSP) task based on the multiplication and subsequent addition of signals (Multiply-&-Accumulate - MAC). As an output we get the partial inner products (DP_i) that have to be properly combined into the final result afterwards (P). Because the inner products given in the particular moment belong to different outputs, we need to provide the synchronization accordingly.

The second part addresses the issue of timing. It combines inner products and at the same time maintains the synchronized state. In other words, it controls the speed of data that flow through the system. The primary focus is on timing because the related inner products have to be combined into the same output.

A. Part 1 – Systolic Elements

The first computation part contains a chain of **systolic elements** that are connected in the sequence. Each systolic element (SE_i) is represented by the N-tap FIR filter that computes one line of the window - 1D convolution. That fact allows us to apply all known and recommended approaches to realize FIR filter in the FPGA. Considering the implementation of the design into FPGA circuit, we refer to the traditional and time-proven methods in [7], [8] that describe various FPGA models of FIR filters using DSP blocks. The abstract structure is straightforward and represents a systolic array [6]. On the other hand, the implementation design exhibits some distinctions in the synchronization associated with the structure of DSP in current FPGA (it uses *2K-1* registers instead of the original K registers as shown for K=3 in upper side of Fig. 3 compared to Fig. 2).

Each DSP block executes the multiplication of the actual input and the corresponding weight. The product is then pushed to the adder and attached to the cumulative output. The registers are inserted between the operators to enable the pipelining and so they increase the maximal operating frequency. The DSP blocks are introduced in the next section.

1) The Structure and Application of DSP in SE

The DSP block provides features that lead to the optimal implementation of FIR. Internal multiplier and post-adder support symmetric rounding and quantization of the results to address the bit growth caused by the arithmetic
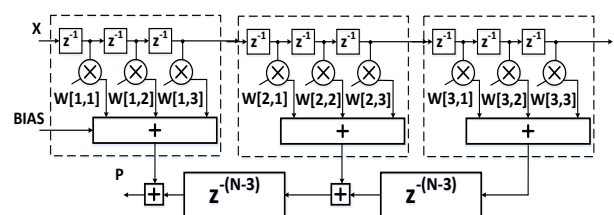
Figure 2. Abstract model of 2D convolver
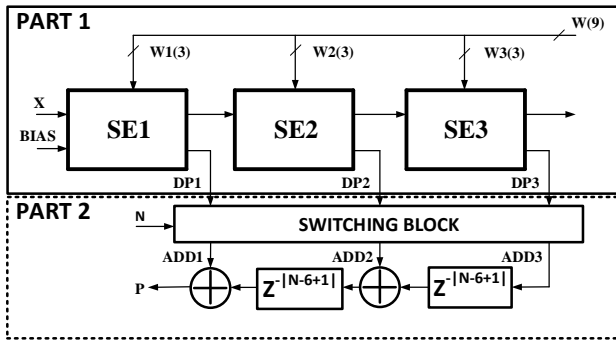
Figure 3. Implementation model of 2D convolver

Figure 4. Exemplar model of SE block

operations and thus eliminate the overflow effect. The cascade internal signals enable fast interconnection of adjacent DSP blocks within the same column and do not consume any FPGA resources - adders, multipliers, storage, and delay elements [8]. A registers placed in front of each operator directly in the DSP enable multilevel pipelining whereas the configurable multiplexers contribute to the flexibility. A temporal storage for the inputs during their use in the multipliers is realized through the line of registers - **data buffer** - of the desired length. Using these components, we can model a cascade of DSP blocks to compute products and gradually combine them through an adder chain into the final sum without external logic.

Considering the requirements of very high sample rate and small number of coefficients, we chose a specific type of parallel FIR filter implementation - **Systolic FIR** - because of its advantages stated in [8]. The systolic FIR is generally considered as the optimal model for parallel processing on FPGA. The additional latency compared with the utilization of adder tree does not have any noticeable impact on the performance. The cascade model significantly improves power consumption and speed. Furthermore, it is limited only by the total number of DSP blocks in one column inside of FPGA [9]. This design reflects the regularity of the arrangement and direct connections between DSP, BRAM and CLB blocks. The exemplar design of SE block is shown in Fig. 4.

The documents [7]–[9] provide lists of suggestions that can highly improve the overall performance of the final design when thoroughly met. They also address the implementation including the DSP instantiation and configuration in HDL.

B. Part 2 – Delay Buffers and Adders

The 2D convolution is executed on the matrix, which does not correspond to the shape of incoming pixels (lines). After the first design part computes inter-products, the second part needs to rearrange the results to allow their combination in the desired way according to the mathematical formula of 2D convolution (1). The delay buffers (in Fig. 3 the blocks between adders) are used to regulate data flow so that the right sets of inner products are combined together and the synchronized state is kept. We see in the visual representation of 2D convolution applied on the input image that the gap between partial results corresponding to the same window is equal the
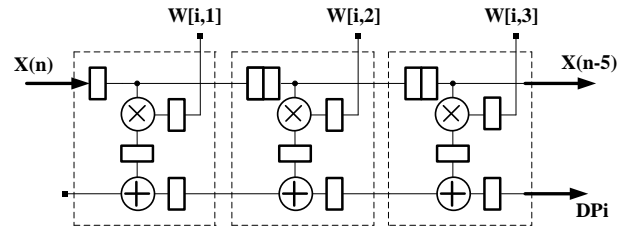
width of the image. It means, the distance between adjacent partial results of the same output equals N time units. After we subtract the delay caused by the SE chain, we get the remaining required delay of $N-2K+1$ time units that delay buffers are responsible for (Fig. 3 – Part 2).

The sequential arrangement of delay buffers in combination with adders substitutes the adder tree - a common choice used in current methods. The sequential approach brings an advantage of simple implementation and effective time utilization. The additions are executed while we wait for the remaining inner products of the computed output and so no additional delay is present compared with the adder tree based alternatives.

IV. STRUCTURE OF CONTROL PATH

The data path is controlled via the control signals that determine validity of output features considering the validity of inputs. The control path is realized as a Finite State Machine (FSM) tailored to our needs. The interface of the FSM consists of one input and one output signal, which represent validity of current input and output features.

The current design of the FSM exploits the determined width and height of the output feature map and the constant length of the invalid intervals to periodically setup and check binary counters in advance. The automaton counts valid inputs and generated outputs and jumps between the states according to the counter values. The states represent distinct cases of the window placement in the input feature map.

We differentiate three cases of window transition through the input feature map:

- the transition inside of the feature map,
- the transition through the vertical borders - the transition to the next line within the same feature map,
- the transition through the horizontal borders - the transition to the next feature map.

The results obtained during second and third enumerated periods (illustrated in Fig. 6-9) are **invalid** and have to be ignored in the further processing. Thus, only the results obtained by the window inside of input feature map are valid. The reason of invalidity is described in the next section.
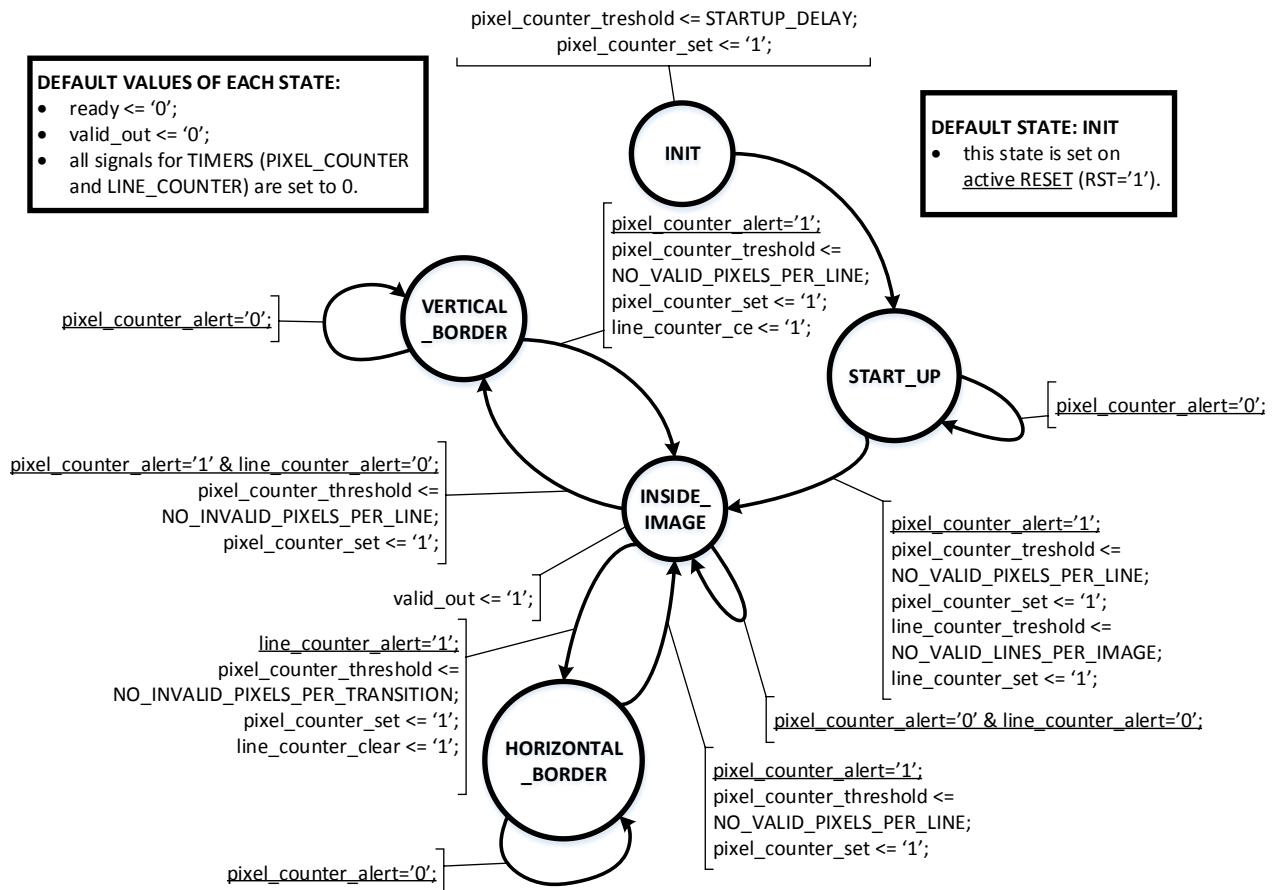
Figure 5. State diagram of FSM representing the control path

The FSM is visually displayed in the Fig. 5. It consists of five states that directly map beside the mentioned window situations also the initialization and start-up periods. The controller implements two counters with dynamic upper limits - *PIXEL_COUNTER* and *LINE_COUNTER* in the VHDL code. Each counter is responsible for the particular transition between states. The current form of the FSM operates only when the input is valid, otherwise it waits in the last state without change of any attribute, such as the current value of counters. This chosen behavior simplifies its design and in the same way influences the operation of the data path. In other words, data path waits without action during the invalid inputs.

V. DESCRIPTION OF THE PROPOSED SYSTEM AND ITS TIMING CONTROL

A. Data processing by the SE chain

To interpret data processing by the SE chain, we use a simple visual model. Computation of 2D convolution consists in scanning the input feature map by technique of moving window that is gradually used for computation of individual output features. Considering this process, the SE cluster can be visually expressed as a pattern built of K blocks shown in Fig. 6. Pattern blocks in the figure are divided into K lines and each contains exactly one highlighted line. The form of pattern depends on the assignment of weights from the original kernel to individual pattern blocks. Every pattern block represents one SE that computes its highlighted line. In other words, the particular pattern block colors always the specific line

of all windows in the input map. Therefore, we require a window to be finally covered by each block in order to compute all its lines - partial inner products (inner sum in equation (1)). We can imagine the task of pattern blocks as a coloring of the assigned line of windows. The processing of the window is complete when all its lines are colored by the corresponding pattern blocks. Because the visual shape of pattern specifies different positions of blocks, inner products returned from SE blocks in the particular time point correspond to different windows in the original feature map. Thus, they cannot be directly combined to the final output, but they have to be reorganized at first. The rearrangement of these products introduces the synchronization performed by appropriately placed delay buffers. The adders finish the computation and merge all related inner products to the common output.

Regarding the form of the pattern (Fig. 6), blocks visit a window sequentially in order from the left block first. The gap between two adjacent blocks is exactly *N-K* time units based on the line-by-line movement of the pattern. Therefore, inner products of two adjacent blocks taken in time points t and $t+N-K$ belong to the same result. By applying this principle to the chain of K blocks, the inner products taken from blocks in $t, t+N-K, ..., t+(N-K)\times(K-1)$ constitute one output feature. This time shift is a reason for the deployment of delay buffers to adequately adjust time points of all inner products. Thus, the length of each delay buffer regarding the abstract model is equal *N-K*, as shown in the Fig. 2.
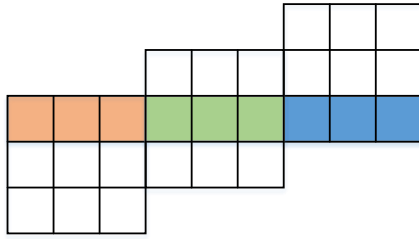
Figure 6. SE blocks pattern

The pattern sequentially moves through the input feature map as a consequence of the inputs continuously streaming into the system data buffer. The regular movement of the pattern line-by-line in the predefined direction (depends on the direction of data streaming) influences the validity of outputs based on various situations that are described in the section related to the design of the control path.

During the pattern transition through the vertical border, the SE chain processes input features that form an incoherent and thus invalid window (Fig. 7 - (b) and (c)). Similar situation occurs during the pattern transition through the horizontal border to the next image. In that case, processed windows include data from both adjacent images and therefore are incorrect (Fig. 8 - (b) and (c)). As a consequence, **all results obtained through the combination of invalid inner products are also considered as invalid**.

Due to the specific values of parameters N and K, we can derive valid and invalid areas of outputs. The numerical expressions are used in the control path to clearly identify validity of outputs in advance. The Fig. 9 depicts areas of valid and invalid outputs including their size based on N and K parameters.

B. Data processing by the SE

The principle of the introduced SE block design as a systolic FIR, which performs all numerical computations, lies in a different speed of the top and bottom data flows
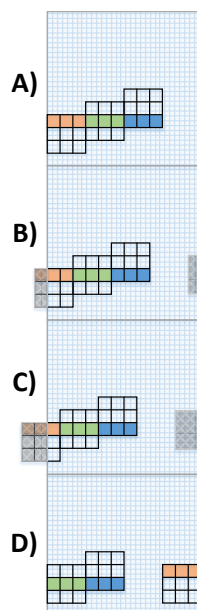
Figure 7. Transition through vertical border
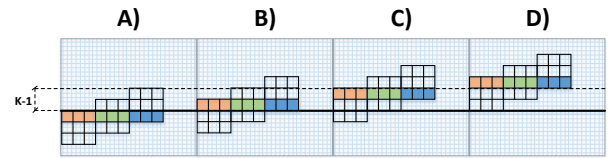
Figure 8. Transition through horizontal border

caused by the additional registers in the top path (Fig. 4). Therefore, the top flow is slowed down to the half speed of the bottom flow that represents the partial sum of the products. Because the current input and its product are actually the last element of the corresponding output (currently on the left side of the cascade), this partial sum has to reach products of several previous inputs (the particular number equals the number of coefficients). The increased speed of the sum flow compared with the input flow provides always the correct results on the right side of model but with a latency (the streaming of final sum to the output takes K cycles measured from the arrival of its last input).

C. Relationship between abstract and implementation model

The model of the SE in FPGA implemented through the systolic array requires additional registers in the input data path that were not included in the abstract model. As the Fig. 4 shows, the total delay (the number of registers) in data path of the SE chain is equal $2K-1$ instead of K. Therefore, the overall length of delay buffers in the second part has to be recalculated to meet the original timing requirements set in the abstract model - we subtract the additional delay of data path from the original length of delay buffers, so each buffer delays inner products by $N-2K+1$ time units.

D. The issue and solution of negative buffer length

When the buffer delay length is non-negative, i.e. $N>=2K-1$, the original design exhibits the desired behavior. But in the case of a small input feature map, i.e. when the inequality $N<2K-1$ is valid, the delay buffer should have a negative length considering the operation requirements. The buffer of negative length cannot be practically realized and so constitutes a complication. We
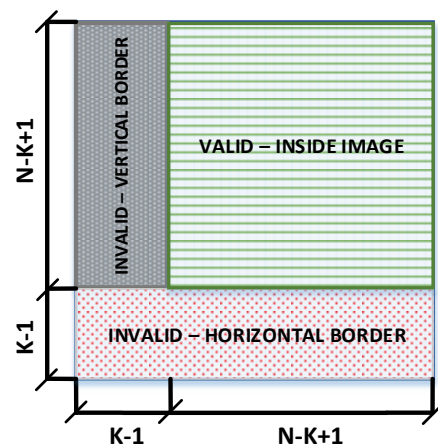
Figure 9. Valid and invalid regions

need to change the perspective to overcome the stated problem. If we add a delay buffer of the positive length to the signal path, actually we slow the speed of the signal that spreads inside the system. That means, the other signals will be faster than the delayed one. On the contrary, the delay buffer of negative length should have an inverse effect, hence it should speed up the corresponding signal in relation to the other signals of the system. We can accomplish the same behavior corresponding to the negative-long buffer through slowing down all signals but the particular one. The synchronization state of the system stays untouched. Switching block inserted between the first and second part (Fig. 2) provides the desired operation.

The particular structure of the second part enables us to exploit its symmetry (all delay buffers have same length and are connected in a raw) to design the switching block. In the case of negative delay, we reverse the connections of the inner products coming out of the SE blocks to the individual adders, i.e. the last inner product will be connected to the first adder; the first inner product will be connected to the last adder. In practice, we reach it via a set of multiplexers (shown in Fig. 10) that are appropriately controlled via the selector - a signal defined by the sign of the statement *N-2K+1*.
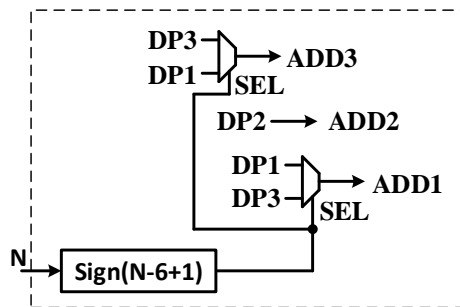
Figure 10. Switching block model

VI. DISCUSSION

A. *The desired operation of the proposed model*

The correctness of the abstract design is grounded in the mentioned documents [6], [7], [9]. The right behavior of the proposed model including control path and data path was practically validated through a behavioral simulation. The simulator integrated into Vivado [10] was used as a simulation tool. We carried out the controlled simulation with stimulus and evaluated the results.

Fig. 11 shows the waveform diagram of the proposed model simulation. Because of the length, the waveform is split into two diagrams belonging to the same simulation run. The important signals of data path and control path are displayed with their values in different time points. The first diagram displays the transition of window through the vertical border with emphasis on the *pixel_counter_alert* signal. This signal represents the activity of the PIXEL_COUNTER, that counts the processed input pixels. Its active state (value 1) indicates coming transition to other state of control path. In similar way, the second diagram displays the transition of window through the horizontal border with emphasis on the *line_counter_alert*.

This signal represents the activity of the LINE_COUNTER, that counts the processed lines of the input image. It indicates the transition to other state of control path in the same way as the previous alert signal. The progress of signal *valid_out* corresponds to the areas in Fig. 9.

The simulation run of the system captured in the diagram matches the desired behavior of both parts of the proposed model. Simulation outputs were also compared with results of the experiments performed on the GPU under same conditions - the kernel and input images. The results are almost same considering the sufficiency of the accuracy and so they serve as a proof of the desired behavior of the proposed model.

B. *Contribution of the proposed model*

The proposed model introduces a novel structure considering the delay buffers position. The other common models insert the delay buffers before the computation blocks to arrange the input pixels into matrix format at the entrance to the multipliers. That approach requires the adder tree placed after the sets of multipliers to merge the inner products, which increases the latency. Our approach inserts delay buffers after the computation blocks. The buffers are interconnected with the adders in the scheme that does not require the adder tree at all. By applying this construction, we save time of signals spreading through the adder tree and so we decrease the total latency of the outputs.

VII. CONCLUSION AND FEATURE WORK

The paper emphasized the important role of the convolution in various areas and the need for its continual improvement from the implementation aspect. Therefore, we proposed a model with increased effectivity compared to other common models mentioned in second section. The chosen approach - systolic array – suits well the architectural structure of FPGA. The paper presented the detailed structure of proposed model together with description of its processing. Regarding the discussion about functionality of the model we proved its correctness in the computation of 2D convolution.

However, the proposed design exhibits drawbacks that limit format of supported input data via the static *N* and *K* parameters in the whole system. The potential improvements of the model consist in providing the additional flexibility through the dynamic setup of *N* and *K* at run-time. If we assume the variability of these parameters with the purpose to enable reuse of 2D convolver blocks for inputs and kernels of distinct size, we need to adjust the model architecture. All components, that depend on these parameters, must be modified to preserve their correct dynamic behavior. These components are SE chain and delay buffers.

In case of the SE chain, we could use the neutral element of summation - zero - and replace all extra inner products considering the current value of *K*. This functionality could be implemented as a part of the switching block.

The dynamic length of delay buffer could be realized by application of the BRAM, as described in [11]. In that implementation of FIFO as a delay buffer, the variable

Figure 11. Waveform diagram of simulation

length represents an offset between address pointers to the current write and read memory positions. If we change the addresses and their offsets appropriately, the buffer length will adapt accordingly.

VIII. ACKNOWLEDGMENT

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Experience in Flipping the Classes in Engineering Study

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Abstract—The paper discusses experience gained in flipping classes of Automatic Control Systems carried out in the 2nd and 3rd years of Bachelor study and in a leveling course to Master study of Automotive Mechatronics at the Faculty of Electrical Engineering and Information Technology of the Slovak University of Technology in Bratislava. It points out similarities and differences appearing when comparing our experience with equivalent courses and activities reported abroad. These are mostly caused by the significantly different higher education framework in Slovakia. The importance of simulations and real time experiments, as well as student's motivation are accented and the corresponding technical arrangements are briefly described. At the end, the new approach evaluation by the students is briefly mentioned.

Index Terms—flipping classes, virtual and remote experiments

I. Introduction

In [1] A. Rossiter discusses main aspects of flipped classroom courses https://en.wikipedia.org/wiki/Flipped_classroom, www.uq.edu.au/teach/flipped-classroom/ on basics of Automatic Control carried out at University Sheffield, UK. They represent one of many possibilities available in replacing the traditional teacher-centered lectures by student-centered activities. New media and ICTs brought into organization of learning activities numerous new degrees of freedom, sometimes considered as a revolution of open and flexible learning [2]. These may equally be appropriate for different mix of distance and blended learning, as well as for the on-campus-classes. When going through Rossiter's report, one may agree with majority of his conclusions and directly take over, or adapt many patterns of his learning framework. Nevertheless, in offering flipped engineering courses in Slovakia there exist also several significant differences.

II. Bachelor Engineering study context in Slovakia

Similarly as in all EU countries, the decreasing student numbers represent the first significant feature of the recent development. However, in Slovakia they do not only follow from the demographic development, but also from the massive exodus of the young generation from Slovakia due to its frustration by the political situation in the country.

On the one hand one may argue that Slovakia still may be considered as one of the stable and well prospering countries in the world. Four big car producer (VW, Kia, Peugeot, Land Rover) make it to an automotive world power (with the highest number of cars produced per one inhabitant). Also the IT sector seems to be well prospering. Some EU statistics based on the gross regional product give Bratislava to the 5th place in the rating of the richest regions in Europa, higher than the nearest Vienna, Budapest, or the Czech capital Prague. Of course, such statistics do not fully correspond to the real life aspects, but still have strong impact on education: schools and universities in Bratislava may not apply for a support from several EU funds, living costs for teachers in Bratislava are much higher than in the rest of the country, etc. Thereby, for example, in applying for EU projects in Socrates Erasmus+ (http://ec.europa.eu/programmes/erasmus-plus/sites/erasmusplus/files/files/resources/erasmus-plus-programme-guide_en.pdf), the teachers in Bratislava get the same fees as in the purest regions in Europa - a professor gets less than a secretary in the neighbouring Czech Republic and more than 2 times less that a secretary few kilometers away in Vienna.

But, the sometimes absurd EU regulations and other EU issues (as e.g. the differences of food quality in the traditional and new EU countries) do not represent the only jeopardous moment bringing the young generation to move. After the persecutions brought by the WWII and by the communist putsch in Czechoslovakia in 1948, the democracy in the country continuously declined. This negatively influenced all aspects of the society, including the education system. Whereas the Czechoslovakia founded in 1918 by the university professor T.G. Masaryk and the recognized researcher M. R. Stefanik represented one of the leading world economies (among the top 7 in the world) with an excellent educational system, its power continuously decreased. The political persecutions and manipulations, together with the decreasing social and financial status of teachers and increasing bureaucracy resulted in a decreasing space for creativity.

Because the political changes after the "velvet revolution in 1989 did not substantially change the political elites, these degrading processes continued, firstly by splitting the Czechoslovakia into two independent countries, which was felt by many as "division of prey by the winning political parties. Trends of the political decline, when the majority feels to be manipulated and robbed by the newly established "nobility", living over the law valid for ordinary people and in style of mafia, demonstrating to "own" everything, hunting for titles,

privileges[1], or even military ranks, illustrate the main factors bringing the young generation to move abroad.

This all dominantly concerns the active part of the young generation - just about 15% of secondary school graduates leave to study in the neighboring Czech Republic, mostly without planning to turn back. Thereby, the number of students coming to study to Slovakia from abroad is negligible there is no grant system (comparable, for example, with the Czech republic) for supporting such students in the study and they are facing serious problems in getting working permission, if they wish to finance their studies by themselves. Since at all education levels the teacher staff is not regularly refreshed by the best university graduates, creativity in schools at all levels decreases. As a consequence, the universities have to fight with two problems with decreasing number of incoming students, but also with the problems of their decreasing quality.

A. Undeveloped, motiveless, without study skills

Thus, besides of the problems introduced in [1], the universities in Slovakia must also face the declining number of students and the loss of a large proportion of active students in their crews. This moment, when the study groups are lacking on students ready to ask and discuss, to establish a competitive environment, the role of teachers becomes much harder. How to lecture for students which seem to be motiveless, not ready to make some remarks, or to do the home work? In these aspects, the newly coming students are strongly different from the elite students entering the faculty two-three decades ago. However, whereas earlier the student interest was significantly higher than the expected graduate numbers, the 50% success rate was considered to be reasonable. Now, with the radically lower figures of the entering students, the 30% success rate essentially threatens sustainability of the study programs and contributes to the lack of qualified workers in industry.

III. Accepted measures

As a reaction to the appeared changes, we have radically changed character of the learning processes. Reinforced by similar observations made by M. Egersted (see his plenary lecture at IFAC ACE 2016 https://www.youtube.com/watch?v=I4erpLUnNKQ), we have abandoned the traditional division of learning units into lectures and exercises and replaced them with the "sandwich"-like units trying to keep students as active as possible by limiting the teacher to speak no longer than 5-6 min. The role of the teacher concentrates on motivating the students, explaining importance of the given tasks in practice, warning of possible misunderstandings, helping in overcoming their problems, stimulating mutual cooperation and team work, taking and assessing their results (where possible, students are included also in this step). The lectures are running in computer rooms and supported by Matlab/Simulin, with every

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[1]as an illustrative example, we could mention the former Minister of Education, who achieved the title "professor of educational technologies" without having a single publication indexed by Scopus; high penetration of similar "experts" into the assessment of projects have recently (after a Rector rebellion) resulted into cancellation of a 600 mil. EUR call on EU research projects and to its resignation

student obliged to record and interpret all results achieved, programs used and problems faced. Of course, such a learning framework needs a rich course materials to be prepared in advance:

- all task descriptions,
- support learning materials,
- some sample programs,
- guides for their modifications,
- entry and formative tests enabling to check students preparation to the lecture and to reinforce the needed terminology and main theoretical concepts, etc.

From this point of view, the Slovak learning context is significantly different from that one in English speaking countries and facing the much more limited resources available in Slovak language and the yet more limited student's interest to invest into buying some existing course materials.

At the same time, it requires to work with each student individually during whole lectures, because they easily fall back into a "sleeping mode".

IV. Interactive Tools for Education

There exists also another different point of our flipped courses not mentioned in [1]. In order to wake up student's motivation in control theory, we are trying to illustrate all considered concepts by examplex from a car, or motion control. By using laboratory scaled model as the thermo-opto-mechanical system [3]–[5] and simple physical analogies, students may, for example, practice design of a cruise control, temperature control, etc.

The interest of students can also be increased by using various online educational tools as interactive examples and animations.

Interactive examples enables to solve predefined computational tasks where user can enter own parameters and he or she receives the corresponding numerical result.

Animations offer to an user also graphical presentation of the problem. They are usually built as two dimensional but nowadays also the number of three dimensional presentations grows. One of such examples is shown in Fig. 1.

This online 3D animation presents Segway vehicle which dynamics can be described by following differential equations [6]:

$$\frac{(\alpha + \beta)}{R} + (3m_w + m_b)x'' - (m_b d cos\varphi)\varphi'' + (\psi'^2 + \varphi'^2)m_b d sin\varphi = 0$$

$$\frac{L}{R}(\alpha - \beta) + [m_w(3L^2 + \frac{1}{2}R^2) + m_b d^2 \sin^2\psi + I_2]\psi'' + (m_b d^2 sin\varphi cos\varphi)\psi'\varphi' = 0$$

$$m_b gd sin\varphi - (\alpha + \beta) + (m_b d cos\varphi)x'' - (m_b d^2 + I_3)\varphi'' + (m_b d^2 sin\varphi cos\varphi)\psi'^2 = 0$$

where

Interactive 3D WebGL Segway model
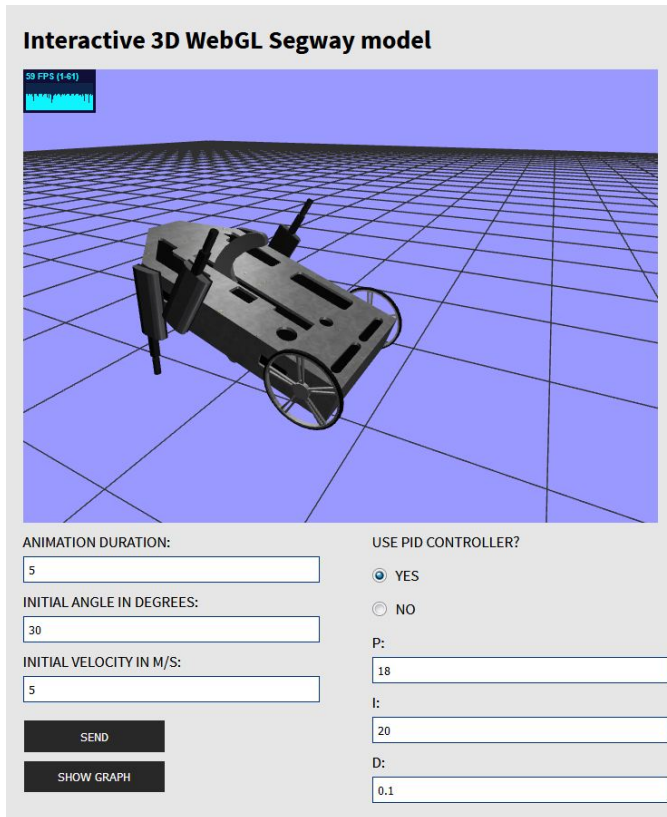
Fig. 1. Final presentation of the application in web browser

m_b	mass of the main body
m_w	mass of each wheel
L	half of the distance between the wheels
R	radius of each wheel
D	distance between the center of the wheels axis and the vehicle center of gravity
I_2, I_3	moment of inertia of the body about selected direction
G	gravitational acceleration
φ	pendulum tilt angle
ψ	yaw angle (orientation of the vehicle)
x	segway position
U	control variable

The illustrated problem enables to solve various tasks from control area. The presented snapshot shows the web application enabling to control the system by standard PID controller. In similar way it is possible to demonstrate the functionality of other types of controllers, too. The model example can be used in several courses from basic to the advanced ones. In spite of the fact that the model is originally nonlinear, it can be simplified and used also in courses dealing with linear systems.

In our case the whole simulation is running in background simulation software that is installed on the server. We used OpenModelica environment [7] that is available for free use. The results are visualized both by animation and by graphical presentation of followed variables (angle of inclination, and Segway position), as well. More details can be found in [8]. In similar way we also prepared presentation of two other dynamical systems. In present time it is still three tank system [9] and towercopter. The set of these experiments will be increased in future.

In spite of all advantages animation presents a little bit artificial environment. All parameters are exact and user cannot meet any unmodeled or unexpected situation. More realistic experience can be gained by experimentation with real device instead of animated model. Considering online environment the remote experiments can be taken into account. In spite of the fact that the experimentalist cannot touch the device personally (since he or she is not sitting in the same lab where the plant is placed) such experiments force user to work with real noisy signals and to consider variables that are usually neglected such as friction, ambient temperature, natural light, etc. Remote experiments usually enables users to choose the task that should be solved, to set parameters, to execute the experiment and then to follow measured values of outputs. They can often be downloaded to enable user to process them in own software. The problem can consist in the fact that remote approach usually enable experimentation just with predefined structures. Just rarely the user can set own control algorithms. It is mostly from safety reasons since it is not so easy to take care about all situations that can happen in an universal web environment. More variability can be achieved using remote desktop access via for example TeamViever software. We tried this approach during the first control course when we were prepared to access up to 8 experiments via remote desktop. However, it was necessary to have one person available to solve connection problems.

V. DISCUSSION

Flipped education should combine theoretical and practical way of teaching in such a way that the student could receive better experience and in this way to enhance his or her skills.

This approach could also help to work with two inhomogeneous groups of students. In following we can introduce three examples. In each classroom one can find excellent students that have no difficulties to solve all required tasks in short time and also students that have problem to master the topic that is taught at all. It is necessary to attract attention of both groups. The teacher needs to reflect the situation and to try to extend skills of everyone. It means to deepen knowledge of weaker students and to support excellent students in their effort to achieve better understanding of topic. Both groups require another approach and various procedures.

Similar situation arises at the beginning of university master study. Students usually continue in the area where they received their bachelor degree. However, some of them like to change area they study. In spite of the fact that they fulfill all prerequisites for the study they usually do not have the same knowledge as their colleagues who have been profiling from the beginning of the study. It is again necessary to respect both groups.

University study in Slovakia mostly consists from two main parts as the lectures and the more practically oriented laboratories. Mainly in higher grades of study students often skip lectures (they prefer to work in various companies) and they attend just laboratories. However, laboratories usually require theoretical knowledge of the problem that should be solved and it can be achieved during lectures. The textbooks are not always available. Since not all students follow lectures, during laboratories two groups of students can be met – one with theoretical knowledge of the topic (gained during lectures) that can be deepened and another one without any idea about the discussed issue. It is again very difficult to teach both these groups in one moment since each one requires another approach. In spite of the fact that situations described in previous three paragraphs have different background they both require working with students that do not have equal level of gained abilities. It can be solved by either combination of traditional and unconventional tasks that can be interested for all students or/and by offering additional interactive teaching materials supporting self-education in the relevant area. Such flipping with classical way of teaching can bring better theoretical or practical understanding of a subject and skills acquired through experience and education.

VI. Evaluation by Students

Generally, it is very important to have a feedback in order to enhance the quality of education. Therefore our university information systems automatically offers students a possibility to evaluate individual subjects which they have just finished. This evaluation is a valuable source of information not only for teachers but administrators and managers of education as well. The system provides different outputs of the evaluation. Managers and administrators are maybe interesting in general statistical data but lecturers and tutors should take into account all individual student responses. After introducing the flipping classroom learning method we were very interested how students would accept this new approach. Therefore we got through all responses that students provided us in the evaluation process.

Generally speaking, there were positive and negative responses, similarly as in [1]. We were pleased by positive responses but we highly appreciated the negative feedback students gave us that enables to improve the quality of provided courses by solving specific problems appointed by students. From the student responses we can conclude that most of them consider the new method as interesting. In comparison with classical methods the new method attracts more attention of students. They can immediately see the purpose of learning as they apply theoretical knowledge to the practical problems. In courses where the experimental part was not sufficient or was completely missing we got negative responses. This reflects today's life of young generation that is full of interaction and communication and students would like to bring these customs also to the process of learning. They do not want to wait to special exercise hours to apply the theory to real problems.

They just want to do it immediately. Therefore the differences between lectures and exercises are suppressed.

Beside a possibility to work on practical assignments students positively evaluated the existence of self-assessment quizzes. They appreciated not only the fact that they were better prepared for the final exam but also the process of passing the self-assessment quizzes when they got additional knowledge. Students like competition and they liked to have a chance to repeat quizzes in order to higher the score they reached.

But experiments and quizzes were not the only one features the students considered positively. They also appreciated that the style of learning provided more freedom. And even when they from different reasons could not participate on classes presently they were still able to follow the classes.

As it was mentioned above not all responses were positive. There were students that had problems to accept the new learning approach. They were accustomed to traditional learning methods and these strong relations together with a lack of flexibility caused that they felt loss and could not switch between different types of learning units immediately. They were right that concentration to the main idea can be decreased when the learning process is split to many different activities. Therefore it is always necessary to stress the aims of learning units and to provide students clear orientation within the learning process. As we did it for the first time we found out that this should be improved in the future.

Another problems with flipping classes method were connected with the technical limitations. Of course, university computer rooms rooms are not laboratories and it was hard for us to provide corresponding equipment to let students realize different tasks from exercises. With the help of virtualization and remote experimentation we partially solved these problems. But we understand that the presence in laboratories could not be fully replaced for some specialized subjects. In those cases where it is possible, it is necessary to pay higher attention to preparation of flipping classes as concerning the technical point of view.

To summarize the evaluation of applying the new method to learning three different control engineering subjects we can consider to be successful and we are satisfied with all positive and also negative feedbacks provided us by students. Most of the students accepted the new method and they expressed they liked it. Several students had some objections that were reasonable and they showed us the way how to improve the application of the new method. The statistical evaluation of corresponding subjects made by students was not perfect but very good and we got marks above the average (Fig. 2). This gives us an argument to enhance the new method and apply it to the learning process also in the future.

VII. Meeting the Students After One Semester

After the next meeting with our former students denoted above as "undeveloped, motiveless, without study skills", which brought us one semester ago a lot of frustration, we were dramatically impressed by the big progress they made
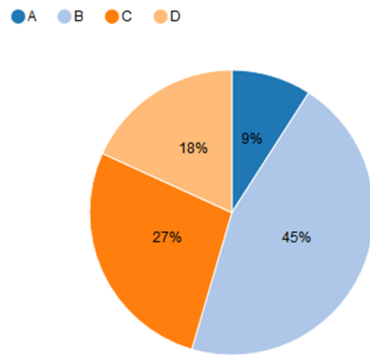
Fig. 2. Evaluation made by student on the scale from A (best) to FX (worst).

from our first meeting. Adopted to the style of flipping courses, from the first moment they started to work actively, independently, to discuss in teams – simply as fully different people...

VIII. Conclusions

The above described experience and the dramatic progress of our students shows that after accepting appropriate measures the universities could significantly increase success rate of the incoming students. However, at the same time we must ask, why the students enter the university as "undeveloped, motiveless, without study skills" and to appeal to Slovak and European politicians to realize the status of our education and to take steps to stabilize it until it collapses. There is no need to write studies with hundreds of pages. Just keep in mind that when the average starting earnings of our graduates are over 1500 EUR, the 600 EUR starting fee at the university, or at schools will not keep the best in education. And without the best the education suffers, which will later be felt by whole society.

Acknowledgment

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A ranking-free evaluation of universities: an intellectual capital approach

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Abstract:

Universities are being compared according to a number of rankings and evaluations designed by several institutions and agencies. A qualified well-designed ranking system helps future undergraduate and graduate students make decisions about their studies following an appropriate set of quality parameters such as attractiveness, research performance, student satisfaction, graduate employment, etc. However, the world rankings operate with different metrics, datasets, methods and a limited number of indicators based on their availability. Less reliable or context-free data are often utilised. These discrepant approaches of composite indices produce inconsistent results which casts doubt on the veracity of the rankings.

Admittedly, internal and external evaluations of the quality of teaching and research are carried out periodically and other bodies justify the universities according to quality assurance standards. In addition, governments require the publishing of annual reports, long-term strategic plans or recommend the universities carrying out a self-evaluation. All in all, the external pressures follow a "one size fits all" standard. This approach defines a global ideal by the framework and structure of parameters and thus neglects the importance of the diversity and context in which universities operate.

A new approach is advocating a ranking-free setting of strategic objectives which would integrate the intellectual capital approach, annual reporting and long-term plan into one coherent strategic management system. This set of flexible indicators, included in the intellectual capital categories, is proposed to be part of the annual report and is aimed at monitoring the proper strategic goals.

I. INTRODUCTION

There is intense debate on the role of universities, their profiles and performance in the post-industrial age and the induced changes brought about by globalisation and the Internet. Furthermore, the competition for research resources and skilled students has been increasing. This has put universities under pressure to reconsider their long-term goals, the proper way of functioning and consequently to reassess their portfolio and quality of services. The evaluation and quality assurance of universities was, until recently, a matter mainly for the ministry responsible for higher education and the rankings only existed at the national level (Wächter et al, 2015).

It is indeed possible to question whether universities by their very nature meet the needs of the 21st century and should not be interchanged by a new model. It is uncertain whether universities are able to meet the demands of such a differentiated society and erratic labour market.

In the second half of the 20th century, there was a global shift when the university sector expanded also in developed countries; literally in the entire world, independent of the degree of economic development in the country. Nearly 20 percent of secondary school leavers in the world go to university and a university degree is no longer a matter of the elite or male population (Karabel, 2005). This development has resulted in an increasing number of higher education institutions in all countries and increase in the number of students (Meyer et al, 2006).

The massive expansion of higher education is thus a result of the conviction that it brings benefits and social progress to society and promotes economic growth (Barro and Sala-i-Martin, 2005). However, the mechanism which brings social and economic progress is somewhat unclear. While the factor of higher education as a source of economic growth is considered to be obvious, a recent debate on over-education has started to recognise several negative effects especially in the context of supply and demand in the labour market.

It can be said that there is intense external pressure on institutional and functional changes at universities so that they respond more to the demands of different parties. It is being debated as to whether the very functioning of universities as a specific type of organisation with its own elements of functioning, known as "organised anarchy", (Cohen et al, 1972) should be changed and modernised. Universities are often criticised for being too theoretical and detached from practice, focused on basic research and disregarding present employers' demands. The other typical features of universities are collegiality and academic discussion as well as diversity resulting from different foundations of the universities in Germany, France or the Anglo-Saxon countries.

Knowledge in the university as a specific type of institution is not primarily tied to jobs. In the sense of the university title itself, knowledge is mainly created to tie particulars to universals (Musselin, 2007). It is interesting to look at the case of post-communist countries which underwent a different development from western European countries in the second half of 20th century. Central and Eastern European countries (CEECs) have experienced the building and development of universities as subjected to political control as well as to central planning. This has been in the form of given student

quota rates in different fields to correspond to the centrally planned requirements of state-owned enterprises. Even after obtaining university autonomy during the transition to a market economy in CEE countries, there is still a common way of thinking about universities as being directly related to the needs of employers.

Today, higher education has a global character where various nationally based concepts exist parallelly (Humboldt, Anglo-Saxon, etc.). These are built on different fundamental principles with different legislation, having undergone a lengthy process of evolution. Excellent universities are set differently in different countries and cultures. The British universities represented by Cambridge or Oxford emphasise academic freedom and strong institutional autonomy as well as a close relationship between the tutor and students in order to educate well-rounded individuals. In comparison, the educational system in continental Europe is considered more bureaucratic, influencing the universities by directives and laws. The critical role of the state in connection with decentralisation is typical of France in particular. However, the German Humboldtian model of higher education is again singular, highlighting the combination of research and teaching together with institutional independence and academic freedom guaranteed by the state and prominent professors (Clark 1983).

II.   NEW ROLES FOR UNIVERSITIES

There has been a new way of thinking about the university mission which has also been adopted by governments and administers a third role for universities in addition to education and research. By this, to be more enterprising in management, more business-focused in research and more socially relevant and career-enhancing in curricula (King, 2009). However, this should not lead to a contradiction in the freedom of undertaking basic research. The non-commercial character of research is commonly recognised as beneficial for society as a public good. Most countries continue to fund public universities in order to support world-class research. In particular, there is a difference in the USA where private research is also markedly funded from public sources.

Such trends have confirmed older and quietly discussed opinions aimed at transforming universities into more entrepreneurial bodies which would enforce commercialisation of research and enable close cooperation with the business sector. For this objective, technology and knowledge transfer centres at universities have been established to serve as an interface between universities and the business sector.

Many universities in the world have adopted entrepreneurship as the third element in addition to the traditional two of education and research. The regional innovation system approach highlights the proximity of the innovation actors (Asheim et al., 2011) and amplifies the essential role of universities in collaborative innovation processes. The concept of the entrepreneurial university (Clark, 1998; Etzkowitz et al., 2000) contributes to prosperity and development by active involvement in commercialising knowledge outputs in collaboration with the business sector through patents, licensing and spin-off firms. The entrepreneurial focus is clearly more conceivable for technology and science-oriented universities. However, the business culture in academia is not always perceived positively because it implicitly restricts the freedom of research by promoting (primarily) commercially-attractive research.

There is, however, a fourth considerable objective for universities which is accentuated in less developed regions. This is to assume the university role as one of the driving forces of local and regional development. This fourth role is in principle contrary to the universal goals of universities which are generally set up independently of local society and economy needs. The concept of an engaged university embodies the voluntary and purposeful adjustment of university functioning to regional needs (Uyarra, 2010), focusing on regional economy and society.

First, such an engagement is typical for younger and more flexible universities with less of a rigid academic culture. The second factor of taking responsibility for the development of the region relates to the location in a less developed region. Specifically, there is a shift towards university engagement in the European Union which is intensively funding regional and local development and the creation of regional innovation partnerships, comprising of local higher education institutions (Boucher et al., 2003). European research programs (Framework Programme, Horizon 2020) often support projects addressing local issues such as transport and mobility, health and urban development. These involve local universities in cooperation with cities and regions.

III. GLOBAL RANKINGS AND GLOBAL UNIVERSITY

The global rankings of universities were initiated at the turn of the 20th and 21st century as a step forward from national evaluations and comparisons. In order to establish ranking of higher education institutions (HEI), several indicators for comparison are selected with the aim of comparing and ranking higher educational institutions globally. The results are usually published once a year giving rise to considerable attention because the rankings promote the self-confidence of HEIs and provide "proof" of quality in an international comparison. Several institutions prepare global HEI rankings, either adopting modest or more complex methodologies, resulting in the construction of a composite index and corresponding ranks of the HEIs chosen in the sample. A brief look at the methodologies of the ranking institutions brings many questions about their quality and comparability. The key concern is whether a credible HEI world ranking can ever be created without taking into account the national context and only based on a limited

available set of information. Is there ever a best university in the world and what is the ultimate ideal in terms of quality and performance? Should the size of the university be taken into account along with the history, attractiveness, reputation, the demand and the number of students, recognition of the research results and capacity to boost economic development?

To illustrate the underlying statistical population that is being evaluated, the most encompassing ranking "The Ranking Web or Webometrics" includes 26,368 universities in its 2017 edition.

Other rankings assess a significantly lower number of HEIs, publishing the best 500 or 1000. The selection is based on the postulation that poorer-quality HEIs are less well-publicised and therefore, from a practical point of view, the selection is restricted to only the universities with sufficient information availability. At the same time, apart from the top universities (for example, the 100 best ones), the ranks are hard to defend and therefore the ranking institutions only create classes composed of 100 or 200 HEIs instead.

The sample is typically selected according to some basic indicators of performance and reputation although it is partially based on positive discrimination to cover more countries in the sample. Furthermore, methodologies are changing and improving over time, using modifications and innovations, relying on better and better data quality. As a result of the changes in the methodologies, the HEIs which belong with their research results to the better world average are often confronted with a situation of inclusion or exclusion from the ranking list.

The most influential global HEI rankings are:

– ARWU: the Academic Ranking of World Universities published by the Shanghai Ranking Consultancy and first issued in 2003,

– WUR: World University Ranking prepared by The Times Higher Education (THE) established in 2004,

– HEEACT: The Higher Education Evaluation and Accreditation Council of Taiwan is a bibliometric ranking which began in 2009,

– QS World University Rankings published by Quacquarelli Symonds together with US News & World was formed after separation from THE in 2009.

Comparing the quality of education objectively is hard to imagine, and that is why all the ranking are completely based on a comparison of the performance indicators in science and research. The indicators which take into account the number of Nobel prize laureates or articles in Science and Nature only make sense for best 100 universities, and therefore rankings have transferred their focus to the number of articles and citations in top journals in the fields.

The plausibility of any ranking results is in simple terms justified if the best scores are assigned to American and British universities with a strong world reputation. Therefore, new approaches seek to obtain, besides the best quality science and research databases, their own

primary data collection. Currently, they are trying to reach out to universities themselves in order to engage them in data collection on the basis of self-assessment as well as assessing other universities. In this way, the university's reputation becomes an essential factor of the ranking. This also entails data degradation due to the large number of universities and experts involved.

It is evident that each ranking is derived from the ideal qualities attributed to the Anglo-Saxon universities with the greatest global reputation - Oxford, Cambridge, Stanford, Harvard, MIT, etc. Then, an analysis of their characteristics helps to identify the essential indicators that distinguish them from thousands of other higher education institutions around the world.

There is a longer-term debate about the essence, the very nature of an ideal university, as well as its evolutionary path (Philpott, 2010) and"isomorphic development path" to entrepreneurial university (Etzkovitz et al., 2000). Europe has an established tradition of the Humboldtian university model and a global university model is the subject of criticism for neglecting local and historical evolutionary context and problematical direct applicability.

At present, even more than in the past, higher education institutions have a question about their image: either respecting global trends and demands, or maintaining their own specific culture and their own way? Or to find their own way somewhere between these two possibilities? Therefore, from a global perspective, the key to HEI quality is respecting diversity in goals and instruments that lead to innovation not only through the imitation of successful models which exist under other conditions.

In this paper, the goal is not to compare and assess the quality of particular ranking methodologies. Instead, it aims to draw attention to the diversity of university models and to present an approach that enables higher education institutions to implement their inventive self-evaluation system and incorporate it into strategic management.

IV. SELF-EVALUATION AND INTELLECTUAL CAPITAL APPROACH

The actual rankings look for universal evaluation criteria to compare and rank higher educational institutions all over the world and provide the public and students with a transparent tool for comparing their performance. The quality of ranking and evaluation is improving although remains undeveloped. The materialisation of the idea of a university in every ranking is realised in the form of a set of indicators, limited by the availability and quality of data associated with the ideal.

If a university wants to get to the top, it can try to follow the way of a classical academy like Cambridge or Oxford, the technology and entrepreneurship design of Stanford, Massachusetts Institute of Technology or California Institute of Technology, or the European research and technology model of ETH Zurich or LMU Munich. Successful models are so diverse that every

strategic decision about the direction and strategy of the institution is a matter of detailed analysis and strategic decision-making followed by a long process of institutional formation and improvement. A development path can also be formulated free of imitation and global rankings, primarily focused on internal goals and built on the own strengths.

The ranking positions are very strongly correlated with their proximity location in capital-intensive regions. Territorial factors such as the presence of capital and big multinationals as well as the attractiveness of the place/city etc., play an essential role in attracting the best researchers, professors and students. This means that a successful university is also associated with the quality of the place that affects the potential for future success. The arguments lead to the conclusion of keeping an eye on the global rankings, especially the ones which are based on the reliable research databases for benchmarking. However, at the same time, a ranking-free approach is needed to focus on self-defined quality criteria which in the end will possibly bring some small steps in the world ranking.

In the EU, the European Commission and related institutions have published studies and policy documents having recognised the importance of evaluations and comparisons and looking for new higher education quality approaches and quality assurance. Although assurance and rankings have profoundly different purposes (Wächte and Kelo, 2015), European approaches seek to suppress overcompetitiveness rather enforcing independent quality assurance mechanisms.

On the basis of the German national evaluation and ranking, a sophisticated U-multirank approach has been developed and put into practise in its test version. This seriously takes into account the complexity of current higher education and also in the sense of diverse institution types and missions.

Other examples are the OECD pilot project AHELO (Assessment of Higher Education Learning Outcomes) and the HEInnovate project (cooperation of the EU Commission and OECD). All European approaches fully respect HEI diversity and require self-assessment mechanisms. The ranking itself is either not the primary goal, is presented only as a side effect of quality assessment or is not used at all.

Many external pressures call for rethinking and redefining the university roles, to find their own way within existing external multiform evaluation pressures and to develop a legible self-evaluation multicriteria system corresponding to the situation of a given university. Multiple roles in a university cause different tensions within them as well as with stakeholders. This therefore requires an integrated conceptual framework which enables a more effective self-evaluation system and incorporated into the clearly legible strategic management of the higher education institution.

At a university as an inherent knowledge-intensive institution, it is essential to study how knowledge is generated, disseminated, retained, absorbed and utilised to obtain economic and social returns (OECD, 2008).

There are many methods for evaluating knowledge assets and one of the most respected approaches is an intellectual capital one which can be used for managing and developing knowledge resources of an organisation as a critical competitive factor (Stewart, 1997). Intellectual capital essentially represents value creating elements not apprehended in financial statements. The intellectual capital approach serves as a strategic and communication tool for adding value to an organisation (in this case a university) and is not principally projected to calculate the value of knowledge in financial terms. Hence, if recognised, it can be used for strategic academic management and reporting to stakeholders. Such an approach has been adopted, for example, by the Austrian Ministry of Education, Science and Art and the Austrian universities are required to publish so-called Wissenbilanz annually (Intellectual Capital Reports). These annual reports in the form of intellectual capital statements include a collection of data and information classified into three basic categories of intellectual capital: human, structural and relational.

Intellectual capital is mostly defined as the sum of the three components. Two components are human and relational capital and the third component is called structural or organisational capital (Leitner 2004; Sánchez et al, 2009; Amiri et al 2010):

A.Human capital (HC) is the sum of valuable and useful skills and knowledge accumulated by people in education and training processes. It brings together knowledge, skills, habits and talent. Productivity is measured by categories of indicators: competence (efficiency, learning ability and qualities), creativity (innovation, ability to work independently) and attitudes (satisfaction, identity with corporate culture).

B.Relational capital (RC) exists in the flow of knowledge and resources that are acquired through the interaction of the internal and external environments. It is present in the external relationships with key individuals and organisations, regulatory authorities, alliance partners, community, suppliers, customers and so on. Customer brand value is associated with branding so getting new customers and keeping older ones is considered as the primary goal in achieving performance in this dimension. In the case of HEIs, all economic, political and institutional relationships with non-academic partners are included (companies, public bodies, local government, prospective students, alumni, society) as well as reputation, goodwill, appeal, reliability, etc.

C.Structural capital (SC) covers hardware, software, organisational structure, databases, trademarks, patents, and all other capabilities that support productivity and innovation through the transfer and sharing of knowledge. In many cases, organisational capital and structural capital are exchanged so that it can be resolved by dividing Structural capital into two components:

C1.Organisational capital (OC) relates to the operating environment in which interactions exist between research and management, valuating administration, internal procedures and organisational routines, values and

corporate culture, the quality of the information system etc.,

C2.Technology capital (TC) includes technological resources available at the university, such as bibliographic and documentary resources, archives, technical development, patents, licenses, software, databases, etc.

V. IC-STRUCTURED LONG-TERM PLAN

Higher education institutions publish their long-term plans that include specific goals. In Slovakia, each HEI and its faculties are obliged to define and publish in detail their mission, objectives and tasks in the form of a long-term plan for at least a six-year period. Another compulsory public document is the annual report. This includes statistics on key performance indicators in education, science and research, entrepreneurship or external relations. Both documents should be ideally interlinked; the annual report should been pursuing the ongoing fulfilment of the strategic objectives set out in the long-term plan.

A survey conducted at Slovak faculties shows that such interconnection is somewhat more random than targeted and therefore can be considered an untapped opportunity in strategic management. The first phase of this research points to the lack of connectivity. However, there is another improvement that can be suggested at this point. Both documents can be reasonably in line with external rankings, evaluations, accreditations and quality assurance. The indicators used in all external and in-house evaluations can be merged into one set of indicators (a long list of indicators). Each of the indicators can be classified into one of the three components of intellectual capital. This brings a whole new perspective such as the consistency between external and internal indicators, as well as the distribution of indicators according to the three dimensions of intellectual capital - human, relationship and structural capital.

Not surprisingly, there are relatively large differences between faculties in target setting by intellectual capital dimensions. The following table shows the relative representation of selected faculties of Slovak universities in the long-term plans.

The following table (Table 1) shows the relative representation of selected faculties of Slovak universities in the long-term plans:

FITT STUBA (Faculty of Informatics and Information Technologies STU in Bratislava),

FE CU (Faculty of Education, Catholic University in Ružomberok),

FME ŽU (Faculty of Mechanical Engineering, University in Žilina),

FNS CPU (Faculty of Natural Sciences, the Constantine the Philosopher University in Nitra),

LF TU (Law Faculty of Trnava University), FOETC UŽ (Faculty of Operation and Economics of Transport and Communications, University of Zilina),

FHC PU (Faculty of Health Care, Prešov University),

FE TUKE (Faculty of Economics, Technical University of Košice).

TABLE I.
PERCENTAGE OF THE LONG-TERM PLAN INDICATORS ACCORDING TO IC DIMENSIONS. SELECTED SLOVAK FACULTIES.

Faculty	% indicators in the long-term plans according to IC dimensions			
	HC	OC	TC	RC
FITT STUBA	34.5	19.0	8.6	37.9
FE CU 23.2	30.4	17.4	29.0	
FME ŽU	36	20	12	32
FNS CPU	50	17.7	0	33.3
PF TU	31.0	35.7	4.8	28.6
FOETC UŽ	23.6	14.5	20.0	41.8
FHC PU	60	5	0	35
FE TUKE	21.7	21.7	4.4	52.2

A new proposed way of dealing with external and internal indicators can be explained in the following diagram (Figure 1). The HEI of interest will review all external and internal ratings and create a consolidated sum of indicators as a long list. The indicators will be assigned into one of the categories of intellectual capital. Subsequently, a new long-term plan is formed, which takes into account the existing external evaluations and internal evaluations as well as setting new objectives in the long-term plan. The short list of indicators will then come up with several of the indicators used so far, but also newer ones that have not been collected so far. The entire shortlist will be used in the same structure in the following annual reports which serves as a strategic tool for evaluating long-term goals.
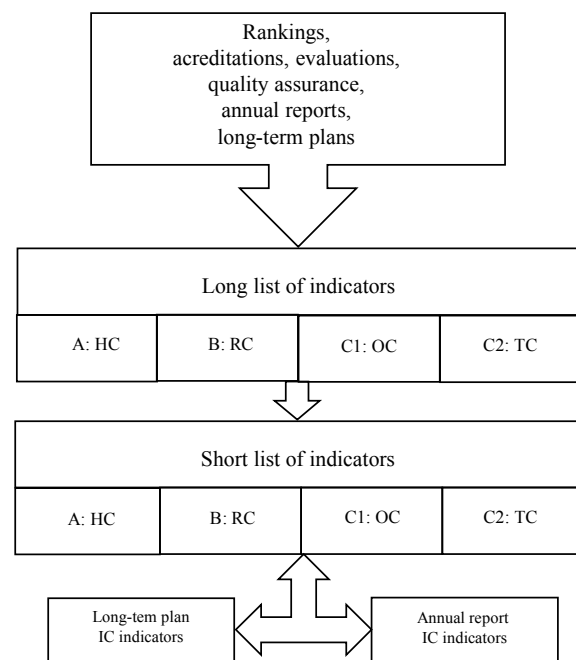
Figure 1: IC-structured Long-term plan approach in HEI strategic Planning

IC-structured Long-term planning is a novel approach of university strategic management that has been already tested on the example of the Technical University of Košice and the Slovak Technical University in Bratislava in 2017.

VI. CONCLUSIONS

Intellectual Capital and its three major categories provide an exciting optic for strategic processes at HEIs. Long-term plans could contain, in addition to the main objectives, a list of the relevant indicators leading to the achievement of goals and improvement. The very division of parameters into basic varieties explains how many of the objectives and structural parameters relate to the development of human capital, to the development of relationships with the external environment and to the improvement of technological infrastructure and organisational processes. This parameter set-up as a short-list of indicators is created so that it can easily be reflected in the content of the annual report and monitored every year.

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A Training Tool for Speech Driven Human-Robot Interaction Applications

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Abstract—Following the integration of voice control software with a robotic system at Mississippi State University for use with a tactical team, it became clear a training tool was needed to facilitate a more natural interaction between police officers and a voice-controlled robotic platform. In order to facilitate this more natural interaction, a training tool was designed and developed, which used the same voice recognition software, to prompt the user for input and then score that input, in order to provide them the ability to practice, without being co-located with the robotic system. The design of this system allows this training tool to be used in a variety of settings beyond the police domain for which it was designed. Since the system scores the user's ability to successfully interact with the voice recognition software based on the vocabulary given to the tool, this training tool allows anyone using the Julius voice recognition system the ability to test how successfully they can interact with it and to learn the commands available in the system.

Keywords—Human-Robot Interface, Automatic Speech Recognition, Robotics, Training Tool, Human-Computer Interaction

I. INTRODUCTION

Research into the successful integration of robotic systems into law enforcement tactical teams has received less attention relative to other areas of human-robot interaction research. Traditionally, robotics research has focused on search and rescue functionality [1], social and therapeutic technologies, and medical usages. Previous examinations of the potential for combining robots with teams of operators has identified primarily supportive [2] or assistive [3] roles for robotic systems. Technological limitations and perceptions of robotic systems as a tool, rather than as a team member, has limited the introduction and assimilation of these platforms to provide a mechanism for safer overall awareness during slow and methodical search scenarios.

At Mississippi State University, research was conducted [4] that investigated the integration of a robotic system as a team member, rather than a tool. By designing effective methods for interaction with a robotic system, such that the entire tactical team could learn to operate the robot dynamically, the need for an outside operator was removed.

The robotic platform, in this case was a Jaguar V4, a small unmanned ground vehicle, that acts as a forward member of the team, searching dangerous areas without putting the officers in harms way (see Fig. 2). As a way to extend this work, Dr. Matus Pleva visited Mississippi State University in order to apply his skill and expertise in voice recognition systems to the robotic system. By exposing much of the underlying system functionality through voice commands (see Fig. 1), it was hoped that a more natural interaction would take place between the robotic platform and the tactical team members. In order to accomplish this integration, the Julius voice recognition system was integrated with the Jaguar V4 robotic system [5].

In our system, the Julius software [6] is used to recognize key words, which correspond to commands the officers wanted the robot to execute. The command list included activation of spot lights and strobe lights and issuance of pre-recorded voice recordings, such as "exit the building." During laboratory testing of the integration of the voice recognition system with a local law enforcement tactical team, several key problems were identified. Among the key issues was the lack of familiarity of the officers with these types of voice control systems. Issuing commands to the robotic system by voice seemed unnatural and forced to many of them since they were unsure of how they should address the robot.

Additionally, the means in which they communicated with the robot, whom they considered part of the team, were very different from the way they would speak with other team members. Within the team, there is a mutual understanding of terminology, key words, and gestures that are highly contextual and involve limited verbal communication, which obscures the intentions of the team during operations. Issuing direct commands using specific words, as with the voice recognition system, did not feel natural to the team members. In addition, the voice recognition system used specific key word commands for operating the robot and many officers struggled to recall the specific commands during operations.

Finally, due to the varied nationalities of members of the team, as well as several variations in dialects present in the southern United States, many of the officers had slightly different pronunciations of the specified commands. This led
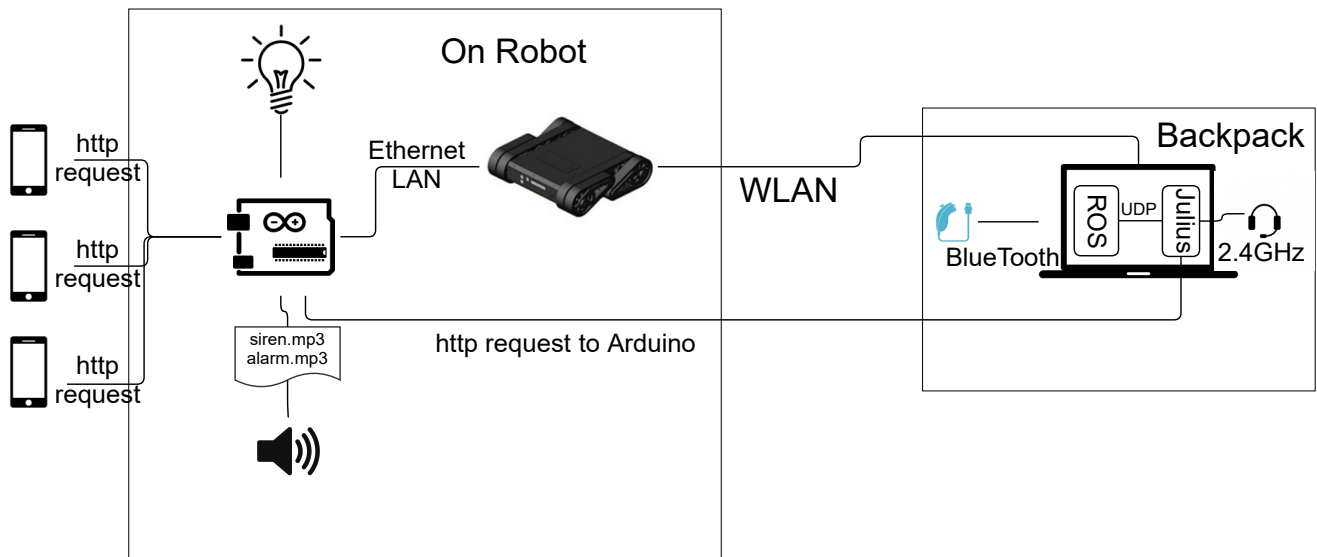
Fig. 1. Overview of the Robot Control System

to a system, which to the officers, left much to be desired despite its potential.

Based on feedback, the officers saw the benefit of being able to communicate verbally with the robotic system, but found they had difficulty in successfully conveying their desires to the robot. In an effort to remedy this, it was decided several things needed to occur.

First, the officers needed to spend more time interacting with the voice control system, so that the novelty of the system would be diminished. By making voice interaction less foreign to them, and allow a more natural interaction to take place.

Second, the officers needed a way to practice the commands they wanted to issue to the robotic system. The modified Jaguar V4 platform provided the officers with a variety of tools for use and each of these tools required a specific command to initiate. The officers needed a way to practice the commands so that they could not only remember them but also execute them successfully.

Finally, a database containing the different pronunciations of the command words needed to be built, such that the underlying system could be adapted to account for differences in dialect and pronunciations among the team.

This paper outlines the implementation of a training tool designed to address these needs, which will be installed at the local police station for officers to train on the voice control system during their free time without the need for access to the robotic system.

The training system, while presented within the scope of law enforcement robotics, is not constrained to the target domain of the research, which inspired the creation of this tool. It was decided that this tool should be usable with any platform that utilizes the functionality provided by the Julius voice recognition software. The voice recognition training tool was designed to be applicable to anyone who has a desire or need to train a user's interaction with the Julius voice recognition software.

II. EXISTING SYSTEM AND THE PROBLEMS

Research at Mississippi State University has led to the development of a robotic system adapted for use with tactical teams in a manner that treats the robot as an independent team member rather than as a tool, which requires an individual officer's full attention and resources to operate. The system is commanded using a number of interfaces including touch-screens, joysticks, and voice recognition systems. The core components of this system include the following:

1) The robot control software is housed in a backpack unit, which includes a laptop running the Robot Operating System (ROS) [7] (see Fig. 1). The laptop runs all of the robot control software including the Julius voice recognition software. All commands to operate the robot are routed through the laptop, in the form of ROS messages from the external interfaces. The Julius voice recognition software parses speech and passes text messages to ROS.

2) Wireless communication over a range-extended local area network is used to bridge the connection between the laptop control unit and the robotic system. A local access point is created for the touchscreen devices to connect to the network via a wireless connection and messages are passed as commands to the ROS laptop for execution.

3) Any Android phone equipped with a mobile application for control of the robotic system may issue commands to the robot. The mobile application allows the operator to activate various distraction devices on the robotic system through the touchscreen interface, such as strobe

lights and/or sirens. Additionally, the mobile application allows the user to select and view camera feeds from the robot from two different viewing angles.

4) A game controller is used to provide input for directional commands for controlling the robot's movements (refer to Fig. 2). In the current implementation, both a Logitech controller and an Nintendo Wii Remote Joystick can be leveraged to operate the robot's movements.
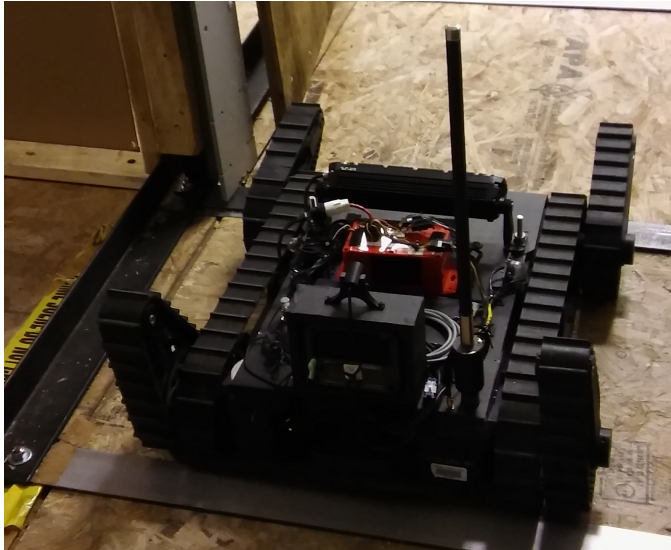
Fig. 2. Jaguar V4 robot with attached distraction devices

This system, while functional, presents several challenges for tactical teams. The first challenge is "backlighting" of the tactical team. Officers may use mobile touchscreen devices to activate a variety of distraction devices and view camera feeds from the robot. The light emitted from the touchscreen device acts like a spotlight on the officers during low-light scenarios. This lighting effect makes any officer using the system vulnerable by exposing their exact location increasing their likelihood of being the target of an attack.

The second problem is that interaction with the system requires the use of at least one and often both hands. In order to activate a light or sound, in any given situation, a member of the team must use one of their hands to press a button on the touchscreen device. Performing this motion often will require that the officer lower his/her weapon during a potentially hazardous time.

Voice control matches, at least in part, current team communication methods, it has no lighting implications, it frees officers' hands, and has the potential to support many commands. It was thought that providing a more natural interaction with the robotic system through voice control would allow maximum functionality without the risks of "backlighting" or requiring officers to lower their weapons when controlling the robot. In order to do this, the Julius Speech Recognition Software was used to prototype this approach [8]. A concern with this approach is making sure that the number of commands

are limited to not require officers to recall many different commands while under high stress and dynamic situations.

III. AUTOMATIC SPEECH RECOGNITION MODULE

The detailed description of the speech command automatic recognition module was published in [5]. We decided to use a simple grammar with keyword activation to avoid issues with background noise and incidental speech. The robot should not be activated when officers happen to speak a command as part of their regular conversation. A similar problem arose when the robot was reproducing recorded speech such as "Put your hands in the air!" or "Get down on the ground!" Ensuring that there is a phonetic dissimilarity between incidental language, recorded messages, and the command set was critical for ensuring proper activation of expected commands.

After testing many acoustic models, it was decided to combine the Wall Street Journal (WSJ) with TIMIT (database recorded at Texas Instruments - TI and transcribed at Massachusetts Institute of Technology - MIT) to form a baseline acoustic model [10] that was used with noise models mixed from a Broadcast News corpus built by the Technical University of Kosice [11]. The system models were trained with a 16kHz sampling rate and a 16-bit resolution microphone records, so only higher resolutions allowed when using the system. The noise models were crucial for helping the recognition engine to identify the pauses between the inputs in the grammar or determining when speech had terminated, especially when there were loud noises in the background (e.g., playback of a siren or recording of a dog barking) [12].

Another important result of the first test was that the choice of microphone could play a critical role in the system's reliability. The system uses scenarios and assumes background noise and recommends the use of a closed-talk dynamic microphone with a headset for optimal operation. Increased noise in the test recordings when a typical off-the-shelf low-cost condenser microphone was used.

The recognition module was modified for the training tool through the addition of a logging feature, which captures all of the audio data sent to the recognition module and stores it together with a time stamp. These recordings are linked with logs from the training tool including the target command word and the words recognized by the voice recognition system. The combination of audio files and user performance data provided important data for future improvements of the acoustic models and the phonetic dictionary expansion derived from the new pronunciation variants observed from user input. The acoustic model could be adapted for the specific users who were trained with the tool. For the tactical team scenario, team members could have a personalized acoustic model and phonetic dictionary for their specific purpose and use.

IV. DESIGN AND IMPLEMENTATION OF THE SPEECH TRAINING TOOL

In order to provide for the most flexibility in the training tool, it was implemented as a stand-alone independent system. The stand-alone system had to be portable, expandable, and
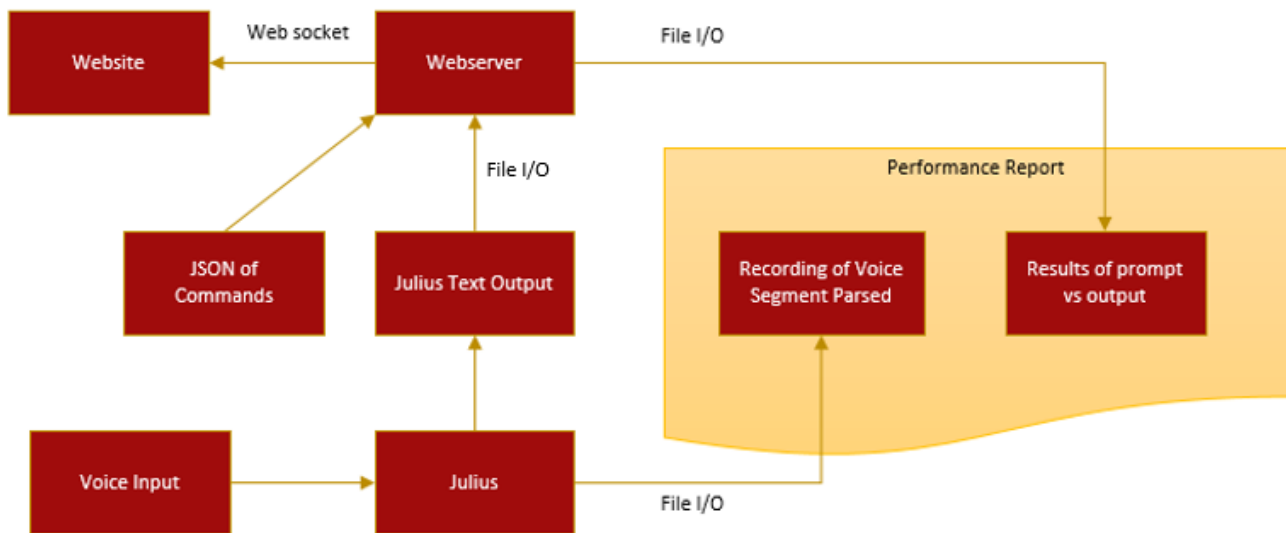
Fig. 3.   Program Flow

easy to use. This allows the police officers to train on the system without having to be co-located with the robotic system and without having to be experts in the technical software system.

The discovery of the need for this type of training tool led to the development of system requirements, which would allow anyone to be trained who would need to interact with a Julius-based speech recognition system and provided instruction on how to properly interact with that type of system. These requirements are as follows:

- The system needed to be simple to use.
- The system needed to be portable.
- The system needed to operate in a prompt and listen capacity.
- The system needed to provide immediate feedback on success and failure to the user.
- The system needed to force the user to attempt to say the word correctly, but provide the ability to skip after several failed attempts.
- The system needed to save out recordings of the voice snippets for each command issued to the system.
- The system should provide the user with an overall report of their performance during the training session.

In order to provide the capabilities discovered during the testing of the voice control software for the robot, the system needed to be able to detect what the user was saying, record the command they attempted to issue, and provide feedback on whether that command was correct or not. To accomplish this, the Julius voice recognition software was reconfigured and recompiled so that it would save a sound file for each command it parsed. By saving these recordings, access was provided for the different ways specific words were said during a training session. In the future, it is expected that these recordings could be used to improve the model's parsing of

what each officer said in an attempt to improve the accuracy of the detection of commands by the Julius software.
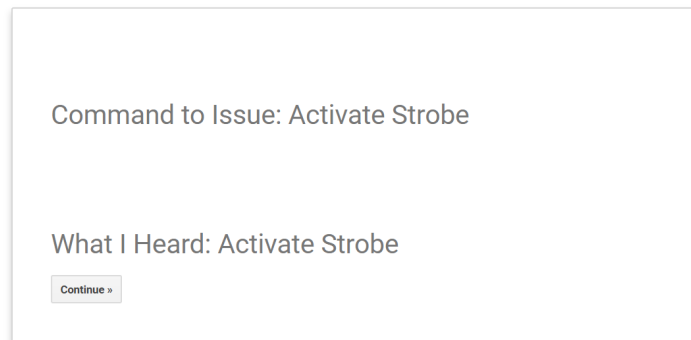
Once the Julius software parses out what the user says, it appends the results of its interpretation into a file for the training tool to read. The information produced by the Julius software provides any recognized word(s) and the system's assessment of the probability that it had accurately recognized what the user had said. This data is then processed in the training tool by a JavaScript function that displays what the Julius voice recognition software recognized to the user on the web-based interface (see Fig. 5). The immediate feedback provides the user with insight into how the recognition system recognized what they said and displays this on the website for the user. This feedback provides an opportunity for the user to adjust their speech and allows them to make multiple attempts at getting the command spoken correctly to the software training tool.

Example Commands	Purpose on Robot
Siren	Activates the siren on the Robot
Dog	Plays a recording of a dog barking through the robot's speaker system
Alarm	Plays a recording of a car alarm going off through the robot's speaker system
Quiet	Silences all sound coming from the robotic system's speakers
Strobe	Activates the strobe lights on the robot
Spot	Activates the spot light on the robot
Stop	Turns off all lights on the robot

Fig. 4.   Example Commands

In the current implementation, target commands are presented on-screen to the user in random order. The participant is expected to speak the target command into a microphone (see example commands in Fig. 4). After doing this, the Julius

Voice Recognition Training Tool

Fig. 5. Training Tool Interaction

voice recognition software processes the spoken clip and the system displays the results to the user. If the results do not match the target command, the system records that the attempt failed to be correctly recognized. The user is initially not allowed to proceed to the next target command word and the training tool will prompt the user to try again until the target command is successfully recognized. However, if the user's spoken attempts are not recognized as the target command on three consecutive attempts, the system allows the user to skip that command. The system records that the command word was skipped by the user and factors the miss into the final user performance report provided to the user at the end of the training session.

At the end of the training session, each user is provided with a performance report which summarizes their training session. The report displays which command words were not successfully recognized, which words were recognized, and how many attempts were made for each command. A composite score is calculated based on the overall results and provided to the user to allow them to track their progress for each interaction they have with the system.

V. Automatic Speech Recognition Integration

In order to integrate the automatic speech recognition system into the training tool, a program was written to receive updates from the Julius speech recognition system, in order to do comparison's with what the user was prompted to say (see Fig. 3). The system works by keeping a JSON[1]

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[1] JavaScript Object Notation http://www.json.org/

dictionary of the target commands that the user will be learning. A JSON dictionary was chosen so that the training tool could be expanded in the future to add and remove target commands. By allowing for the ability to make simple changes in the dictionary, it is possible to support training on specific command sets for multiple different domains and applications.

Once a user begins the training, a webserver queries the JSON dictionary and selects a target command as the next prompt. The selection of the word is randomized so that the user can train on the same set of commands, without learning the order in which the words will appear. Future iterations could adapt to user performance and preferentially select words that the user is having difficulty with.

Upon selection, the web-based interface is updated to display the word. The webserver then monitors a text file for updates from the Julius voice recognition system. The Julius voice recognition system is always running in the background and is providing updates as it recognizes words received by the microphone input.

When a new word and probability appears in the monitoring text file, a comparison is performed between what the automatic speech recognition system heard and what the user was prompted to say. At the same time, a time stamped recording of the input is saved to file. When a recognized word matches the target command word, the web interface is updated to provide a 'correct input' message. The user is then provided with the option to progress to the next word (refer to Fig. 5). If the user incorrectly pronounces the command, the interface displays a notification that the system did not hear the correct word and instead displays the textual representation of what

was recognized based on their speech.

Each attempt is logged with the attempt number, the word the user was prompted to say, and the textual representation of what they said. After three failed attempts, the user is provided the option to advanced to the next word, in order to keep the training moving forward. If this happens, the word is flagged as one that the user could not successfully provide, so that they can train on the word at a later time, or so that the word selection for that command can be evaluated as one that might need to be changed.

VI. Conclusions

This training tool extends the Julius voice recognition software, by providing an interface that user's can learn and train with different dictionaries and can be applied to different domains. This ability, applied to the use case of police robotics for the purpose of this paper, is expandable to any application which might want to use the Julius voice recognition software. This common interface provides an easy to use system for training on voice recognition, ensuring that end user's can proficiently interact with the voice recognition system, and provides for the ability to increase performance with the system through repeat exposure.

This training tool is an independent system that can be used with different dictionaries and in different settings including classroom settings for learning about voice recognition as part of the curriculum.

VII. Future Work

The development of this training tool highlighted several things that could be improved moving forward. While the system meets the original specifications for training law enforcement officers on the voice control of the robotic system, providing easier interaction with the system could allow for wider adoption of the training tool for a variety of different tasks, applications, and domains.

- The software could be used to collect a series of training data for the automatic voice recognition system. The dictionary of words, which we need to recognize is fairly limited currently and by collecting the recordings of a variety of dialects, we expect to account for multiple ways of pronouncing the words associated with different commands for robotic platforms in order to maximize the overall effectiveness of the system.
- Provide a simple cookbook for adopting the training tool for other speech-enabled applications.
- Test new acoustical models freely available for the English language and additional noise models from different outdoor noise databases (including gunshots, glass breaking, etc.) [13].
- Host the training tool on a public website and allow anyone to initiate a training session using their own dictionary uploaded to the website.
- Provide a simple tool for displaying and adding new pronunciation variants of the current prompt by end-users.

- Implement profiles to allow records of training over multiple sessions in order to document improvement over time.
- Implement Pause and Delete buttons. A user may need to pause training to interact with someone else by voice or a user may need to delete some private information accidentally recorded during a training session.

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University Leadership and Role Distribution

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Abstract **Universities are large corporate structures where many of the operations functions, that are imperative for the effective operation of the university, are not directly connected to education or research. Therefore, the structure of these managerial functions requires a variety of abilities and skills in which typical academician are not trained and experienced. The specific aim of our paper is to dispute a Central Eastern European (CEE) conviction that only academicians can become appropriate academic leaders and occupy higher functions in the university organizational structure. Since a majority of positions at universities are knowledge workers, our paper uses a knowledge management perspective in our analysis of the university workforce. In pursuit of this, the following questions are discussed:**

Can the expected abilities and skills be categorized to cluster university knowledge workers? What do we expect out of individuals belonging to a particular cluster? Are there knowledge workers of every cluster present at our universities in sufficient proportions and number? Are these knowledge workers recognized and adequately rewarded?'

Our analysis does not provide an optimistic outcome for universities in the CEE and in particular the Slovak Republic due to the intransient position and the limited desire and motivation of the academic community to transform its traditional structure.

Keywords—university knowledge worker; university human resources; university management; balancing explicit and tacit knowledge;

I. INTRODUCTION

Traditional managerial approaches are concentrated on people as manpower, not on the exploitation of their intellectual capital. Peter Drucker [1] was the first one who pointed to the fact that people's knowledge is another production power and awarded the persons who "think for living" by the term "knowledge worker". These people's primary source of income exploits their cerebral capacity and intellectual capability. Their position in the production process in very specific – they are rarely involved in it directly: which is a logical consequence of work distribution.

From this point of view, the situation at Slovak universities, and similarly at many universities in CEE, is not consistent with Drucker's perspective of managerial positions. The university top management is not only selected among educators – they are expected to continue their education and research work in parallel with their executive functions. Such an approach is not consistent with the belief that the main aim of work distribution is specialization – the process of concentrating on and becoming expert in a particular subject or skill. The person in CEE universities are expected to be simultaneously an educator, a researcher and a top manager. Thus, these individuals can hardly develop his/her knowledge and intensify his/her skills in all three directions. In addition, the Slovak University Law [2] indirectly mandates this. The Rectors and Deans are elected for the periods of four years, their deputies are nominated for the same period. All of them can hold the same function one more four-year period only. Since their future destiny in the university environment is unspecified, they continue acting in the two other positions. As a result, these individuals often even do not try to become experts in management. Furthermore, the old adage applies to the Slovak university manager: 'if you try to do too many things at once you ultimately will not be successful in anyone of them'. Thus, due to the academic administrators' intensive managerial duties, both their skills as a manager and their expertise in education and research suffer.

II. MANAGING KNOWLEDGE WORKERS

In companies, knowledge workers occupy a variety of positions: designers, developers, marketing managers, etc. Each of them requires different knowledge, skills and experience influenced by their education, position, and practice. Knowledge worker positions also vary substantially and, consequently, shape the individuals occupying them. Due to it, a knowledge worker cannot be shifted from his/her positions to a new one without a detailed consideration whether the person is capable of adapting to it.

Traditional managerial approaches address organization of production. Thus, they do not fit to knowledge worker's outcomes which are often invisible or virtual [3]. Traditional management can be (to a certain degree) applied to explicit knowledge extension and depth – they can be tested and measured which can hardly be functional to handling the knowledge worker's tacit knowledge. Unfortunately, élite knowledge workers are "selling" the latter one, thus, moving the expert above average. Mládková [4] responded to this challenge by presenting tailored methods of approaching them where the knowledge workers' typical driver is implementation motivational approaches over orders. In this, Mládková stresses that excellent knowledge workers are more motivated by difficult tasks than extrinsic rewards.

To find an appropriate motivation strategy is not possible without taking into account specifics of the particular branch of industry and the typical structure and functions of its knowledge workers. For example, Bohumelová and Hvorecký [5, 6] applied Knowledge Management to the field of exhibitions in museums and art galleries. Rábeková [7] exploited a similar dialogue-based approach to adult education. She designed and developed a method of facilitating educators' potential via their

collaboration with their would-be learners. In accordance to her methodology, the learners become co-designers of their course – they collaborate on designing the content and educational approach. This method is appropriate for training of small groups of professionals in a narrow field relevant to their expertise [8]. Šestáková [9] points to the importance to distinguish between different approaches to knowledge development for specialists executing higher positions in banking and finance.

Compared to the preceding examples, universities in the Slovak Republic (and other universities in the CEE) represent more complex bodies with huge numbers of specialists from very distant and diverse fields, often focusing on very broad and complex problems that border on the edge of existential bodies and knowledge. Solving difficult problems requires setting up very specific conditions and their systematic, uninterrupted development. Nonaka and Takeuchi [10] denoted the term *"ba"* as the environments designed and developed for knowledge workers to enhance originate, dialogue, exercise and systemize their knowledge.

In complex environments (which universities undoubtedly are) building appropriate *ba's* represents a key to success. Consequently, a substantial portion of knowledge workers' effort must be devoted to their design and development. To maximize the outcomes, the work distribution is needed. To outline its directions and to classify them is our paper's aim. Thus, it might help us to understand better how the university goal-related duties can be accomplished to the benefit of its entire community.

In our paper, we will primarily concentrate on two problems of university management: First, on leadership and second, on academic role distribution. In order to tackle the first problem, we will explore distinctions between book-smart and street-smart individuals. Using Kess' typology [11] where he allots knowledge workers into six categories, we will look at university workers role assignment, where some members design and develop university's *ba*, while others exploit their outcomes to attain the maximum results in education and research. Without their mutual collaboration and information exchange, the university do not reach their expected standards of quality and high performance.

III. BOOK-SMART VS. STREET-SMART LEADERS

In this analysis, we will look first at: book smarts vs. street smart leaders.

At Central Eastern European Universities, there is a consensus that the leaders must come from the university community on the principle *Primus inter pares* (first among equals) – the traditional principle presuming that the leader of the community must be elected from it. It refers back to Middle Age continental Europe with the universities as the only islands of freedom of speech [12]. To protect the privileges and to minimize the risk of its loss, the promotion to leading position within academic community was based on a stepwise promotion, that being that candidates were only selected from those "consecrated" i.e., those whose loyalty and steadiness were vetted beyond any doubt. As universities have been built upon academic excellence, the leading positions were and in

Central Eastern Europe still are occupied by individuals with high academic achievements. The Urban Dictionary [13] denotes such individuals as "book smart" ones in comparison to an opposing group of "street smart". (This is not to say or infer that a book smart person can't have street smarts, but frequently there is a focus on one or the other).

The concepts and their definitions were originally developed to explore the "figuring" of smartness through the perspectives of marginalized youth [14] and to capture why some of them are regarded as reputed personalities and/or leaders. The concept of street smartness is a direct challenge to the dominant discourse of smartness as it operates in schools and universities and uses a completely different criterion to measure it. To the marginalized youth, "street smarts" are more important because they are being able to maneuver through structures in their lives such as poverty, the police, street culture, and abusive "others." Street smart individuals' intelligence is practical. It has been gained using their specific experiential way, primarily through trials and errors or by self-learning. They tend to be impromptu, are ready to take risk and capable to solve sudden problems in the event of crisis. A street smart individual has a lot of common sense and knows what's going on in the world. This person knows what every type of person has to deal with daily and understands all groups of people and how to act around them. He/she also knows all the current changes going on in the "streets" and everywhere else and knows how to make his/her own right decisions, knows how to deal with different situations and has his/her own independent opinions. He/she occasionally sets up his/her own rules of game which are then accepted by his/her neighborhood by the power of authority.

Conversely, the *school smart* beings are valued by "well-mannered" communities especially for their predictable and systematic behavior. They have highly developed analytical skills obtained during their education at schools and universities and further professional development. They think things through, tend to be organized and thoroughly prepared with having pre-elaborated back-up plans in case something goes wrong. During the years spent in their profession, they learned to rely on their expert knowledge. In extreme cases, they presume that their systematic and well-elaborated methods applied in their beloved area can equally be applicable to every life situation. As a result, they often fail because the situation requires a substantially different approach. As an example, let us mention a university president – a former marine biologist – whose every example in management related to dissection of some sea animal.

The antinomies and similarities between those two natures can be learned from Blair's book [15]. This text shows that entrepreneurs have to become (at least to a certain degree) street smart in order to successfully compete in their "entrepreneurial jungle". The universities are organizations and, despite their distinctions from production-oriented bodies, they share many features with them. Likely, the most important one is the necessity to compete with all other entrants present in the same field of activity. This also means that academic leaders have to possess a certain degree of street smartness. A good academic leader has to be familiar with all the current changes going on in the "streets" (i.e. not only within his/her internal academic community but also in its surrounding world), to have his/her

own independent opinions, to be able to formulate and take his/her own right decisions, and to have the skill to deal with evolving situations including needed compromises. It is necessary to add that many of these skills are also part of university courses. Thus, it implies that compared to "pure" street-smart leaders, the street smart university managers do not need to rely on their uninformed experience only; they can exploit knowledge stored in books and other sources. However, in reality the book-based knowledge is insufficient for excellence in leadership (it is often the debated topic can leadership be taught). If it truly can be obtained through books alone, every attentive reader could become a top manager. In business life, there are many situations in which fully-rational decisions do not bring optimal solutions. Also, data show that the managers apply rationality in their decisions much less frequently than the readers of textbooks on Management might think [16].

IV. Role Distribution Among Knowledge Workers

Using the Knowledge Management terminology [17], book smartness is primarily based on explicit knowledge whilst street smartness benefits predominantly from tacit one. Prospective academic leaders must demonstrate both of them in accordance to their positions and situations they face. The dominance of book smartness with its dominating accent on explicit knowledge and suppression of intuition becomes a worldwide issue. The numbers become a "golden calf" to be praised by scientists [18]: "*In the Netherlands, counting output started off with the number of publications, then international publications, after which only English-language publications, counter hereafter articles in high-impact journals, and eventually often-cited publications (leading to a high 'h-index')*." All this leads to the suppression of intuition, creativity, comprehensive and longitude thorough analysis and synthesis.

In this section, we therefore study the relationship between explicit and tacit knowledge. Many of the readers of this paper are aware of the "knowledge iceberg" where Nonaka and Takeuchi in their book The Knowledge-Creating Company [19] highlight the distribution of explicit and tacit knowledge. Following our above specification, by explicit knowledge we designate book-smart-oriented knowledge as one facilitating systematic, well-organized knowledge; i.e., "true-academic" one. By tacit knowledge, it is a knowledge which is more intuitive, difficult to be prescribed and its implementation requires a certain level of risk-taking. Exploiting their proportions in an individual will help us to form several levels of them and make a smoother distinctions between "pure book smarts" and "pure street smarts" and demonstrate their influence on the university management.

Kess [11] identified six categories of knowledge workers and distributed them by different proportions between their tacit and explicit knowledge – see Figure 1.
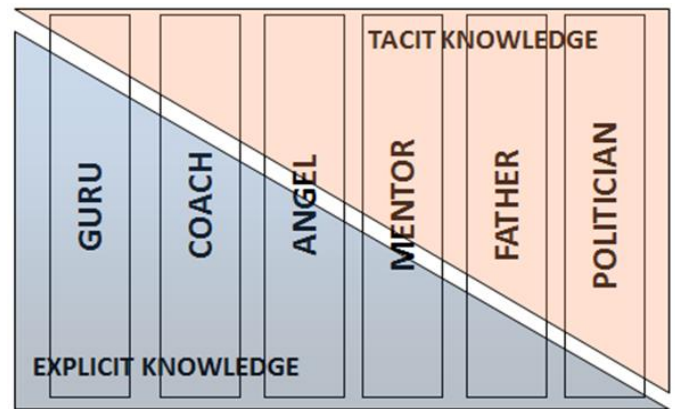
Fig. 1. Kess' typology of knowledge workers.

A. Guru

Gurus have deep professional knowledge about their specific area. Their interests are strongly connected to his/her expertise and may not go far beyond it. Their long and rigorous expertise helps them to solve their professional problems in a creative and innovative way – more efficiently than most specialists working in the same field would do. Their tacit knowledge is both extensive and intensive in their domain of expertise but may not be applicable in areas outside it. This makes the gurus a bit "autistic". As a result, they are quite impractical in solving problems beyond their own specialization. When it is exactly defined (mostly as a narrow field of science or technology), they demonstrate their high qualities.

The guru has a book smart oriented personality. As a pure thinker, he/she is entirely focused on his/her field of expertise and is devoted to it. (Often, he/she has never been requested or expected to perform anything else.) The amount of his/her field-oriented knowledge can be tremendous but it is primarily tied to his/her daily routine whatever "routine" it is. As an indirect result of his/her external interests, he/she tries to measure all the world by the criteria of his discipline and, whenever it is possible, express their opinions by numbers or formulas. In the University environment, the individuals with this style of thinking create and enforce scientometrics [20] as a quality measure only, and are convinced that it is the best metrics. Often, their most effective place within the universities are laboratory settings where the university will benefit from their knowledge and they are most happy as their expertise will be maximized here. Interestingly, even gurus working in humanities, tend to stress exact components of their discipline. They concentrate on introducing a solid and rigid terminology and on defining and utilizing strict rules of manipulations with the terms. This helps them to advance and promote the formalized subdivisions of humanities. Their systematic character corresponds to their orientation and mentality.

A problem with gurus can be their unwillingness to share their knowledge with their neighborhood in order to hold "knowledge power" i.e. a disciplinary power [21] based on strengthening their own position by keeping certain knowledge exclusive for themselves and by prohibiting others from obtaining it – they keep it close to the chest so to speak and use it as a source of power.

B. Coach

The coach is also a specialist in a narrow and well-defined discipline but – unlike a guru – he/she also comprehends the importance of making connections between his/her field and the rest of the world. He/she is interested in them, in their mutual intersections and their reciprocated influences. He/she is capable of innovativeness, not only inside his/her specialization, but also in creating new links between it and its surroundings. Due to this, the coach understands informal (unspoken) requirements on his/her field's outcomes applicability. It makes him/her capable to tailor these outcomes to their future users' needs with respect to their qualification, mentality and habits.

Coaches are those who bring gurus' results to life. The combination of their expert (explicit) knowledge with knowledge relevant to their field (tacit) bridges the newly gained guru's knowledge with partner fields such as engineering, technology, psychology, marketing, education and others. Coaches are often ready to make a step out (of their domain and specialty) and search for applications of their "mother" specialization. Often, they can ignite interdisciplinary research or open a new research field. While guru's dreams are discoveries, coaches are satisfied with inventions because they are looking for prosperity coming from new knowledge. At universities, they often benefit in positions oriented to collaboration with the university community partners in industry, social services, health care, education, etc.

The coach personal characteristics are highly valued around the world because they communicate their university's results to the public. Unfortunately, it does not apply in our universities in Slovakia. The accreditation criteria in the Slovak Republic (and often other CEE nations) expect everyone to have a narrow orientation. They, the accreditation bodies, do not support interdisciplinary activities [22]. Due to its standards, Slovak accreditation commission often refuses to recognize an interdisciplinary-oriented research publication because the paper does not fit within a clearly defined "box". As a result of this indirect pressure, interdisciplinary studies have been substantially reduced during the last decade. Similarly, it often discounts and neglects the value of inventions, new surgery methods and other innovative approaches and techniques. For example, a coach who is absent at Slovak universities is a "textbook writer" – an individual capable of presenting his/her field of knowledge in the way relevant for novices. Again, this function is not adequately valued by university officials and does not substantially contributes to the person's promotion. Surprisingly, uninformed outside observers may get opposite feelings because the publication of learning materials (named "skriptá") is an obligation for promotion to the docent or associate professor position. However, frequently the applicant can write material of any quality – there is no rigorous checks and balances, where many works of low quality, sometimes even plagiarized, are passed through.

Unless the Slovak tertiary education system develops incentives to activate and incentivize its potential coaches, no progress in this area will become noticeable in the near future. The coaches of all directions will remain extinct species.

C. Angel

Angels are facilitators, so called engines of progress. They do not need to belong among the top field specialists, they build conditions to their optimal work conditions. Their main role is to facilitate the development of appropriate *ba* for other knowledge workers – "true" field specialists (gurus and coaches). Their contribution to their particular field is made indirectly by assigning needed resources or by their capability to acquire them and to control their effective and efficient utilization. The angel's tacit knowledge must include a broad understanding of their surroundings and the disciplines in the field, and the ability to identify areas in which his/her team's efforts can be expanded in ways which will bring the maximum benefits. The angel's determination is critical for the success of the team.

Angels are another extinct species at Slovak universities. As stated above, they are the persons taking care of the optimal working conditions for others. They should systematically build working environments, enhance positive atmosphere and build and develop organizational culture for all partners. They do not need to be top experts but have a good orientation in the field. They must possess organizational skills and emotional potential to create friendly atmosphere to maximize the efforts of the team and to "sell" it to community in order to gain further resources to the team's growth, progress and prosperity.

Universities in the Slovak Republic and elsewhere in CEE nations, which want to prosper should open relevant positions and assign appropriate persons who could serve as potential "Angels". For example, former researchers have solid and well-consolidated knowledge making them capable of estimating future trends and looking behind horizons. The university should give these individuals decisional power (including finance) to support the university's progress in promising areas selected by them. Often, no additional new positions would need to be created; e.g. when professors' emeritus could be used in this capacity. Angel's roles could also be executed by the heads of departments. Unfortunately, in Slovakia the decisional power of department heads is very limited by the University Act [2]. In addition, the budget of Slovak public universities is stated separately for every calendar year. Thus, this restricts their freedom for long-term planning and may make angels' long-term visions obsolete.

D. Mentor

Both angels and mentors are characterized by their balance between tacit and explicit knowledge. While angels are oriented to the development of their field of knowledge, mentors typically are willing to share their knowledge with the community. In this way, they prepare the followers who presumably will join their field of interest. Their tacit knowledge must therefore include the ability to select gifted candidates. To them, they will deliver their knowledge, experience and skills. The mentors also contribute to the development of their field by organizing its "marketing" i.e. by presenting it to publics. (Here, the term "marketing" is used in a very broad sense describing any promotion activity and publicity related to the field/product/idea.) By their daily activities, the mentors guarantee that the field will continue to exist and will remain vital.

In a way, the mentors' key role is to guarantee that the university will fulfill its functions at the expected level of quality, i.e. they make the future coming. As educators, they pave the road to the massive application of guru's and coaches' knowledge by designing and developing new study programs, by verifying vitality of their ideas, by spreading the concepts among laymen, by designing, developing and trying new teaching methodologies and performing experiments in laboratories and so on. They cooperate with gurus in order to perform their respective activities in their intended (simplified, public-oriented) ways and communicate with angels who plan and sponsor these activities.

Often, the mentors also collect information from external sources – research centers and leading universities – in order to facilitate design of an innovative and competitive university vision and to develop a realistic strategy for its implementation. The university must have an army of high quality mentors to fulfill its functions in both education and research. To keep their faithfulness, their efforts should be regularly recognized and adequately rewarded.

E. Father

The father represents the "face" and the historical background of the business. For his/her organizational neighborhood, he/she serves as a symbol. (In our interpretation, the "family" can be any team glued by its members' collective vision, values and collaborative activities.) Father's knowledge is strongly combined with his/her "family" values. The "father's" sheer presence ensures to the outsiders that *everything is as it should be,* i.e., demonstrates historic continuity. As Kess [11] shows, fathers play their critical role in two moments of life: during launching of the company and during its depression. In the first case, their enthusiasm can inspire the others and lead them toward new aspirations. In the second case, he/she has to demonstrate the team's vitality and to engage it into its regeneration. Hence, the father has to be a compassionate leader. In academy, he/she has to be capable of setting up a holistic vision across the university's research and study fields.

Currently, one can hardly speak about any true fathers at Slovak universities. "Being a father" is a lifelong duty and must be taken by a person who is ready to dedicate his/her soul to it. For that reason, the fathers are quite exceptional in all organizations. In addition, at universities, another problem arises. Due to the size and complexity of these structures and organizations, it is not easy to find a person with a vision covering the entire (or at least substantial) field of their interests. For this reason, he/she can hardly be found among book-smart persons. To understand and properly interpret the mutual interests of many groups with frequently contradicting interests, requires a street-smart personality. Therefore, it implies that the university top management should be selected from among fathers.

In Slovakia, as well as other CEE nations, this is a difficult task due to legislative mandates. The University Act [2] limits durations of academic functions to the maximum of eight years. This same act also gives a significant power to self-governing bodies (the academic senates). One can express it by "*Rectors and Deans are responsible for the University but have no power while academic senates have power, but no responsibility*" [23].

The fathers can therefore lack the power to implement their vision. They can manage it under presumption that they persuade the academic senates to follow their vision. Unfortunately to them, many Slovak academic communities are conservative and not ready to leave their "comfort zones". Consequently, they are not ready to accept those visions which threaten disrupting the status quo.

Currently, a new national strategy of education named Learning Slovakia is under preparation [24]. Hopefully, it will give more autonomy to universities. This could ignite (at least some) universities to form an organizational structure which simplifies implementations of their father's visions. Hopefully, some "fathers" capable of designing and implementing positive visions still live and will elevate the system.

F. Politician

The last category of knowledge worker identified by Kess [11] is the politician. For Kess, politician have to have substantial knowledge about local, national and even international policies relevant to their business operations. In organizations, they are leading the varied bodies of the entire company (or of its relevant part). They communicate on behalf of their groups and present their interests to their surroundings. The role of politicians is to "open door" for the particular business to the society, e.g. by building demand, getting public and private sources, as well as making steps towards changing legislation in the directions suitable for his/her business. It all implies that he/she must have excellent negotiation skills, too.

The politician has to be capable of creating the organization's long-term visions and of implementing short and long-term strategies. The politician does not need to be capable of solely formulating these strategies, but he/she must be a key voice in helping shape them, and very importantly in communicating these strategies to both inside and outside the organization. The true politician puts an equal sign between his/her personal success and the success of the vision he/she (re)presents.

Among all types of knowledge workers, the politicians' dependence on their tacit knowledge (e.g. on instincts and intuition) is the greatest. In order to obtain quick and short-term gains and results, they must be capable of performing qualified guesses which must have a high probability of success. These estimates should address social trends, business opportunities and risks, market trends, future innovative technologies, areas of investment and others. Since all of the guesses will not be correct, he/she must be capable and able to orient themselves in unexpected situations and to find the path to navigate through their mistakes and these troubles.

V. UNIVERSITY AS A COLLABORATIVE WORKPLACE FOR DIFFERENT TYPES OF KNOWLEDGE WORKERS

Based on the above cases of book-smart gurus and street-smart politicians, one can easily guess that Kess' knowledge typology predetermines success of a particular type of knowledge worker in a particular position. The human resources policy at universities should respect the typology in assigning people into their positions. Not doing so would lead to their individual discomfort and sub-optimal performance.

For example, the gurus are "pure thinkers" focused on their field of experience (and not looking much around). The positions of leading researcher, as previously mentioned, are appropriate for them. In such a role they can concentrate on their topics and exploit their explicit and field-oriented tacit knowledge to the maximum. They will not be troubled and distracted by other duties. To create optimum working conditions for them should be a duty of others; e.g., coaches within their field of expertise. In contrast, placing such people outside their narrow scope of knowledge would require them to change their orientation and might result into unwanted problems. In this case, they would most likely continue applying their formerly learned routines to the new field (mistakenly) presuming that they are omnipotent and applicable to all life situations. The usage of scientometrics as an omnipotent measuring method of research, technology and innovation outcomes is a typical example of such a faulty practice. It neglects the fact that research publications must have their added value(s) exceeding their sheer existence.

This leads us to propose a model of role distribution at universities. Its application presumes that the current management is capable to recognize the potential of its knowledge workers, to motivate them, to select the best fit for people in respective positions, and to organize their optimal collaboration. Thus, following the dictum for [4], knowledge workers, these individuals can't be ordered to execute a particular task, they must be invited to join the respective team(s). Therefore, the university processes must be based on a voluntary process with a focus on intensive collaboration among its knowledge workers. In existing university environment, the model should work as follows:

- Fathers propose their vision of the university development; for example, the establishment of a new study program or research field. The motivation or impulse to do so will likely come from coaches who have discovered new opportunities for university's activities due to their communication with gurus and mentors, and their (coaches') capability to excerpt innovation elements from their notes.

- Politicians evaluate their suggestions and decide which of them might be worthy of "investment", i.e. of their implementation as a new element of the university's profile.

- The fathers then invite coaches to design the research or educational project. The fathers' responsibility will be to build bridges between existing (traditional) fields and the proposed ones, in order to find its appropriate "marketing" strategies, as well as to motivate relevant candidates to join the concept – especially among gurus (in the case of research projects) and mentors (for study programs).

- When the vision is approved, politicians and fathers invite angels to start forming conditions for its implementation inside the university (including inviting appropriate external staff to relevant positions). The politician's role will be to find external financial and organizational support for it. (That's why the marketing strategies must be already prepared.)

- When the new field gets its final green light and relevant *ba*'s have been built, gurus and mentors are invited to accomplish the vision.

- Eventually, the loop can start again.

Notice that the model defines the roles slightly differently. For example, the *father* is unlikely the founder of the university. As the lifespan of universities is counted in tens or even hundreds of years, he/she is rather the person who fulfils the father's role of intensive constant support: He/she guarantees that his/her university "family" will not come into a recession or, if so, it will get out of it and prosper again. He/she is therefore a person guaranteeing that its academic trek will follow the needs of society, lead them and benefit of them.

Similarly, the politicians should set up the university policies, to not to get involved into politics made by politic parties at the national or regional level. On the other hand, keeping the appropriate numbers of fathers and politicians is a condition *sine qua non* for the academic institution. Their abundance might lead to struggles, possibly "wars", among them – with disastrous consequences.

On the other hand, all study branches and areas of research should have their own gurus, coaches, angels, mentors and fathers. They will guarantee its development in their respective academic fields. To progress, they should cooperate with each other on the development of interdisciplinary areas. There is no reason to waste their precious time by internal struggles. Sooner or later these would be reflected in the university image as shown in [23].

In reality, the role distribution in the above meaning does not exist at Slovak universities. Their traditions (verbally also expressed by the accreditation rules [22]) expect each and every academician to become a guru in his/her discipline. This community mindset discourages potential and appropriate candidates to aspire to other roles "until they do not reach the guru status". Then, it is usually too late to reorient the person's knowledge, skills and mentality as the following examples indicate:

- A politician cannot stay in the position of a true guru. The guru must be strongly concentrated to activities in his/her field of professional knowledge. As every field develops quickly, he/she will soon lose the contact with its edges and stops being a guru.

- A guru does not fit to the role of a politician. The politician must be equally open to the needs of all university branches. He/she cannot prefer one towards the others – conversely, he must design and develop the optimal opportunities for the most prospective ones, perhaps by lessening those of his/her "parental" one.

All this indicates the inevitability to educate all categories of knowledge workers. The process is to be long-lasting but should start as soon as possible otherwise no progress would be made.

VI. KNOWLEDGE WORKERS' LEADERSHIP DUTIES

The described typology can serve as a framework for the university human resource departments of those universities which wish to become Learning organizations [17]. Their organizational learning should primarily concentrate on the most urgent challenges [25, 26]:

- Recent failures and their remedy: About a quarter of high school graduate's leaves Slovakia to study abroad, primarily to Czech Republic. The fathers and mentors should concentrate on the roots of the problems and on developing educational methodologies attracting them not to leave or return.

    In 2012, Slovak Accreditation Commission was expelled from ENQA - European Association for Quality Assurance in Higher Education. Fathers should redesign the university philosophy and change its priorities to make it compatible with the ENQA principles. The politicians should ask for implementing these measures into legislation and return Slovakia back to the European mainstream.

- Changing current practices: No Slovak university belongs to 500 top universities in the ARWU ranking [27]. The university strategy should focus on employing only the mentors, couches and gurus capable of demonstrating internationally recognized outcomes and get rid of these who produce average and low-quality ones.

    To a high degree, the lagging behind is caused by almost-zero academic mobility. The most of educators and researchers are staying all their life at the same department. Their everlasting stability reduces their readiness to get adapted to ever-changing conditions and look over their local horizons. Again, the politicians should concentrate on measures leading to more intensive mobility and getting "fresh blood" from outside their institution.

- Building universities of the future: The Slovak (as well as most CEE) universities prioritize so-called Humboldt model. It puts research to the top followed by education and neglects the third university role – service to community. Šima and Pabian [28] proved that the Humboldt model was never implemented to its full extent because it fits adequately to the doctoral study only. At Bachelor and Master levels, the university is more oriented to the "mass production" of professionals requested by business and industry. With the increasing role of research and development in product and services innovation, the collaboration between industry and universities is intensified and leads to a new model – the entrepreneurial university [29]. This concept is factually unknown in Slovakia and exceptional in CEE. Some acts included in the Slovak legislation directly or indirectly contradict to it. Logically, most universities do not build visions which would respect it.

Generally, CEE universities insufficiently work on their development towards the most contemporary university models and their sustainability. They are in need of enlightened leaders – especially Fathers and Politicians. Without their deep professional involvement, there hardly be any progress because there is no one ready to set up visions and specify milestones on the road to them. Some of the hindrances causing their absence are caused by the legislation. For example, the Rectors and deans are elected for four years and they cannot occupy their posts for more than two consecutive terms. Due to that, many of them do not see a reason to professionalize their management-oriented knowledge and leadership skills. Without relevant modifications in legislation, the progress is hindered.

Nevertheless, a considerable portion of guilt fall on the Slovak academic community. It does not do intentional harm to universities; its guilt lies in something else. The academic community is:

- Conservative: It refuses all changes that might modernize the university environment. Recently, the eight biggest universities signed a document in which they rejected the proposal Learning Slovakia and the amendment to the University Act changing the legal status of the Slovak Accreditation Commission [30]. Both documents want to open door to the international academic community and local stakeholders.

- Passive: Its passivity is an indirect consequence of the conservativism. To avoid any changes, the academicians does not come up with initiatives that would lead to innovations and might affect *status quo*. For example, the above-mentioned refusal was not accompanied by a proposal what else to do for modernizing the tertiary education system.

VII. CONCLUSION

Slovakia belongs to a small group of countries which quality control mechanism is not compatible with European standards. To comply with the Environmental, Social and Corporate Governance (ESG) 2015 standards [31], the university should build its own scaffolding thus supporting the design, development and critical control of its own activities based on Kess' typology. The shift should primarily lead to lessening the accent on explicit knowledge and to the higher recognition of the tacit one and to facilitating the collaboration among the knowledge workers of all types.

Unfortunately, the author is quite pessimistic about Slovak universities implementing some of the aforementioned changes in the foreseeable future. Many of them are divided into smaller alliances by particular interests or groups of departments and faculties. In addition, to some extent, the current ill-fated state-of-the-art is caused by the low budget assigned to public universities and education in general [22]. Also, it is allocated for one year only. It limits any long-term planning. Due to it, the role of fathers and politicians is very rare or non-existent.

A substantial portion of Rectors and Deans is therefore convinced that the excellence in research and education will automatically appear with greater funds [30] and refuse making any changes prior to the substantial budget increase. Their fear is not a complete fiction. The lack of money led to tensions among university faculty. There is a real danger that releasing these tensions might lead to open wars between the various parties or even to the total collapse of the institution. At the same

time, they neglect the fact that an increase in the university budget will not automatically lead to better management, and that a university budget (high or low), does not correspondingly translates to better fiscal and operational management.

The proposed Learning Slovakia program [22] presumes that the organizational structure of university would be in its hands, with this the university could modify it as desired. Although, the universities are aware that their current strongly hierarchical structure is outdated, they are afraid of changing it. However, their organizational structure cannot change until they have got sufficient numbers and proportions of knowledge workers in all six directions. To respond to the above described challenges, the roles of Politicians, Fathers and Mentors in the university sustainable development should be strengthened. To prepare the future changes, the management should pay its attention to their education. This preparatory stage could also reduce the current conservativism and passivity.

It is obvious that the organizational culture of Slovak universities, as well as others in this group of nations in the CEE must change significantly. In the previous years, their growth was primarily extensive [32]. This way does not offer a further potential due to the declining demographic curve [22]. Incoming changes must address the quality of tertiary education, in particular its diversity. However, to change is to upset the status quo, but as Peter Drucker said: "Not all change is improvement, but without change there is no improvement". He further said: "Change is a gift – it is an opportunity to start again" [33]. Thus it is change that is needed to bring Slovakia and other CEE universities in line with Universities in the 21st century.

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Behavior of Job Candidates and Current Labor Market Development in the Area of Information Technology in Slovakia

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Abstract — **The study utilizes the data about behavior of job candidates in the area of Information Technology from Profesia – Slovakia's largest job portal. The first part of the study focuses on current labor market development – what are the trends in the number of vacancies and published job advertisements at Profesia and also trends in availability of job candidates to these positions (differences across regions are also discussed). The second part of the study is devoted to various aspects of behavior of job candidates – e.g. how many job advertisements they view and to how many job advertisements they apply to, whether they look for a job strictly within the area of Information Technology or also in other industries. We segment the webpage users into various categories based on how intensive they search for a job and what are the implications for availability of candidates for the companies. The final section presents current trends in both financial and non-financial remuneration and compares these trends between the area of Information technology and selected other industries.**

I. INTRODUCTION

Positions in the area of Information technology (IT) are currently the most demanded by employers on the Slovak labor market. Due to favorable economic situation in the period between 2014 and 2017, the number of vacancies in this market segment grew very rapidly. However, the pool of talented candidates on the market became very limited and it became much harder for employers to fill their vacancies.

The main objective of this study is to provide an overview of the most recent labor market trends in the area of IT and describe how job candidates in IT search for a job at Slovakia's largest job portal – Profesia. We utilize data from published job advertisements as well as from CVs of job candidates in Profesia's database. We also work with the data from salary survey from the website www.platy.sk.

The first chapter of the study summarizes the overall labor market development in IT in the period between 2011 and 2017. Chapter II discusses the regional differences in Slovakia and compares the availability of candidates between various regions. It also focuses on travel patterns of job candidates. Chapter III examines the behavior of job candidates at the website – we monitor the lifecycle of candidates from the point of view of how many job advertisements they click at, what position they are interested in and whether they look for a job strictly within IT area or also in other fields. We compare the behavior of job candidates from IT with other market segments.

Chapter IV shows how a competition at the market creates a strong pressure to increase salaries and forces employers to compete also in providing more compensation in terms of non-financial benefits. In order to attract skilled IT professionals, companies today need to provide much more than they used to a couple of years ago.

II. LABOR MARKET IN THE AREA OF INFORMATION TECHNOLOGY

In this part of the study we discuss the most recent developments on the Slovak labor market in IT segment.

A. Size of the market

Fig. 1 shows how many job advertisements in IT area were published at Profesia between 2011 and 3rd quarter of 2017 (on a quarterly basis). In the period between 2011 and 2014, the number of published job advertisements was much lower than in the period between 2015 and 2017. The number of job opportunities increased thanks to positive economic situation in the country. In the 3rd quarter of 2017, 7 343 job advertisements were published which is by more than 31% more than in 3rd quarter of 2014. Thanks to this increase, job candidates are now able to choose from larger number of vacancies and it is very easy for them to find employment.

However, there are also signs of stabilization in the number of published job advertisements and saturation of the market. If we compare years 2016 and 2017, the number of published job advertisements was very high in both years. However, in 2017 it wasn't growing any more. 23 444 job advertisements were published in the first three quarters of 2017 which is very similar number as in the same period one year ago (23 127 advertisements).

Therefore, it is very likely that the growth of the labor market in IT area in 2017 already reached its limits. Due to favorable economic outlook for the upcoming 2 years (Slovak National Bank expects annual GDP growth at a rate of 4.2% in 2018 and 4.6% in 2019), it is very likely that the number of new vacancies in IT will remain very high. However, the growth in the number of new job postings is no longer likely to continue and the demand for workforce of Slovak employers will likely remain at its 2017's levels.
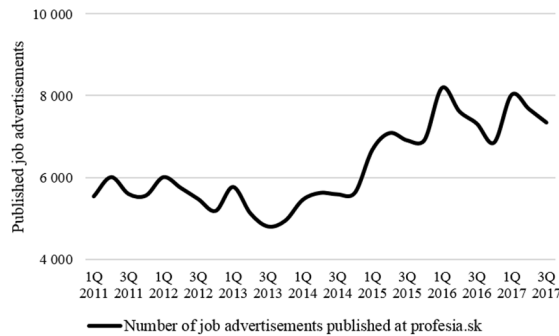
Figure 1. Number of job advertisements published at profesia.sk in IT segment for the period between 2011 and 3rd quarter of 2017 on the Slovak labor market

Figure 2. Average number of job applications to advertisements published at profesia.sk in IT segment for the period between 2011 and 3rd quarter of 2017

Table 1 compares the most recent development in the number of published job ads in IT with selected other industries and market segments. Due to favorable economic conditions, the majority of market segments are still growing. Also the whole labor market in Slovakia is booming (14% year-to-year growth in the first three quarters of 2017). The fastest growing industries in 2017 in terms of year-to-year growth are Industrial Production, Transport & Logistics and also the Service sector. On the other hand, the slowest growing industries are Agriculture and also the segments of Banking and Insurance. IT currently belongs to the latter group.

Fig. 2 shows the development of the availability of candidates in time. This is measured by the average number of job applications to a job advertisement in IT. The availability of job candidates is in a negative relationship with the number of job opportunities. In the period between 2011 and 2014, employers could on average choose from a considerably larger number of job applicants. The average number of job applicants dropped in years 2014 – 2016. In the 3rd quarter of 2017 only 4.2 job candidates applied to positions in IT. In the third quarter of 2014 6.4 candidates applied. Such a low number of job candidates means that there is a problem with shortage of job candidates on the Slovak job market, especially skilled professionals.

Table II comes up with a comparison of the availability of job candidates between IT and other market segments (those with the largest availability as well as those with the lowest availability). The segments with the largest availability is Administration, followed by Human Resources, Marketing and Commerce. All these segments receive on average more than 20 job applicants per position and are well above the market average. On the other hand, among segments with very low number of responses are Technology & Development, Mechanical engineering and Telecommunications. Job advertisements in these market segments received on average less than 10 responses from job candidates. The last place belongs to the segment of Information technology with only 4.2 candidates per position which means that the situation with the shortage of suitable candidates is the worst in this market segment.

The competition between job candidates for vacancies is therefore very low, contrary to the competition between employers who have to struggle hard to fill their vacancies. Job candidates have a very favorable position.

TABLE I.
NUMBER OF PUBLISHED JOB ADVERTISEMENTS IN FASTEST AND SLOWEST GROWING MARKET SEGMENTS IN FIRST THREE QUARTER OF 2016 AND 2017

Market segment	2016	2017	Year-to-year change
Industrial production	21 891	30 103	38%
Transport & Logistics	16 938	21 971	30%
Services	3 373	4 172	24%
Construction & Real estate	6 499	7 857	21%
…	…	…	…
Labor Market in Slovakia	181 457	206 999	14%
…	…	…	…
Insurance	2 733	2 888	6%
Information technology	23 127	23 444	1%
Banking	11 044	11 061	0%
Agriculture	1 762	1 665	-6%

TABLE II.
AVERAGE NUMBER OF JOB APPLICATIONS TO JOB ADVERTISEMENTS IN SELECTED MARKET SEGMENTS IN FIRST THREE QUARTER OF 2017

Market segment	Labor Market as a whole
Administration	30.9
Human resources	25.4
Marketing	22.8
Commerce	20.5
…	…
Labor Market as a whole	
…	…
Technology & Development	9.0
Mechanical engineering	7.2
Telecommunications	7.1
Information technology	4.2

B. Demand for job candidates

Besides a chance to actively look for employment at Profesia, job candidates also have an opportunity to create a CV in their online account and to make it publicly available for potential employers. Such CVs than enter a database which can be browsed by recruiters and headhunters. If a recruiter is interested in the profile of a candidate, then there is an option to view contact information of such a candidate (a paid service provided by Profesia). Based on the number of such views, it is possible to measure the quality of a candidate. The more views the CV receives, the more attractive the candidate is for employers searching for talent.

Table 3 compares the attractiveness of candidates between various market segments measured by the average number of views of those CVs in which candidates declared their interest to work at least at one position belonging to the area of IT. We take into account the number of views a CV received in the first three months after its publication at the website.

Job candidates in IT are highly demanded. Their number of views is considerably larger than in case of other industries. Whereas an average CV of a candidate at Profesia receives 4.2 views from recruiters, in case of IT segment it is almost twice as much (8.1 views). IT is therefore on the 1st place in the attractiveness of job candidates, followed by Technology & development, Customer Support and Electrical & Power Engineering.

Table IV presents the most demanded positions in IT. The most attractive positions are IT Architect, Systems Engineer and Software Engineer. Due to the fact that IT is now the most attractive segment for employers, it can be said that these positions are also the most attractive on the Slovak labor market as a whole.

TABLE IV.
POSITIONS AT WHICH CVs RECEIVED LARGEST NUMBER OF VIEWS FROM RECRUITERS IN THE FIRST THREE QUARTERS IN 2017

Market segment	Labor Market as a whole
IT Architect	13.8
Systems Engineer	10.8
Software Engineer	10.6
IT Project Manager	10.2
Programmer	10.2
Database Analyst	10,1
User Experience Expert	9.8
IT Security Specialist	9.8
IT Analyst	9.8
IT Consultant	9.7
Systems Administrator	8.7

C. Regional differences

From the regional point of view, the largest number of opportunities in IT are located in Bratislava region, which is followed by Košice and Žilina region. The gap between the capital and other regions of Slovakia is very large. The size of the market in other regions of Slovakia is considerably smaller. Table V presents the number of published job advertisements for the first three quarters of 2017 in each of 8 Slovak regions and compares this number with the situation from the previous year.

Table VI compares the availability of candidates measured by average number of job applications to job advertisements. Regions with largest number of job opportunities are also the regions with the highest shortage of job candidates – job advertisements in Bratislava, Košice and Žilina regions receive on average considerably less job applications than in the rest of Slovakia.

TABLE III.
AVERAGE NUMBER OF CV VIEWS IN THE FIRST THREE MONTH AFTER PUBLICATION IN THE FIRST THREE QUARTERS OF 2017

Market segment	Average number of CV views
Information technology	8.1
Technology & Development	6.5
Customer Support	6.4
Electrical & Power Engineering	6.0
...	
Average for all candidates	4.2
...	
General labour	3.8
Textile, Leather, Apparel Industry	3.8
Agriculture, Food Industry	3.7
Tourism, Gastronomy, Hotel Business	3.6

TABLE V.
NUMBER OF PUBLISHED JOB ADVERTISEMENTS AT PROFESIA FOR THE FIRST THREE QUARTERS OF 2017

Region	Number of published job advertisements
Bratislava region	16 059
Košice region	2 849
Žilina region	1 364
Banská Bystrica region	800
Nitra region	649
Trnava region	587
Trenčín region	563
Prešov region	426

TABLE VI.
AVERAGE NUMBER OF JOB APPLICATION TO JOB ADVERTISEMENTS IN IT FOR THE FIRST THREE QUARTER OF 2017 - REGIONAL COMPARISON

Region	Average number of job applications
Nitra region	10.4
Banská Bystrica region	8.5
Prešov region	7.5
Trenčín region	7.1
Trnava region	6.8
Košice region	6.2
Žilina region	6.0
Bratislava region	4.2

How does it look like with mobility of job candidates in IT across Slovak regions? We present the results based on the sample of 3 249 CVs created in the first three quarters of 2017 in which job candidates expressed an interest to work at least at one position belonging to IT area. Job candidates in their CVs can fill both their place of residence as well as regions where they are looking for employment. By comparing these two types of information, it is possible to evaluate what percentage of job candidates would like to work in each region of Slovakia depending on their region of residence.

Table VII focuses on willingness of job candidates to relocate to the capital city (e.g. to Bratislava region). It compares the proportions of job candidates with their residence in each of 8 Slovak regions who expressed willingness to work in Bratislava region.

The further is the place of residence from the capital city, the lower is also the proportion of job candidates willing to relocate there. Almost all job candidates living in Bratislava are also looking for employment there. The largest share of candidates willing to relocate to the capital was observed in Trnava region where more than two thirds of candidates are willing to work in Bratislava (this is very likely caused by geographical proximity of Trnava region to Bratislava). The lowest share of job candidates willing to relocate to Bratislava have the candidates living in Košice region. Very low proportion in case of Košice region is caused not only by large geographical distance from Bratislava but also due to the fact that Košice is a region with a lot of IT opportunities. Interestingly, Prešov region which is similarly far from Bratislava as Košice region has much larger proportion of candidates willing to relocate to the capital city (33.4%). This difference is very likely caused by low number of job opportunities in this region. Regions with the largest number of job opportunities in IT are also regions where the lowest share of job candidates indicate their preference to work in Bratislava region.

Table VIII shows the willingness of job candidates to relocate to Košice region which is currently the region with the second largest number of job opportunities in IT area. These results are very different from the results for Bratislava region.

TABLE VII.
SHARE OF JOB CANDIDATES IN IT WILLING TO RELOCATE TO BRATISLAVA REGION DEPENDING ON REGION OF THEIR RESIDENCE

Region of residence	Share of candidates with preference to work in Bratislava region
Bratislava region	98.7%
Trnava region	67.8%
Nitra region	50.3%
Banská Bystrica region	35.1%
Trenčín region	34.5%
Prešov region	33.4%
Žilina region	30.7%
Košice region	13.3%

In case of Košice region, slightly lower proportion of job candidates who have their residence in this region also want to look for a job there (almost 92%). However, the proportion of job candidates from other regions of Slovakia who are willing to relocate to Košice region are very small (less than 5%). The only exception if Prešov region – 44% of job candidates in IT with residence in Prešov region indicated that they are looking for a job in Košice region. The reasons for this is geographical proximity and larger number of job opportunities in Košice region in comparison to Prešov region. For job candidates in other regions of Slovakia, work in Košice region is quite unattractive.

Table IX shows for each 8 Slovak regions the proportions of job candidates with residence in these regions who want to stay there (i.e. they would like to remain working in their region of residence). It is possible to see that job candidates have a tendency to remain in those regions where there is large number of job opportunities (Bratislava, Košice and Žilina regions). On the contrary, job candidates have a low tendency to remain in those regions where the unemployment rate is high and the number of available vacancies is very low (e.g. Prešov region and Banská Bystrica region). The low proportion of job candidates in case of Trnava region can be explained by its geographical proximity to Bratislava region.

TABLE VIII.
SHARE OF JOB CANDIDATES IN IT WILLING TO RELOCATE TO KOŠICE REGION DEPENDING ON REGION OF THEIR RESIDENCE

Region of residence	Share of candidates with preference to work in Košice region
Košice region	91.8%
Prešov region	44.0%
Banská Bystrica region	4.9%
Žilina region	3.7%
Trenčín region	1.7%
Bratislava region	1.3%
Nitra region	1.2%
Trnava region	1.0%

TABLE IX.
SHARE OF JOB CANDIDATES IN IT WILLING TO WORK IN
THEIR OWN REGION OF RESIDENCE

Region of residence	Share of job candidates willing to work in region of their residence
Bratislava region	98.7%
Košice region	91.8%
Žilina region	79.1%
Nitra region	74.5%
Trenčín region	74.4%
Banská Bystrica region	73.1%
Trnava region	70.6%
Prešov region	62.7%

III.   BEHAVIOR OF JOB CANDIDATES IN IT AT PROFESIA

This chapter focuses on selected aspects of behavior of job candidates at the job portal. We examine how many job advertisements job candidates view and to how many job advertisements they apply within their field. We compare these results also with other market segments.

Table X shows the average number of views and average number of job applications per job candidate (these numbers reflect only job advertisements in the same market segment). The results are based on the sample of logged users of the website who viewed at least one job advertisement in selected market segments in the first three quarters of 2017. The table compares the activity of job candidates in IT with TOP 10 fields in terms of number of published job advertisements at Profesia.

Administration and Commerce are two areas where job candidates on average view and also apply to the largest number of job advertisements as they search for a job at the website. IT is on 7th place in the average number of views and on sixth place in the average number of job applications per candidate. This suggests that job candidates in IT do not have to view or apply to so many job advertisements as candidates in other areas to finish their job search.

TABLE X.
AVERAGE NUMBER OF JOB ADVERTISEMENT VIEWS AND
JOB APPLICATIONS PER JOB CANDIDATE IN SELECTED
LABOR MARKET SEGMENTS (VIEWS AND JOB APPLICATIONS
ONLY WITHIN THESE SEGMENTS)

Market segment	Average number of job advertisement views per candidate	Average number of job applications per candidate
Administration	27.3	6.5
Commerce	22.7	6.3
Transport & Logistics	17.6	4.5
Management	15.9	4.8
Industrial production	15.0	4.2
Economy & Finance	14.3	3.8
Information technology	12.0	4.1
Banking	8.1	2.9
Mechanical Engineering	8.9	3.0
Tourism & Gastronomy	8.9	3.6

TABLE XI.
SHARE OF JOB CANDIDATES IN DEPENDING ON HOW MANY
JOB APPLICATIONS THEY SENT TO POSITIONS IN IT IN FIRST
THREE QUARTERS OF 2017

Average number of sent job applications to positions in IT	Proportion of job candidates
1	58%
2	16%
3-5	14%
6-10	6%
11-20	3%
More than 20	2%

Table XI provides a detailed look on the average number of job applications of job candidates in IT. It displays the proportions of logged users depending on how many job applications they sent in the first three quarters of 2017 (we consider only job applications to job advertisements in IT area). The analyzed sample of logged users of the webpage contains only those users who reacted to at least one job advertisement in IT area.

A large majority of job candidates who reacted to at least one job advertisement in IT sent only one job application in the first three quarters in 2017. Only each 10th candidate sent more than 5 job applications. This suggests that job search of candidates in IT is not very intensive. It is very likely caused by the fact that a majority of job candidates in IT who look for a job at Profesia are employed and they are only occasionally looking for exceptional job offers which would be better than their current job. They do not send many job applications.

So far we considered numbers of views and job applications of candidates within the same market segment. However, do job candidates in IT look for a job strictly within their field? Or are they also willing to work in other areas? Table XII shows TOP 10 market segments to which job candidates who applied to at least one position in IT also applied (segments are listed in decreasing order of importance).

TABLE XII.
TOP 10 MOST COMMON MARKETS SEGMENTS WHERE JOB
CANDIDATES IN IT ALSO APPLIED

TOP 10 segments
Commerce
Administration
Management
Economy & Finance
Transport & Logistics
Marketing and PR
Customer Support
Banking
Mechanical Engineering
Telecommunications

IV. FINANCIAL AND NON-FINANCIAL REMUNERATION IN IT

This section provides an overview of the situation in salaries and provision of non-financial benefits in IT in the first three quarters of 2017. We utilize the data from salary survery at the website www.platy.sk.

A. Salaries in IT

Table XIV shows the average monthly brutto salaries in TOP 5 and BOTTOM 5 labor market segments in terms of average salary. The area of Information technology is the third best paid market segment right after Top Management and Management and average salary in this field is much above the average wage level in Slovakia (944 EUR in the second quarter of 2017). An average employee in IT in 2017 earned 1 706 EUR.

Table XIV presents regional differences in average salaries. The highest salary is currently in Bratislava region. The difference between Bratislava and other regions is very large. The second largest salary is earned by employees in Košice region. The differences between other regions are smaller and the lowest average salary is in Prešov region.

Average salary in IT increases very quickly with years of working experience. An employee with 3-5 years of previous working experience in IT earns on average 1 782 EUR which is by 37% more than employee with less than one year of experience (1 301 EUR). Table XV compares this differences between IT and selected other segments (those segments where the difference between the two groups of employees is the largest as well as with segments where it is the lowest).

The largest increase of salary depending on previous working experience was observed in case of Telecommunications and Law & Legislation. In these two segments, those with 3-5 years of experience earn more than 50% higher salaries than those with less than one year of experience. IT with its 37% difference is right behind these two fields and is at the 3rd place among all market segments, followed by Banking (35%) and Marketing (31%). On the other hand, there are segments where the difference between experienced and junior workers is very small.

TABLE XIV.
AVERAGE MONTHLY BRUTTO SALARIES IN SELECTED MARKET SEGMENTS IN THE FIRST THREE QUARTERS OF 2017

Market segment	Average monthly brutto salary in EUR
Top Management	3 058
Management	1 728
Information Technology	1 706
Telecommunications	1 501
Banking	1 301
…	…
Administration	864
Education, Science & Research	847
Service Industries	778
Tourism & Gastronomy	761
Textile Industry	606

TABLE XIV.
REGIONAL DIFFERENCES IN AVERAGE SALARIES IN FIRST THREE QUARTERS OF 2017

Region	Average total brutto salary in IT (EUR)
Bratislava region	1 890
Košice region	1 484
Žilina region	1 384
Trnava region	1 370
Trenčín region	1 335
Banská Bystrica region	1 298
Nitra region	1 294
Prešov region	1 240

TABLE XV.
COMPARISON OF AVERAGE SALARIES IN EUR BETWEEN EMPLOYEES WITH LESS THAN 1 YEAR OF EXPERIENCE AND 3-5 YEARS OF EXPERIENCE IN THE FIELD

Market segment	Working experience < 1 year	Working experience 3-5 years	% Difference
Telecommunications	967	1 565	62%
Law & Legislation	898	1 393	55%
Information Technology	1 301	1 782	37%
Banking	1 045	1 413	35%
Marketing	1 094	1 428	31%
…	…	…	…
Customer Support	1 032	1 137	10%
Tourism & Gastronomy	687	748	9%
Transport, Logistics	839	900	7%
Translating, interpreting	1 040	1 079	4%
General labour	570	570	0%

B. Provision of non-financial benefits in IT

Table XVI presents the percentages of respondents from the salary survey at platy.sk who indicated that their employer provides them with selected non-financial benefits. The most commonly provided benefits by employers in IT are: company events, home office and free drinks at the workplace. In comparison to 2012, these are also the benefits with the largest increase in the extent they are provided. It can be said that the provision of non-financial benefits by employers in Slovakia improved it the period between 2012 and 2017.

Table XVII compares the proportions of respondents who indicated that their employer does not provide them with any non-financial benefit. Situation in IT is considerably better than in other market segments: only 14% of respondents in the survey said they are without any non-financial benefits. Only a few other segments can match this result (e.g. Insurance, Banking, Telecommunications and Top Management).

TABLE XVI.
PERCENTAGES OF RESPONDENTS WHO INDICATED THAT THEIR EMPLOYER PROVIDES THEM WITH SELECTED NON-FINANCIAL BENEFITS

Non/financial benefit	2017	2012
Company events	51%	15%
Home office	46%	28%
Free beverages (tea, coffee, mineral water,..)	42%	31%
Laptop for personal use	32%	35%
Mobile phone for private use	27%	28%
Sick days	25%	16%
Additional days of holiday	21%	16%
Company contributions to pension savings	14%	14%
Above-standard health care	9%	7%
Reimbursement of commuting costs	5%	6%
Contribution to added health insurance	5%	3%
Car for private use	4%	5%

TABLE XVII.
PERCENTAGES OF RESPONDENTS WHO INDICATED THAT THEIR EMPLOYER DOES NOT PROVIDE THEM WITH ANY NON-FINANCIAL BENEFITS

Market segment	Share of respondents without any benefit
General labour	58%
Textile industry	55%
Services	47%
Tourism & Gastronomy	37%
Agriculture, Food Industry	36%
…	...
Information Technology	14%
Insurance	14%
Telecommunications	12%
Banking	11%
Top Management	11%

V. CONCLUSION

This paper came up with selected findings about the situation on the labor market in the area of Information technology in Slovakia. We focused on trends in labor demand and labor supply and various aspects of behavior of job candidates. We also looked at salaries and provision of non-financial benefits in the field. It can be concluded that IT is one of the labor market segments with the most favorable situation for job candidates. On the other hand, employers in this field face a problem with low availability of workforce and have to compete very hard for the scarce talent.

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Data, Information and Technology services for Research and Management of Science

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Abstract—Science in inherently connected with data. Data are a crucial entity during whole life cycle of research activities: they are inevitable as an input to research, they are produced as a research output - which serve as an input for further research, they are present in the analyzing and evaluation of the research etc. Nowadays, data science offers new possibilities of storing, sharing, analyzing and processing huge amount of data and to generate, derive new, more accurate and more complex information about all research areas. In the past and still today sharing of scientific data was a real bottleneck. Concept of open data and new IT technology development such as cloud, next generation networks etc. offer possible solutions of this problem. In this contribution we discuss and suggest an architecture for implementation of an ecosystem of storing, sharing, analyzing and processing of research data including data for management of science. The architecture supposes sharing of data not only using a central storage, but it is understood as a bridge or an "open market" of scientific and research data, dealing with issues such as reusability, durability, possible use in the future - storing a snapshot of today world for future generation of researchers in a decentralized way. A crucial issue, which is enabled by new technologies is quality and high accessibility of data, which enables to speed up the research process. The architecture also covers social and economic concepts to ensure the sustainability of the whole research ecosystem, which we consider as a necessary condition of the realization of open data concept. As a use case, we will show an outlook of the ecosystem for research and management of science in Slovakia. The use case includes further development of systems for storing of research and scientific data running at CVTI, Slovak Center of Scientific and Technical Information.

I. Introduction

Science can principally be understood as a process of information and knowledge mining from data a and previously gathered information and knowledge. Thus, data, information and knowledge create an input of the process of scientific exploration. They are a necessary condition to perform research activities. A lot of today research results as well as recent scientific development was enabled by availability of data from the different periods of past. Well known examples includes Darwins's evolution theory, geological history of Earth, which together enable to reconstruct the history of life on Earth. The data samples of the same kind from different points of the time axis are often crucial for the particular research. A lot of the data from the past used in today research were not recognized as useful in the time of their origin. There is no surprise that data have been recognized as the commodity with a multiple utilization value in the knowledge based society. The same data can be used in different research areas and with different purpose, even those which are not known by the data recording. From the point of view of the knowledge based society data belongs to the most important heritage of the human kind, because of science as an accelerator of the knowledge based society. It follows the commitment of the society to devote the data attention corresponding to their importance, including suitable infrastructure for storing, sharing, analyzing and processing all the data, which are used or can be used in any future research. As a side effect, the data can be used for more accurate evaluation of research and more effective distribution of resources.

The necessary infrastructure, single processes of data retrieval, platforms for storing, sharing and processing data, processes of research evaluation, schemes for distributing resources for research etc. [1] cannot be treated separately, but should be investigated as a *ecosystem*.

Such ecosystem must deal with different aspects of data, including size, quality, availability (social aspects such a as type of access, e.g. open access) accessibility (including technical aspects such as speed etc.), format of data, durability, etc.

In this paper we try to outline a set of requirements and an architecture of such ecosystem, which we call Science Data

Ecosystem, shortly SDE. We also present illustrative examples of scenarios and use cases. As a use case, we will show an outlook of the ecosystem for research and management of science in Slovakia. The use case includes further development of systems for storing of research and scientific data running at CVTI, Slovak Center of Scientific and Technical Information [2].

II. Scientific Data Ecosystem

The proposed ecosystem has to work with possibly huge amount of data. An ambition of SDE is not the gather data itself, but it has to enable any researcher to insert the scientific data, information and knowledge, collected during the research, to SDE. The architecture of SDE has to be cloud-based. Here, by cloud-based architecture we mean that a user can insert data themselves to an existing network of SDE nodes or by adding a node running by the user with the stored data to the network of SDE. Thus, SDE includes as a set of possibly distributed nodes storing data, creating together SDE repositories. In order to add a node to a distributed cloud-based SDE, requirements on durable accessibility and security of the node has to be satisfied. The processes defining how to add or remove a node from/to the repository should be defined, including licensing of the data, as well as processes specifying how to deal with data by removing a node (Can they be copied to another node, which is not run by the original node?) etc.

At the same time SDE has to enable to any researcher to access the data inserted to repositories by other researchers. Here, the concept of the open access plays a crucial role. The effective concepts must guarantee sustainability of the system. The suggested concept of SDE for sustainability should satisfy:

- if data, information and knowledge stored in SDE is used for a non-profit scientific research in order to achieve the data, information and knowledge that are proposed to be inserted to the SDE, then the data, information and knowledge stored in SDE are free open accessible;
- if data, information and knowledge stored in SDE is used in order to achieve the data, information and knowledge that are not proposed to be inserted to the SDE, then a fee should be paid to cover SDE operation and further development;
- if data, information and knowledge stored in SDE is used for a profit, then the data, information and knowledge stored in SDE are open accessible, but a part of the revenue should be return back to cover SDE operation and further development;

Thus, behind the main aim, which is to store the data, SDE is about data sharing. In the past and even today sharing of data is a real bottleneck. Open data concept and technology development such as cloud, next generation networks etc. provide necessary tools in order to build an infrastructure for data sharing. Data sharing is not only about repositories, but it should be understood as an "open market" of scientific and research data, which enables reusability and possible use in the

future, storing a snapshot of today world for future generation of researchers.

In order to achieve the first two main goals, to store and to share the data, one has to build data *repositories* and *indexes* of the data stored in the repositories. Although technically repositories and indexes can create a unit, conceptually we propose to make a logical difference between them, with the repositories understood as a tool to store the data and the data indexes understood as a tool to store references to data and metadata about the data. The third main goal of SDE is to offer researchers the tools for data *analytics*. Over this three main building blocks - *repositories*, *indexes* and *analytics* one can build the *services*.

One of the first information systems, which can be understood as a design pattern for SDE is a web search engine, such as Google. A web search engine can actually be understood as a Web Pages Data Ecosytem over Web. It stores copies of crawled web pages in its own repositories, but the servers, where original web pages actually are stored can be understood as external distributed repositories too. A search engine builds an index including references to crawled web pages, web graph including references between crawled web pages. Analytics include functions which compute the rank of each web page, it may contain also other kinds of functions computing for example number of clicks from the search engine page to a web page, ratio between number of appearances and clicks for a web page etc. The core of a search engine is an index over expressions (words, phrases) found in crawled web pages. Finally, the main service over a search engine, namely the search itself is build up over the web page repositories, indexes and analytics, providing for given input search phrase the list of web pages containing the searched phrase, ordered by importance or relevance computed by analytics.

III. Repositories of Scientific Data

There is a lot of literature about data repositories [3], [4], [5], [6], [7], [8], with many different definitions, some of them including technical details, implementation details etc. For the purpose of this paper, we understand *scientific data repositories as possibly distributed information systems which store the scientific data*. The purpose of the data repositories is on one hand to archive the data and on the other hand to enable access to data in order to share them, to analyze them etc. We propose to distinguish two logical parts of repositories, namely *archives* and *operational storages*.

Physically, archives can have different layers or be of a different technical nature. Nevertheless, their common role is to store the data for a long term period and to satisfy the durability. The function of the archives is to restore the data after a physical medium is out of date, to transform the data into an actual data format if the data format is out of date, to keep and actualize the software and hardware tools needed to write and read data etc.

The role of operational storages is to keep the data, which are actually manipulated because of some service request. Here the services are the basic services such as to insert the new

data returning the reference for indexing, to offer data to a user based on a request using an index service, to analyze the data using analytics and further services build over the basic services.

For example, if a service requesting the insert of new data is called, then the data should be put into operational storage of the repository, the service is called that write the data into archives and return the reference to the data in the archive to the operational storage which is over the archives. The reference is stored in an index over the repository.

If a service requesting a data searched via an index by a user is obtained, then the operational storage is calling its own service reading the data from appropriate archive and loading the data to the operational storage. The data from operational storage are then accessible to the user for further actions (analytics, copying etc.).

The main requirement to archives is to satisfy durability of data and reliability. On the other hand, the main requirement to operational storages is to satisfy fast access. Together, the repositories have to satisfy durability and availability of data. With the huge amount of data expected, not all the data have to necessarily be in an operational storage all the time, but there should be a service, that all the data can be loaded to the operational storage upon request in reasonable time and stored for a requested period of time necessary to perform the actions over the data.

There are many other important issues, which have to be solved by repositories, such as data formats, degree of redundancy to satisfy reliability etc., but go beyond the scope of this paper because of the page limitation.

IV. Indexes and Metadata

Indexes and metadata are crucial for the operation of SDE. We understand indexes as information systems, which store information about data stored in repositories, mainly reference to the location (in which repository and where in the repository are the stored data). Indexes are the key component for searching and finding the data. Once the indexes are lost, the data still exist in repositories but cannot be easily found.

The main problem of indexing scientific data is to choose what should be the information about the data, which is stored in the index as indices[1]. We call this information stored in an index as *metadata*. Briefly, metadata contain information about stored data, which mostly in a structured form describe the content of data. Very simplified, the metadata form the search phrases (search filters), according which one can search for the data.

There has to be made a conceptual distinction between searching *for* data according to the phrases over the *values of metadata* and between searching *in* data according to the phrases over the *values of data* itself.

The main operation function build over an index is to return the references to the data according to a search query over the

values of metadata. However, intelligent searching should also support search queries over the values of data too.

Let us illustrate the functionality of indexes on a typical and well known example of an index, namely the index of scientific publications. Imagine one has build repositories of scientific publications - a digital library. An index build over such a repository should at least contain the metadata about the publications stored in the repository, such as the title, authors, publisher, year of publishing, number of pages and key words. The index should not only be a list of metadata about publications, with the possibility to filter the entries in the list according to search queries over metadata, but it should also contain the references (links, pointers) to the places, where the publications are physically stored. After a search filter is returning the list of the publications satisfying the search query, it should be possible to request the publication itself (for example via a link for downloading). Moreover, an intelligent search should also enable to search not only over the publications over metadata, but should enable also searching any phrase in the fulltext of publications. Thus, for example, it should not only return all the publications of some author, but it also should be able to return those publication of an author (metadata value) that contain in fulltext a phrase (data value not contained in metadata).

In the SDE of the future, such repositories and intelligent indexes should be build for any kind of data in any format, including scientific data from experiments with metadata about the methods, how the data are gathered, types of measurment devices etc., with possible intelligent search over metadata values and data values. An example may be an indexed repository of unstructured data such as videos or pictures with searching not only according to metadata, but also according to scenes or persons appearing in the videos, which are able to return e.g. videos or pictures containing a specified object. The methods for such intelligent search can already be understood as a subject of analytics.

In Figure 1 and Figure 2 we illustrate an example of a simplified workflow process of the SDE indexed repository functionality as a Petri net. By internal storage/archive we mean the storage/archive of a user, which produces the data, while by external storage/archive we mean the storage/archive which does not belong to data producer. In order to make this paper self-contained, in the following paragraphs we briefly recall the basic definition of Petri nets, which are one of the most used tools for modeling workflow processes [9], [10], [11]. Using Petri nets one can easily formalize functional requirements on SDE on an abstract and yet formal level.

V. Petri nets

Let $\mathbb{N}$ denote the *nonnegative integers*.

Definition 1 (Petri net). *A Petri net N is a quadruple $N = (P, T, I, O, m_0)$, where P is a set of* places*, T is a set of* transitions *such that $P \cap T = \emptyset$, $I : P \times T \to \mathbb{N}$ is an* input function*, $O : P \times T \to \mathbb{N}$ is an* output function*, and $m_0 : P \to \mathbb{N}$ is an* initial marking *of N.*

---

[1]In order to make a clear distinction, we use plural *indexes* to denote several index information systems and plural *indices* to denote several entries in an index
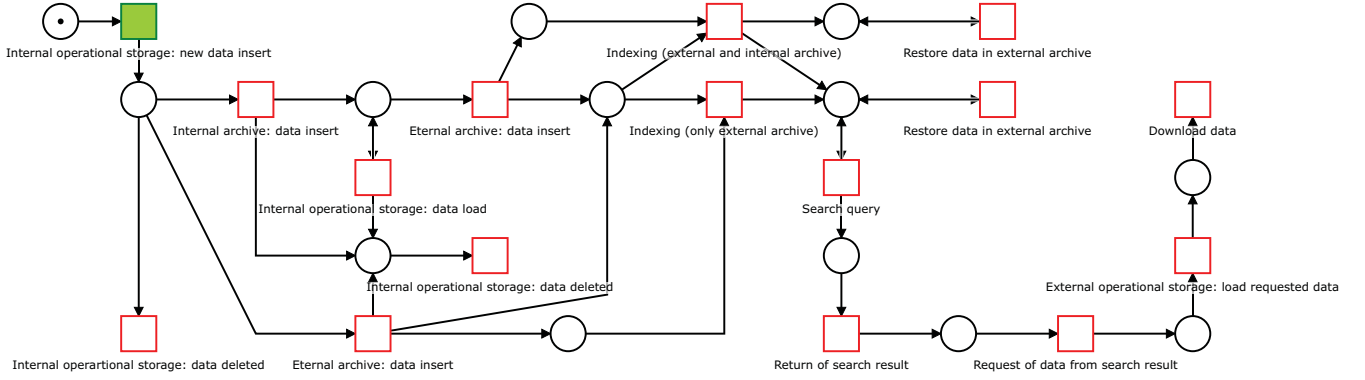
Fig. 1. A Petri net model of an example of a simplified process of the SDE indexed repository functionality.
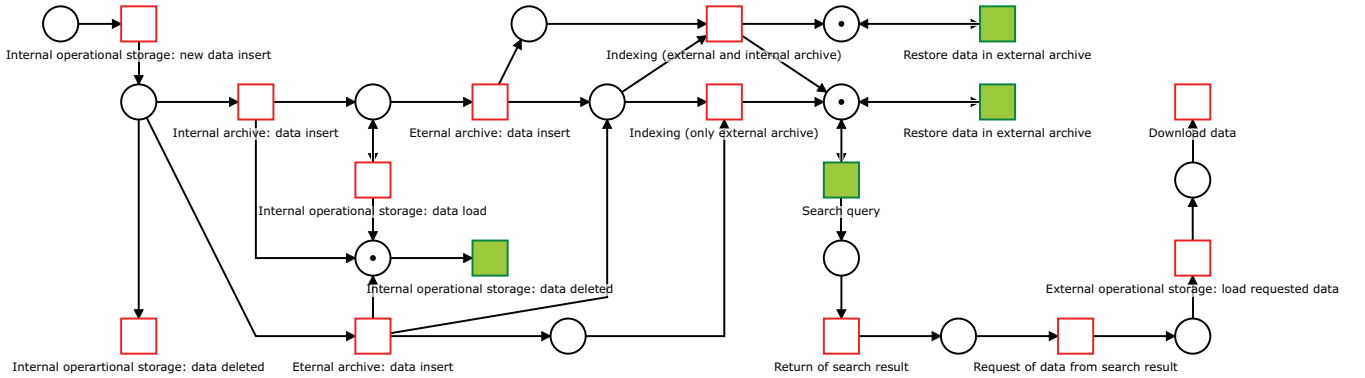
Fig. 2. A Petri net model of an example of a simplified process of the SDE indexed repository functionality after storing data in both internal and external archive and after indexing.

A transition $t \in \mathbb{N}$ is *enabled to fire in a marking* $m : P \rightarrow \mathbb{N}$ if $\forall p \in P : m(p) \geq I(p, t)$. Firing of an enabled t in a marking m causes the chage of the marking m to the marking m' satisfying $m'(p) = m(p) - I(p, t) + O(t, p)$ for each place $p \in P$.

Places are graphically expressed by circles, transitions by rectangles, non-zero elements of input function by integer weighted arcs from corresponding places to transitions and non-zero elements of output function by integer weighted arcs from corresponding transitions to places. Markings are expressed by corresponding number of black tokens inside of places. Those transitions, which are enabled to fire are filled in Figures with green color, while transitions not enabled to fire are drawn by red color and unfilled.

Intuitively, firing of a transition consumes the number of tokens given by the input functions from places and produces the number of tokens given by the itput function in places. A transition can fire, if a marking contains enough tokens to be consumed.

VI. TOOLS FOR ANALYTICS

Let us recall the example of a search engine over web, which we use as a design pattern for SDE. The main factor of a success of search engines, such as for example Google, was that it returned the most relevant web pages containing the search phrase as the results. In the case of Google, behind this success was the well known page rank algorithm [12], that associated a rank to each crawled web page. Roughly speaking, according to [12] the page rank of a web page, say *a* was a number given by the sum of a dumping factor (representing a probability that one starts to browse at the web page *a*) and contributions from all web pages, which contain a link to the web page *a*. A web page with rank *r*, which contains a link to *n* other web pages, contributes to the rank of those web pages by *r* divided by *n* which can be interpeted in such a way that a web page propagates its rank, i.e. its *importance*, by dividing its rank by the number of referenced web pages [12]. For the purpose of this paper we understand algorithms such as the page rank from [12] to be functions or tools for analytics. Thus, in analogy to microservice oriented architecture the tools for analytics are losely coupled microservices (such as the page rank algorithm) over which services (such as the rank based search) are build.

More common and more obvious methods and tools for analytics are standard methods of statistics, different methods of data classification, different methods based on artificial intelligence, machine learning, deep machine learning / neural network based methods, methods of scientific computing, which can offer microservices over which services such as intelligent search or any other service leading to knowledge

mining are build.

Naturally, the most obvious use of tools for analytics is to get new research results over scientific data in repositories creating new knowledge (for example proving a correlation between data).

However, tools for analytics can also be used to evaluate research results. Rather than going into details and a complete list of the methods and tools for analytics, let us discuss one more example, which will illustrate how even very simple analytics can bring more accurate results in evaluation of a publication impact. As an example, consider the current system, how the financial resources for scientific publications are granted to public universities in Slovak republic [13]: a university is granted by *the same* amount of financial resources for a paper in a journal indexed in Current Content Connect Database [14] in computer science, metallurgy and ecology. This is still a relict of the past, where not enough data were available to state the *price* of such a paper by relation to average, median or maximal number of papers published per researcher more precisely, distinguishing between fields and even sub-fields.

Another example is evaluation based on impact factor of a journal, which should be used to predict the expected number of citations for a paper. However, after a period of time, a normalized value according to the year of publication and the field should give a more precise impact of the paper [15]. One can for example apply page rank algorithm on a graph with published papers instead of web pages and cited references instead of links between web pages [16]. Other attributes, such as number of views and number of downloads can be used to evaluate the impact of publications as well.

By these examples we want to demonstrate, that having enough data (for example about publications) and good tools for analytics, one can get more precise and more accurate results even in evaluation of science.

VII. SERVICE LAYER

The service layer of SDE should enable to assembly services over data stored in repositories, over metadata stored in indexes and over tools of analytics. The proposed architecture of SDE supposes that functionality of repositories, indexes and tools of analytics is implemented according to microservice oriented architecture, providing that these microservices can be composed and causally ordered to workflow processes resulting in services which can include complex reports over data and metadata. It should include the specification and modelling language, which will enable to specify workflow, data and microservices which should be used and roles and user management properties for the composed service. The specification language should also enable to specify logical appearance of user interface.

The service layer with the help of tools for analytics, indexes and repositories should enable an intelligent search. Such an intelligent search should take into account not only what is searched but also who is searching and for what purpose. Thus, for different needs and the same searched phrase the results

might be different. It depends whether the same keywords are searched by a user writing his diploma thesis or by a user writing a new original research paper. For the first user, the most relevant results could be the survey papers, while for the second user these could be the most recent results from the subject containing the keywords. It means that quality of data, for example quality of scientific publications depends on a use case. We can distinguish different dimensions of quality, such as originality, state of the art, educational dimension, pioneering (founding) dimension. Clearly, different methods of data science and different systems can be used to evaluate the quality of publications, such as antiplagiarism system to detect duplicate content, citation indexes to detect the impact of the paper etc.

VIII. USE CASE

As a use case, we will show an outlook of the ecosystem for research and management of science in Slovakia. The use case includes further development of systems for storing of research and scientific data running at CVTI, Slovak Center of Scientific and Technical Information [2]. The comprehensive description of the state-of-the-art at CVTI can be found in the paper [17] in this proceedings.

The further development of the existing systems should start with the analysis w.r.t. the SDE architecture resulting in the categorization of single systems. For each system a detailed plan of development has to be made in order to extend the system according to the processes and functionality stated by SDE architecture. The integration layer should be added. The tools for analytics, which are not yet the part of the CVTI infrastructure should be build according to microservice oriented architecture. Use cases have to be defined in detailed level. Based on the use cases, the concrete services for the service layer should be assembled.

Now, let us illustrate these steps on particular systems operated by CVTI.

The key information systems at CVTI are/will be:

- Repositories (SCIDAP - Scientific Data Analysis Platform)
- Open Access Publication Platform (planned)
- Modul for Management of Research Data SVD (planned)
- Current Research Information System SK CRIS
- Analytics for Evaluation of Science (planned)

From the SDE point of view, SCIDAP and its further development as planned by CVTI fulfills the repository definition, including possible integration of institutional repositories not operated by CVTI.

Open Access Publication Platform should mainly fulfill a definition of an index linked with published journal and books. It will enable to store links between the publications and scientific data. It also has a functionality of a tool for analytics and a service layer as it should enable to insert data (to publish publications), and to search.

Modul for Management of Research Data SVD should be a modul for planning of research projects and for inserting the research project data into SCIDAP repositories. It should also

have the function of an index over the scientific data from projects in SCIDAP (including the index of datasets).

Current Research Information System SK CRIS should serve for registration and searching of researchers, institutions and projects itself in order to create research teams and to get an overview of research projects. It mainly fulfil a definition of an index.

Analytics Modul for Evaluation of Science should offer tools for analytics and a service layer for evaluation of results of research and scientific institutions. It should serve accreditation committee, evaluators, grant agencies, evaluated organizations, governing bodies, but also private public partnership and even industry and public (e.g. students) to evaluate the research results for different purposes, including distribution of financial resources to scientific institutions and universities (from the state, grant agencies, by endowment etc.). It will be integrated with SCIDAP repositories and will enable scientometric analysis and will offer different rankings of scientific institutions and universities. These rankings and evaluations should be available online. Thus, the complicated accreditation of universities from the past should be replaced by an automatic and continuous evaluation and ranking by this module.

There are other information systems, operated by CVTI, which should be extended and integrated into SDE. Most important of them are:

- The Central Registry of Publications Activity CREPC
- The Central Registry of Artistic Activity CREUC
- The Central Registry of Theses and Dissertations CRZP
- System for plagiarism detection ANTIPLAG.

The Central Registry of Publications Activity CREPC and the Central Registry of Artistic Activity CREUC are nowadays lists of publications, but do not contain the links to all publications from these lists. Thus, they have not full functionality of indexes. They should be extended to full indexes and connected with SCIDAP and repositories of publishers originally publishing the publications.

The Central Registry of Theses and Dissertations CRZP (CRZP) is a repository with an index offering a tool for searching. It will be integrated with SCIDAP.

System for plagiarism detection ANTIPLAG will be integrated with SCIDAP repositories. It has a functionality of a tool for analytics.

Another functionally important modules of information systems operated by CVTI are: Integration layer, Presentation platform (portal) and Integrated System of Services. They together create the main part of the service layer of SDE. Their functionality should include single sign-on access of users, intelligent searching using a common user interface, central user management, autentification and access control of users of SDE.

As it was already mentioned, the whole architecture of SDE operated by CVTI will be based on microservice oriented architecture.

CVTI operated SDE contains also Databases of third parties EIZ, which contain third party indexes such as Scopus, Elec-

tronic Resources Management System ERMs, which contain a database of prepaid information resources of third parties, and a search engine PRIMO. The search engine should be extended in order to offer not only fulltext search, but an intelligent search over as many different types of scientific data as can be stored in repositories.

CONCLUSION

This paper discusses a concept of an architecture for an ecosystem for collecting, storing, sharing and analyzing scientific data in order to get new information and knowledge in research as well as more accurate information for evaluation and management of science. The concept is illustrated on simple examples and the application of the ecosystem architecture is outlined for information systems operated by Slovak Center of Scientific and Technical Information CVTI or information systems, which are planned to be build by Slovak Center of Scientific and Technical Information CVTI.

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Dimensional Unit as an Aid in Students Identification

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Abstract— **The aim of this paper is the proposal of the solution that is to enable identification of students based on their height and facial dimensions of specific face elements. Analysis of approaches that allow estimation of the height from the image is presented. Following the analysis, the experimental software solution is developed and consisted of two applications. The first enables the estimation of the height of a person standing in front of a video camera. Final prototype of the solution utilizes the technique of background subtraction from the foreground with the aim to separate of the object of interest. The ArUco marker is used as a reference object to allow exact height estimates. The second application follows the detection of a face and extracts the distance ratio among specific features of a face.**

Keywords— ArUco markers; Background subtraction; Haar classifiers; person identification

I. INTRODUCTION

One of the five senses is the sight. People can perceive surrounding world using the organ of sight, i.e. eyes [1]. There is no problem to recognize and describe objects in environment where the person is located, providing the person has a good sight. Also, there should be no issues in recognizing the people in the picture, define the count of humans in the picture or define how they felt. But how can it be done using a computer and its vision?

The research in computer vision area began in 1970s. Various milestones were set beginning from its origin up to the present times. Today, we have a lot of applications that are able to explore the real 3D objects and allow computer scientists and technicians to handle created object using computer device. Many applications allow to create a model of object from pictures where different views of object are captured. Some applications are able to recognize human in image and can identify the person based on acquired information. Despite countless successes in area of computer vision, this area provides an opportunity for enthusiasts, who can contribute to this research by own effort.

The goal of presented research is the development of software solutions that will allow recognition of the students during the lectures of exercises. Further, these are to allow to extract the parts of the face, determine their dimensions and the distance between them. All the extracted information may then serve as input to the larger system for the recognition.

II. ANALYSIS OF EXISTING SOLUTIONS

Many tools for recognition of person in the image exist, also many accompanying parameters can be extracted. Scientists BenAbdelkader and Yacoob in their research [2] focused on the estimation of the height of person in the image created by uncalibrated camera. Known facts from the anthropometry for estimation of person height is utilized. The estimation process relies on the person present in the image, who is standing straight in front of camera. Then well visible and defined canonical points are determined. These points divide person figure into *n* segments. Every distance between two canonical points represents one anthropometric property. From these distances 39 ratios is created, from which the estimate height is calculated.

Authors of the research [3] focus on the estimation of height of objects in image. They utilize minimum amount of geometric information that can be obtained from image. Images are created using uncalibrated cameras, hence no camera parameters are available for processing of height estimation. For the estimation of object height, the vanishing line of reference plane and vanishing point of reference direction have to be extractable from the image. Authors processed primarily the images that contain a lot of planes and parallel lines. When estimating the height of the object in image, the authors relies on three types of measurement, which are closely described geometrically and algebraically:

- measurement of the distance and hence the height of the object between reference plane and any other plane, which is parallel to the to the reference plane,

- measurements on these parallel planes,

- establishment of the camera position with respect to reference plane and reference point.

Next method, which is utilized for the estimation of the height of object in image depends on acquired camera parameters. The authors of research introduced in [4] formulate the basic assumptions: the person has to stand straight, stand on the ground and the camera is to be placed parallel to the ground. The first step for the height estimation is determination the distance of object from camera. For this step, the view angle which is measured to the bottom part of object (the feet of the person) in the image has to be determined, then the altitude of the camera from the floor and the orientation of its optical axis is required. Considering the ideal conditions, it is possible to calculate the height of object in the image by the detected distance and view angle according to the highest recognized point of object.

III. PROPOSAL OF SOLUTION FOR PERSON AND FACE DETECTION

The principal goal is the development of a solution for identification of person in the image. The overall solution presumes development of two experimental software solutions. The first is aimed to detected student in the image with subsequent estimation of height of detected object in the units of length and the role of the second solution is the face detection in

the image with calculation of ratios of distances between facial landmarks.

Following the analysis of various frameworks, the OpenCV library [5][7] is to be used in the experimental implementation. This library is open source computer vision library, mainly used for an image processing. It started at Intel in 1998 and currently is available under the BSD open source license. Today, the library provides the tools for image processing and high-level algorithms required for face detection, pedestrian detection, tracking objects in videos, object identification or camera calibration. The great advantage of this library is its broad documentation and the support of community. It is a multi-platform library and can be used in combination with different languages, various libraries or frameworks.

A. Solution for Person Detection

The prerequisite for the correct recognition of person in front of camera is to acquire two input images - one, which does not contain the person, i.e. background, and another one that actually contains the person, the one we want to estimate the height. In order to achieve this premise, it is necessary to ensure that the camera will be fixed at the one place permanently without any movement throughout running of whole program. It is also useful to have manageable light conditions to reduce the occurrence of undesirable effects such as shadow. These can have the impact on the accuracy of the height estimation.

The next prerequisite is the presence of reference object with known dimension in the image. Such object allows to calculate the real height to the 1 pixel in the image, according to the formula (1), which we will be also applied in the formula (2) to calculate the estimated height of the person,

$$pm = h_{rop} / h_{ros} \qquad (1)$$

where h_{rop} is the height of reference object in pixels and the h_{ros} is the real height of reference object. The calculation of the estimated height of person will be realized according to the formula (2). The height is calculated as a ratio of the height of person in pixels and the value of the real height calculated to the 1 pixel in the image.

$$h_o = h_{op} / pm \qquad 2$$

Reference object has to be located in one plane with the person we measure. This represents another premise that improves the height estimation. The ideal situation is, if the reference object is located directly on the person. The other premise is that a reference object must be easily recognizable on the person by shape and color.

B. Solution for Face Detection and Facial Distances Estimation

The input to the experimental solution is in form of image that contains the face of a person. The prerequisite to the good face detection and detection of all facial landmarks to capture the face directly while looking straight into the camera lens. All the elements of the face (eyes, mouth, nose) should be clearly recognizable in the image for the best possible detection of elements and subsequent calculation of the distances between the elements. The following distances were selected for calculation of distances:

- between eyes,
- right eye and nose,
- right eye and mouth,
- left eye and nose,
- left eye and mouth,
- nose and mouth.

The distance between the eyes is taken as the unit, reference, distance. To this distance will be compared all other calculated distances between facial features and so the ratios of distances between the elements of the face will gained.

IV. EXPERIMENTAL IMPLEMENTATION

Previously we stated that two experimental software solutions are implemented as a part of this research. The first application is aimed to recognize the person in the image while the subsequent step is to estimate the height of the recognized person. The role of the second proposed solution lies in the face detection while subsequently having determined the ratios of distances between the elements of face.

A. Solution for Detection of Person

The solution runs in the real time and the camera is being the basic element of the entire application. Images are captured by the application using the camera device once the initialization process is completed. The captured image represents the input image to the system that is as well used as the input for detection of person and detection of reference object. The camera was calibrated prior to the deployment of camera device to the system. Thus, the components of the application contain the camera parameters. These very parameters remove the distortion of the input image and thus improve the calculation of the estimated height.

The estimation of the height of the person in the image utilizes the reference object with known dimension. This object is placed in front of the camera and is placed directly on the person throughout the estimation process of height. For this very purpose, the ArUco marker with dimensions of 100x100 millimeters was used as the reference object. The ArUco model from OpenCV library is utilized for detection of ArUco marker. This module provides functions that allow detection of the reference object in the image. The result of the detection of marker is a vector, which contains coordinates of 4 corner points. These points define the boundary box around the reference object. Bounding box and a reference object ID are displayed around the reference object in the application output to show the correct detection of a reference object. Based on the obtained coordinates of points, we calculate the height of the reference object in pixels. Then, simply through division of the object's height in pixels and the actual object's height we obtain a pixel metric, a real-world height value calculated to 1 pixel.

Another important component of the solution is detection of person in the image. Two approaches were deployed. The first one relies on histogram of oriented gradients (HOG) and support vector machine (SVM). This approach allows detection of person, however requires high time detection requirements that are undesirable effect in real-time applications. The second

drawback of this approach is too large bounding box around the detected person, which has had a negative impact on determining the height of the person in the image.

Bearing in mind just stated also another option is implemented in the prototype version of the application, i.e. the background subtraction. In this approach, the first captured image represents the background. Every other captured image is a foreground. Then the foreground and the background are subtracted. It means that the value of each pixel in the foreground image is subtracted from the value of pixel in the background image at the same position in the image. This step distinguishes the object located in front of the camera. Both images, the foreground and the background, are transformed to the HLS color space before subtraction, with which the objects in front of the camera were better recognized.

The results of this approach are coordinates of 4 points, defining the bounding box around the resolved object, in our case the person in front of the camera. The estimation of height is based on calculating the height of the person in pixels and the calculated pixel metric. Through the division of the height of person in pixels and the pixel metric we obtain the estimated height of person in real length. The last step in the solution is to provide visual output of the calculated height in the application's graphical interface (see Fig. 1**Fig. 2**).

Fig. 1 The output of the first application with estimated height

B. Solution for Face Detection and Extraction of Facial Dimensions

The input of part of solution presents the image that contains a face. The face along with its facial landmarks must be displayed directly as if it were looking into the lens of the camera. To face detection is utilized using Haar Classifiers. The basis of the whole application is the object of the CascadeClassifier class. Using this object the face detection is performed and the input image for detection of facial elements is obtained.

Once the successful face detection is carried out, we can detect face elements. In this step the Flandmark library is deployed. Similarly to OpenCV, it is an open source library and its task is the detection of facial landmarks [6]. Using this library, we get the coordinates of eight points that represent facial landmarks. Calculation of the distance between the elements is achieved only through the information of one point that represent one facial landmark. Two points represent each of

facial elements. Therefore, we create only one point from these two points that will represent an element. This point is calculated as a midpoint between points that represent the element, the nose being an exception. In this case, we use one of the two points that are used for its representation. Subsequently, the distances between facial elements and the ratios between individual facial landmarks are calculated. The last step in the application is to display calculated values in the graphical interface (see Fig. 2).
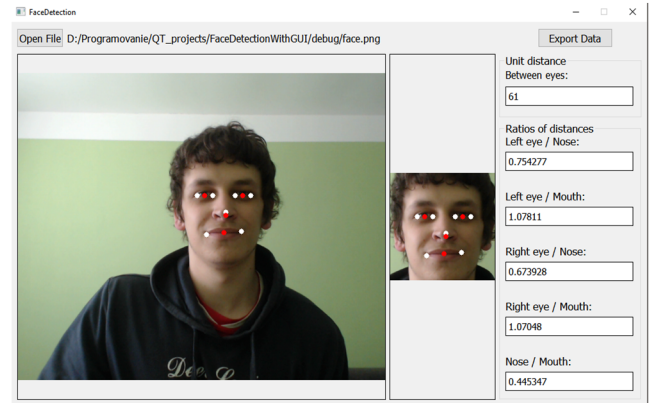
Fig. 2 The output of the second application with calculated ratios

V. Experimental Testing

The prototypes of both parts of the research were experimentally tested. Testing was carried out on a sample of various respondents. Both solution help in soft identification of the person based on the height of the person and the distance between facial elements.

A. Detection of Person

The prototype of the software solution aimed on the estimation of the height of the person in front of camera was experimentally implemented. The application was tested on a set of 17 respondents. The measured values of both the actual and the estimated height are summarized in the Tab. 1.

	Actual height [mm]	Measured height [mm]
1	1810	1809,5
2	1680	1671,83
3	1630	1614,41
4	1620	1600,58
5	1840	1853,68
6	1890	1910,65
7	1850	1871,31
8	1660	1658,42
9	1770	1784,31
10	1770	1772,01
11	1730	1711,01
12	1680	1700,63
13	1720	1711,21
14	1580	1581,99
15	1830	1819
16	1890	1872,15
17	1660	1681,68

Tab. 1 Table that contain actual and measured values of height

From the data presented in the table, the average measurement deviation is 12.83 millimeters. The highest person

whose was estimated to 1890 millimeters and the lowest person to 1580 millimeters. The testing procedure yielded that the most accurate results of the estimated height were achieved when the person was still in front of the camera at a distance when the height of the reference object was approximately 17.8 pixels. Testing took place in the room under controlled lighting conditions.

Goal of the implementation was to limit the impact of undesirable factors. Throughout the testing of solution, we encountered several factors that influenced the accuracy of the measurement or detection of a subject in front of the camera. The first issue is the detection of the reference object itself. Inaccuracies in calculating the estimated height can caused by imperfect detection of the reference object, resulting of this phenomenon is incorrectly calculating the real height to 1 pixel and thus an incorrect estimation the height of the person. Lighting conditions in front of the camera are the second most serious problem with used method. Person who is standing in front of the camera can cast a shadow that is then a part of the detected person. Thus, the bounding box around the person can get larger and introduce deviation of values.

B. Face Detection and Estimation of Facial Distances

The prototype of the second software solution focuses on the calculation distances and ratios of the distances of facial elements. This was tested on a set of 14 images where the face of the person was captured. The common features of all the input images were that the human face was at different distances from the camera while the person in front of the camera was looking directly into the camera lens.

	Eyes	Left eye/ Nose	Left eye / Mouth	Right eye / Nose	Right eye / Mouth	Nose / Mouth
1	43,1856	31,1448	51,4782	34,8281	55,5428	24
	100	72,1185	119,2022	80,6475	128,6142	55,5741
2	98	84,6463	116,778	79,8812	116,778	40,1995
	100	86,3738	119,1612	81,5114	119,16122	41,0199
3	64	47,4236	83,672	47,4236	81,3449	41,1096
	100	74,0994	130,7375	74,0994	127,1014	64,2338
4	66	52,8015	76,9415	54,037	74,3236	26,3059
	100	80,0023	116,5781	81,8742	112,6115	39,8574
5	92,7793	84,22	114,49	78,8733	110,145	35,2278
	100	90,7745	123,4004	85,0117	118,7172	37,9695
6	68,0661	56,3028	81,0274	57,4891	79,1581	27,074
	100	82,7178	119,03826	84,4607	116,2959	39,7760
7	54,0833	46,0652	66,1287	50,3289	66,6483	21,095
	100	85,1745	122,2719	93,0581	123,2327	39,0046
8	47,0425	37,2022	54,7814	37,5366	55,9464	21,095
	100	79,0821	116,4509	79,7929	118,9273	44,8424
9	46	35,4683	52,8015	35,4683	53,6656	21,0238
	100	77,105	114,7858	77,105	116,6643	45,7039
10	33	22,0227	38,4838	21,2603	38,9102	21,0238
	100	66,7354	116,6175	64,4251	117,9096	63,7084
11	39,0128	25,4558	46,2385	28,3196	49,1935	25,02
	100	65,24986	118,5213	72,5905	126,0957	64,1327
12	48,5077	38,2884	59,2368	42,72	67,2309	26,1725
	100	78,9326	112,1183	88,0684	138,598	53,9553
13	68	55,9017	73,8241	46,6154	72,8972	27,6586
	100	82,2083	108,5648	68,552	107,2017	40,674
14	66,0681	50,2096	71,5891	49,8197	73,3485	27,0185
	100	75,9967	108,3565	75,406	111,0195	40,8949

Tab. 2 Table of measured values from second tested application

The Tab. **2** contains the values as measured by the application and the recalculated values of the distances, which were created by multiplying the measured distance by the coefficient *k*. We calculated this coefficient according to relation, where 100 is the

value in pixels to which all the distances between the eyes were recalculated to achieve better comparison, and *dbe* is the measured distance between the eyes.

$$k = 100 / dbe \qquad (3)$$

Following the values as shown in the Tab. **2** we can conclude that the method for identification of persons based on the distance between face elements is not very reliable. Testing has shown that the result of the method may be caused by inaccurate detection of facial elements. This can be result of inadequately opened eyes, shadow in the area of the face element, or rotation the face in two different photos at the same or different distance from the camera.

VI. CONCLUSION

In this paper, the solution for identification of student based on the specific dimensions of human body, i.e. the height of person and distance ratios of facial elements, was introduced. The experimental implementation of two software solutions was described. The detection of person located in front of camera is primarily based on background subtraction technique, having the detected person marked by the bounding box as the result of the process. Height estimation utilizes ArUco markers as a reference object with known dimensions. Thus, introducing the reference height to the image. Height of person and reference object in pixels were used as the inputs to calculate the estimated height of person. Input for second part of proposed solution is the image with captured face. The application detects the face and its selected facial elements. Ratios of the distances between the face elements are calculated based on obtained distances of facial features. Both of just described solutions prototypes allow detection of both, person, or face. Experimental testing proves usability of the first application prototype and achieves results having the deviation of the measurement of 12,83 millimeter. Further, testing showed that second application is not very suitable for the identification of the person. The success ratio of the used method is only 20% in case where the face was captured in different distance from camera. Enhanced results were achieved when face of the same person was detected in the same distance from camera. The success was 40% in this case.

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Changes in human resources in education sector and its institutions in Slovak Republic

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Abstract—**Education and its quality is an important qualitative parameter of labor force level of given country. Changing situation in learning techniques and study approaches may change also the need for employed teachers, lecturers. For instance, flipped class-rooms can require more teachers. This backdrop was a motivation for observing changes in human resources in education sector that is being modernized every year. This paper provides reader with empirical data on employment in sector of tertiary education in regions of Slovak Republic. Results confirm the agglomeration effect that also occurs in artistic sector due to spillovers.**

I. INTRODUCTION

Unlike the traditional view of the economics, which has been linked to productivity and economic growth, nowadays attention is mainly drawn to the development of modern technologies, services and the knowledge economy.

The world is developing at a rapid pace in fields of nanotechnology, energy and energy, air transport and technology, communications technology, information technology, and, last but not least, biotechnology. These are sectors that spin the world around and the world economics as well [10].

Knowledge and information can leak from one company to another, through suppliers, consultants, former employees or reassembling and assembling of the product. The value chain is therefore widely used across various sectors of local and international companies.

In the last decades, numerous studies have examined the economic impact of diverse actions such as sports events [2, 5], large-scale cultural projects [30], and industrial sectors [13]. Interesting examples of supply chain optimization using the value chain can also be found on the example of airlines [34], agriculture [29,12] or educational institutions [35].

This paper has focused on tertiary education institutions as representatives of higher education institutions, which, like other sectors, are a form of organization and, as business or institutions, are embedded in a particular environment.

In further text terms such as tertiary education institutions, universities are meant to be identical subjects that provide university / tertiary / education. These terms are used in the context of the analyzed problem and in accordance with a way these terms are used also in the OECD, EU or Slovak Republic.

It has been widely recognised that universities generate a wide range of benefits with impacts on the economy, society, and their nation's cultural life [11, 15]. It can be stated that universities are influenced by many external and internal factors on daily basis.

We are conscious that a narrow economic focus on the 'impact' of higher education is partial and incomplete. The social, personal, and cultural benefits both economic and other of a thriving and effective higher education system are not amenable to easy metrification and are not captured here.

The paper`s main focus was emphasizing the importance and quality of human resources in tertiary education institutions. In our opinion, tertiary education is of utmost importance for the growth of human capital as a source of knowledge society. There is a highly qualified workforce in it, without which the development of a knowledge-based society is not possible. Regional policy should focus on the quality of human resources in the region and pay particular attention to the regional education system, which should ensure the availability of education for everybody who is interested in it.

The article represents partial and selected results of the research project VEGA 1/0961/16 that is focused on the application of theme specified as follows: "Economic Implications and Perspectives of the Participation of Slovak Republic in the Process of Production activities Fragmentation within Global value Chains".

Main goal of paper is to find out if there are changes in employment location quotients in regions of Slovak Republic in the time span of eight years. The reason for searching those data was to find some evidence for either increasing or decreasing the number of employees because of the introducing new technologies or / and new pedagogic approaches such as flipped classroom approach. Regarding this it was also intriguing to see linage between education and other sectors.

The following tasks were designed to achieve the stated goal:

– carry out a theoretical analysis of the development of human potential and define its importance in tertiary education;

– research the regional contexts of the development of human potential and to identify its importance in advancing the social and economic development of the Slovak Republic regions.

II. HUMAN RESOURCES IN EDUCATION SECTOR AND ITS QUALITY

This paper concentrates more on human resources in quantitative perspective; however the link to the quality is being made by change of technology and teaching approaches. These are found in description of a situation that follows in particular for Slovak Republic as well as in general.

A. General description of situation in tertial education in Slovak Republic

One factor influencing the implementation of the region's development program is the relationship of actors involved. The main actors in the region, whose activity may effect the attractiveness of the region, its potential and development include tertiary education institutions (universities), enterprises, state administration and self-government institutions, and third sector organizations.

Over the last few decades, the tertiary education in Slovakia has experienced a considerable expansion, with the pace of change significantly increasing since 1989. There are currently 40 universities in the SR, of which 20 are public universities, 3 are state universities, 12 private universities and 5 foreign universities [23]. This is a disproportionate amount for Slovakia. It is rather a lot, because according to the European Association of Universities ("EUA") it is optimal to have 4-5 universities for 5 million people. Hungary (with double population) has fewer universities than Slovakia. Austria has less of them, too. The capacity of Slovakia is simply not enough for such a number of universities. With the increase in the number of universities, their quality is naturally also decreasing. In Slovakia there are universities that are at the level of a higher European standard, but there are also universities that are below it.

When applying the Porter Model of the Value Framework, we find that the activities of the tertiary education institution influence and are influenced by many institutions and entities within the overall value framework of the learning process. These include entities such as publishers, development and authoring tools vendors, portal integrators, enterprise education systems, and more. Each of these organizations is established within the model at some points in the value framework to maximize their profit while minimizing their costs. In this context, the importance of human capital is emphasized. Qualified human resources are irreplaceable in the process of creating and transferring knowledge that we perceive as a requirement for a long-term sustainable economic development [25].

The set of activities linked to science and research is determined by the number and structure of highly educated professionals who have required competencies in terms of knowledge and development of the world trends in individual disciplines, in terms of introducing new technologies, increasing the competitiveness of the economy and deciding on the allocation of investment resources.

Human capital is a subset of intellectual capital, which together with financial capital forms the market value of an enterprise. Intellectual capital, according to OECD [24], is the economic value of two classes of intangible assets of the company, namely:

1. organizational (structural) capital (Social Capital),

2. Human Capital.

Human capital relates to the education, knowledge and skills that an individual acquires in the process of education and training. Thus it human capital is output from tertiary education sector. At the same time, the importance of universities as actors directly involved in innovation processes of companies is growing, whereby the greatest flow of knowledge is through the mobility of human capital, meaning education invested to employees.

The entire value chain of knowledge / information flows is shown in Figure 1 [6].
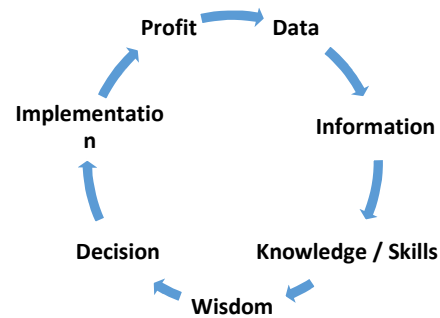
Figure 1 Value chain of the knowledge process
Source: own processing based on

People cannot be commanded to share knowledge, but we can manage an environment in which knowledge can be created, discovered, captured, shared, extracted, verified, transmitted, received, edited, and applied. And that is the role of corporate culture that eliminates barriers to sharing (technological barriers, business processes, human behavior) to make knowledge flow freely and to use meaningfully information to implement the strategy. The data and information need to be verified and trusted and put into context. [4]

B. Education sector in perspective of science and art

To educate and to be educated is an art where cooperation with client is of great importance. It is actually a picture that some teacher is painting into students' mind, perhaps later on also to the soul and heart. Painting such an educational picture also needs a very good canvas. Some masters used to have their special methods of how to prepare it. Thus even before education itself starts one has to have a preparation of getting all necessary tools. The thing is that students must have a willingness and trust to let somebody paint into their minds. This analogy was inspired by Andersson [1], who states that artists benefit from agglomeration economies at least as much as scientists and other occupational groups. As [1] states it is primary metropolitan statistical areas where artist are clustering and so it applies to education. However, in Slovak Republic there are exceptions to this rule. In this situation than one can doubt the quality of such art or education for the knowledge spillovers are more likely to happen in agglomerations.

While location economics is concerned with agglomeration within an industry the urbanization one is concerned with agglomeration across the industries. Occurrence of agglomeration regions can be evident from spatial Gini measure of agglomeration compared to data of

employment that provide indirect evidence of agglomeration. Although skilled labor dispersion does not help to explain agglomeration differences systematically. [26, 28] Larsson [18] distinguishes between "mid-ranged regions" and "urban regions". This paper also analyzes regions and one of them is urban region, i.e. Bratislava the capital city of Slovak Republic. The other three regions do have cities, but can be rather understood as mid-range regions. This paper focuses on labour market aspect of agglomeration.

C. Questions and motivations

Modern School of the 21st Century is teaching through tablets, e-learning and digitization of the curriculum at universities. Today's students simply need modern school and change the form of communication and study itself. Today it should be taken into account the lifestyle of the so-called "generation Millennials, which follows Generation X (sometimes referred to as the "generation of MTV") [14, 32].

This means having an instant online access to educational content, sharing, commenting, adding digital content, taking advantage of interactive presentation of the lesson, or direct communication with experts, from abroad or from experience.

However, any modern form, be it a computer, tablet, virtual reality, etc., is just a learning aid. Decisive factors are the person of the teacher and the learning content. Everything else is just a tool. It should be borne in mind that modern information technology puts much greater demands on the content and quality of teacher training for a lesson. We are inclined to the idea that the importance of these two factors is growing. Rather, we need to strike a balance between the digital and human approach.

Some examples: Flipped class-rooms [19] are newer techniques in learning and teaching. These activities allow both lectures to be viewed before class in some distance region and class-room activities to be performed in one place be it urban region or place of a choice. In this change of pedagogical approach also change of number of employees would be reasonable. While for direct instruction that was provided to a group only one teacher or lecturer was sufficient, the dynamic interactive learning of group of students is more demanding either on skills or simply manpower. This is approved by a first-hand experience in teaching at Technical University of Košice, Faculty of Economics; Quantitative Microeconomics with experiments of game theory throughout three years.

At least one administrator is need for helping out with experiments. Knowledge intensive sectors tend to outsource and externalize activities contrary to vertical integration present in other sectors. Would this apply to education sector as well? Some evidence on sources and destinations can be found by analyzing employment as a source of education activities. Destinations are regions and their inhabitants, who migrate to acquire positive spillovers of knowledge.

III. METHODOLOGY OF CHANGES DESCRIPTION AND MEASURMENTS

In general, interregional smaller scale of researching the production activities dates back to 1951 to Isard model (IRIO – interregional input-output model), which in 1953 was sketched as "balanced regional model" by Leontief.

The shift in two years was also in label, instead of using interregional, Leontief model refers to international input-output model. This was accompanied by "Chenery-Moses model", i.e. multiregional input-output model – MRIO.

The basic analysis of input-output models may apply the regional supply proportion p_i^r. It is used to show direct input coefficients in the regions. Thus the differences among regions are noticeable by plugging in data on total regional output x, export e and import m for industry i and region r as is shown in (1) in [22]:

$$p_i^r = \frac{x_i^r - e_i^r}{x_i^r - e_i^r + m_i^r} \qquad (1)$$

Formula (1) leads to regional input coefficient matrix estimated as $A^{rr} = \hat{p}A^n$, where p "hat" (estimator) is a column unit vector of regional supply proportions for all sectors i in the region r. It denotes diagonal matrix of technical coefficients either regional or national ones.

Following the basic version of input-output model (2):

$$x = Ax + y = (1 - A)^{-1}y \qquad (2)$$

we can apply location quotient (LQ) into coefficient matrix. We use the location quotient as an indirect way of measuring the output and expressing the values for input output tables in [6, 7]. To be precise we apply here the Cross Industry location quotient – CILQ (3):

$$CILQ_{ij} = \frac{SLQ_i}{SLQ_j} = \frac{RE_i/NE_i}{RE_j/NE_j} \qquad (3)$$

where "RE_i denotes regional employment (or output) in supplying sector i and NE_i denotes the corresponding national figure. " in [8].

Consumption of each sector concentrates on inputs for instance labor in [16, 20, 27, 31, 33], which is the subject of small-scale analysis. Even the disaggregation for smaller units, regions or counties can avoid bias [3]. An example of cluster analysis that is a possible outcome of use of location quotients in tourism sector of Slovak Republic was done by Gajdová [9].

Following empirical evidence could had been accompanied by an Ordinary Least Squares (OLS) regression[17]

$$LQ_{sj} = a_0 + a_1 LQ_{mi} \qquad (4)$$

A relevant parameter is a_1 for if it is positive it indicates that there is co-location of manufacturing sector (LQ_{mi}) and intermediate producer service sector (LQ_{sj}). Another possible combination of the local quotient method could be the Quadrant method by [21]. This method is easy to implement by clustering sectors into four groups: growing (where LQ is greater than one, above the threshold of 1.25, the sector is exporting), emerging (where LQ is less or equal to one, above threshold of 0.75, the sector is importing), transforming sectors (to distinguish them from growing sector these are sectors that are not competitive) and declining sectors. The latter mentioned follow-up method was applied here bearing in mind that another perspective is available.

IV. HYPOTHESIS AND FINDINGS REGARDING QUOTIENTS

Analysis of human resources in education sector has been done for NUTS 2 regions of Slovakia. Table I. shows the names of relevant regions, their population and population density.

TABLE I.
REGIONS OF SLOVAKIA

NUTS 2 regions	Population	Population Density (persons per km2)
SK01 Bratislava Region	625 167	300
SK02 Western Slovakia	1 866 500	120
SK03 Central Slovakia	1 350 600	83
SK04 Eastern Slovakia	1 587 300	100

[a] Source: Own elaboration based on data retrieved from Eurostat, 2016

First hypothesis (H1): *Ratio of employed in sector of education has not changed during the course of observed years in individual regions has.*

Results based on data in Table 2 as well as in Fig. 2 provide some insight to situation of time span 2009-2016 in regions. The situation was relatively stable. The least divergence was in ratio of employed persons in education sector for Eastern Slovakia region, where values of SLQ were ranging in 28.3%-29.5%.

Table 2 shows proportion of the number of employees in education sector in particular region and number of employees in education sector in the Slovak Republic overall. Equationused is numerator from (3):

$$SLQedu = \frac{RE_{edu}}{NE_{edu}} \qquad (5)$$

Eastern Slovakia consists of Prešov and Košice regions. Typical factors for support of regional competitiveness were not developed in sufficient way in the Prešov region. Therefore, this part of Eastern Slovakia is recommended to focus on such factors in order to secure the sustainable economic growth and raise of competitiveness. Košice region can be labeled as region where production is placed and region for the source of raising impacts. This shift from the region as a place of production to a region with label of source of raising impacts can be confirmed by continues fall of ratio of primary and secondary sector and raise of tertiary sector proportion to Gross Domestic Product (GDP). Precisely the primary and secondary sectors are

TABLE II.
PROPORTION OF THE EMPLOYEES IN EDUCATION SECTOR IN PARTICULAR REGION AND EMPLOYEES IN EDUCATION SECTOR IN SLOVAK REPUBLIC IN TOTAL

SLQedu	Bratislava	Western	Central	Eastern
2009	12.6%	31.5%	27.1%	29,00%
2010	16.8%	29.9%	25.3%	28.3%
2011	16.2%	30.6%	23.9%	29.5%
2012	16.3%	31.7%	23.4%	28.7%
2013	16.5%	28.2%	27,00%	28.5%
2014	16.9%	28.4%	26.5%	28.4%
2015	17.2%	28.4%	26,00%	28.6%
2016	17.1%	27.9%	26.7%	28.4%

Source: Own elaboration based on data retrieved from Eurostat, 2016

making up a significant ratio in regions focused on production as a consequence of low production costs.

The highest values of SLQ_{edu} were in Western Slovakia region, where the range was 30%-31% during 2009-2012, subsequently followed a low drop to 27.9% in year 2016. The lowest ratio of employed in the sector in question was recorded in Bratislava region, where the values were around 17% since 2010. The biggest shift in SLQ_{edu} in this region was between years 2009-2010, where SLQ_{edu} has risen by 4.2% from level of 12.6% to level of 16.8%.

Bratislava region with the capital city Bratislava as only one in Slovakia can be labeled as region of knowledge centers. It is characterized by higher density of population and higher sustainable economic growth. The most international companies are localized in Bratislava region and due to better job opportunities it offers to inhabitants, it also attracts sophisticated production that is demanding on highly skilled and educated labor force. Its growth is based on "knowledge". Bratislava region has great potential to keep this position and status for future because it is there, where almost 50% of research and development potential in Slovak Republic is present.

Therefore, it can be concluded that the ratio of employed in educational sector does not changed significantly, apart from one of the significant shift on yearly basis.

Table 3 shows proportion of the number of employees across all sectors in particular region and number of employees across all sectors in the Slovak Republic overall Equation used is numerator from (3):

$$SLQall = \frac{RE_{all}}{NE_{all}} \qquad (6)$$

As one can see, the highest proportionof employed people, approximately 32%, has Western Slovakia. Proportions for other regions are very similar between 21% and 24%.
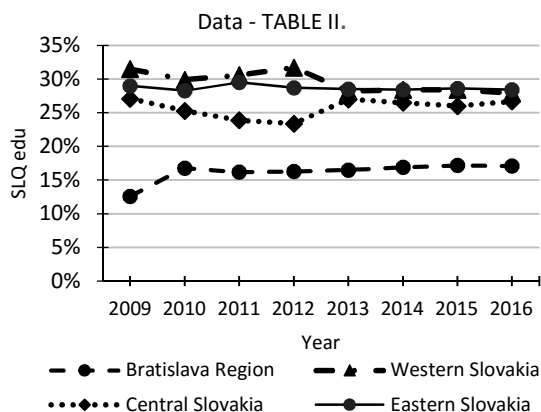

Figure 2. Proportion of the employees in education sector in particular region and employees in education sector in Slovak Republic in total

TABLE III.
PROPORTION OF THE EMPLOYEES IN ALL SECTOR IN PARTICULAR
REGION AND EMPLOYEES IN ALL SECTOR IN SLOVAK REPUBLIC IN
TOTAL

SLQall	Bratislava	Western	Central	Eastern
2009	21.6%	32.5%	22.4%	23.5%
2010	21.8%	32.4%	22.3%	23.6%
2011	21.5%	32.8%	22.1%	23.8%
2012	22.5%	32.5%	21.7%	23.4%
2013	23.4%	32.1%	21.8%	22.8%
2014	23.7%	32.1%	21.7%	22.6%
2015	24.3%	31.9%	21.7%	22.4%
2016	25.4%	31.2%	21.4%	22.1%

Source: Own elaboration based on data retrieved from Eurostat, 2016

Second hypothesis (H2): *Regarding high concentration of industrial companies and financial institutions in Western Slovakia the localization quotient was expected to be lower than 1 for Bratislava region as well as for region of Western Slovakia.*

Table 4 shows location quotients for four Slovak NUTS 2 regions. The formula of location quotient LQ was received from Cross Industry location quotient (3) by comparing the situation in the education sector with the situation across all sectors in Slovakia:

$$LQ = \frac{SLQ_{edu}}{SLQ_{all}} \qquad (7)$$

As seen in table 4 and fig. 3 values of location quotients are the lowest in Bratislava region. This is considered being natural for there is existing high employment in most of the sectors. Contrary in the Central and Eastern Slovakia there exist lower employment in other sectors, however in Eastern Slovakia there is more universities concentrated in cities: Košice and Prešov, where the LQ values are exceeding 1.

The LQ has not almost changed when observing its development in time in Eastern Slovakia. In the course of 2009-2016 the LQ values were 1.22-1.286. Somewhat higher fluctuation of LQ values were noticeable in region

TABLE IV.
LOCATION QUOTIENT

	Bratislava	Western	Central	Eastern
2009	0.584	0.970	1.210	1.235
2010	0.771	0.923	1.135	1.200
2011	0.754	0.933	1.082	1.240
2012	0.725	0.976	1.079	1.227
2013	0.706	0.879	1.239	1.250
2014	0.714	0.885	1.222	1.257
2015	0.708	0.891	1.199	1.277
2016	0.674	0.895	1.248	1.286

Source: Own elaboration based on data retrieved from Eurostat, 2016
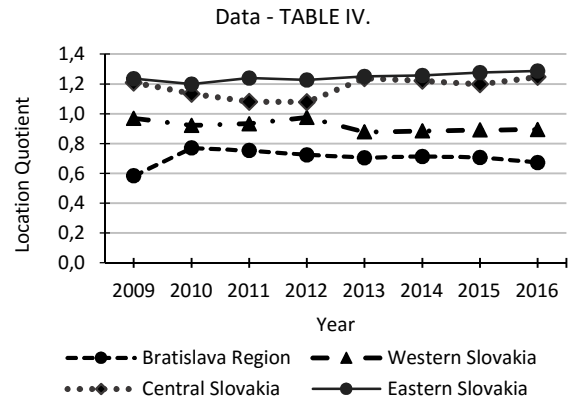
Figure 3.   Location quotient

of Central Slovakia, where the values ranged from 1.079 to 1.248. The biggest changes in LQ were in Bratislava region, where in the time span of 2009-2010 the value of LQ was raising by 0.187 from 0.584 to 0.771. Afterwards this value dropped slightly for the level 0.674 in year 2016.

V.   RECOMMENDATIONS AND CONCLUDING REMARKS

The non-data-driven decision making is usually applied in practice [21]. The same authors were employing the quadrant method as more efficient method for community to manage the sources and its destinations. In our case, the education sector in regions of Central and Eastern Slovakia belongs to growing sectors, moreover Eastern Slovakia can be considered as exporting (from 2013 till now). Education sector in Western Slovakia with LQ between 0.87 and 0.98 can be considered as importing sector. And finally, education sector in Bratislava region belongs to transforming sectors, which is rather surprising. Nevertheless these results are rather confirming the agglomeration effect mentioned above.

Buyer-supplier linkages that input-output analysis usually describes focuses on one underpinning factor such as here employment. Then this model does not portray the complete picture or dynamics of the industry cluster. Therefore, paper provided location quotient and descriptive characteristics of education sector.

Public policy on human resources must create the opportunity for all citizens to continually learn, absorb new information and move from one job to another. The basic step in ensuring Slovakia's long-term competitiveness in the field of human resources is to complete the reform of primary and secondary education with an emphasis on reforming the content of education in order to provide the necessary basic skills and quality for all pupils. At the university level, it is necessary to focus on expanding capacities where labor market requirements require and to significantly improve quality. Most working-age populations will need another injection of knowledge and skills sometime during their lives. For this reason, it is necessary to quickly create an accessible, modular and market-based system of a lifelong learning.

Overall, according to recent results of the KAM (Knowledge Assessment Methodology), Slovakia is significantly weaker, less ready for the transition to the knowledge economy and thus for the process of shifting to

the global value chain as some comparable economies. If the tertiary education sector is to succeed successfully in the globalized competitive environment of an information / knowledge society, it must have a well-developed strategy for information processing / management. A knowledge-based society for the Slovak Republic, irrespective of its future sector priorities, will necessarily require quantitative and qualitative development of the workforce. The results can help representatives of Slovak universities in their work, when establishing new tools to achieve development of qualitative growth of the university environment in the regions of Slovakia. Moreover, the intra-industry transmission of knowledge fostered by education can provide advantage for region in various spillovers.

While the market and competition play a major role in balancing regional differences, the state and local government can intensify the process by creating suitable conditions for enhancing the quality of the university environment even in stagnant regions.

Contribution to the analysis of local quotients in education sector represents an open system and research can be cyclically repeated and developed in coming years. It would create a timeline of the development of important indicators for evaluation and development of the quality of the university environment in the regions.

Research and observation of location quotients has highlighted some weaknesses of the university environment in selected regions in terms of employed staff. It pointed out the transformation in Bratislava region or growing sector`s quality of education, science and research in Central and Eastern Slovakia. The methodology used can be further extended with sketched OLS method. The results can serve the decision-making processes in the development of tertiary education at national and regional level.

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Digital Games in Education and their Development

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Abstract— **As a result of the rapid increase in the access of internet and modern technologies by end-users, there are more and more children getting in touch with them at a very early age. Often this contact is uncontrolled and therefore this phenomenon is considered negative by the society. A great deal of time spent on screens is dedicated to playing digital games on various platforms. Therefore, this paper is focused on digital games, their often overlooked positive effects on children and their possible utilization in the educational process. Technologies which can be applied for the design and implementation of digital games making use of educational components have become important research areas. Thanks to the combination of games and educational elements, pupils can be strongly motivated. The added benefit is thus the increased attractiveness of the curriculum whose understanding is strengthened by pupils in an entertaining form. Our work provides a proposal for an educational portal where it is possible to include a module of educational games with the use of modern technologies.**

Keywords—educational portal; digital game; game modes

I. INTRODUCTION

Education is a process which helps to learn or gain knowledge, skills, habits, opinions and values. It is an extremely important element for the life of all people and this element plays a significant role in the development of the individual but also of the whole society. Through knowledge people can develop their independent thinking, which is the basis of any innovation. Changes are taking place in all areas of life at a current time of rapid technological process and education is no exception. Since the beginning of this millennium there have been many trends in the area of education which are based on new technologies and devices providing several advantages over traditional education. The introduction of digital games into the education process in schools is such a trend.

II. DIGITAL GAMES

In general, games can be divided into three relevant categories with regard to the educational component: a) traditional (non-digital) games used in education; b) digital games used in education; and c) commercial computer games intended for entertainment. These categories provide different ways of how to view games.

In [1] attribute two characteristics to games: rules and competition. The competition can be among the players or against the gaming system itself. However, this type of definition does not provide much space for educational elements. The following categorization can be created from the point of view of the interaction of a participant in the game:

- opponents are required (sports);
- randomness plays an important role (gambling);
- simulations and games of varying perception (roller coaster).

Of course, most games are a combination of the above mentioned types. Suitable games for education are games based on puzzles which do not really fit into these types. In [2] the author focuses on the education part of games more and he defines game as some sport or activity which involves skills, knowledge or randomness where the player keeps established rules and tries to win over an opponent to solve a puzzler or task.

The definitions coming from the designers of commercial games show another perspective. Most of them agree with elements such as representation (fantastic version of reality), interaction (with the game or other players), and conflict or challenge where the consequences of acts do not affect the reality.

In [3] games usable for education are defined as applications which apply the characteristics of computer games for the creation of engaging education experiences with the intention of meeting specified learning goals.

Basic game components can be characterized as rules, competition, challenge, goals, interactions, results, players and game environment, respectively.

The **rules** are a set of limitations and conditions which determine how to play the game. In digital games, these rules are embedded in the game itself directly. Therefore, the player learns on the basis of previous experience which allows him/her to go through the game more smoothly.

The **competition** exists if the goal of the game is to win over the opponents. It may take place in real time or at different times.

The **challenge** consists in the difficulty of particular non-trivial tasks, or the game itself. Difficulty has various levels which determine the effort which needs to be done for the completion of the task. The challenge can take various forms: mental (puzzle), social (negotiation between players) or even physical from (for non-digital games).

The **goals** allow the player to understand the meaning of the game and also determine what (s)he must do to win and complete the game or task. So, as well as competition and challenges, the goals have a motivation purpose.

The **interaction** is understood as the ability of the player to influence the game which keeps changing because of the influence and it gives some feedback that can be used by the player for further gaming.

The **results** relate to the goals of the game, feedback and competition to a certain extent. They allow us to measure the extent to which the player has achieved the goals of the game. An evaluation system allows us to compare the results of the players, which increases the competition.

The **players** are the main element of any game. Games can be categorized based on access to simultaneous play.

The **game environment** is an important element of the game not only from the point of view of its attractiveness. The exploration of the environment is a natural part of the game experience where the player interacts with the elements of the environment – objects, characters, animals, and so on. Some evidence may be the fact that one of the largest game worlds has an area of about 1000 square kilometers. The game environment is also a safe place where the players can experiment without the consequences in the real world [4].

Visual design can be understood as the area of visual material creation so that an experience is created. It is not easy to determine the quality of the visual design in games because some factors which affect it are very subjective.

The quality of the visual design can also depend on the game type. Graphics is not primary in puzzles or adventures while games such as RPGs require graphical quality and realism to create a strong experience.

The target group of players, their age and expectations are important as well. Players who play games in their spare time have bigger expectations. In the case of an educational game, it is important to consider the extent to which attention should be paid to the quality of the visual design. Excessive visual attractiveness may divert attention from the educational component of the game in some cases.

III. THE PEDAGOGY OF DIGITAL GAMES

Digital games often face stigmatization by both the professional and lay public. They are termed a bad influence on children who are violent, asocial, hyperactive or foolish as a result. Nevertheless, there are many studies which confirm the opposite and attribute digital games a positive role not only in adolescence, of course, provided that the playing time is reasonable.

Games, however, can be an appropriate addition to education which provides new technological solutions to long-term problems.

Game-based learning allows presentation of facts interactively and within a certain context instead of the learning of isolated facts.

Gamification is the use of game elements, mechanisms and techniques in a non-gaming context or situation. Due to its versatility, gamification is becoming popular more and more. In [5] authors understands gamification in education as a method which makes use of game mechanisms, aesthetics and game thinking so that people are engaged and motivated to act and thus learning is promoted and problems are solved.

According to Kappa, there are many reasons why to use gamification in education. These following reasons can be included among them:
- creating creativity in the learning process;
- overcoming non-engagement, non-involvement;
- providing opportunities for deeper ideas and reflection;
- positive changes in behavior;
- genuine practice.

Inappropriate reasons for the application of gamification are:
- it is funny;
- everyone does it;
- education will be easy, without further effort;
- everyone loves games and simulations;
- it is easy to create gamification.

IV. RULES OF GAMES SELECTION

The main criteria for choosing a game to be introduced as a part of the lesson usually include catchiness, the ability to entertain and the value of the educational component or its effectiveness. Catchiness is related to its visual and sound design, characters and its story.

However, the catchiness of the game should not have the same importance as its ability to entertain and particularly its ability to educate. These latter two parts together form the main mechanism of the game and the mechanism should be the most important criterion. In educational games there is an academic subject (mathematics, geography, etc.) embedded in this mechanism directly. A major factor is time-consumingness of the game as well.

Games can be divided into two categories based on their time-consumingness: a) short-time games; and b) long-time games. Short-time games sometimes resemble commonly available games for smartphones and often tend to develop one skill. The playing time for this type of game can be only minutes to hours. These games are a good interactive addition to learning which does not often exceed 40 minutes. An example of their use during some lesson can be alternating gaming – the teacher lets some of the children play and this allows her/him to focus her/his attention on children who are not just playing. Long-time games have a more open end than the games of the first type, starting with the simplest and widening over time. This makes it possible to use them during the whole lesson. Some advantage of this type of game is the increased motivation and engagement of pupils which result from long-term goals provided by this format. It also helps develop skills such as critical thinking, collaboration, communication, creativity, and problem solving. Another criterion when choosing a game is its type. These were described in our previous text together with the benefits which they bring [6].

The national survey on the use of digital games among teachers conducted among 513 US primary school teachers has also shown other factors which are critical for the selection of educational games. Many teachers follow the opinions of their colleagues and students but decisive factors are also own experience, the possibilities offered

by the game, other factors such as its cost, evaluation or review and research (Fig. 1). This survey also found out what qualities of the game the teachers valued the most – 55 percent of them said that it was important for them to be able to motivate students having bellow-average results and students in special education. This was followed by: making the learning of groups with mixed abilities easier (24%), students can use the game independently (23%), adaptation is allowed (21%), collaboration among students is supported (21%), content is available without direct instructions (17%) and others [7].
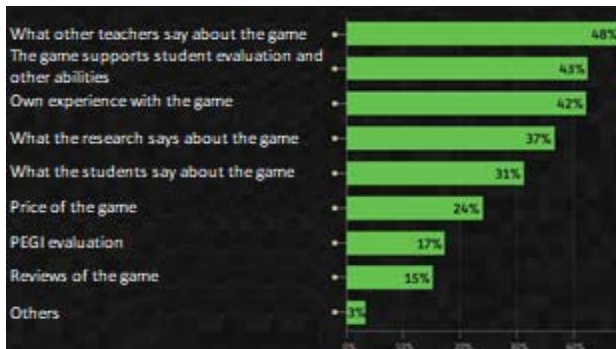
Figure 1.   What are decisive factors among teachers for the selection of games?

Issues

Employing games into a curriculum can bring several issues which the teachers have to deal with. The above mentioned American survey has revealed the 10 biggest issues which can be encountered by teachers willing to use the games in the curriculum.

Lack of time has been marked as the biggest obstacle. However, this issue does not have to be a real issue as it is based on the false assumption that the game reduces time for the education of students. Therefore, it is only necessary to change thinking and start seeing digital games as an add-on which is able to clarify or practice the subject matter in the same way as traditional forms of teaching. Of course, it is necessary to consider what kind of game is appropriate and also realistically deployable in the lesson within a limited time frame.

In fact, these days, there are already enough free educational games which are commonly available on different platforms and devices and lack of technical equipment may be another real obstacle. Luckily, it is already common nowadays that schools have their own computer rooms or interactive boards. In addition, tablets and other mobile devices are becoming popular in schools more and more. So, it can be said that this issue is significantly smaller than in previous periods.

Portals such as graphite.org or educate.org or stores such as Google Play, Apple App Store and Windows Store can provide a solution, however, some limitation is that many of the games there are in English without any Slovak localization. In spite of this, children are able to understand the game mechanism mostly while the educational component of the game is preserved. The assistance given by the teacher is important here as (s)he can explain the

content presented in a foreign language. How big obstacle the language represents depends on the type of the game and its target subject. Other expressed obstacles included emphasis on standardized testing, some uncertainty where to find a good-quality game, the inability to integrate the game into the curriculum, unknowingness of technologies, and lack of administrative and parental support [8].

Harmonization of traditional education and digital games

The traditional form of education is understood as teaching where the pedagogue has the dominant role and is the main source of knowledge. In this scheme the teacher gives instructions about what to do and the students are receivers of information and creators of its meaning most of the time. Modern media do not transfer education on the side of the students and they only serve as providers of information in the same way as the teacher.

There are many ways of how to integrate games into the education of students and a lot of things are dependent on various factors such as the environment and the way of teaching. The way of interaction between the pupils playing a game can be a point of view – the pupils interact fully online or face to face. It is more difficult to put the students into context in online interaction than to have the teacher directly in the room. In the latter case, a pupil can consult the teacher or other classmates more easily when having difficulties with the interface or goal of the game.

When the game is used as a form of homework, it is necessary to explain the game to the students personally immediately at the beginning. However, this form may also provide some degree of anonymity and privacy, which makes the student feel less controlled and more relaxed, which can lead to improved results. Conversely, integration of the game into the lesson gives the teacher greater control over the students and the use of the game. In [9] author says that regardless of the way in which interaction would take place, the education game should not focus on victory but more on working together and achieving group goals.

A one-time use of the game is the simplest model that is especially suitable for introducing a game-based learning to students. This is a one-time use of an education game within one lesson to cover a part of the curriculum.

Multiple use of a game serves as a direct replacement of parts of or several whole lessons. Repeated use allows the teacher to introduce the game better, utilize the time more effectively and include other activities between sessions.

Voluntary gaming consists in the utilization of the game as an additional activity. Mostly, it is about playing after school, so there is no replacement of traditional lessons.

Embedded game is the fourth model which allows the teacher to change the learning process completely. An educational game is embedded in the curriculum of the subject fully and it becomes the main means of teaching. A disadvantage is that the whole subject is dependent on the game and it is more difficult to meet the required educational standards. This model is applicable in the best way at universities where it is possible to create a new course which is based on the use of an educational game as the main means of education.

Online games are another model. It consists in the utilization of an online game as a part of a fully online course. The students play the game synchronously or at different times. However, this model cannot be applied at elementary schools for obvious reasons.

V. IMPLEMENTATION OF A MODULE FOR GAMES

Prior to the implementation of the module of educational games – a prototype with an attractive graphical environment and with the ability to test the players (pupils) during gaming, it was necessary to acquire knowledge related to education and digital games, their types, properties and suitability for utilization in the educational process from professional literature. After the study of the issue, it was necessary to design the module of games itself, its role and deployment in the intelligent educational portal since the module should be closely linked to the other parts of the portal. This module became the practical part of this paper. Another task was the implementation of the module itself, but it was preceded by the necessary choice of appropriate means for its creation. Given that there are a number of suitable and available technologies, it had been necessary to evaluate their properties and make a comparison between them. The selected means (programming language, development environment and other software tools used for the creation of particular components of the module) and the procedures used are described in more detail in the following text. The aim was to create an adaptive module (prototype) which would allow effective testing of the knowledge of children. This module does not serve only for testing, it also acts as a tool for consolidation of obtained knowledge. It is a module that is capable of displaying the content in a form suitable for a digital game. The content means questions and the corresponding answers from different subjects and their categories which are obtained from the database. The module allows to answer two types of questions: a) questions with multiple options; and b) questions which answers have to be written for. All responses are logged and their accuracy is evaluated. The questions which the pupil could not answer or decided not to answer simply are logged as well. The module is embedded in a digital game which acquired an education component due to it. The game was created after the design of a suitable game mechanism and visual part. The process of its creation is described in particular subsections. However, this is not the definitive solution to a rather complex issue, as the aim of the solution is to show the possibilities of introducing educational elements into digital games using modern technologies.

Module

The module of educational games is designed to be deployed in the educational portal, therefore, its design is described in the subsection. A portal of this kind can be divided into several layers (modules) which should work together so that a comprehensive solution is provided: virtual world, educational games and administration interface (see Fig. 2).

Educational portal is the first layer and it serves as the main interface of the whole system. It represents an
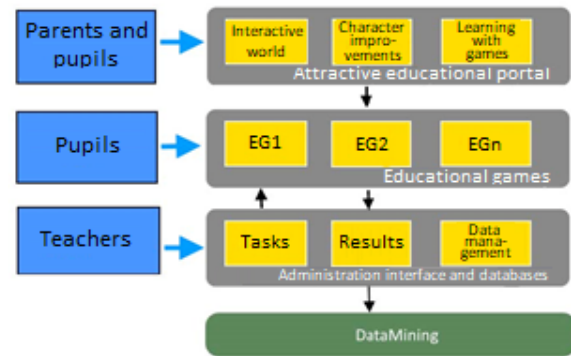
Figure 2. The educational portal with layers

interactive virtual world which allows pupils and teachers to register and sign up. Of course, this portal should provide additional features such as possibilities for its modification or some selection of characters (avatar), some ways of communication among the users, and so on. The main element is an attractive virtual environment which allows the character to be controlled within the world and thus it makes particular educational games available. The results achieved in the games can also be projected onto the environment where the user can keep improving her or his character based on the obtained points, which serves as motivation.

Educational games are the second layer of the system. The aim of this module is to allow the pupils to strengthen their acquired knowledge in a playful way, or to teach them completely new knowledge. The games can be of various types (adventure, platformer, …) with different or the same focus (math, geography, …). Games can also be implemented so that they can be used independently of the subject. However, such universality does not have to be feasible at any game type, and it only applies to game which allow to practice acquired knowledge. An important part of education games is some evaluation system. This determines the correctness of solutions for tasks, when the goals of the game were fulfilled and it rewards the pupils with points, medals or other assessment elements. These can be utilized in the virtual word as it has been mentioned.

Game states

A game can be understood as a process. In general, a process is a sequence of operations, activities or events which have a certain duration and therefore it has its beginning and end. Such perception of games allows to create a more transparent and overall-better structure since the game is divided into smaller logical units (states) which are executed separately. In the Sort dictionary of the Slovak language, state is defined as "an aggregate of properties which are typical of someone, something at some time". It is therefore clear that each state which the game will be in changes its properties and thus it bears responsibility for another part of the game mechanism. Framework Phaser [10] states are supported natively and so fast access to camera, quick cache, to inputs, audio and

more are provided. State Manager is responsible for loading, setting and switching states.

The first defined state in the created game is state Starting (see Fig. 3). Its main task is to start the physical system and then execute state Loading. This state is responsible for retrieving all existing elements of the game – especially pictures and sounds. After they are loaded, the next states start. State Menu displays the desired elements – background picture, buttons, text and possibly it starts music and sounds. Its main task is to give the player the possibility to control the flow of the game which is usually divided into two or more next states here. In this particular case, state Settings and state Playing are there. State Settings contains own graphical elements in reality and allows the player to change the settings of the game related to sound, game mechanism, picture, and so on. Once the settings are saved, the flow of the game returns to state Menu. State Playing is a place where the game logic is processed and other game elements are created and stored. After the game is completed, the flow moves to state Evaluation where achieved results are summarized and displayed. The player can decide here if (s)he moves back to state Menu of the game where state Playing can be accessed or ends the game.

Game mechanism

Game mechanism can be understood as a set of principles which the game works on. They specify how to work with time, space, player tasks, and so on. These rules interact with state Playing directly, and therefore, in principle, provide gameplay. Each game has its game mechanism and this is largely dependent on the game genre since it forms basic features of the game. The genre of the created game is considered to be a platformer. The platforms in the case have the form of pillars emerging from water. The player is supposed to jump from one pillar to another so that (s)he does not fall into the water. After the fall, the game ends and a scoring window appears. The game is controlled with the mouse, specifically by the left button which serves for jumping. When this button is pressed, a green rectangle is displayed above the character representing the player. This is prolonged according to how long the button is pressed – the longer the mouse button is pressed, the longer the rectangle is displayed. This rectangle represents the jump strength. So the player
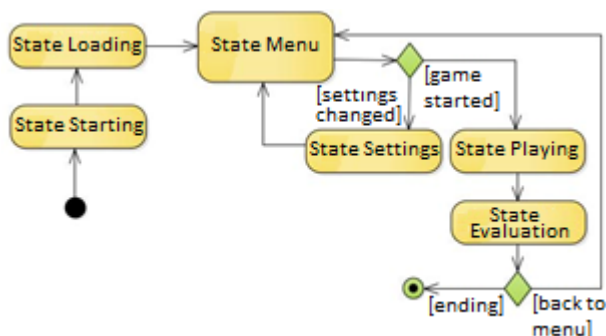
Figure 3. Possible game states.

Figure 4. Non-blocking game mode.

Figure 5. Blocking game mode.

has to figure out how intense the jump should be to get to the next platform. The game is designed as an endless "platformer", so it cannot be won. Instead of victory, the motivating factor is the score and its overtaking.

Educational component

The addition of elements which make up the educational component of the game changes its appearance as well as its mechanism. The game can be played in two modes: non-blocking and blocking. The non-blocking game mode (see Fig. 4) does not force a player to answer the questions displayed in the panel which is located at the top of the board. In this case, the game mechanism is modified so that the narrow pillar which is the closest to the player is widened after the correct answer to the question and the score is increased. This is a form of reward which makes the advancement of the player easier, which allows her or him to achieve a higher score. It is therefore a form of motivation for answering the questions which help the pupil strengthen the curriculum. The player is not penalized for not answering or incorrectly answering the question. The game mode can be seen as a more difficult of the game.
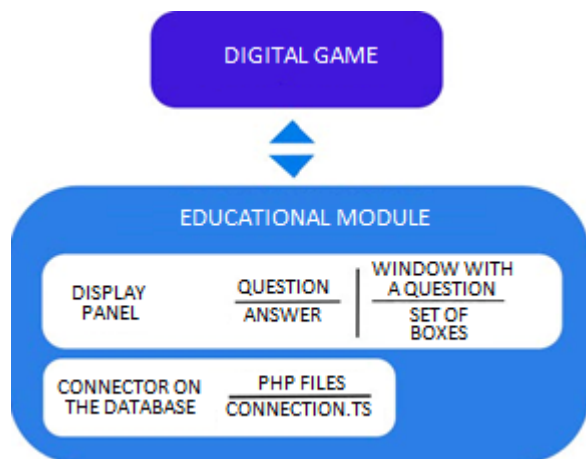
Figure 6.   The scheme of the created prototype.

The blocking game mode (see Fig. 5) does not allow the player to continue without her or his answer to the question (blank answers can be confirmed though). The game mechanism is modified so that all the pillars are wide and if the player answers the question incorrectly, the nearest pillar is narrowed. This complicates the advancement of the player in the game. This is therefore the opposite form of motivation for the correct answers of the questions. The player gets an increased score for the correct answer. This mode is our added value of this game.

The created game can be enhanced with multiple features further. An example may be some addition of other types of control, such as keyboard or touch control. Especially the touch control can be desirable in the case of focus on the browsers of mobile devices. This type of control would also allow the game to be exported to the smartphone or tablet format.

VI.   CONCLUSIONS

Our created prototype can be divided into two parts: a) digital game; and b) educational module (Fig. 6). Both parts are separate and their structure can be modified without the need for more pronounced interventions in the other part. The module is universal and it can be used in other games as well.

The prototype is ready for real deployment where only simple adjustments would be required. These would be based, in particular, on the structure of the educational portal which the prototype would be deployed on.

Any changes would be related to the database connection mainly. In the created PHP files, it would only be necessary to adjust the settings and commands used for working with the data in the database. Also the initialization data such as the category of questions would be sent from the portal or administration interface directly. All created elements are expandable. For example, the display panel can be expanded with other elements such as pictures which would represent answers. It is easy to change the visualization of the created elements as well, the appearance of the button can be changed with a checkbox and so on. It is therefore an adaptive solution. In the future, it would also be interesting to include data mining techniques such as neural networks which would allow us to learn about students and offer automatic adaptations of the module based on collected data.

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IT Fitness Test for Elementary Schools

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Abstract— **The sixth year of IT Fitness Test was traditionally organized in Slovakia by IT Association of the Slovakia. The ambition of the testing was to find out a level of Analogously to the previous two years, it was comprised of two tests – one for respondents over the age of 15, and another for pupils and graduates of elementary schools. The scientific contribution presented in this paper is focused on the test results from the elementary schools.**

I. INTRODUCTION

In 2010, the European Commission launched a massive campaign called European eSkills week. It was designed to support the development of IT skills, especially of young people. The first national IT Fitness test [1], as part of this campaign, was held in Slovakia. The main intention was to analyze the level of basic IT skills, especially of the young population. The target group consisted of secondary school and university students.

This testing took place every one to two years [2,3]. Starting the fourth year of testing, in addition to the basic test, it also includes a test targeting the pupils and graduates of elementary schools.

Both target groups were tested using web portal itfitness.sk, and the testing was available since the beginning of April until the end of June 2017. 26,048 respondents participated in testing. Filtering out the incorrectly completed tests yielded data from 24,638 respondents. These data were evaluated separately for both tests.

In the presented research we focus on results from testing of pupils and graduates of elementary school.

When compared to the previous two years of testing, the number of respondents in this target group increased several times. However, the average success rate slightly declined, indicating an unfavorable tendency of the IT skills and knowledge of pupils.

Internet has again become the area in which the pupils have achieved the best results. Analysis of the data obtained from testing proved considerable lack of knowledge in all other tested areas.

II. IT FITNESS TEST FOR ELEMENTARY SCHOOLS

A. Test Characteristics

The test was available to all regardless the age, yet the primary target group was ninth grade of elementary school and its graduates. The test was designed to be feasible for pupils that are about to finish the elementary school or its fresh graduates, i.e. the optimum age of 14 to 16 years. Tasks were focused on various areas of informatics. They were designed to test the skills, specific subject competences and also certain key competences. We tried to avoid testing of specific knowledge, facts, and encyclopedic knowledge. Instead, we focused on testing of the abilities to analyze input information; understand context, and draw conclusion; solve problems; and think critically.

Tasks at various cognitive levels were also part of the tests. Some tasks were more complex, and several steps had to be taken to manage them successfully. Examples include: finding a profile on the social network, and within this profile, seek the information and understand it; find the information on a web page and obtain the data following the given criteria; analyze the properties of specific process, estimate its rules, and prejudge the following behavior, etc.

B. Test Areas and Tasks

Tasks in the test were divided into six areas:

  I. Internet.
  II. Safety Aspects and Computer Systems.
  III. Complex Tasks.
  IV. Office.
  V. Collaborative Tools and Social Networks.
  VI. Online Marketing

The first five areas are the traditional areas of the IT Fitness test. In this year, the test was extended with the *Online Marketing* area supported by Google [1].

Each of these areas included five tasks with the following types of responses:

- one correct answer selected from the four options (a, b, c, d),
- one correct answer selected from multiple options (through Combo box),
- cluster of dichotomic tasks (multiple sub-tasks with two options – true/false or yes/no). The respondent should select only statements that are true or false. Only correct answers regarding all the statements added one point per task.

The test was generated randomly for each respondent from the pre-prepared four variants per each task. This was done to reduce the risk of obtaining the test tasks

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[1] The Google company promoted testing through the collaboration with the Digital Garage project (in Slovak *Digitálna garáž*). (https://learndigital.withgoogle.com/digitalgarage/)

from the respondents who have already completed the test. The expected optimal time for test was 45 to 60 minutes (time was not set in the implementation).

Utilization of Internet (browsing) was required in the test – especially in tasks regarding the *Internet* and *Collaborative Tools and Social Networks*, but also in the area of *Complex Tasks*.

The goal was to set the test having the tasks of various difficulties, however we tried to avoid very difficult and very easy tasks. Following the testing theory [5], the optimal difficulty of task is approximately 20-80%. The aim of the test is to distribute the tested subjects properly, thus it was designed to achieve the average success rate of about 50%. However, the tasks were not pre-piloted, we could only predict the average success of the test.

III. DEMOGRAFIC DATA

The total number of respondents in case of elementary school was 11,094. Out of these we excluded: 217 respondents that were out of range <7, 16> and 780 respondents who did not have the student status. Thus, the data from 10,097 tests are used in the evaluation process, these correspond to the age category from 7 to 16 years. Such a high participation, in case of elementary schools' test, was recorded for the first time. Compared to the previous editions of the test, it is a 3.7-fold increase (compared to 2015) and 2.8 times the number of respondents (as compared to 2014).
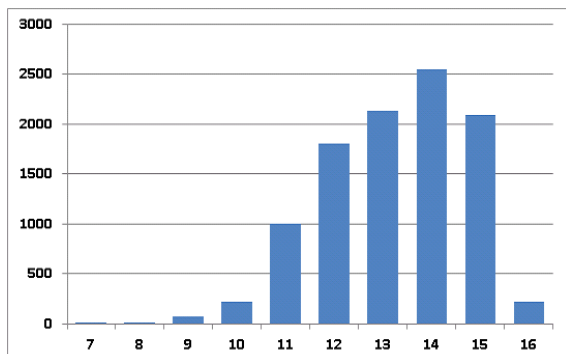
Figure 1. Distribution of age categories

The most numerous groups of respondents were composed of pupils aged between 13 and 15 years. Total distribution of participants by age is depicted in Fig. 1.
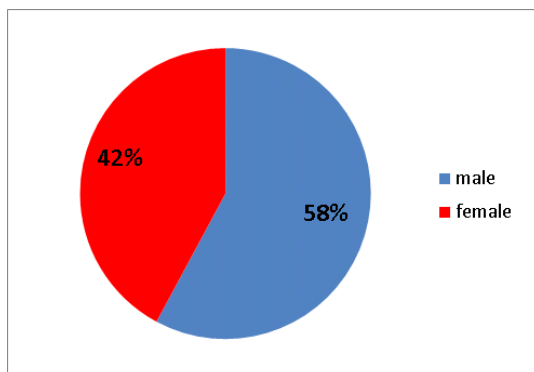
Figure 2. Gender of respondents

The ratio of male and female respondents was 58% to 42% (see Fig. 2).

IV. THE RESULTS

A. Overall results of the target group

The maximum number of points one could score in the test was 30 – one point per question. Fig. 3 shows so-called "a raw score", which shows the number of respondents who have achieved particular scores.

The raw score distribution corresponds to the Gaussian curve, having its maximum shifted to the left. This could indicate increased difficulty of the test. The overall
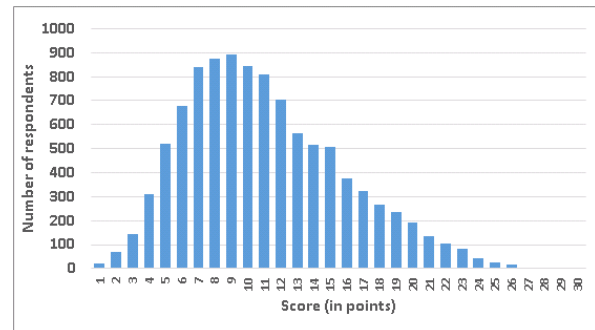
Figure 3. Distribution of raw scores

average test result also confirms this presumption: the average score was 39.56%. Only the areas I.-V. were to be considered in comparison of the results with the previous year of testing, since the *Online Marketing* test area was only introduced this year. This comparison showed that the average success rate in above stated areas fell from 41.27% in 2015 to 37.19% (this year).

B. Age categories

The most successful group of respondents, as expected, were the oldest pupils, i.e. the highest age category (16 years). They achieved an average success rate of 52.80%. The next three age groups (from 13 to 15 years) reached an average success rate lower by more than 10%, see Fig. 4.
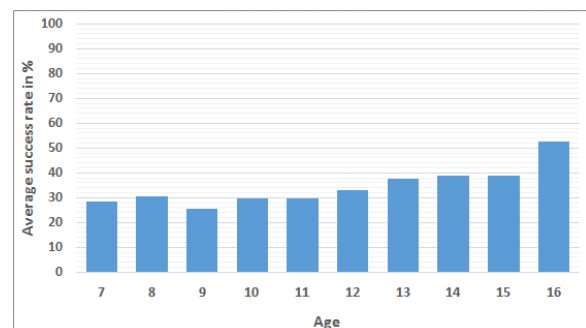
Figure 4. Average success rate for age categories

C. Test topics

Different test areas varied greatly in terms of the success rate (as depicted in Fig. 5). Internet turned out to be the most successful topic – the pupils achieved an average success rate of 55.94%. While Office was the least successful – only 21.79%. The average success rate in the other test categories ranged from 33.80% to 38.69%. The result of the Online Marketing category was rather unexpected. Although its success rate was rather

low, even weaker results were expected, as it is a new, yet untested area that is not part of the computer science subjects at elementary school.
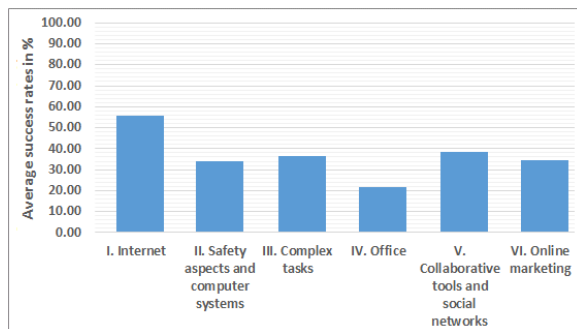
Figure 5. Average success rate for test topics

D. Tasks and variants

Each test area contained five tasks and each task had four possible variants. Fig. 6 shows the average success rate of all 30 test tasks, it is calculated together for all the variants of each task. More detailed and comprehensive results regarding the success of specific task variants can be found in the Report on IT Testing Test 2017 (in Slovak *Správa o výsledkoch IT Fitness testovania*) [4].

The graph below (Fig. 6) shows that three out of five tasks, with an average success rate of over 50%, correspond to the area with the highest average success rate – the *Internet*. Two of these tasks achieved an average success rate of 75.25% and 68.80%. The third most successful task was from the area of *Safety*. Success over 50% was also achieved in one task from the area of the *Collaborative Tools and Social Networks*.
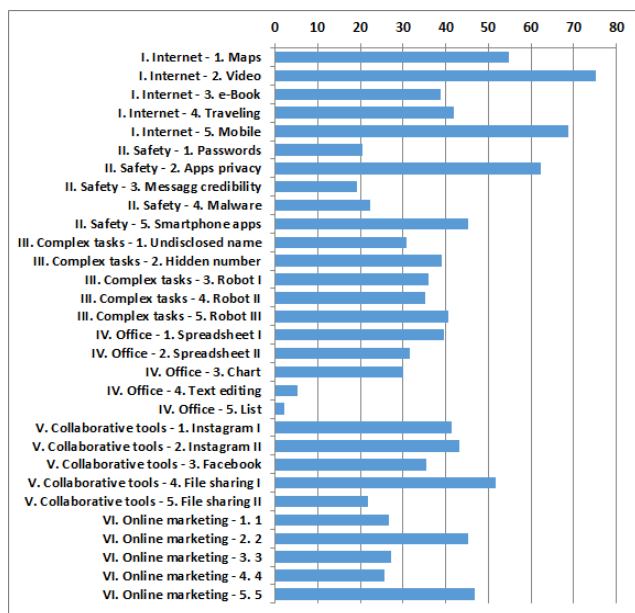
Figure 6. Average success rate for particular tasks

Similarly, the two least successful tasks correspond to the least successful area – *Office*. The average success rate of these two tasks was only 5.39% and 2.24%. Unsuccessful tasks (less than 20%) include also a task from the area of *Safety*, its average success rate reached only 19.10%.

E. Tasks with the highest success rate

The task with the highest success rate of 79.98% was one of the variants of task no. 2 from the area of *Internet*. The task reads as follows:

On 9th of September 2016, the MIT Media Lab released on a video YouTube titled "Reading through closed books". What can we see on video at 0:48?
   a) letter "s"
   b) view of the pavement
   c) 1964
   d) closed book

The other three variants of this task achieved next highest success rates (74.34%, 73.96%, 72.82%).

Another successful task was variant of task no. 5 from the area of *Internet*. The task reads as follows:

What is the thickness of the Apple iPhone 6S Plus smartphone?
   a) 7,3 mm
   b) 7,5 mm
   c) 7,7 mm
   d) 8,5 mm

This specific variant of the task reached a success rate of 72.16%, the other variants of the same task reached 71.09%, 68.93% and 62.87%.

The next successful task (65.64%) was a variant of task no. 2 from the area of *Safety*. The task reads as follows:

Peter wants to protect his privacy as much as possible. The options below represent the camera settings on his smartphone. Which of the following settings is the most secure in terms of privacy.
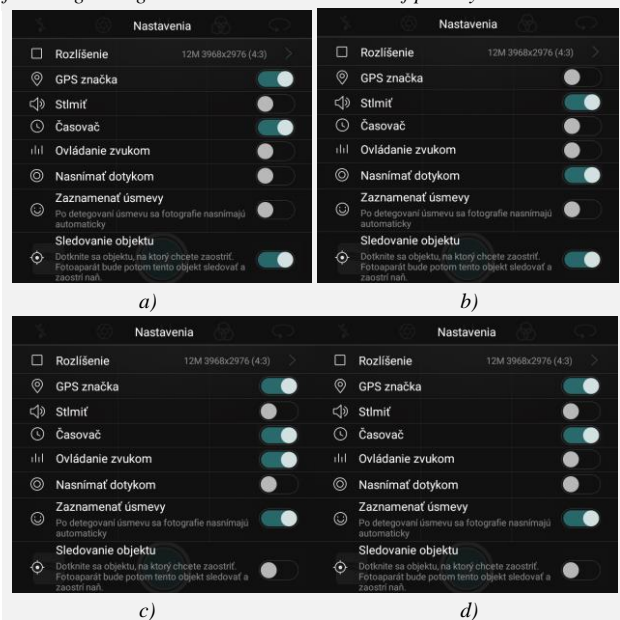
The success rate of the other three variants of this task was 63.93%, 63.96% and 55.87%.

The task with the fourth highest success rate (61.99%) was the variation of task no. 4 from the area of *Collaborative Tools and Social Networks*. The task reads as follows:

Jack created a shared folder called "backup" using Google Drive https://drive.google.com/drive/folders/0B1OCkFLw7Td-QkNzdngtQm5pa0E?usp=sharing.
In this folder, he created more folders and saved there some photos. Which photo depicts the wing of the aircraft?
   a) photo_1.jpg
   b) photo_2.jpg
   c) photo_3.jpg
   d) photo_4.jpg

Other variants of this task had a slightly lower success rate (57.20%, 45.15%, 42.98%).

F. Tasks with the lowest success rate

The task that hit the worst results in the whole test was variant of task no. 3 from the area of *Safety*. Its success rate was 0.00%. It was focused on message confidentiality, and it reads as follows:

Andrej read the following message on some web page:

Europol warns not to send sensitive data on public WiFi networks
Europol, the EU agency for co-ordination the police forces in the Member States, warns EU citizens not to send sensitive data over the public free WiFi networks or to use services that work with such data. Mr. Troels Oerting, the head of Europol's Cybercrime Division, warned the people over the UK public television BBC. Europol's warning comes after the increase of cases in Europe where the offenders steal information, identity, passwords, and money from users using free WiFi networks.

Use the Internet to verify this message and decide whether the following statements are true or false:

1 This is a junk message (SPAM) that spreads mainly through the email. TRUE / FALSE

2 To consider it trustworthy, the message should be published on, at the least, two websites. TRUE / FALSE

3 Message can be considered as trustworthy because it refers to Europol. TRUE / FALSE

Other variants of this task had a significantly higher but still low success rate (25.64%, 23.37% and 23.63%).

The task with the second lowest success rate (0.94%) was the variant of task no. 5 from the area of *Office*. The task reads as follows:

Little Ivanka wanted to know which member countries belong to the European Union. Her father found a list of EU countries, sorted by the alphabet. He did not hesitate and redraw the list by the year of joining the EU. Thus, they had a better overview of how many countries joined in each year.

The original list (originally in columns):

Austria (1995) - Belgium (1958) - Bulgaria (2007) - Croatia (2013) Cyprus (2004) - Czech Republic (2004) - Denmark (1973) Estonia (2004) - Finland (1995) - France (1958) - Germany (1958) Greece (1981) Hungary (2004) Ireland (1973) Italy (1958) Latvia (2004) - Lithuania (2004) - Luxembourg (1958) - Malta (2004) Netherlands (1958) - Poland (2004) - Portugal (1986) Romania (2007) - Slovakia (2004) - Slovenia (2004) - Spain (1986) Sweden (1995) - United Kingdom (1973)

The new list:

EU Member States (member since). The European Union has 28-member countries:
1958: Belgium, France, Germany, Italy, Luxembourg, Netherlands
1973: Denmark, Ireland, United Kingdom
1981: Greece
1986: Portugal, Spain
1995: Austria, Finland, Sweden
2004: Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia
2007: Bulgaria, Romania
2013: Croatia

Decide whether below given tool <u>can</u> or <u>cannot</u> be used to change the grouping of countries by the year they became members of EU, in the same way as it is done in the "new list".

Cutting the text	*CAN / CANNOT*
Text centering	*CAN / CANNOT*
Bold font	*CAN / CANNOT*
Changing the font style	*CAN / CANNOT*
Font underline	*CAN / CANNOT*

Other variants of this task also achieved exceptionally low success rates – 4.13%, 2.96% and 0.96%.

The third of least successful tasks was a variant of task no. 4 from the area of *Office*. The task was focused on the text editing, and it reads as follows:

Edo prepares a classroom magazine and wants to publish a short text (a citation from Wikipedia) about vitamins. He wrote this text in the text editor:

A vitamin is an `organic compound` and an essential `nutrient` that an `organism` requires in limited amounts. An organic chemical compound (or related set of compounds) is called a vitamin when the organism cannot `synthesize` the compound in sufficient quantities, and it must be obtained through the diet; thus, the term vitamin is conditional upon the circumstances and the particular organism.

By convention the term vitamin does not include other `essential nutrients, such as dietary minerals, essential fatty acids and essential amino acids.` Thirteen vitamins are universally recognized at present.

What should Edo do with the text, so that he follows the text creation guidelines and also makes it suitable for the school magazine. Bearing this in mind, decide whether the statements below are true or false:

1 Text must be divided to paragraphs.	*TRUE / FALSE*
2 Image should be created from the text.	*TRUE / FALSE*
3 Type of used font must be unified.	*TRUE / FALSE*
4 Important terms must be highlighted and underlined.	*TRUE / FALSE*

This task had success rate of only 4.14%. Other variants of this task also belong to less successful tasks (5.42%, 7.50%, 4.44%).

The task with the fourth lowest success rate (of 9.76%) was task variant of task no. 1 from the area of *Safety*. The task was aimed to test the knowledge of creating the secure passwords:

Claudia found on the Internet the recommendations for a good password:

Instructions on how to create a good password.

1. Choose an easily memorable sentence that contains only letters. For example: I want holiday.

2. Omit all the vowels and the gaps between the words from the sentence. (generates: wnthld)

3. Add a number and one special character to the entry. (For example: 2wnthld%)

You need to create a password that has at least 8 characters.

She and her friends talked about this tutorial and about the password security. There were further claims in their discussion. Decide on the truthfulness of their claims regarding the instructions on password security:

1 A long enough password becomes easier to guess by omitting the vowels.	*TRUE / FALSE*
2 The sentence should contain at least 6 letters.	*TRUE / FALSE*
3 Password should be written down and stored (e.g. to wallet) so we do not forget the password.	*TRUE / FALSE*
4 Password created following these instructions is safe and we do not have to change it in the future.	*TRUE / FALSE*

The success rate of the other variants of the same task was quite different but still quite low: 16.42%, 27.33% and 28.84%.

V. INTERPRETATION OF RESULTS

When compared with previous testing, almost four-fold increase in the number of respondents was recorded in case of the elementary school testing. The average success rate has fallen by four percentage points when compared with previous testing. However, results from different years are difficult to compare, since each test edition

contains a different structure of tasks. The dissimilarities between the task variants (that have as goal the same success rate) indicate differences often by 20 percentage points. This fact strengthens just mentioned statement. Despite the evidence that the average success rate of this year's test is lower than predicted, the test is considered as appropriate and effective because it distributes well the tested participants (i.e. has a good sensitivity) [5].

The tendency of decreasing average success rates per year is, despite of difficulties in the comparison, very evident. We believe that the level of success recorded this year is depended on a higher rate of participation. We assume that the respondents with the highest interest in testing are among the first, especially due to their interest in IT area. Monitoring of the ongoing average success rate, which gradually decreases during testing, confirms this assumption.

Analysis of the data, as gained from testing, confirmed that pupils have major deficiencies in all tested topics. This, however, does not apply to the area of *Internet*, where they traditionally achieved the best results. The unexpected output is significant decline of success rate in the *Office* area, which has fallen by almost 20 percentage points as compared to the previous testing. We estimate that it was caused by the increase of the cognitive difficulty of two tasks in this category.

Improvement of the results in the area of *Complex tasks* by 10 percentage points is considered as a success. Nevertheless, the results in this area are still not satisfactory.

The results of our research show minor improvements of pupils in the analysis of process characteristics, estimating the rules of its behavior, and prejudicing its future the behavior. One fact still holds true, pupils are better in solving of standard tasks, or tasks that include analogous skills and competencies they had encountered in other (past) tasks. We can see gradual increase of success in tasks that were typologically new three years ago but were regularly in focus during the testing. This confirms that this testing also spreads the awareness among professional teachers.

VI. CONCLUSIONS

Testing, as part of IT Fitness Test for elementary schools, has been carried out for the third time this year. Its goal was to examine the level of knowledge and skills of elementary school pupils and its graduates in basic IT areas. Another goal was to compare, at least roughly, the outputs with previous years.

In view of the above presented findings (see section on *Interpretation of Results*), we encourage teachers to focus more on the implementation of the tasks and complex projects that demand combination of knowledge from different areas. In broader contexts, we suggest deployment of activities that require higher cognitive operations (analysis, evaluation, creation), ask student to find mistakes or solve non-standard problem (also divergent) tasks, etc. Further, it is necessary for the pupils to encounter less traditional assignments and tasks. Increased attention should be paid to development of critical thinking, evaluation of information and assessment of its quality, credibility, and truthfulness.

ACKNOWLEDGMENT

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The architecture of manufacturing process

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Abstract—**Nowadays, simulation as a progressive virtual application as well as a didactic method is playing a more and more important role in not only in the automation industry, where it saves time and costs development. Simulating the production processes can bring massive cost savings. Technically demanding applications such as metal forming, machining, heat treatment, casting and plastics injection molding require powerful material and geometric non-linear capabilities, adaptive meshing and a user environment that speaks the language of manufacturing and process development engineers.**

1. INTRODUCTION

Now, when the use of computers can be met in any field of industry it could easily lead us to the digital factory. The digital factory is a computer generated representation of a real factory consisting of machines, robots, manufacturing and assembly lines, warehouses, buffers, transport devices and last but not least humans (figure1). It comes without doubt any processes, products or models can be run, analysed and hence simulated virtually. The results obtained are then applicable in a real production process, which obviously brings cost savings, production size and quality improvement. It should be also taken into account that the simulating the processes virtually could be faster than real testing of the manufacturing process. The competitiveness of any company is improved as well [1].

The concept of Digital Factory concept is a promising prerequisite to be successful in current business world. Therefore, the concept should be considered with respect in any manufacturing plant. "Digital Factory" concept is a generic professional terminology for a comprehensive network of digital models, methods, techniques and tools, including simulation and virtual reality visualization; which are integrated by a continuous data management system. The objectives of a Digital Factory concept are different; for example re-organisation of the production lines and optimisation of the production through the simulation of the production cycle; training of the workers; working on a virtual prototype in design phase; virtual environment is a good network place where people can virtually meet to co-design the product or the production line. The Digital Factory concept application has become more and more important for complex design of products that are tailoring for customers.

Today the manufacturing plants are under the strong pressure of domestic and foreign competition. Influence of competitiveness is growing by globalisation. The mentioned situation is forcing manufacturers to adapt to new circumstances and to respond flexibly to the demands of their environment. The flexibility that is required from current market situation is dependent on production flexibility and shortening of the production cycle.

Fulfilment of requirements to reduce the overall production cycle at the lowest possible cost in the production is the most important prerequisite for business success [19]. The stringent environmental standard and a leaner work force have become more crucial to the company's success and a lot more costly. Today's factories must not only be flexible enough to accommodate multiple product series and short product lifecycles, but periodically a significant design change may require a complete reconfiguration, or the construction of an entirely new facility [20]. As a result, manufacturers are seeking [19, 20]:

✓ to shorten every phase of production planning;
✓ to increase productivity in small production batches;
✓ to flexibly respond to the production mix of components or subassemblies;
✓ to reduce the size of the warehouse and material stock;
✓ to quickly solve problems, etc.

This is where the Digital Factory concept can help. The Digital Factory concept serves to the thorough preparation of production and logistics before "physical" production and logistics. There exists a comprehensive source of materials defining and describing Digital Factory concept [21].

The Digital Factory [3] toolset will be able to support collaboration among different sites and users during designing, prototyping and manufacturing through an interactive environment with the aim of meeting the challenge of delivering better quality products and services. The use of such a technology will reinforce SMEs' competitiveness in the European industry since it will provide benefits as follows [2].

Figure 1. Digital factory
(http://www.greenmanufacturer.net)

- Increased Efficiency: team members will be able to collaborate anytime, anywhere making faster decisions and gaining approvals instantly.

- Reduction in Complexity: the employees will be able to seamlessly work together, and extend communication and collaboration beyond their organisational boundaries.

- Reduction in Physical Mock-ups: the Digital Factory environment will allow testing ideas on digital (virtual) configurations, employing advanced paradigms of immersive interaction and collaborative work without having to rely on large numbers of physical mock-ups or experiments and tests.

- Enhanced Organisational Intelligence: the information will be collected and organised in a single place. New members will be able to view all the history and information very quickly and to start working with the other members is less time, thus improving the productivity.

- Highly Skilled Employment: the novel methods and tools to be used in the Digital Factory

environment development will require highly qualified jobs based upon the necessity for new engineering and IT skills that will support the intelligent design procedures, using high-end simulation technology and knowledge-based approaches to decision making instead of semi-empirical methods and physical testing.

- Better working conditions: as a result of the above, employees will have the opportunity to work with advanced supporting tools that will make their lives easier and safer.

I. PLANT SIMULATION

Tecnomatix® Plant Simulation (figure 2) software enables the simulation and optimisation of production systems and processes. Using Plant Simulation, you can optimise material flow, resource utilisation and logistics for all levels of plant planning from global production facilities, through local plants to specific lines [5, 6].

Benefits (www.siemens.com/tecnomatix):

✓ Enhance productivity of existing production facilities by as much as 15-20 percent.

✓ Reduce investment in planning new production facilities up to 20 percent.

✓ Cut inventory and throughput time by 20-60 percent.

✓ Optimise system dimensions, including buffer sizes.

✓ Reduce investment risks by early proof of concept.

✓ Maximize use of manufacturing resources.

✓ Improve line design and schedule.

Plant Simulation helps users:
(www.siemens.com/tecnomatix)

❖ Detect and eliminate problems that otherwise would require cost- and time-consuming correction measures during production ramp-up.

❖ Minimize the investment cost of production lines without jeopardizing required output.

❖ Optimize the performance of existing production systems by taking measures that have been verified in a simulation environment prior to implementation.
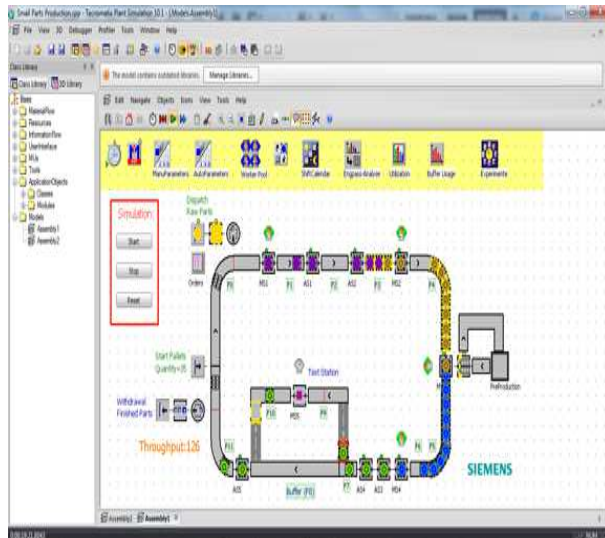
Figure 2. A plant model for analyzing utilization and throughput, created in Tecnomatix Plant Simulation (www.deskeng.com)

Figure 3. 4D Systems LLC (http://4dsysco.com/siemens-plm/tecnomatix)

II. PROCESS SIMULATION

Process Simulate (figure 3) enables you to validate the assembly plans virtually, from the concept through to the start of production to help you mitigate these risks. The ability to leverage 3D data of products and resources facilitates virtual validation, optimisation, and commissioning of complex manufacturing processes, resulting in faster launches and higher production quality. Process Simulate can verify the feasibility of an assembly process by validating reachability and collision clearance. This is done by simulating the full assembly sequence of the product and the required tools. Tools such as sections, measurements and collision detection allow the detailed verification and optimisation of assembly scenarios [4]. Process Simulate is fully integrated within the Team-centre platform, thus enabling the manufacturing engineers to re-use, authorise and validate the manufacturing processes. It facilitates simulation of assembly processes, human operations, and mechanical procedures of tools, devices, and robots [5, 6].

Benefits (www.siemens.com/tecnomatix):

✓ Reduce risk of production changes late in implementation.

✓ Reduce planning time through automatic sequencing and validation tools.

✓ Reduce cost of change with early detection and communication of product design issues.

✓ Ensure ergonomically safe processes.

✓ Select the best production method by simulating several manufacturing alternatives.
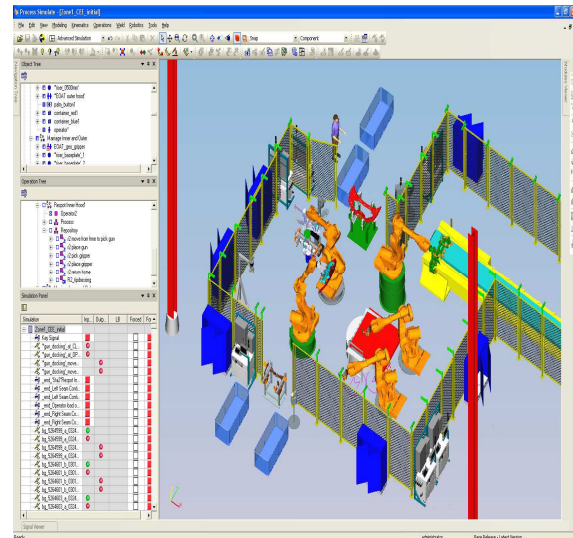
The digital factory is the goal and the result of the integrated digital production engineering process. The enabling technology is an integrated engineering environment for the overall product creation process from the initial design studies to the virtual validation of the start-up of production based on an integrated virtual resource model.

III. DIGITAL HUMAN MODELS

Digital human models are software models of the physical human in the form of an avatar, or a virtual human. These models are intended to assist designers in testing the physical design of workspaces at an early stage.

Current digital human models provide the designers with the tools for analysing the physical design of workspaces in a virtual environment. These tools are limited in a number of significant ways. First, the models of human motion for predicting the posture and movement are limited in their capability. Digital human models are basically virtual manikins that must be carefully positioned in a reasonable posture by the designer himself. Some currently used models allow the designers to utilise inverse kinematics algorithms. These algorithms may have a limited validity in predicting the reasonable postures [13].

Either the designer or the IK system may select erroneous postures that do not accurately represent likely postures in the environment. Given a vehicle interior, a designer must directly arrange the avatar in the seat in a plausible way with little assistance from the digital human models software. Any dynamic motion, such as reaching from the steering wheel to the centre console, must be provided by the designer, potentially through the use of motion capture or by direct manipulation of the avatar [8].

Second, digital human models simulate only the physical attributes and capabilities of a human. The digital human models are an empty shell directed by the designer and the software toolset. So far it is not possible for the designer to place a digital human model into a vehicle interior and simulate the physical motion of the digital human models during the driving task [9].

Figure 4: Digital human models architecture

In the process of assembling the database of movements, the HUMOSIM group has captured the data from over 200 subjects to collect almost 100,000 motion data sets [12, 13]. The database includes motions for reaching toward a target, transferring objects, reaching and grasping objects, looking toward points, exerting force on handles, and pushing buttons. The continuously expanding database provides real motion capture data to provide the foundation for the development of models capable of predicting the motion. There are two methods for predicting the motion under development within the HUMOSIM group. The primary method, functional regression analysis – can predict joint angles during the motion of a hand toward a target in terms of inputs such as the stature, age, and gender of a subject. The technique was used to compare the relative importance of stature, age, and gender in seated reaching motions. The second method relies more directly on the motion database. The motion modification method, searches the motion database for "root motions" that can be analysed and modified slightly to create a desired motion. Both methods are potential tools for creating the dynamic human models capable of predicting valid postures and motions for ergonomic analyses [9, 11, and [12].

The A3I Program was initiated in 1985 to support exploration of computational representations of human-machine performance to aid designers of crew systems. The major product of this effort was a human factors computer-aided engineering system called MIDAS (Man-Machine Integration Design and Analysis System). MIDAS is intended to revise the system design process in order to place more accurate information into the hands of the designers early in the process of human engineering design so that the impact and cost of changes are at its minimum. It is also intended to identify and model human-automation interactions with flexible representations of human-machine function and the crew station development process, as it is currently undertaken. The design proceeds from the requirements and capabilities in conceptual design through increasing the specifications for hardware and software prototypes and simulation tests. Human performance evaluation occurs after the prototype design and development. Results from testing the prototype are then used to guide the prototype redesign [7, 9, and 10].

MIDAS is intended to meet these challenges by including the following characteristics: [7, 15]

- ✓ Modifiability and manipulability: The basic mode of operation for MIDAS users is to explore the impact of changes to the baseline design. Thus, the capability for systematic change is critical. Of equal importance is the system of extensibility. To be generally useful, the modelling environment should be applicable to many types of design changes, and to many operational domains. The MIDAS architecture is designed to allow extensions of this type with minimum disruption to the existing core MIDAS system.

- ✓ Transparency: The analysis system must provide the designers with explicit and transparent reference to the rules, decision-making strategies, heuristics, and assumptions under which the human-machine system is assumed to be operating as well as predicted performance.

- ✓ Dynamic analysis capability: The simulation system must produce a stream of behavior in the form of dynamic timelines describing not only its state and structure, but also sequences of action over time and contingent responses of the human/system behaviour. The system must support testable hypotheses. Designers must be able to analyse the events occurring in the simulation scenario and relate this performance to man-in-the-loop simulation data. In MIDAS, each action taken, decision made, and communication event is logged by the analysis system [14].

The structural architecture of MIDAS is that of a federated set of models organized into groupings that represent the various agents in the simulation. We will concentrate here on the structural integration of the models that compose the human operator(s) in the MIDAS modelling system. These models have been developed in a structure that represents an empirically based human information processing model. This

structural integration has been termed as a first-principles model, based on its intentional integration of cognitive models that represent separable elements of the cognitive process. The first-principles models of human performance are based on the mechanisms that underlie and cause human behavior. First-principles models integrate human perceptual and cognitive systems and human motor systems, thus incorporating the higher-level behaviours that are characteristic of human performance. This incorporation supports the emergent human behaviour based on elementary model function [7, 10, and 15].

IV. USING ANTHROPOMETRIC DATA IN DESIGN

Anthropometric data describe the body sizes of people in standardised erect postures. Such information is basic for the design of workspaces and equipment, of tools, and of clothing, which must fit the human body.

The "Normative" Adult:

- ✓ "normal" anthropometry, with all body dimensions (such as stature, hand reach or weight) close to their mean values;
- ✓ "normal" physiological functions, such as of the metabolic, circulatory and respiratory subsystems; whose nervous control functions, sensory capabilities and intelligence are all near "average".

In reality, however, there hardly exists any person who is average in all or many respects; instead, "extraordinary" persons and population subgroups abound: very big or small individuals, temporarily, or permanently impaired persons, women during their pregnancy, children and juveniles, or elderly people [17]. So, instead of using the imaginary "normal adult" as a design prototype, we must consider the variability that exists naturally among "not-ordinary" people of different body sizes, genders, ages, and abilities [18].

Guidelines for the conversion of standard measuring postures to functional stances and dimensions:

Slumped standing or sitting – Deduct 5–10% from relevant height measurements.

Relaxed trunk – Add 5–10% to trunk circumferences and depths.

Wearing shoes – Add approximately 25 mm to relevant standing and sitting heights; more for "high heels".

Wearing light clothing – Add about 5% to relevant dimensions.

Wearing heavy clothing – Add 15% or more to relevant dimensions. (Note that heavy clothing may strongly reduce mobility).

Extended reaches – Add 10% or more to relevant reach measures for strong motions of the trunk.

Use of hand tools – Centre of handle is at about 40% of hand length, measured from the wrist.

Forward bending of head, neck and trunk – Ear-Eye Line declines to near horizontal.

Comfortable seat height – Subtract up to 10% from popliteal height.

Useful steps in designing for fitting clothing, tools, workstations, and equipment to the body are as follows:

Step 1: Select those anthropometric measures that directly relate to important design dimensions. A few examples: hand length relates to handle size; knee height and hip breadth relate to the leg room in a console; shoulder and hip breadth relate to escape-hatch diameter; head length and breadth relate to helmet size; eye height relates to the heights of windows and displays; stature relates to the height of a door frame [19].

Step 2: For each of these pairings, determine whether the design must fit in only one given percentile – minimum or maximum – of the body dimension, or a range along that body dimension. Examples: the escape hatch must be big enough to clear the extreme largest values of shoulder breadth and hip breadth, enlarged by clothing and equipment worn. The handle size of pliers should probably best fit a smallish hand; the legroom of a console must accommodate the tallest knee heights. The height of a seat should be adjustable to fit persons with short and with long lower legs. A door opening should be higher than the tallest person to avoid bloody scalps [16].

Step 3: Combine all selected design values in a carefully devised sample, computer model, mock-up, or drawing to ascertain that they are compatible. Example: a tall legroom clearance height, needed for sitting persons with long lower legs, may be very close to, even interfere with the height of the working surface, which depends on elbow height [120].

Step 4: Determine whether one design will fit all users – if not, several sizes or adjustment must be provided to accommodate the users. Examples are: one extra-large bed size fits all sleepers; gloves and shoes must come in different sizes; seat heights should be adjustable [21, 22].

The main (a synthetic aim) of the project design is proposal of the process of transforming the contents of an ergonomic program into practical output of the company management activities through integrated action of the modules QMS, EMS, HSMS. The description of the main (synthetic) aim of the project solution may limit this framework of the sub-aims of the solution:

1. Analysis of the knowledge base of the area an ergonomics and program its implementation as well as in the area an integration of the quality management, environment and health and safety of the work.

2. The research of practical application an ergonomic program in condition of industrial companies and state of the practical application ISO standards in area quality management, environment and health and safety management.

3. The proposal options and the process of transformation an ergonomic program into company management structure through integrated models QMS/EMS/HSMS.

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Educational Robotics as a Method of Schoolboy' Competences Development and Their Professional Orientation

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Abstract—**The problems of educational robotics, development of schoolboy competences and their professional orientation are considered in this article. The aim and program tasks are put on educational robotics. Forms and methods of educating are shown. Conception of programming of the intellectual robotics systems is considered. The tasks of robotics competitions are analysed and events on their realization are offered here.**

I. Introduction

Currently, the process of popularization of the profession of an engineer is an actual task. The fourth industrial revolution more well-known as "Industry 4.0" has begun, and the "cyber-physical systems" are being intensively implemented and developed in the productive processes. "Industry 4.0" will form the high-autonomous decentralized configurable production, distinctive by a continuous informative exchange between his sub-systems and objects of production within the framework of executable productive and logistic processes.

Engineers in the areas of mechatronics and robotics are required in Russia, who is able to do our country a leader in "Industry 4.0". Intensive use of robots in manufacturing, agriculture, building, medicine, way of life, at emergencies and in battle actions requires, that engineers possessed modern knowledge in area of mechatronics and robotics.

For the increase of prestige of the profession of an engineer it is necessary to inoculate schoolboy' interest to robotics and mechatronics. To attain the high level of the creative thinking and necessary competences for realization of projects on robotics, the schoolboys must pass all stages of constructing and programming of robots. It is necessary to remember that such projects on robotics maybe executed only then, when schoolboys have a certain level of knowledge, experience, abilities and skills in IT and physics.

II. Industrial Inovation Complex

The program of reforming the military and industrial complex implemented in Russia requires the formation of a rational organizational model of regional industrial innovation complexes [13]. One of the possible forms of implementation can be a regional cluster policy which implies a close interaction of implementing individual projects with external sources of knowledge, i.e. consultants, laboratories and universities [14]. The regional industrial innovation cluster of the Udmurt Republic reasonably requires the approach related to the theory of cluster policy aimed at the full support of the development of a particular cluster with the help of carefully planned activities in the field of supply and demand [15].

The priority tasks of the Udmurt Republic within the regional industrial complex are: introducing advanced technologies for processing and assembly; manufacturing new products for both military and dual use; manufacturing competitive products for civilian use. Hence, now it is necessary to talk about the formation of regional industrial innovation complexes which combine several public and private structures to organize efficient production management of science-driven civil and defense products [13]. One of the most required professional competencies are specialists in the fields of mechatronics and information systems. The analysis of professional activities has distinguished 4 variative units of professional training which provide an opportunity of selecting an individual trajectory of forming innovation and educational potential in accordance with the required professional competences of a workplace: design and engineering; design and technology, and production and technology; installation and commissioning, and service-operational; research and innovation; organizational and managerial.

To perform the set tasks the infrastructure of a regional industry complex has to fulfill the functions of

generating and diffusing innovations due to the effective collaboration of research institutes, business incubators and technology parks, innovation centers, industrial companies, small innovation business, technology transfer and consulting centers.

The structure of an industrial innovation complex has to include training centers, vocational education establishments, which, in relation to the general vector of their development choose conceptual models of institutional development (partnership, research, project-oriented, innovation and entrepreneurial), each of which involves the interaction with enterprises and organizations in the area of forming specialists' professional competences. The considerable change of a single specialists' role in the field of mechatronics and information systems requires the creation of a mechanism of its development in order to involve and improve its readiness to take part in innovation processes.

The existing transformational processes have revealed non-conformance of the workers' professional level with the requirements of modern technological processes, while in the innovation economy it is professional competences which are considered as the most important resource of increasing the production efficiency. The system of vocational education does not have time to respond to the labor market requirements. On the one hand, it is caused with the difficulties of changing the trajectory of forming mechatronics specialists' professional competences within the shortest time period in accordance with the requirements of the modern production; on the other hand it is due to the lack of mechanism of interaction and coordination of interests of innovation and educational systems [16].

III. CONDITIONS FOR FORMATION OF SPECIALISTS

The conditions for the effective formation of professional competences of specialists in the field of mechatronics and information technology are: compliance of the training structure with the structure of the professional competencies of workplaces and close connection of the graduate departments and employing enterprises.

The trend of integration of education and manufacture involves continuous improvement of mutually beneficial relationships in the directions of development of material and technical base, development of strategic partnerships, the forming individual educational trajectories within the regional industrial complex.

The effective forming of mechatronics specialist's competences takes place in the innovation and educational system of the regional industrial complex consisting of their educational and innovation subsystems. Thus, the synthesis of innovation and educational and scientific and innovation policies within the innovation development implies the increase of the efficiency of social partnership [5]. Managing the subjects' interaction in the regional industrial complex implies creating the favourable organizational and economic conditions of interaction; selection, evaluation and forming of the effective forms and technologies of interaction; regulation of development of the interacting subjects in the direction of harmonizing their needs and forming innovation potential in order to change the characteristics of specialists' professional competences and the interaction results.

The study of organizations' interaction has revealed that the reference relationships are the ones agreed in terms of the programs, objectives, strategies and of systemic nature [17]. The success of the organizations' interaction depends on the coordination of processes and activities, management social capital, mutual trust, shared responsibility and experience [18].

In this regard, the principles of subjects' interaction can be nominally divided into interconnected groups: organizational and informational, related to the essence of the interaction process; basic theoretical and methodical principles of managing the interaction process. By nature of the subjects' interaction process the timely access to information flows in a single information system has to be provided. The implementation of the information principles of interaction can be provided by means of the information-analytical system of monitoring, which is based on a data bank of professional competences.

The principle of individuality is based on the fact that specialists increase their professional competences in different ways, the standard of development of the latter being innovation and educational potential. The harmony of subjects' interests requires various trajectories (the principle of multi-variant and flexibility) of forming innovation and educational potential adapting to the degree of its development and prospects of its further formation.

From the standpoint of managing the interaction of the subjects of the regional industrial complex such level of harmonization of interests with their equal rights is to be achieved that the direction of formation of professional competences and innovation and educational potential would meet their objectives and ensure the development of innovative processes, which causes a synergistic effect. The balance of interests is achieved by means of continuous improvement of the level of innovation and educational potential taking into account the dynamics of the innovation processes within the regional industrial complex; consistent distribution of functions between the subjects ensures the effectiveness of their interaction. Such approach to the management of harmonizing subjects' interaction is based on a number of statements:

- ✓ interaction takes place at the stage before the learning process by means of harmonizing the interests of university, individual, enterprise and state; First point
- ✓ creating advanced training programs causes the necessity to predict and take into account the trends in the development of the regional industrial complex; Second point
- ✓ subjects' direct interaction is regulated by the formation of a given level of innovation and educational potential of the regional innovation complex;
- ✓ individual approach to the formation of a set of professional competences determines the possibility to control the formation of innovation and educational potential of the regional industrial complex .

The collinearity principle of development vectors of the subjects of the regional industrial complex meaning that the individual goals of individual subjects contribute

to solving corporate tasks results in a synergistic effect, which is the subject of the focused effort of coordinated interaction of all subjects.

IV. EDUCATIONAL ROBOTICS

Now there is a row of problems in educational robotics: absence of educational standards in the area of educational robotics, insufficient amount of educational-methodical literature, shortage of skilled teachers and absence of training of the teachers to this direction in educational establishments, insufficient financing for acquisition of Lego meccano, sets of elements on the base of Arduino, multimeters, power, textbooks and of teachers' salary. Unfortunately, the presence of these problems brakes development of educational robotics substantially. Basic methods of work and principles of the intellectual robotics systems' development are brought in educational-methodical literature [1-12].

It is suggested to conduct studies on educational robotics on next directions: constructing, design of robots, development of algorithms and management programs. In the course of mastering the program implementation the collective and individual creative projects are provided.

A program's aim on educational robotics is the development of interest in technical work and constructing through development of robots, algorithms and management programs.

Based on the aim the basic tasks are set:
- ✓ forming of the creative thinking in the process of development of robots, algorithms and management programs;
- ✓ development of vocabulary and skills of communication at explanation of work of robots, algorithms and management programs;
- ✓ establishing causal connections;
- ✓ analysis of results and search of new decisions;
- ✓ collective development of ideas, persistence during realization some of them;
- ✓ experimental research, estimation (measuring) of influence of separate factors.

During realization of studies it is suggested to use the following forms and methods of educating: cognitive method, method of projects (at mastering and creative application of skills and abilities in the process of development of own models of robots), systematizing (conversation on the topic, drafting of systematizing tables, graphs and charts etc.), method of control (at the exposure of quality of mastering of knowledge, skills and abilities and their correction in the process of practical tasks implementation), group work (used for the joint assembling of robots, and also at development of projects), individual work (used for work with the gifted children, at preparation for the competitions and olympiads).

V. METHOD OF SCHOOLBOY

As a result in schoolboy' following competences must be formed: informative (to use the fixed assets of receipt of information; to work with literature, magazines, catalogues, in the internet; to have concepts about text and graphic information; to perceive and estimate information from the screen of PC; to use corresponding software), general educational (to own basic information about mechanical elements, sensors and drives of robots; to expound to the idea, to find answers to the questions, to analyse a working process; to demonstrate economic feasibilities of models of robots; independently solve technical tasks in the process of development of model of robots and management programs), communicative (to share information for implementation of general work; to process information to present it in a writing and verbal form; to observe the order of work set by a group).

One of the ways of overcoming the methodical vacuum is conception of programming of the intellectual robotics systems. Conception relies on the fact that during all cycle of studies on educational robotics the student must acquire knowledge and skills on certain themes, allowing to become acquainted with those disciplines that are studied in the process of preparation for "Mechatronics and robotics" in the technical universities of mechanic, electronics, informative devices, microprocessor-based technique, theory of automatic control, methods of artificial intelligence).

Within the framework of this conception at formulation of tasks next basic themes are offered: mechanics, informative devices, automatic control, localization, planning and navigation, multi-agent systems.

The basic task of mechanics is description of robot's motion through a mathematical tool. Examples of tasks: calculation of mechanical transmissions, moving of mobot to the set distance on encoder, transferring of manipulator to space. One of the most essential tasks for robots is a receipt of data about an environment by means of informative devices - sensors. It will be realized by measuring of parameters and subsequent extraction of meaningful information different sensors from these measuring. Examples of tasks: distance-finding from a robot to the obstacle by means of ultrasonic sensor, determination of descriptions of object (color, form, length, weight etc.).

Automatic control of actions of the robot implies a robot without participation of a man in accordance with the set aim of management and beforehand set algorithm. Examples of tasks: motion of mobot on a contrasting stripe. Localization as the major stage of navigation consists in ability of robot to determine the location in an environment. Examples of tasks: position-fix of mobot in a well-known locality by calculating of crossing, position-fix on the basis of the passed way (odometry). A navigation consists in ability of robot to operate on the basis of the got data and testimonies of sensors so that to move in a having a special purpose location by the most rational and reliable method.

Examples of tasks: laying by the mobot of short cut back in labyrinth, working way at a navigation on a coordinate scale.

Effective co-ordination of autonomous robots at the job processing is required for the achievement of high efficiency of all system consisting of great number of robots. The tasks of co-ordination of a few robots suppose absence of the central point of management, local perception of every robot, that give incomplete information, individual aims and procedures of receipt of the decisions, asynchronous communication, dynamic

surroundings and vagueness. Examples of tasks: determination of location of forward with a ball in relation to a gate on the basis of data of forward and goalkeeper in football of robots.

In the process of educating it is required for students to take part in olympiads and competitions on robotics. Analysing the requirements of olympiads on robotics in the last few years, it is possible to draw conclusion, that tasks become more difficult and the tasks of international olympiads are duplicated at the regional level. Authors consider such approach not faithful. A level of complication of tasks on the olympiads of different level must be various.

For example, task on Competition of creative projects "The First step in robotics", that took place on November, 10, 2016 (http://konkurs.ciur.ru/pervi - shag/) for students from 13 to 15 years is called – Manipulator. In this contest participants must collect an autonomous unmobile robot with a manipulator, that must collect a multistory building from the blocks of the set color according to the sample. Schoolboys, who only began studing robotics, are not able to cope with the task. Such task befits for those, who already has an experience and the name of competition in robotics must reflect his essence, for example, the name of competition "Next to Last step in robotics" befits anymore. Authors consider that it is expedient to divide the participants of competition into novices and "advanced" participants, and to organize two divisions for them, as it is accepted on olympiads on the sport programming in Kalashnikov Izhevsk State Technical University.

For every age category of participants in the competition, the task, corresponding to the set of competences characteristic for this age, must be offered. If these terms will be executed, then competitions will be mass and will demonstrate capabilities and of competence of students, but not their trainers. Mass character implies adequate on a level tasks for participants. For example, in Republic of Tatarstan just on this account a category "Beginners" is entered, in which the tasks of "Kegelring-Kvadro" and "Track: speed" will be proposed.

Priority of technical education allows to solve the following tasks: involving schoolchildren in the scientific and technical sphere of professional activity, increasing the prestige of scientific and technical professions, identifying and supporting technically gifted children. In Izhevsk the Municipal budgetary educational institution of additional education "Engineering and technical center "Foresight" organizes its activities on the basis of the social order, i.e. requests and demands that are made by social actors.

Taking into account the requests of social subjects, the pedagogical team of ETC "Foresight" defined the goal of its activity - the formation of a continuous system of education in the field of science and technology aimed at identifying, developing and realizing the creative potential of children and young people, depending on their individual needs.

As well as the priority areas of activity:

1. Increase of children's technical associations, attracting students of secondary and senior school age to technical creativity.
2. Introduction of a training and research laboratory for mechatronics and robotics for schoolchildren in the Industrial District.
3. Networking with educational organizations on the issues of vocational guidance of schoolchildren, taking into account the individual needs of students.
4. Development of human resources, raising the professional level of teachers.

In accordance with the municipal assignment for 2016-2017 academic year, the municipal service is implemented for 49 additional general development programs for technical, artistic, social, pedagogical and natural-science purposes. The programs have terms of realization from 1 to 4 years, they are calculated for all age categories of students.

There are such educational programs in the areas: technical, artistic, social-pedagogical, natural science.

In recent years, the directions of "robotics" and "lego-designing" are becoming more and more popular. In this academic year, an application was received for training in educational robotics and lego-designing programs from 9 schools in the district (No. 8, 52, 69, 72, 82, 39, 64, 84, Humanitarian Lyceum). In the last academic year, robotics was taught for students in five schools (No. 72, 69, 82, 84, 64). Also for the period from 01.05.2016 to 01.10.2016, there were more than 20 individual applications from parents wishing to enroll their children in robotics classes.

TABLE 1.
Number of schoolboys by orientation

Academic years	Tech-nical area	Robotics area	Artistic area	Social-pedago-gical area	Natural science area
2013-2014	1056	69	430	247	0
2014-2015	724	90	740	495	0
2015-2016	1038	385	448	114	0
2016-2017	934	635	396	159	97

The programs on radio electronics and circuitry are also in demand. In this academic year, 9 associations in this direction were opened, 8 of them for junior school age and 1 for senior school age. Programs on radio electronics for children 7-10 years are short-term, aimed at developing interest in this area of technical creativity and

early identification of motivated schoolchildren. Under the program "Electrical engineering.

Projects on Arduino» (adolescents 13-16 years old) are engaged in schoolchildren who have passed a 2-year course on educational robotics. This is a professionally-oriented schoolchildren who have chosen their educational trajectory.

The number of schoolboys by fields (including robotics) is shown in the table 1 and figure 1.

The analysis of the programs shows that in comparison with the previous academic year, the number of programs designed for high school students has increased three-fold. This testifies to a well thought-out strategy of the institution in addressing the problem of "involving adolescents" in the technical sphere.
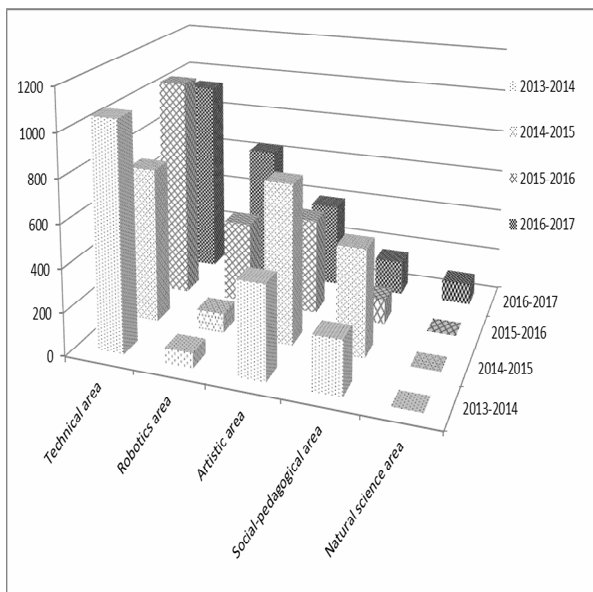
Figure 1. The number of schoolboys by fields

The analysis of the programs by terms of training shows that 63% of the current academic year are programs designed for 1 year of education (last year 52%). Basically, these are programs designed for junior schoolchildren and the program of newly opened associations "radioelectronics", "lego-designing".

Training on these programs contributes to the definition of a further educational route in the chosen area of activity. Programs for a period of more than 1 year are 26% (last year 36%), which indicates the degree of satisfaction of students with the quality of services provided and the presence of positive motivation for continuing education in the chosen area of activity.

Overall, the programs analysis shows the content of the optional educational programs aimed at forming and development of creative abilities of students, personal qualities, the identification, development and support of talented children, professional orientation.

Recently, the sphere of additional education has become a priority direction of development in the city of Izhevsk. This was confirmed by a larger number of grant events. The Engineering and Technical Center "Foresight" annually successfully participates in these events. That allows not only to improve the material and technical

base, but also successfully implement the best pedagogical practices, modernize all types of activities: methodological support of the educational process, advanced training, support for the implementation of programs and projects, and much more. During the reporting period, "Forsyth" successfully implemented a project on networking of educational organizations of the city and the center became a republican innovation platform "Integration of general and additional education aimed at developing technical creativity of children". Therefore, new directions in the work of the center are emerging. New organizational and managerial structures are being formed and a transition is being made from temporary creative design groups to self-management teams and development of management activities. To ensure joint activities to harmonize the goals, mechanisms, interaction schemes, determine the educational results, a permanent body is established - the Governing Council. Coordinator of activities, general control and management of the "Foresight".

The functions of the Governing Council are coordination and control over the implementation of all innovative processes in the institution.

The Council includes Kalashnikov Izhevsk State Technical University teachers and district school directors. It is a professional community providing for expansion of business contacts, information support, increasing the prestige of educational projects and programs, as well as social support in the development of the institution. The establishment of additional education for "Foresight" creates conditions and an opportunity for a quality implementation of educational programs in robotics. To increase the attractiveness and accessibility of technical (including robotics) focuses, the modernization of the material and technical base of this direction is required, which will encompass a larger number of schoolboys. "Foresight" successfully implements a set of informational and methodological materials and developments in robotics, introduces electronic robotic laboratories in the educational process and organizes practical internships for senior pupils, which will allow children to orientate in choosing a profession in the field of robotics and system engineering.

Thus, when solving the problems of accompanying technically gifted children, we take into account the requests of the city's educational policy, the schoolboys and their parents, the personal and professional potential of teachers, the material and technical base, the information and methodological resources of educational institutions, the possibilities of the urban environment and social partners. Together with the Kalashnikov Izhevsk State Technical University teachers during the reporting period, the refresher courses "Introduction of educational robotics in the educational process" for teachers of computer science, physics and mathematics were held. Thus, we began to train the personnel for the implementation of innovative projects.

VI. CONCLUSION

According to the theory of cluster policy for the regional industrial innovation cluster of the Udmurt Republic, an organizational and economic mechanism of formation of professional competences is required, which would provide the needed level of innovation and educational potential.

The main condition for the effective formation of professional competences in the regional industry cluster is the development of connections between its subjects and the integration of educational and innovation processes. The formulated principles of subjects' interaction in a regional industrial cluster are the theoretical basis for the formation of innovation and educational potential ensuring the effective functioning of the innovation economy in Russia.

Thus, the basic problems of educational robotics, necessary competences of schoolboys, are discussed in the article. The aim and program tasks are put on educational robotics. Forms and methods of educating are shown. Conception of programming of the intellectual robotics systems is considered. The tasks of competitions are analysed on robotics and events on their realization are offered in this paper.

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Success of Social Networking Sites: Evidence from the University of Novi Sad

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Abstract—In the higher education industry, web-based marketing has already been widely applied to service current students, as well as to attract new ones. All major universities in the world have incorporated their websites with social networking sites (SNSs), but it is likely that a significantly larger proportion has no clear knowledge of how successful their SNSs are. Accordingly, this study proposes an integrated model for evaluating the effectiveness of SNSs from a student point of view. This model is based on the use construct and seven socio-demographic conditions.

I. INTRODUCTION

Social networking sites (SNSs) such as Facebook have flourished in recent years [1]. SNSs are systems that allow individuals to create a virtual public profile, articulate a list of connections, and view and traverse that list [2]. On such an online system, users can jointly investigate network contents, share their experience and build up a relation for different purposes, such as social, or educational [3]. In the era of digital economy, many organizations utilize SNSs to market their services to potential customers [4]. The popularity of internet and information technologies has provided a platform for all organizations, not only to deliver information for advertising and promotion directly to their consumers, but also to establish two- way communication [4].

In the higher education industry, the application of e-business through web-based marketing has already been widely applied to service current students, as well as to attract new ones from various high schools and industry. Educators nationwide have tapped into the potential impact of SNSs on enrollment and education [1]. All major universities in the world have incorporated their websites with SNSs (e.g. Harvard University, The University of Oxford, The University of Cambridge). Even though e-business strategy towards the use of SNSs is popular, it is likely that a significantly larger proportion of organizations has no clear knowledge of how successful their SNSs are [4]–[6] especially during the selection and pre-enrollment phase. In addition, the understanding of the primary antecedents of students' intention to use SNSs is limited [1]. Recent studies in websites and SNSs have examined the role of demographic characteristics [7] and their importance in the prediction of the use of technologies [8]–[12]. A better theoretical understanding of demographic characteristics and IS use is needed to benefit research in the IS field [13]. A study on various social factors for expanding the horizon of the research on the SNSs users and the effects of SNSs use needs to be conducted [14].

This study presents an empirically validated model for assessing the success of university SNSs during the selection and pre-enrollment phase from the students' perspective. In our research, we used the construct use from the updated DeLone and McLean [15] IS success model and seven constructs proposed by Nam [9] and Stefanovic et al. [12]. The data was collected from 604 freshman students from the University of Novi Sad, Serbia using a questionnaire. The students were using the university SNSs (i.e. Facebook, Instagram, Twitter) during the selection and pre-enrollment phase.

II. BACKGROUND AND RELATED WORK

A. Social Networking Sites

Social networking sites – such as Facebook, Twitter, and Instagram – enable users to create a public profile as well as to build relationships with other people, peer groups or organizations [16]. For example, Facebook, a leading SNS, has more than 2 billion monthly active users as of June 30, 2017 [17], and the site is still exponentially growing in popularity. Among users there is a prevalence of young people who are at college or university [18].

The introduction of SNSs has brought operational benefits for organizations, and all their stakeholders (e.g. employees, customers). Organizations regularly use SNSs to disseminate information about their products and services [19]. Universities use SNSs to distribute information such as text, images, audio and video, to service current and potential students [20]. They use their SNSs to promote their study programs, facilities, student life and all relevant elements for prospective and current students. Universities can easily engage with students through SNSs pages [6]. New postings are shared directly with users who follow the university. Besides, SNSs affect communication, marketing, and instruction, they have changed students' information-seeking behaviors [21]. The wealth of user-generated content allows students to share experience with other students and seek for everyday-life information. Since SNSs have become readily available and accessible through smartphones and tablets, students can create, discuss and share information on different topics anywhere, anytime.

In 2014, Serbia had about 3.5 million Facebook users, 53% of whom were men [37]. Most Facebook users (1.18 million) are between the ages of 18 and 24, which is approximately 33% of the total number of users in Serbia. According to the data published in 2013 by the Ministry of Trade, Tourism and Telecommunications of the Republic of Serbia (http://mtt.gov.rs), the most popular social networks in Serbia are Facebook and Twitter, and

93.4% of the population between 16 and 24 years of age has a profile on at least one of these two social networks.

B. SNSs at the University of Novi Sad

The educational system of the Republic of Serbia consists of five state universities and two private ones [38]. The University of Novi Sad is the only university in the northern province of Vojvodina. Students can finance costs of university education through a government scholarship or self-funding.

The University of Novi Sad uses three SNSs (i.e. Facebook, Instagram, Twitter) for attracting new students. The process starts in February with the creation of new SNSs for each generation, with the aim of targeting the third grade of high school students, and ends in July the following year when high school students enroll at the university. During the 18-month campaign the main objective is to attract many members since the university found a high degree of correlation between the number of SNSs members and university applications. With face-to-face events (e.g. University open day, Education fair, high school visits) the university attracts new members for the SNSs. There are two purposes of attracting new members – dissemination of information and establishment of two-way communication. The University disseminates information regarding offline events, promotional articles and videos, news from the university website, application requirements, important dates, et cetera. The use of SNSs is voluntary since high school students could get the same information by visiting the university website. Two-way communication is the most important aspect of the strategy since it represents the best way to engage with high school students and provide answers to all their questions. The policy of the university is 12-hour response time. Since the University of Novi Sad receives additional income from self-funded students, the authors used the funding option as a factor of socio-demographic characteristics.

C. Conceptual model and hypothesis

In this paper, we tried to use the concepts and models mentioned in similar studies, considering the views of students, and provide a model for measuring the success of SNSs, extending previous research. Based on the review of previous research results [9], [10], [15], [22], we designed the initial conceptual model, presented in Fig. 1. Brief definitions of each measure in the model are as follows:

- Intention to use/Use – the degree and manner in which potential students utilize the capabilities of SNSs [23]. In the context of academic institution SNSs, this construct measures the behavior and attitude of users in regard to frequency of system use, use for information retrieval, as well as tendency and duration of use [22], [24].

- Socio-demographic conditions – demographic and social characteristics of SNSs users. Based on the call of Yoo and Jeong [14], and previous research in the IS field (e.g. [7], [9], [12]) we have included the following socio-demographic conditions in this study: gender, age, monthly family income of the students as proxy measures of socioeconomic status,
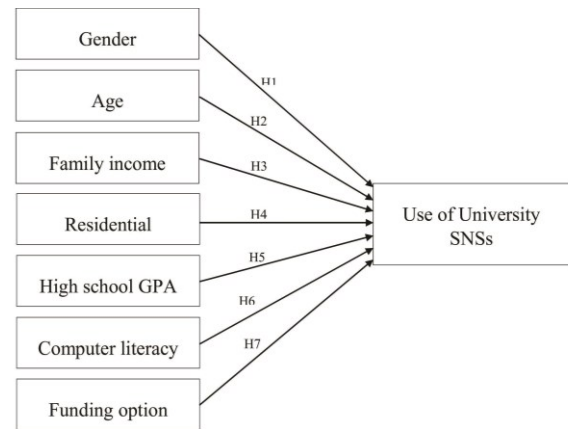
Figure 1. Conceptual model

residential categories – where the student comes from, high school GPA as proxy for education, computer literacy as a measurement on how well the student is technologically skilled, and funding options – the way the student pays for his or her education.

According to Fig. 1, the use construct is coupled with socio-demographic characteristics to measure the success of SNSs. Nam and Sayogo [25] found that socio-demographic conditions strongly matter for information system use. A finding from the study conducted by Nam [9] revealed that socio-demographic conditions influence the usage level of various functionalities of information systems. In a study conducted by Stefanovic et al. [12] it was found that socio-demographic conditions have a limited impact on the decision to use an information system. According to the Diffusion of Innovations Theory, early adopters of any technology innovation share common characteristics: young, well-educated, and higher income [26].Therefore, it is hypothesized that:

H1: Gender of students have a positive effect on use of SNSs.

H2: Age of students have a positive effect on use of SNSs.

H3: Familiy income of students have a positive effect on use of SNSs.

H4: Residential status of students have a positive effect on use of SNSs.

H5: High school GPA of students have a positive effect on use of SNSs.

H6: Computer literacy of students have a positive effect on use of SNSs.

H7: Funding option of students have a positive effect on use of SNSs.

III. MATERIALS AND METHODS

A. Measures

The indicators and construct of the conceptual model have been determined based on previous research on IS success. The measures that were used to analyze the success of various types of IS in previous studies and which have been adopted in this study are listed in Table I. We used 5-point Likert scale for this construct.

B. Sample and data collection procedure

The data used to test the conceptual model were obtained from a sample of newly enrolled students from the University of Novi Sad, Faculty of Technical Sciences, Serbia. The focus was on students that have

TABLE I
CONSTRUCT MEASURES

Construct	Indicator	References
Use of SNSs	Frequency of use	[24], [29]
	Duration of use	[30], [31]
	Use to retrieve information	[32]

TABLE II
DEMOGRAPHIC DETAIL OF THE RESPONDENTS (N=604)

Measure	Items	Frequency	%
Gender	Male	338	56.0
	Female	266	44.0
Age	<19	77	12.7
	19	459	76.0
	20	35	5.8
	>20	33	5.5
Family income	Less than $200	69	11.4
	$200 to $400	157	26.0
	$401 to $600	188	31.1
	$601 to $1000	117	19.4
	More than $1000	73	12.1
Residential place	Urban	355	58.8
	Suburban	112	18.5
	Rural	137	22.7
High school GPA	More than 4.5	384	63.6
	Between 3.5 and 4.5	203	33.6
	Less than 3.5	17	2.8
Computer literacy	Professional	157	26.0
	Advanced	394	65.2
	Beginners	53	8.8
Funding option	Government scholarship	395	65.4
	Self-funding	209	34.6

used the university SNSs. 87% of students reported that they used SNSs during selection and pre-enrollment. The Faculty of Technical Sciences is organized into 13 departments which in total enroll 2323 students. We used online survey tool to collect data. A total of 638 responses, that were using SNSs during the selection and pre-enrollment phase, were received over a period of ten weeks, representing a response rate of 27.5%. Detailed descriptive statistics relating to the demographic characteristics are shown in Table II. For the use construct, 3 indicators were measured with the five-point Likert scale [27].

IV. RESULTS

For hypothesis testing, linear regression analysis was conducted by IBM SPSS.

A. Simple hypothesis testing

Please see Table III for descriptive statistics of all factors. To examine the relationship between each individual hypothesized construct and its relationship to use of SNSs, a correlation matrix was produced. Please see Table IV. As predicted, each factor was significantly correlated and correlated in the expected direction with the use of SNSs; this provides initial support for all hypotheses.

B. Model testing

To test the overall model, we used linear regression. The overall model was significant, Adjusted R^2 = .30, $F_{(4, 159)}$ = 19.8, $p < .001$. Two predictors had a significant coefficient – residential place (B = .08, t = 1.97, $p < .05$) and funding options (B = .25, t = 3.3, $p < .001$). However, gender (B = .13, t = 1.82, $p > .05$) and family income (B = -.05, t = -1.91, $p > .05$) were not significantly different from 0. This confirms support for hypothesis 4 and 7, but undermines support for hypothesis 1 and 3.

Age (B = -.01, t = -.29, $p > .10$), high school GPA (B = .09, t = 1.42, $p > .10$), and computer literacy (B = .01, t = .17, $p > .10$) were not significant. Hence, support for hypotheses 2, 5 and 6 was not found. Table V summarizes hypothesis testing.

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TABLE III
DESCRIPTIVE STATISTICS FOR VARIABLES PREDICTING USE OF SOCIAL NETWORKING SITES

Factors	M	SD
Gender	1.44	0.497
Age	2.04	0.635
Family income	2.95	1.18
Residential place	1.64	0.828
High school GPA	1.39	0.543
Computer literacy	1.83	0.564
Funding option	1.35	0.476
Use of SNSs	3.52	0.841

TABLE IV
CORRELATION MATRIX FOR ALL FACTORS

	Variable	1	2	3	4	5	6	7	8
1	Gender	-	-0.035	-0.056	-0.004	-0.131**	0.312	-0.091*	0.064*
2	Age		-	-0.86*	0.002	0.190**	0.005	0.168**	0.027
3	Family income			-	-0.118**	-0.001	0.034	-0.035	-0.095*
4	Residential place				-	-0.013	-0.016	0.019	0.090*
5	High school GPA					-	-0.023	0.340**	0.095*
6	Computer literacy						-	-0.068	0.017
7	Funding option							-	0.155**
8	Use of SNSs								-

* $p < 0.05$
** $p < 0.01$

V. DISCUSSION

This research has addressed the problem of measuring the success of SNSs deployment from the perspective of freshman students as primary users during the selection and pre-enrollment phase. In this study we empirically assessed socio-demographic characteristics and their influences on the use of University SNSs. Our results revealed that: (1) the researchers have advocated extending and revalidating past theories and framework in a new context [28]. As such, the current study represents the first comprehensive examination of the socio-demographic conditions and success of SNSs using scales derived from the existing literature. The results have implications for practitioners in the education sectors in terms of social networking based communication and marketing, for the SNSs managers in terms of instructional design and development of SNSs, and finally for the future researchers to use this instrument as a reference. (2) Looking at the socio-demographic variables that are related to use of university SNSs, the results demonstrate that residential place and funding option are the most influential variables. From this point of view, one can draw the conclusion that the residential place and funding option are discriminating factors to predict the use of university SNSs. Therefore, it is worth observing that

TABLE V
SUMMARY OF HYPOTHESIS TESTING

Hypothesis	Relationship	Result
H1	Gender → U	Marginally Supported
H2	Age → U	Not Supported
H3	Family income → U	Marginally Supported
H4	Residential place → U	Supported
H5	High school GPA → U	Not Supported
H6	Computer literacy → U	Not Supported
H7	Funding option → U	Supported

the students who are coming from the suburban and rural areas are using SNSs more than students from the urban area. In addition, students with financial aid use SNSs less than self-funding students. On the contrary, gender and family income have a limited impact on the decision to use SNSs during the pre-enrollment process. Slight differences were found with females preferring to use SNSs to retrieve information in the pre-enrollment phase. Furthermore, students coming from the lower income families tend to use university SNSs more often. This result is in line with previous research that also found a positive influence of gender on the use of information systems[8,9] and especially the use of SNSs [11].

This finding is also consistent with more general studies on Facebook or Twitter usage showing that females spend more time on Facebook and have more Facebook friends[15]. As a final point, marketing managers need to be aware that potential rural students, self-funding students, female students and lower income students tend to use SNSs (i.e. Facebook, Instagram, Twitter) more than male students and students with government scholarships.

From practitioners' perspective, the findings of socio-demographic conditions, related to the use of SNSs, provide managers/designers with an insight that they should carefully re-examine students' socio-demographic characteristics when they develop or update their SNSs. In practice, university managers need to measure the quality of marketing operations to assess the productivity and efficiency of their SNSs. This needs to be done annually[67]. More than 50 percent of online teens, and more than 80 percent of college students, use SNSs for their academic as well as their everyday-life information-seeking purposes[22].Using our instrument, managers could assess the overall strength, as well as the effectiveness of their SNSs. Such information allows decision makers to carry out corrective actions to increase the effectiveness of e-business strategy regarding SNSs, develop strategies to address problems, provide better service for students to attract more prospective students. We are hopeful that our research findings can benefit developers to be more effective by ensuring that the SNSs strategy contributes to a positive attitude of the SNSs audience.

VI. CONCLUSION

This research examined the success of the university SNSs on the individual level of analysis from the students' perspective. A field survey was conducted at the University of Novi Sad, Serbia to test the model. Our analysis showed that socio-demographic characteristics of the students had a positive impact on use of university SNSs. It has been shown that residential place, funding option, gender and family income do confound the use of university SNSs.

Other than socio-demographic conditions included in this study, there could also be other factors influencing usage. Dong et al. [24]presented benefits of social interaction as factors that influence the usage of SNSs. Further research considering these factors could enhance an understanding of success determinants for SNSs. The data that were used in this study were collected in only one country, Serbia, and the narrow data focus may limit the generalization of the results. Future research may replicate this study from a global perspective.

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Numerical Models of Active Devices Utilized in the Optical Communication Systems

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Abstract—**Numerical modeling is still very important part of designing a new devices or whole optical communication systems. The important criterion in selecting suitable numerical model is fact it should match with particular problem solution. The suitable numerical model is sufficient accurate, time effective and provides all needed information about its signal characteristic. For numerical modeling of optical communication systems and their active devices, they seem to be appropriate models based on the equivalent circuit models. Output signal characteristics of modelled devices are comparable to the measured characteristics of real devices. It is possible simply integrate them to the wider group of numerical models that can form numerical model of whole communication system. Dynamic characteristics of numerical model of semiconductor laser and photodiode play key role in the optical systems and can led to many detrimental effects like inter symbol interference. This article is focused on the analysis of steady and transient state of the laser and impulse response of the photodiode.**

I. INTRODUCTION

Optical communication systems include wide area of passive and active photonics, optoelectronics and electronic components simultaneously. There are also algorithms that are implemented in digital signal processing (DSP). Important role plays numerical modelling in optical communication systems. Nowadays there are many numerical simulation methods that are utilized and implemented into the numerical tools. The basic task is to choose the best numerical model. It is not straightforward and from this reason is suitable to take into account several requirements [1 – 4].

First of all: is our goal simulate characteristics only one device or whole transmission system? Next, is it important to know information that provides complex electromagnetic field or only approximation of his significant parameter? At the end, computational and time requirements may decide which numerical model is usable for solving our problem [3].

For design new types of devices and subsequently their optimization are suitable numerical models that deal with their exact dimensions, arrangement of particular layers and material composition. In this case are utilized numerical tools that solve all parameters of electromagnetic field on the base of Maxwell equations. Therefore are often used finite difference time domain (FDTD) methods and finite element method (FEM) in 2 or 3-dimensional variants. These numerical methods provide high numerical accuracy but are time-consuming [5 – 8].

In the case of already existing devices where signal characteristics are known, it is important to find how they impact on the performance of whole communication system. In this case the equivalent circuit model is suitable choice. It is based on the measured characteristics of real devices that are further utilized for creation sets of differential equations that describe dependence between input and output quantities. Impact of the active photonic devices like lasers, amplifiers and photodiodes within whole communication system are the most modeled just through their time-depend characteristics. Advantage of these numerical models is that their output characteristics are comparable with measured characteristics of real devices [3, 9 – 14]. Next advantage is that these numerical models can cooperate together with numerical models based on the Split-step Fourier (SSFM) and finite difference method (FDM) that solve signal propagation through the passive optical components like optical fibre [15, 16].

Semiconductor laser has become key element in the optical network. Due to its low cost, good power and spectral characteristics, it is utilized on the side of transmitters and receivers simultaneously. Until today has been developed many numerical models of active semiconductor lasers. Well known are numerical models of semiconductor distributed-feedback laser diode. These models are able to model noise characteristics of real devices through Langevin noise sources [13, 17].

Similarly, it is possible to use equivalent circuit model for photodiodes. In the optical communication systems are utilized two basic types of the photodiodes, PIN and avalanche photodiodes (APD). Until today it exists wide range of types of these photodiodes and they are different by their structure and usage. Basic numerical model has been developed by Chen and Liu who established several simplifications [18]. The widths of the depletion regions (n and p) are neglected due to width of I region. The uniform electric field in the I region and zero in the N and P regions. This numerical model has been used for $In_{0.53}Ga_{0.47}As$-InP photodiode structure and is valid only for these simple types of photodiodes [18, 19]. For more sophisticated structures have been developed new numerical models like separate absorption and multiplication avalanche photodiode (SAM-APD) [20], transfer matrix of APD [21] and position dependent circuit model for thin APD [22].

This paper is organized as follows: The second section provide fundamental description of numerical models of semiconductor laser and photodiode. Both numerical models are described through rate equations that are representational set of differential equations. In the third section are stated simulations and results. The main intention is imposed on the dynamic characteristics of chosen semiconductor devices. The last section contains

evaluation of results and generally utilization of numerical models within modelling of the optical communication methods.

II. NUMRICAL MODELS OF SEMICONDUCTOR DEVICES

Signal and dynamic properties of semiconductor lasers are described through laser rate equations. These equations can be in different forms, it depends on the structure of particular laser and conditions for Langevin noise sources $F_i(t)$ [17]. Laser rate equations are represented by set of differential equations that model the relation between injected current $I_{in}(t)$ to laser and output quantities like the number of carriers $N(t)$, number of photons $S(t)$ and optical phase $\theta(t)$

$$\frac{dN(t)}{dt} = \frac{I_{in}(t)}{q} - \frac{N(t)}{\tau_n} - g\frac{N(t)-N_0}{1+\varepsilon S(t)}S(t) + F_N(t), \quad (1)$$

$$\frac{dS(t)}{dt} = g\frac{N(t)-N_0}{1+\varepsilon S(t)}S(t) - \frac{S(t)}{\tau_p} + \frac{\beta N(t)}{\tau_n} + F_S(t), \quad (2)$$

$$\frac{d\theta(t)}{dt} = \frac{\alpha}{2}g\left(N(t)-\bar{N}\right) + F_\theta(t). \quad (3)$$

Particular equations take into account construction specifications and materials used within real device, where q is the electron charge, τ_n is the carrier lifetime, τ_p is the photon lifetime, g represent the gain slope, N_0 is the carrier number at transparency, β is the fraction of spontaneous emission coupled into the lasing mode, ε is the nonlinear gain compression factor, α is the linewidth enhancement factor and $\bar{N}$ is the time-average carrier number.

As mentioned before the Langevin noise sources may be different from the particular cases but generally have to satisfy some conditions, it means that $F_i(t)$ satisfy Markovian approximation, as the auto- and cross-correlation functions of the noise sources [17, 23].

$$F_S(t) = \sqrt{\frac{2\beta N(t)S(t)}{\tau_n \Delta t}}x_s, \quad (4)$$

$$F_\theta(t) = \sqrt{\frac{\beta N(t)}{2\tau_n S(t)\Delta t}}x_\theta, \quad (5)$$

$$F_N(t) = \sqrt{\frac{2N(t)}{\tau_n \Delta t}}x_z - F_S(t). \quad (6)$$

The variables x_s, x_θ and x_z are represented by Gaussian distribution with zero mean and unity variances σ and Δt is the time difference between two samples [13, 17, 23].

The carrier and photon density describe inner characteristic of active medium in laser. However, for the purpose of simulation within optical communication system it is better to work with time dependent optical power

$$p(t) = \eta_d \frac{hf}{\tau_p}S(t), \quad (7)$$

and frequency fluctuations that determine spectral characteristic of lasing optical light as follows

$$\Delta\nu(t) = \frac{1}{2\pi}\frac{d\theta(t)}{dt}, \quad (8)$$

where f is the frequency of lasing optical light, η_d is the differential quantum efficiency and h is the Planck's constant. All needed parameters are stated in Table 1 [17].

The same way as in the case of semiconductor lasers the photodiodes are modelled by rate equation and belong to group of equivalent circuit models. For simplicity we are going to deal with numerical model developed by Chen and Liu [18]. These equations represent time-dependent response of photodiode for the incident optical power are valid for reverse-biased structure. For each region are given the following equations:

N region

$$\frac{dP_n(t)}{dt} = P_G(t) - \frac{P_n(t)}{\tau_p} - \frac{I_p(t)}{q}, \quad (9)$$

P region

$$\frac{dN_p(t)}{dt} = N_G(t) - \frac{N_p(t)}{\tau_n} - \frac{I_n(t)}{q}, \quad (10)$$

and I region

$$\frac{dN_i(t)}{dt} = N_{Gi}(t) + \left(\nu_n\zeta_n + \nu_p\zeta_p\right)N_i(t) - \\ - \frac{N_i(t)}{\tau_{nr}} - \frac{N_i(t)}{\tau_{nt}} + \frac{I_n(t)}{q} . \quad (11)$$

The form of the equation (11) follows from the electric neutral condition $P_i(t) = N_i(t)$ in the I region. On the base of equations (9) - (11) the variables $P_n(t)$ and $N_p(t)$ describes the total excess holes and electrons in the N and P regions, $N_i(t)$ the total excess electrons and holes in the I region, q is the electron charge, τ_p and τ_n are the hole and electron life-time in the N and P regions, τ_{nr} and τ_{pr} are the recombination life-time of electron and hole in the I region, τ_{nt} and τ_{pt} are the electron and hole transit-time through the I region, ν_n and ν_p are the electron and hole drift velocities in the I region, ζ_n and ζ_p are the electron and hole impact ionization rates in the I region. The symbols $P_G(t)$, $N_G(t)$ and $N_{Gi}(t)$ represent electron-hole pair generation rates in the N and P regions and the generation rate in the I region respectively.

These variables are directly related to the power of incident light and are mentioned in more detail in [18].

TABLE I.
PARAMETERS FOR LASER RATE EQUATIONS [17]

Parameter	Value
q	1.60217646×10^{-19} C
τ_n	0.33×10^{-9} s
τ_p	7.15×10^{-6} s
g	1.13×10^4 s^{-1}
N_0	8.2×10^6
β	3.54×10^{-5}
ε	4.58×10^{-8}
h	6.62607004×10^{-34} m^{2}kg.s^{-1}

The total current $(I_j(t))$ that flows through the photodiode consist of the hole $(I_p(t))$ and electron diffusion $(I_n(t))$ current in the N and P regions, tunneling and parasitic current $(I_d(t))$ that represents dark current at

the high reverse voltage and current ($I_i(t)$) in the I region [18]

$$I_j(t) = I_p(t) + I_i(t) + \left[C_S + \varepsilon_0 \varepsilon_r (A/W_i) \right] \frac{dV_J}{dt} + I_d(t)$$

. (12)

Where expression $\varepsilon_0 \varepsilon_s (A/W_i)$ define capacity of junction, W_i is the width of I region, C_s is the parasitic capacitance, A is the cross-section perpendicular to the direction of the incident field, V_J is the voltage of junction, ε_0 and ε_r is the vacuum and relative permittivity respective. For purpose of the simulation all used values for the parameters are listed in [18, 19].

III. NUMERICAL SIMULATIONS AND RESULTS

The numerical models of semiconductor DFB laser and photodiode are based on the sets of differential equations. Both of them belong to the group of equivalent circuit model. From the point of simulation view they can be simply implemented in one simulation environment and solving by using one numerical method. In this case have been used 4th-order Runge-Kutta with time step $\Delta t = 10ps$.

Numerical model of semiconductor laser is optimized for the range of injected current from 13 to 25 mA, while threshold current is 10.2 mA [13, 17]. The central wavelength was set on the 1550 nm. In Fig.1 and Fig. 2 are depicted time-dependencies of main quantities, carrier $N(t)$ and photon $S(t)$ density for different injected current $I_{in}(t)$. It can be seen that laser operate in two states. The first state is the transient state and second state is the steady state. Approximately after time 2ns the laser goes to the steady state. The time dependent optical power $p(t)$ that is radiated out of laser has similar dependence as photon density $S(t)$ and is depicted in Fig. 3. These are good illustrations how laser works in the regime of direct modulation.
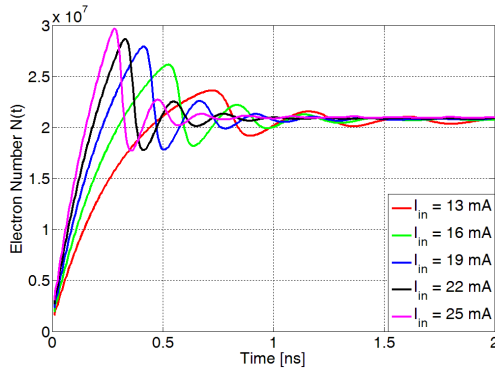
Figure 1. Time dependence of carrier density $N(t)$ in transient state.
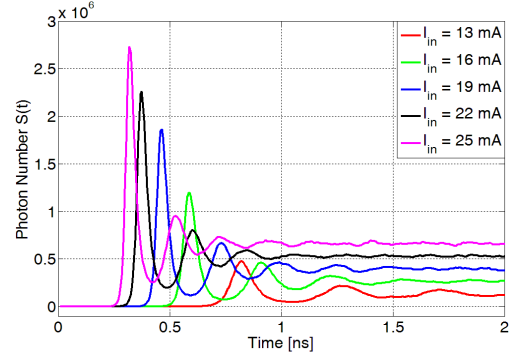
Figure 2. Time dependence of photon density $S(t)$ in transient state.
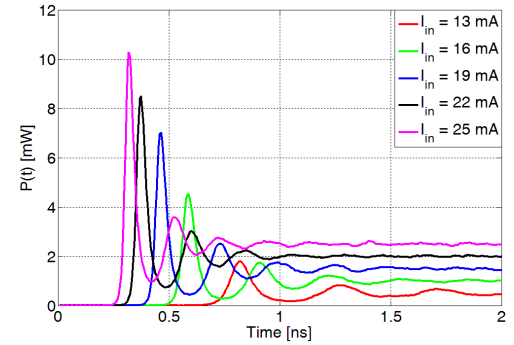
Figure 3. Time dependence of optical power $p(t)$ in transient state.

For practical simulations are most interesting time dependencies in the steady state. In this case the laser has good signal and spectral characteristics. As it is seen in Fig. 4 - Fig. 6, the dominant fluctuation is caused by impact of noise. This is the most used regime of laser called lasing by continuous wave (CW).
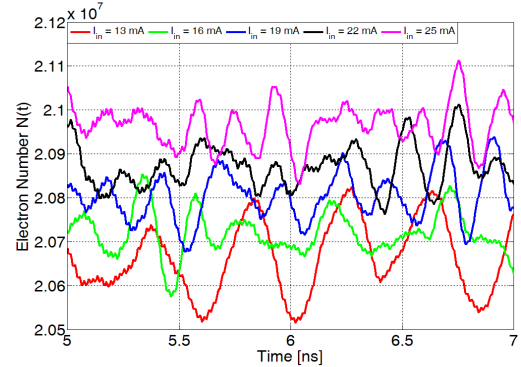
Figure 4. Time dependence of carrier density $N(t)$ in steady state.
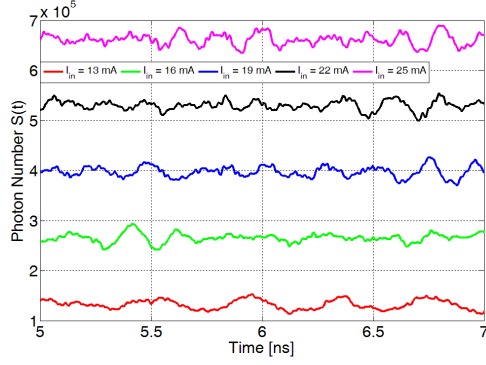
Figure 5.   Time dependence of photon density $S(t)$ in steady state.
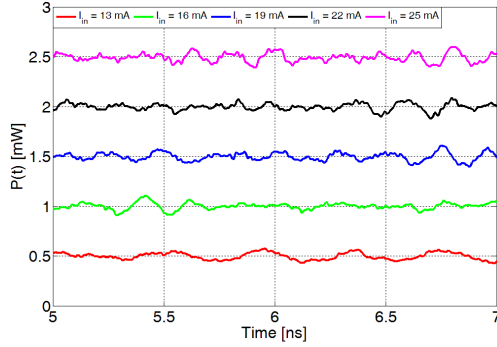
Figure 6.   Time dependence of optical power $p(t)$ in steady state.

Based on time dependencies of the optical power and phase, it is possible determine power spectral density of laser (see Fig. 7 and Fig. 8).
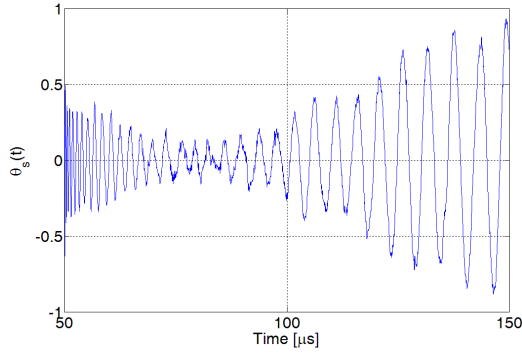
Figure 7.   Time dependence of optical phase $\theta(t)$ in steady state.
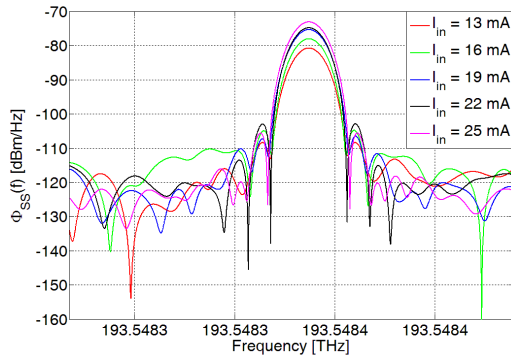
Figure 8.   Power spectral density of the lasing optical power from laser $\Phi_{SS}(f)$ for the central frequency 193.5484 THz.

The key characteristic of photodiodes is impulse response. The impulse response depends on the two main factors. First factor is the time duration of incident optical pulse. This parameter is well known in the form of symbol or bit rate (in the case the one bit is mapped to the one transmitted symbol). Relation between time duration (T_S) of pulse and symbol rate is straightforward $R_b = 1/T_S$. In Fig. 9 is seen the impulse response of photodiode for reverse-bias voltage $V_J = 50V$ and pulse power 1 mW for different bit rates. From the results follow that with increasing of bit rate the impulse response increases too.
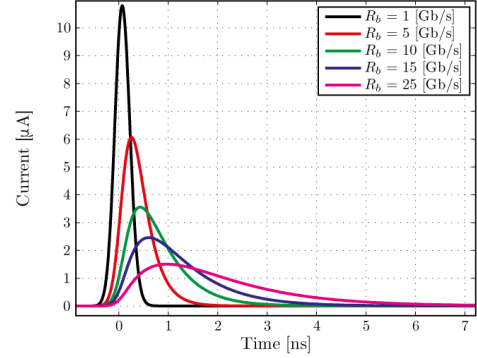
Figure 9.   Impulse response of photodiode for different bit rates.

The second important factor is reverse-bias voltage V_J. In Fig. 10 is the impulse response for different V_J in the range of 40 - 80 V. The breakdown voltage is in this case 80.5 V [18, 19]. Used bit rate has been set on 1 Gbps. The value near the breakdown voltage provides the highest quantum efficiency however the highest impact of impulse response too.
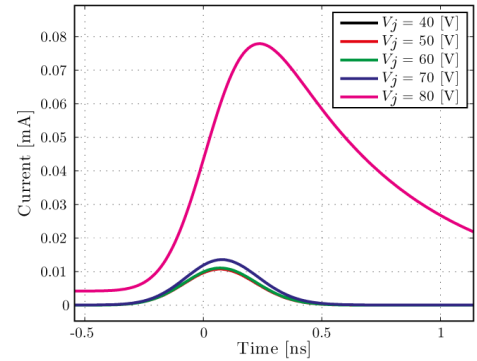
Figure 10. Impulse response of photodiode for different reverse-bias voltage V_J.

The simulations of photodiode shows that parameters reverse-bias voltage and symbol rate are key for the correct functionality on the receivers. The correct and balanced setting of these parameters are important for mitigation of inter symbol interference (ISI).

IV.   CONCLUSION

In this article were shown time-effective numerical models of semiconductor laser and photodiode. Both of these models are type of equivalent circuit model. Their advantage is that their output characteristics are comparable with measured characteristics of real devices. Although in this article both of these models were presented independently, the results show that both of these models can operate in the same range of wavelengths, optical powers and bit rates. In the case of

active optical devices are important their noise, response, transient and steady state characteristics respectively. The Fig. 3 and Fig. 6 show that numerical model of laser can be utilized as directed modulated light source or in the regime of continuous wave (CW). For the wavelength 1550 nm it was achieved output optical power approximately 2.5 mW that is suffice for many optical applications in this time. As key parameter in the case of photodiode it seems its impulse response. Although photodiode provides very high quantum efficiency, this parameter significantly limits usage of high bit rates due to its high impulse response. As seen in Fig. 9 and Fig. 10 combination by very high reverse-bias voltage and bit rate can lead to the degradation effect called the inter symbol interference.

By combining these numerical models, it is possible effectively create the base structure of optical communication system. For creation of whole optical system in any form it is essential utilize more numerical models of optical fiber and other passive optical components.

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The use of the system Geogebra for graphical interpretation of functional dependencies in mathematics teaching

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Abstract — **Dependencies between variables and mathematical functions are included between five basic topic areas in the Slovak national curriculum for teaching mathematics at primary and secondary schools. Students' abilities to analyze data in tables and charts and to interpret functional dependencies between variables belong to the important mathematical competencies. Various monitors and international assessments (such as PISA, TIMSS) pay large interest to evaluate students' knowledge and skills of the use of mathematical functions. The results show that students are lagging behind in interpreting data from tables and graphs, identifying and understanding relationships between variables and they are unable to apply knowledge about functions in solving tasks. Lack of skills in the use of different types of functions causes problems in mathematical modelling of situations from real life. Efforts to achieve better results in the understanding and using functional dependencies by problem solving can be reflected in several areas. One opportunity is to change the curriculum with respect to a greater focus on tasks derived from real life situations. Implementation of modern information and communication technologies into mathematics teaching can play the important role in mathematics teaching innovations. Advanced and effective means for learning functional dependencies are provided by the dynamic geometric system Geogebra. Deficiencies and misconceptions of students in interpreting, symbolic expression and using functional dependencies are analyzed in this paper. The main purpose of the paper is to demonstrate various types of tasks solved in the Geogebra environment which could contribute to the increasing of clarity of teaching and to the creation of the correct concepts in mathematics teaching and to improving the conceptual understanding of functional dependencies between variables.**

I. Introduction

The ability to apply the acquired knowledge and skills in problem solving is an important mathematical competence. The development of abilities of students to solve problems requires the use of different representations of data and different types of models to represent real situations. The important part of creation of mathematical models is expression of relationships between variables. Acquisition of knowledge and skills in the use of simple arithmetic and graphical models is the first step in developing ability of students to use the different types of models in problem solving. The use of the simple models provides students with skills to

understand and use the more complicated algebraic models which require the identification of variables and expression of relationships between variables using equations, inequalities and functions.

Simple functional dependencies, such as direct and inverse proportion, are already included in teaching mathematics in the primary school. Other more complex functions are included into curriculum at the high school. Solving problems focused on functional dependencies should also include the creation of tables and graphs and after performance of calculations and logical considerations also creation of symbolical representation of functions. Suitable topics are for example tasks on motion, geometrical tasks and tasks from financial mathematics. Lack of experience and insufficient skills in designing and interpreting charts and graphs can cause problems in understanding and using of symbolic representation of functional dependencies between variables. These facts emphasize the need to use explanatory graphical models in mathematics teaching. Information and communication technologies (ICT) offer advanced and effective means of creating graphical and dynamical models. Teaching and learning mathematics through computer visualization and interaction with dynamic models can help students to develop adequate conceptions, enable students to understand abstract mathematical content and facilitate students to success in problem solving [1]. The system Geogebra takes a special position among the modeling software, which advanced tools allow the versatile use in teaching mathematics.

II. Monitoring of students' mathematical knowledge and skills in the use of functions

It has been widely recognized that for developing of modern information society it is essential to develop human capital in the fields of science, technology, engineering, and mathematics (STEM). It is the reason that the mathematical competencies of students should be in center of interest of education in many countries. The monitoring and assessment of mathematical literacy is the aim of several international testings, for example TIMSS, OECD PISA.

A. TIMSS (Trends in International Mathematics and Science Study)

TIMSS tests students' achievements in science and mathematics of fourth- and eighth-graders' pupils. TIMSS is administered once every four years, starting from 1995. In the years 2007 and 2011, testing in Slovakia was

conducted on a sample of pupils of the fourth year of primary school. The ability to read and interpret data from a graph was evaluated using the following task: The graph shows the number of blue, red and black pens which a teacher has on the table. How much more are red pens than black?
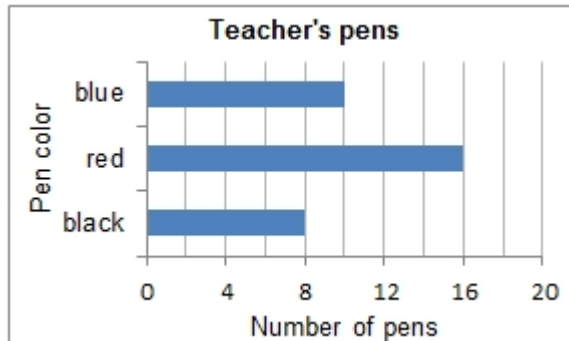
Figure 1. Graph from assignment of the task

Slovak pupil success rate was only 47.3 % in 2007. In the year 2011 Slovak, pupil success decreased by 2 %.

B. OECD PISA (Programme for International Student Assessment)

The international programme PISA surveys scientific, mathematical, and reading literacy levels. It measures how well 15-year-olds can apply their knowledge and skills to solve problems in real-life contexts. PISA is administered once every three years starting from 2000, and each administered year has a different domain focus (e.g. science and mathematics was the main assessed domain in 2003, 2006 and 2012).

The PISA test items are classified according to the main mathematical procedures that student uses to solve the problem. There are three procedures categories:

- formulating described situations mathematically in order to solve a problem,
- employing mathematical concepts, facts, formulas, procedures and reasoning,
- interpreting, applying and evaluating mathematical results.

Assessments from years 2003 and 2012 show lack of students' skills in analyzing data from graphs and charts and in interpretation relationships between variables and in the use of different types of mathematical functions for problem solving. We selected three tasks from this field in which students achieved the low success level.

The first chosen task was oriented on analyzing data from graphs. Graph from the task illustrated the dependence between speed and time during the car drive: *Kelly went for a drive in her car. During the drive, a cat ran in front of the car. Kelly slammed on the brakes and missed the cat. Slightly shaken, Kelly decided to return home. The graph below is a simplified record of the car's speed during the drive.*
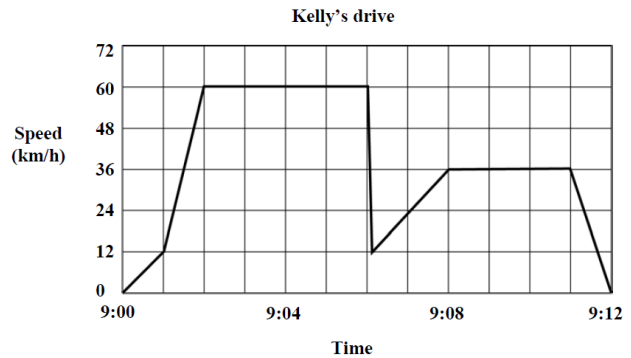
Figure 2. Graph of the functional dependence

Was the route Kelly took to return home shorter than the distance she had travelled from home to the place where the incident with the cat occurred? Give an explanation to support your answer, using information given in the graph.

The average success of students in OECD countries was 29 %.

The second selected task was focused on the interpretation of the relationship between variables: *A formula for the calculation of the drip rate, D, in drops per minute for infusions is:*

$$D = \frac{dv}{60n},$$

where d is the drop factor measured in drops per millilitre (mL), v is the volume in mL of the infusion, n is the number of hours the infusion is required to run. A nurse wants to double the time an infusion runs for. Describe precisely how D changes if n is doubled but d and v do not change.

Only 22 % of Slovak students solved this task focused on a verbal description of the relationship how *D* changes if *n* is doubled but *d* and *v* do not change correctly. The average success of students in OECD countries was 28 %.

The third selected task was focused on the mathematization of a real situation by using the linear functions for the creation of an equation: *Jenn works at a store that rents DVDs and computer games. At this store the annual membership fee costs 10 zeds. The DVD rental fee for members is lower than the fee for non-members. Non-member rental fee for one DVD is 3.20 zeds and member rental fee for one DVD is 2.50 zeds. What is the minimum number of DVDs a member needs to rent so as to cover the cost of the membership fee?*

Algebraic solution can be based on the definition of two linear functions expressing total fees independence of number of borrowed DVDs for member and non-member and their use for creation of the equation. The average success of students in OECD countries was only 17 %.

C. VEMIV (APVV–0715–12: Research on the efficiency of innovative teaching methods in mathematics, physics and informatics education)

We solved the project VEMIV supported with the Slovak research and development agency in the period from 2013 to 2016. The project was focused on the implementation of inquiry approaches into mathematics,

physics and informatics education. The key goal of the project was the integration of modern teaching methods supported by ICT into science, mathematics and informatics education to stimulate active learning. Another goal was to implement the achieved results and experience into the pre-service mathematics, physics and informatics teacher training with the perspective to prepare highly qualified teachers mastering the innovative teaching strategies.

The important result of the project was development of new teaching materials based on the implementation of inquiry approaches into mathematics, physics and informatics teaching. In the second stage of the project solving, the pedagogical experiment was performed at the selected secondary schools with the aim to show the contribution of inquiry approaches to teaching to the conceptual understanding and the development of the inquiry skills. The abilities to analyze data in tables and charts, to determine and interpret relationships between variables belong to the basic inquiry skills.

The solution of the project required the creation of tests to assess the level of development of the selected students' inquiry skills. Several pilot assessments preceded the creation of the final versions of the pre-test and post-test. We chose two tasks from the first pilot assessment. The first selected task was focused on the interpretation of the relationship between variables: *For ideal gas under certain conditions the equation*

$$p \cdot V = const.$$

is true. Choose the correct statement about the dependence between variables p and V.

a) How many times V grows, so many times the p grows too.

b) How many times V grows, so many times p is reduced.

c) If V changes, p remains constant.

d) If p increases, V also increases.

The pilot test was administrated in one class at high school with 26 students. The solution of this task required to describe indirect proportionality between variables p, V. 27 % of students selected the correct answer b). The most students chose the incorrect answer a) (38,5 %). We think that the students were misguided by the right side of the equation. It can be assumed that if the right side of the equation contains a specific number, the students' outcomes would be better. This result is similar to result that students achieved in PISA 2012 testing, although the formula expressed the relationship between only two variables.

The same pilot test also contained a task focused on the comparison of two linear functions. *Given the functions*

$$f(x) = x + 3, g(x) = 2x + 3$$

defined on the set of real numbers. Choose the correct statement for given functions f, g.

a) There is a real number a, for which the equality f(a) = g(a) is true.

b) All the values of functions f, g are positive.

c) For each real number x the value of f(x) is less than the value of g(x).

d) For each real number x the value of f(x) is greater than the value of g(x).

The sketch of the graphs of given linear functions could facilitate the solution of the task. The incorrect answer c) included the common misconception, when students consider that number $2x$ is greater than x for each real number x. 38 % of students chose this answer. 50 % of students chose the correct answer a).

The teaching strategies and teaching materials developed in the project VEMIV was used in real school conditions during the pedagogical experiment. Trained teachers at partner high schools have applied created methodological and teaching materials based on inquiry approaches to mathematics, physics and informatics teaching in selected lessons over five months. The students' development inquiry skills level was tested in the pre-test and post-test. The pre-test was given to 332 students at the six high schools in the beginning the pedagogical experiment. The pre-test contained ten tasks for measuring the development level of the selected inquiry skills. Two tasks in the pre-test were oriented on measuring inquiry skills to determine and interpret functional dependencies between quantities. We selected one task focused on interpretation of the dependence between the distance and the time from the graph: *The presented graph displays the dependency of the distance that runners A, B ran in the race on the time. Based on the graph, decide which of the following statements is true.*

Figure 3.   Graph in the task from the pre-test

a) The runner B ran the first kilometre earlier.

b) The runner A ran for the first 10 minutes of more than 4 km.

c) The runner A caught up with the runner B 4 km from the start.

d) The runner A had higher average speed than the runner B during the first 16 minutes.

e) The runner B was running faster than the runner A since the end of the 10th minute until the end of the 11th minute.

The correct answer e) chose 35 % of the students. Analysis of the results shows that the students often chose the incorrect answer c) (15.4 %) and the combination of the answer c) with another answer appeared in 32.6 % of the students. We see, the reason of this error could be most likely inconsistent interpretation of the data from the graph. The students most often chose from the incorrect answers the option d) (17.5 %) and the combination of the

answer d) with another answer appeared in 33.1 % of the students. This finding could point at the use of incorrect connection between the average speed of runners and mutual position of graphs.

The post-test was administrated at the end of the pedagogical experiment and it contained analogical ten tasks. 312 students solved the tasks from the post-test. The next task was connected with the above mentioned task. Since many students made a mistake in interpreting average speed, we also have included an answer with the average speed. *The presented graph displays the dependency of the distance that runners A, B ran in the race on the time. Based on the graph, decide which of the following statements is true.*
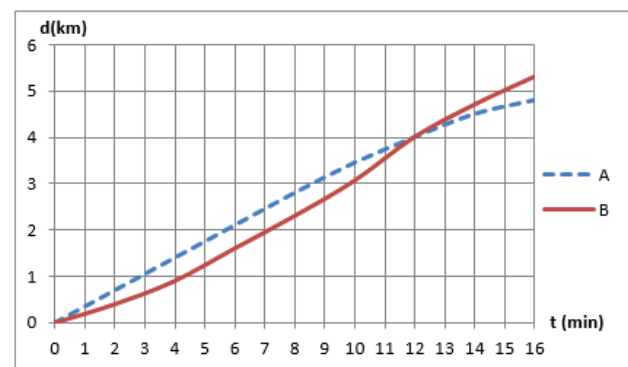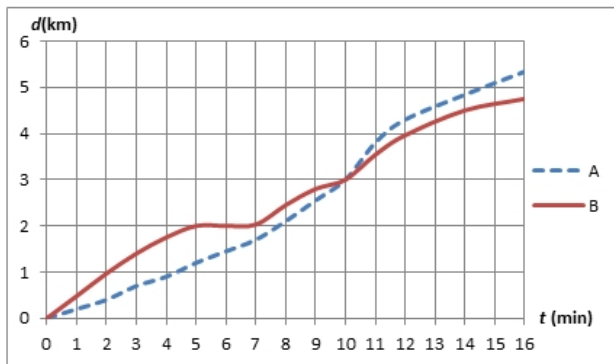

Figure 4.   Graph in the task from the post-test

a) The runner B was running faster than runner A since the end of the 8th minute until the end of the 10th minute.

b) Both runners had during the first 16 minutes at least one minute break, when they were resting.

c) The runner B caught up with the runner A 3 km from the start.

d) The runner A had higher average speed than the runner B during the first 12 minutes.

e) None of the previous statements is true.

The correct answer d) selected 39 % of the students. Nearly 50 % of the students chose the correct answer in combination with another incorrect answer. The results show that the students have improved in interpretation of functional dependence between quantities from graph. Since 300 students solved both tests, these students were included to statistical verification. The analyze of the both tasks in pre-test and post-test showed that systematic and coordinated use of inquiry approaches to the teaching of mathematics, physics and informatics has significant effect on the development of the students' inquiry skill to analyze, understand and express the relationships between variables with the significance level set at 0,05.

III.   CHARACTERISTICS OF THE SYSTEM GEOGEBRA FROM THE VIEW OF MATHEMATICS TEACHING

ICT can play an important role in the creation of the learning environment supporting student's inquiry. Several researches show that ICT can contribute to increase students' motivation for active learning [2]. Successful integration of ICT into mathematics teaching requires a development of learning activities for students and various supports for teachers. In our research, we mainly use the dynamic geometric system Geogebra to create interactive learning activities for investigation of functional

dependencies. The system Geogebra integrates algebraic and geometric tools and it brings new advanced means to visualize and investigate mathematical structures and relationships in mathematics teaching [3]. Geogebra allows the creation of dynamical models which can help students to explore, conjecture, formulate and explain mathematical relationships. This system provide interactive environment to generate appropriate examples and counterexamples from which students can investigate patterns, make conjectures, and develop arguments [4].

Geogebra is free and multi–platform dynamic mathematics software useable for all levels of education that joins geometry, algebra, graphing, tables, statistics and calculus. It allows simply constructing geometrical shapes and investigating and discovering invariant characteristics of the geometrical shapes and their mutual relations by manipulation with the free objects in graphical window. Connections between the algebraically specified equations, measures of geometrical shapes and manipulations represent strong tool for experimental investigation of geometrical models of real situations and solving of various types of mathematical problems.

In the follow part are stated brief characteristics of the Geogebra tools which provide opportunities for the use of this system in the mathematics teaching:

- it is the complex program based on connection of the algebra and geometry, objects can be represented algebraically, geometrically, numerically,

- it is created in Java which enables easy installation, online use of the program on the Internet and also in the mobile devices such as tablets and smartphones,

- the system is further evolving and capabilities and functionality of the program are improved,

- many dynamic constructions for various topics are available for users,

- on-line manuals, tutorials, prepared teaching materials facilitate the use of the program in mathematics teaching,

- portal Geogebra enables users to upload created dynamic constructions and discuss with another users,

- environment is user friendly, intuitive work with the program enables students to learn fast and simple to create shapes and to manipulate with them,

- it is environment for mathematics laboratory which allows modeling, visualizing, experimenting, investigating mathematical relationships [5].

IV.   THEMES FOR THE USE OF THE SYSTEM GEOGEBRA IN TEACHING OF MATHEMATICAL FUNCTIONS

The above mentioned facts confirm that the students' skills to analyze graphs of functional dependencies, to determine and interpret relationships between variables and to use functions in solving tasks are developed at a low level. Learning activities to investigate dependencies between quantities by creating tables, simple diagrams and graphs in the coordinate system should be implemented to the mathematics teaching in a larger extent. Many graphical systems and applets

available on the Internet enable to create learning activities to develop connections between graphs of functions and rules of functions using graphical models which offer possibilities to change the coefficient values in the rules of functions. The investigation of the different functional dependencies between quantities should be oriented to commonly used quantities and to real–life situations.

Function graphs are often used to investigate properties of functions. However, the representation of the assignment of values of one quantity to the values of the second quantity can be more clearly expressed using simple diagrams. The arrow diagram can be an example of a simple representation of the assignment of functional values. Our first example is focused on the conversion between two temperature scales. The dynamic model is based on a diagram in which the temperature scales in °C and °F are placed next to each other. Students can see in the diagram next to each other the corresponding pairs representing the temperature expressed in °C and in °F (see the figure 5). The diagram enables students to find out a temperature expressed in °F corresponding to the temperature expressed in °C using slider. For the selected temperature in °C, it is necessary to set the red marker on the scale for °F opposite the temperature expressed in °C using the left slider. Students can write pairs of corresponding values in the table when exploring this dependency.
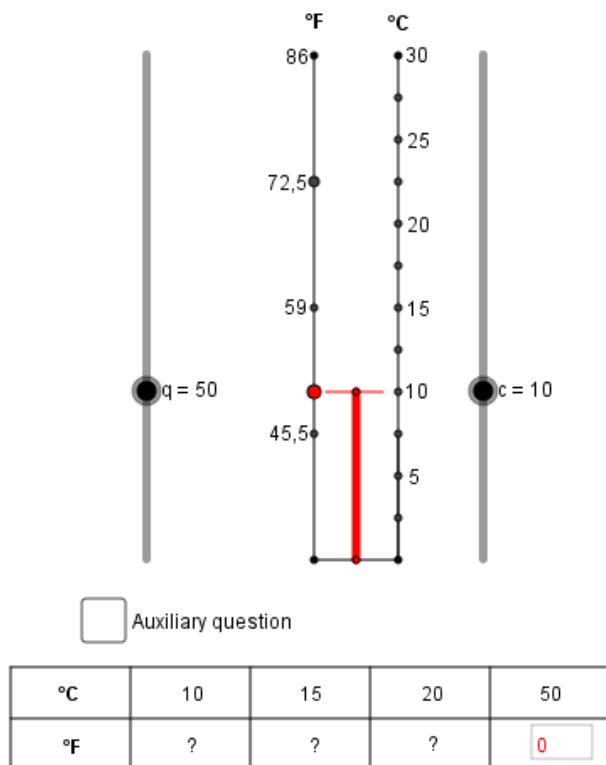
Figure 5. Model for the conversion between two temperature scales

Students should write the temperatures expressed in °F corresponding to temperatures expressed in °C into the table. The corresponding pair of the values is already set in the figure 5. Double click on the question mark causes opening the dialog box in which students can write values.

Students cannot find out the last value corresponding to the temperature 50 °C using the model. For solution of this question is necessary to identify a type of the dependence. The auxiliary question placed under the model directs student's attention on differences between the adjacent values in the table. Students should realize that the investigated dependence is linear. Student could use adding six times the difference between adjacent values in the second row of the table and to get the value 122 °F. Writing of the correct value is checked by the system. Selection of the correct answer (2) causes displaying a new task which requires creation of the rule of the investigated linear function.

°C	10	15	20	50
°F	50	59	68	122

correct

Characterize the dependence between the corresponding temperatures expressed in °F and °C.
(Enter the number assigned to selected answer.)
1. direct proportionality
2. linear dependence
3. quadratic dependence
4. none of the above options

Answer: 2   correct

Write the equation of the line on which lie the points with coordinates representing the corresponding temperatures in ° C and ° F by adding the numbers to the text fields.

$$y = 1.8 \cdot x + 32$$

correct   correct

Figure 6. The evaluation of the correctness of answers

Students can investigate a graph of the linear function using dynamic construction in which can be changed the values of coefficients in the function rule (see figure 7). The created dynamic construction enables students to observe the basic property of the linear function that the same changes of the independent variable x cause the same changes of the dependent variable y. If the changes of the independent variable x are equal to 1 then the changes of the dependent variable y are equal to value of the coefficient a in the linear function rule. Slider k allows changing the difference of the values of the independent variable x.
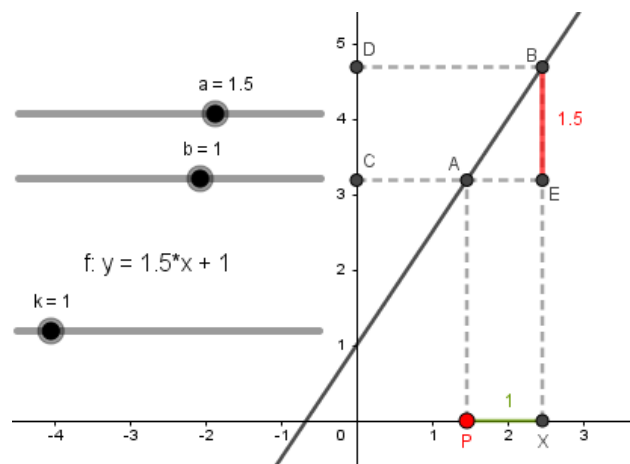
Figure 7. The graph of the linear function

The similar dynamic construction can be used also for the investigation of the quadratic function. In this case the changes of the dependent variable y by the same changes of the independent variable x are not equal, but they increase or decrease evenly and they define the linear function. The figure 8 shows that the differences of the second degree of the independent variable y are equal.
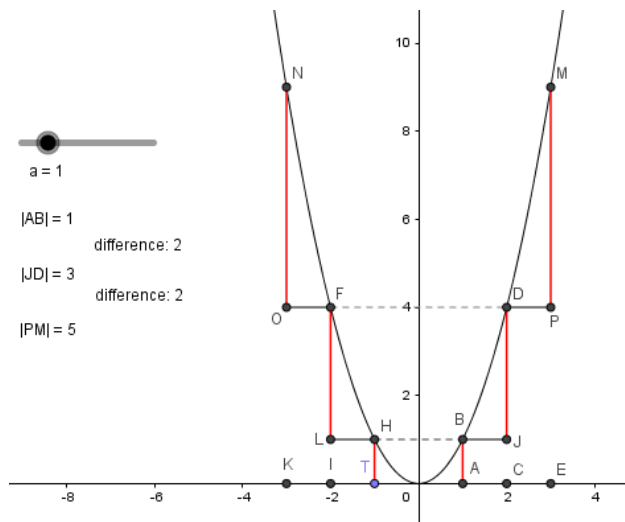
Figure 8.   The changes of the values of the quadratic function

In this construction it is available to change value of the coefficient a in the quadratic term in the rule of the function f: $y = ax^2$.

Dynamic construction could be extended by adding possibilities for changing the values of other coefficients in the rule of the general quadratic function. Some students cannot express the rule of quadratic function which graph is given in the picture. A suitable type of exercise can be based on displaying a function graph in axial symmetry along lines parallel to the coordinate axes. Students should determine the rule of the quadratic function f' which graph was created by transformation in axial symmetry. Then they could compare their result with the rule of the function f' in the window Algebra.

The task contained graphs of functions without coordinate axes can lead to the better understanding of the creation of the functions rules. Students have to determine the position of the coordinate axes. An example for this type of task is showed in the figure 9.
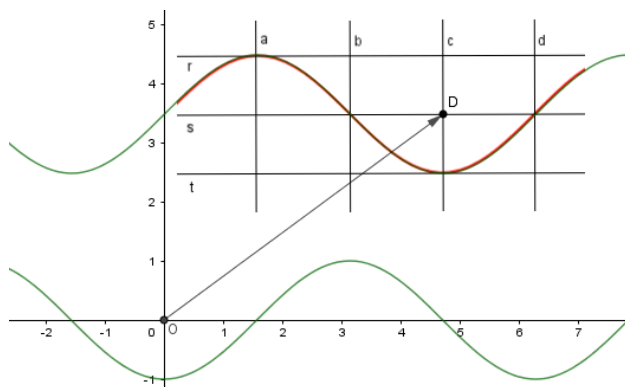
Figure 9.   The translation of the graph of the function

The assignment of the task is in the right upper corner in the figure 9. Students have to determine which of given

lines have to be identical to coordinate axes so that the displayed graph corresponds to the graph of the function f. $y = -\cos(x)$. For checking the correctness of the solution ($s = x$, $c = y$) students can construct the graph of the function f in the origin coordinate system and to translate this graph by the displayed vector.

V.   CONCLUSION

The described activities are used within the IT Akademia Project – Education for the 21th Century. This project has ambition to build modern and creative learning environment by co-operation of the schools and IT businesses. This modern and creative learning environment, supported by the advanced technology infrastructure, enables the long term sustainable education of qualified experts for broad portfolio of the employment opportunities in the IT sector. The education system changes at primary schools, secondary schools and universities, namely in particular by increasing of the education quality in informatics, quality of the mathematical, science and technical education with the orientation on ICT, by pupils' and students' motivation to study informatics and ICT and by scientific competence development of pupils and students. The educational and training model of the young people for topical and perspective needs of the knowledge society and the labour market is the main object of the project.

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The Ability of University Teachers to Recognize and Regulate their Emotional Involvement

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Abstract
The topic of this article is to present the findings of a research into university teachers' skin conductivity changes due to emotions they experience while watching an emotional video. Using a questionnaire we evaluated how much they realize their emotional involvement, how much they process it in their thoughts and whether their feelings (skin conductivity) are affected by previous experiences or memories.

Feelings are the results of emotions that arise as an immediate response to the actual situation in connection with experiences, interests and goals of the individual. They include subjective experiences, physiological changes, changes in focus and reactions, and changes in motoric manifestations. Emotions quickly inform people on how they currently feel and simultaneously affect the quality of received information or situation. According to experts in this field, emotions permeate through the complete sphere of the mind, affect cognitive processes of people, their motivation, value system and physical health including relationships.

Thinking is described as a complex cognitive process happening between a person and their environment. Erroneous connecting of emotions with the brain or its functions leads to a notion that emotions can be influenced by the mind. It is not so. The intensity of emotions of university teachers watching an emotional video and how they afterwards "rationally" describe these emotions are part of this article.

Keywords
Emotion, skin conductivity, galvanic skin conductance, cognitive evaluation of emotions, university teacher.

Introduction
The key term of this article is "emotion", which may cause doubts with intellectuals and the rationally thinking. It is true that emotive processes are not uniformly defined by experts [1]. Some view them from the point of view of biological significance [2], some enumerate their essential characteristics in order to differentiate them from other expressions [1], while others conclude they cannot be homogenously defined because of the uniqueness of experiencing them. The currently widespread notion of the general public that emotions are irrational, in contrast to reason and disorganizingly affecting the human mind should be also noted. There is an ongoing "fight" in sciences between the "objective" reason and "subjective" emotions.

Emotions are commonly viewed as complex phenomena, with significant sensitivity and variability as their typical characteristics. Other mental processes are also sensitive to personal and situational context, however not at the level of emotions. It is held that emotions exist to effectively coordinate various systems on physiological, experiential and expressional levels of the human behavior and enable people to react to challenges and opportunities of their environment. Over the time, neurophysiological foundations of emotional processes were studied, as well as the function of emotions, ways to regulate them and their connection to other psychological processes, especially cognitive processes and motivation. Further studies have explored connections between emotions and a specific personality; between emotions and interpersonal interactions; and how an individual monitors and processes their emotions and emotions of other people, and how the results of these processes shape their current and further experiences [3].

The interconnection between emotions and physical reactions has been of interest for a long time. Given the changes they cause, emotions have quickly become the major interest of physiological research [3]. The founder of the physiological approach to emotions is considered to be James [4], who observed that physical changes come directly

after perceiving a stimulating reality experienced by a person – an experience he labeled as emotion. His view of the matter remains influential to this day.

Emotions are spontaneous, highly individual and lead a person to contact with their own experiencing and stimulate an effort to better understand and accept the emotions [5]. The authors also state that the erroneous connecting of emotions to the brain gives a false conception that emotions can be influenced by reason, adding that ideally, the two can cooperate. They also point out that the internal experience and external display of emotions are not interchangeable, and it is in this division in which lies the borderline for an efficient intervention of the mind and reason.

Searching for specific physiological profiles of various emotions has shown, among other findings, that there is a single outstanding and independent variable, which shows stability, although only in the broad spectrum of emotional states (sadness, fear, anger, disgust); the variable being skin conductance. Complex models of parallel processing of emotional stimuli currently prevail. A significant source of new information in the field of neuropsychology has been provided by modern imaging methods, for example, emission tomography, magnetoencephalography, functional magnetic resonance, etc.

For our goal we opted for Galvanic Skin Conductance (GSC) and measured respondents' skin conductivity while they watched an emotionally charged video. We based the choice of the measuring method on [6] Thompson (1990), who states that emotional regulation is tied to processes which a person uses to influence the emotions they have, when they have them, and how they experience and express them, which can influence the physiological level as well as skin conductivity. At the same time, we believe that skin conductivity can be influenced significantly less than e.g. face expression. Stuchlíková [3] states that experiencing fear, for example, creates characteristic reactions, which are only slightly dependent on interpreting the possibilities of overcoming fear (skin conductivity and muscular tension increases, skin temperature decreases). For that reason, we choose emotionally charged videos that evoked fear and anxiety in respondents. We anticipated the respondents to react differently to the emotional content, in relation to their subjective sensitivity in the given area. We have also decided to find out the level of respondents being aware of their emotions and whether they tried to rationally influence them. We were also aware of the fact that the experience of respondents could possibly have been influenced by our presence and by informing the respondents about participating in a research.

Emotions and Physiological Changes in the Organism

The sensitivity of emotions to changes of personal and situational conditions manifests itself by the fact that emotions may change without any evident changes in objective events, based only on subjective evaluation. This can be observed in one situation evoking the emotion, while in another, identically quintessential situation the emotion is not elicited. Other mental processes do not share this high value of sensitivity [3].

Emotions are closely tied to physical reactions as attested by the psychological approaches that focus on examining peripheral physiological changes or brain processes while the subject is experiencing emotions. The quality of physiological changes in the organism is also affected by the interpretation of what is being experienced because in addition to the current situation there is also the previous experience and expectations resulting from it. The individual realizing this can better understand the psychological processes happening inside them and better regulate their emotions. One of the ways to regulate emotions is to change the way a situation is evaluated. This modification can lead to the increase or decrease of the intensity of a certain emotional reaction. However, LeDoux [7] assumes reevaluation is more effective from the social rather than physiological aspect since cognitive evaluation does not affect the physiological reaction in a significant way. The finding led some theorists to study the interrelation between the psychological and physiological states and to be able to better explain the opposite – i.e. how changes of the physiological state affect the psychological state. One of the possibilities, according to Stuchlíková [3], are techniques balancing between behavioral and physiological interventions, e.g. biofeedback or focusing. By stating that a method to somewhat control the experiencing of emotions exists, we wanted to point out that the respondents of this research had a chance to willfully adjust their physiological reactions to a certain extent.

Experiencing, Realizing, Processing and "Rationalizing" Emotions

Some experts focus exclusively on the information characteristics of emotions. For example, Clore [8] assumes that emotions serve as a source of information that guides the organism and highlights safe and dangerous circumstances. This information further carries motivational consequences, i.e. negative emotions lead a person to examine the danger, while positive emotions signal them to calm down and relax. It is important that a person realizes these processes, is able to connect and "use" them for their benefit. This ability (skill) is mentioned e.g.

by Goleman [9], when he writes about emotional literacy. According to him, emotional literacy includes basic knowledge of emotions, the ability to recognize and regulate an emotion and use it for one's benefit, which facilitates load-handling and leads to personal integrity. Emotional skills arise, expand and deepen by developing emotional abilities, and the ease of that process is based also on the talent of the given individual [10]. Goleman's conception of emotional intelligence as a potential transformed into series of emotional skills which are interconnected, and their lower levels include higher levels, inspired us to find out how well equipped university teachers are in this regard. However, we did not examine the general level of their emotional literacy; instead, with the help of a questionnaire, we focused only on the extent to which they realized the intensity of their experience while watching an emotionally charged video, and whether they tried to distance themselves from the situation shown in the video, i.e. regulate their emotions, or whether the experience was affected by any previous experience. It should be mentioned here that to realize one's emotions including the causes that produced them and to be able to differentiate between them is not as simple a task as it might seem. These skills, however, are a necessary prerequisite for a person reaching the highest level of emotional intelligence – empathy.

Experiencing Emotions, Cognitive Evaluation, Emotional Regulation

Given that university teachers work with young people, they should be able to carry out the abovementioned processes. The more the youth at school under their teachers' guidance learn and train to solve formal and artificial problems, the more they lose their natural ability to express what they feel, to listen and to understand the feelings of others [3]. The effort to train students only in rational thinking and critical reasoning without developing their emotional skills may have unfortunate consequences.

As stated above, it is important to take into account that emotions affect the course of cognitive processes. According to [11], negative emotions narrow down the thought repertoire and according to [12] decrease the focus of attention (especially anxiety and fear). However, Vester [13] assumes that negative emotions can have a positive impact as well, for example in a threatening situation. Vester found out that a person is able to remember and learn quickly.

As far as positive emotions are concerned, they broaden attention and the thought repertoire, enhance the understanding of complex situations, facilitate learning, stimulate less frequent forms of activities (creativity) and facilitate the creation of social interactions [11].

The relation between emotions and memory is complicated as well. It should be emphasized that people remember any information provided on an emotional basis better. On the other hand – an excessively intense emotion can completely paralyze the memory, so it cannot memorize and recall anything [14].

Experiencing emotions also affects the creation and specification of concepts, ideas and judgments about the reality being perceived, as emotional processes co-create the diversity and consistency of mental representations and are an inseparable part of interpretation processes. Put differently: the emotionality of a personality participates in creating cognitive schemes, scenarios and stereotypes [15].

The proponents of the cognitive approach [16], [17] emphasize that the development of the emotion of fear significantly influences a person's expectations; including their attempt to evade the emotion of fear. The proponents suppose that an incorrect evaluation of a situation, i.e. a person overrating the threatening event, underrating their abilities to overcome the situation and under-evaluating the available social support, builds unreasonable levels of fear in the person. Bandura [17] states people start to be afraid the moment they expect horrible results from a situation.

However, experiencing emotions can be regulated. According to [9], this ability is part of emotional intelligence. Regulating emotions can take place on physiological, behavioral and cognitive levels; the cognitive level focusing on controlling one's experiencing by modifying one's thoughts, beliefs, attitudes and views of problems. This technique provides a calming effect and a person can again act effectively, gain another view of their emotions or come to terms with an unavoidable situation. On the other hand, it should be noted that any excessive reliance on the cognitive approach alone is inadmissible. Humans are not machines, but living beings that will always express their emotions in various ways.

It is apparent that the relation between emotions and rationality is a close one, despite some opinions against the idea. It is therefore surprising that many educational institutions have a tendency to underrate the importance of positive emotions in the creation of a favorable social climate and in learning. Teachers should be able to work with emotions; both with their own and with those of others. In reality, this means to realize, control and regulate their own emotions and to use the information gained in interactions with their students and colleagues.

II. MATERIAL AND METHODS

The aim of this research was to measure the intensity of emotional experiencing of teachers watching an emotionally charged video, which was measured with the method of Galvanic Skin Conductivity. Teachers were also questioned whether: they were able to fully focus on the video; they fully realized their experiences in specific moments; they had previous direct or indirect experience with the situation in the video; they tried to deliberately regulate their emotions during watching (trying to distance themselves from the situation); they were disturbed by our presence. We examined, whether their potential regulation of emotions or the disturbing influences of the environment project in the values expressing their skin conductivity via GSR the method.

A. Respondents
The research file consisted of university teachers who were broadening their qualifications under the further learning initiative in the course Engineering Pedagogy by the IGIP standards (International Society for Engineering Pedagogy). There were 39 respondents, 27 women and 12 men aged between 27 and 49 years.

B. Electrodermal activity (EDA)

Emotional excitation affects the skin of the tested person. Electrodermal activity refers to electrical changes, measured on the surface of the skin, that arise when the skin receives innervating signals from the brain [18]. During this excitation, in accordance with the sympathetic response, sweat glands in the skin fill with sweat – a weak electrolyte and good conductor. Resulting in many low-resistance parallel pathways, thereby increasing what can be roughly thought of as "the smooth underlying slowly-changing baseline" vs. "the rapidly changing peaks." EDA can be measured in many different ways electrically including skin potential, resistance, conductance, admittance, and impedance [19]. The EdLab provides a way to capture electrical conductance across the skin (GSC).

C. Questionnaire

For the purposes of the research, a non-anonymous questionnaire with 6 items was created with the aim to find out how the emotionally charged video affected the respondents, whether they were able to fully focus on the video, whether any memories or specific situations emerged during watching, which parts of the video had the highest emotional appeal, and whether they realized what they were experiencing and if they tried to regulate the emotions.

D. Education laboratory board (EdLab)

EdLab measuring device is an interface for connecting up to 2 digital and 6 analogue sensors to a PC over a USB port. EdLab uses a 12-bit A/D converter with the sampling frequency of 2 x 30kHz. EdLab software is used to record and evaluate the measuring, enabling to export the measured data in a CSV format. Skin conductance sensor was used as the main sensor, which utilizes two electrodes placed on the fingertips (see Fig. 1) as if they were resistor connectors (skin resistance). This resistor serves as one branch of a voltage divider. The sampled voltage is filtered and amplified and then evaluated with the EdLab measuring system through a balancing algorithm.

Fig. 1 Location of GSC sensors on respondent's hand

E. Using video as stimulus

To find out how respondents react to an emotionally loaded situation, we prepared a stimulus in the form of emotionally charged video. The video consisted of two parts; the first one was 1.5 minutes long and included 5 scenes of dangerous movement and work at height, the second part was 1.6 minutes long and included emotionally completely different sections, the first inducing a pleasant atmosphere, relaxation and positive experience, while the second section included a drastic experience of violent death of several young people.

G. Research method

When carrying out the research, we played the emotional video to every university teacher individually and measured their GSC. Afterwards, they were served the questionnaire to fill out the individual items. The items were designed to find out whether the respondent realizes the experiences while watching the video, whether they can differentiate and process them (even cognitively), whether they saw a similar video before or had other experience with the content and whether their experience while watching was affected by anything. Afterwards the data collected was processed for the research.

III. RESULTS AND DISCUSSION

A. Evaluating data from GSC measuring

GSC Graphs 1-3 show several relations. In all cases below, there are moments when the teachers experienced emotions of increased intensity. The

intensity levels of experiences are individual, i.e. some teachers reacted highly impulsively to the video, while others without a significant reaction, which can be read from graph monotonies (rising, falling, constant).
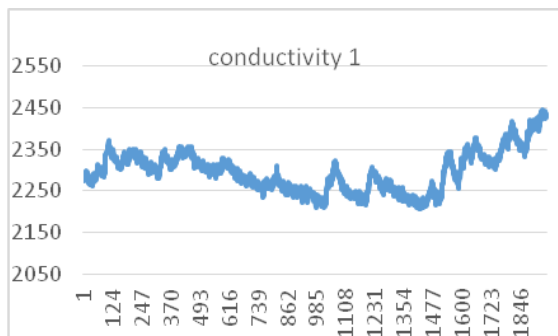
Graph 1 GSC of Respondent 1

Respondent 1 reacted to the first part of the video with dangerous work at heights with less intensity than to the video's second part with a scene of a bomb exploding on a beach full of young people. The scene is especially intense at the end of the second part. The graph shows this story strongly emotionally affected Respondent 1. On the question of what role was played by a previous experience or expectations, the respondent answered they had already seen a similar video and knew "it" would come, and became afraid of that moment "in advance". Their answer shows that expectations can negatively affect emotional experiencing if the situation cannot be changed, which clearly shows in their GSC values. To the first part of work at height, the respondent answered: I am afraid of heights and I could not do this kind of work.
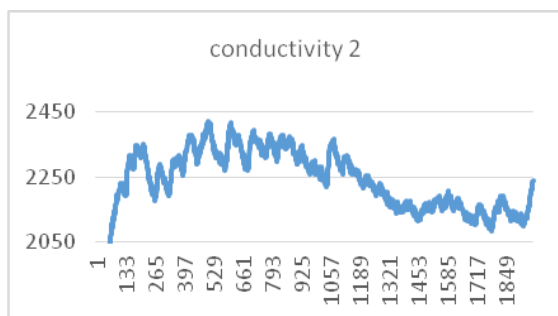
Graph 2 GSC of Respondent 2

Respondent 2 reacted to the first part of the video more impulsively than to the second part, although the ending of the second part still strongly affected them emotionally. In the questionnaire, they answered they had literally acrophobia and did not feel well when watching this part of the emotional video and imagining themselves in the place of the actors. The respondent did not experience the second part of the video so strongly, although we expected it to have a powerful emotional impact on all

respondents. The respondent stated they could not fully focus on the second part after the previous experience, because of the intensity of the previous experience and secondly because they had tried to deliberately calm themselves down.

Graph 3 GSC of Respondent 3

Respondent 3 reacted to the first part of the video with high intensity, while dying students kept them relatively calm. In the questionnaire, the respondent stated he was a "rational" type, but did not know how the measuring would work, which worried them a little in the beginning, before calming down. Watching work at height did not bother the respondent, although they stated they would not want to do that work. They did not let the second part of the video get to them and only watched it as a fictional movie. Judging from the respondent's responses, we could say they were thrown off by the feeling of expected measuring rather than the contents of the first part of the emotional video. The moment the respondent knew how the measuring works, they calmed down and did not experience the videos too strongly.

B. Overall questionnaire evaluation

In the questionnaire, 8 teachers evaluated their psychological state as very good, 26 teachers as average and 5 teachers as rather poor. Completely immersed in the action of the video were 16 teachers, "thoughts were sometimes drifting" for 15 teachers, and 8 teachers were only half-watching. There were 23 teachers who feared heights, which showed on the GSC lines. Memories resurfaced to 31 teachers when watching the video, 8 teachers did not recall anything. The presence of examiners did not bother 30 teachers; 9 teachers could not focus on the video due to that. 28 teachers stated they had tried to "rationally" accept the story unfolding in the video.

IV. CONCLUSION

The aim of our research was to measure the intensity with which university teachers experience emotions while watching an emotionally charged video. We used the GSC method and wanted to find out how much teachers realize their experiences, understand

them and are able to regulate them. We expected that the second part of the video, about young people dying at the beach due to landmines exploding, would generally elicit a higher emotional response from teachers than the first part with scenes of work at height. Our expectations fell short because the characteristics of the graphs were highly individual. We also found out that out of 39 teachers, 35 would not be able to work at extreme heights, not even those who stated that they did not fear "normal" heights. We verified that expectations and the uncertainty of "what is coming" affect the intensity of experiences. Those who recalled a previous experience or already saw a similar video reacted with either more or less intensity. It is obvious that both expectations and previous personal or mediated experience with a certain situation significantly affect the future emotional reaction in the given area. An expectation is also affected by the cognitive processing of previous experience which includes understanding the emotion. Some teachers (especially those aged over 40) were able to differentiate and regulate their emotions (Respondent 3).

We are aware that while measuring the intensity of teachers' emotions, their GSC may be affected by their current psychological state.

We will conclude with the reactions of the university teachers to the research in which they participated. They stated it had been interesting and didactic for them, and the younger ones started to be more interested in how they feel and what an experience can mean in their pedagogical work.

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Multi-parametric Routing Mechanism in Software-Defined Networks

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Abstract—The purpose of this paper is to represent a multi-parametric mechanism of the adaptive routing of different types of traffic based on the current quality of service requirements. Software-defined networking is a technology of the future. The current development trend of communication systems constantly confirms this fact. However, to date, the use of this technology in its current form is only justified in large networks of major technology companies and service providers. Currently, a large number of dynamic routing protocols have been developed in communication networks. Our task is to create a solution that can make it possible to use the ability of each node to make a decision on the transmission of information by every possible means for each type of traffic. This task can be accomplished by solving the problem of the development of comprehensive metric that characterizes the communication channels between devices in the network in detail and the problem of the development of a mechanism of adaptive network logical topology reconfiguration (route control) in order to ensure the high quality of service of the whole network that meets current quality requirements for a particular type of service.

I. INTRODUCTION

Modern society lives in an era of the rapid development of computer technology. According to analysts, in the near future, the telecommunications industry will gradually move to the concept of integrating all devices on the planet into a single computing communication network, the main objective of which will be to provide high-quality services of any type. Various services are different types of traffic (real time/nonreal time), the transmission quality of which is currently regulated by the recommendations of the telecommunications sector of the International Telecommunication Union (ITU-T) [1, 2]. In this regard, the question arises of the need for the uniform traffic control mechanism in joint communication networks that provide different types of services.

Currently, a large number of dynamic routing protocols have been developed in communication networks. Dynamic interior gateway protocols, such as OSPF and EIGRP, can be cited as an example. They are installed on almost all modern network routers. NICE and ZigZag protocols with structured network representations are most commonly used in peer-to-peer (P2P) networks. All of them provide optimal traffic routing based on a particular attribute that relies on a specific set of basic performance characteristics that describe the channels between the nodes. However, none of them has a flexible route control mechanism based on the current needs of the entire communication system. For example, protocols NICE and ZigZag that can be used in problems of optimal real-time traffic routing cannot provide the optimal routing of large amounts of documentary data, the transmission quality of which depends highly on delays in communication channels [3]. In turn, protocols EIGRP and OSPF are considered to be universal in solving problems of the transmission of any type of traffic. However, when routing tables are created, they use a set of primary static operating characteristics (static values taken for the different types of channels, i.e., they are not calculated dynamically); this set of characteristics is meager by today's standards and describes the communication channels. In addition, their application in P2P networks is unjustified because of the large requirements for computing devices on which they operate. However, these are specialized protocols that were created for specialized network devices. The MPLS protocol was one of the first protocols to address the adaptive routing problem. Its mechanisms can fully meet the current needs for the proper redistribution of data flows. However, this protocol requires highly skilled network specialists in order to set it up and does not have an automated flow distribution mechanism according to the current network needs [4].

Software-defined networking can be considered technology of the future. The current development trend of communication systems constantly confirms this fact. However, to date, the use of this technology in its current form is only justified in large networks of major technology companies and service providers. However, the basic principles of software-defined networking (centralized control, network function virtualization, etc.) can be applied to a limited number of stand-alone devices with a single routing policy in order to achieve flexibility in providing various types of services [5].

With new protocols, such as OpenFlow, which is becoming more standard in the industry, software-defined network (SDN) is becoming easier to implement. SDN decouples the control plane from the data plane, thus allowing switches to compartmentalize their two main functions. The control plane generates the routing table, whereas the data plane, using the control plane tables, determines where the packets should be sent to. This is separation allows the network to be abstracted further, which simplifies networking analysis. Many companies use OpenFlow protocols within their data center networks to simplify operations. OpenFlow and SDN allow data centers and researchers to innovate their networks with new ways because it is easier to abstract the network. Updating the Internet brings many challenges because it is constantly being used; it is difficult to test new ideas and strategies to solve the problems found in an existing network. SDN technologies provide a means of testing

ideas for a future Internet without changing the current network [6].

The purpose of this paper is to represent a mechanism of adaptive routing of different types of traffic based on the current quality of service requirements regulated by ITU-T [2]. This task can be accomplished by solving the problem of developing a generalized metric that characterizes the communication channels between devices in the network in detail and the problem of the development of a mechanism of adaptive network logical topology reconfiguration (route control) in order to ensure a high quality of service of the whole network that meets current quality requirements for a particular type of service. The routing table is one of the basic elements of any routing protocol; it regulates the basic rules used by the network function for the traffic transmission. Each network device uses the routing table, which reflects the topology of the network at a given time. The basic unit of representation of the routing table is the routing information (route). The route is considered to be composed of four main parts as follows:

- a network address (prefix) or a destination node;
- the gateway, which indicates the router address in the network to which the packet transmitted to the specified destination address should be sent;
- the interface, which, depending on the system, can be a serial number, GUID, or symbolic device name;
- the metric, i.e., a numerical indicator that specifies the preference of the route; the smaller the number, the more preferred the route (intuitively represented as distance).

II. ROUTE METRIC

The route metric is the most important part of any routing protocol. It is a condition for the addition of a set of routes to the routing table. The better the metric, the greater the likelihood that the network device decides to send the packet by the route that it characterizes. When calculating the route metrics, modern routing protocols are often based on the use of three basic parameters regulated by ITU-T. These include the Internet packet loss ratio (IPLR) on the point-to-point channel between the two network devices, the bandwidth, and the IP-packet transfer delay (IPTD) [1]. For some reason, each parameter has a direct influence on the others. These parameters give only a general assessment of the communication channels, and changes in their values can only be a consequence of the influence of other contributing factors. In the future, taking these factors into account will help to create the most detailed pattern of the connections in the network and in the system as a whole [7].

The load of communication nodes (taking into account the load of its individual computing modules, RAM reserves, etc.) that will handle packets that are sent by the associated route can be considered to be one of these factors. The parameter opposite to the load is the computational efficiency. Ongoing studies show that taking this parameter into account will eventually reduce the probability of packet loss in the communication channel and, as a result, the probability of a delay in traffic transmission with proof of delivery (file-sharing services).

In order to obtain an informative picture that characterizes the communication system, let us introduce the integral metric $W_{(i,j)}$, which takes into account four parameters: the IPLR; the bandwidth; IPTD between nodes i and j; and the computational efficiency j, the task of which is to process the traffic from node i.

Let's imagine a communication network that consists of N devices. The numerical values of the metric $W_{(i,j)}$ can be represented as an adjacency matrix A^W as follows:

$$A^W = \begin{pmatrix} W_{1,1} & \cdots & W_{1,n} \\ \vdots & \ddots & \vdots \\ W_{n,1} & \cdots & W_{n,n} \end{pmatrix} \quad (1)$$

It should be noted that the parameter matrix A^W is not symmetric to $(W_{(i,j)} \neq W_{(j,i)})$.

The minimization of a certain objective function $W_{(i,j)}$, on which a few constraints or limiting values can be imposed, is called the multicriteria optimization [8]. The main difficulty that arises in solving these problems is the ambiguity of the optimal solution at the point where one of the criteria reaches its maximum, while the other can be very far, not only from the maximum, but also from any acceptable value. The metric data convolution by the ideal point method requires all values to have the same dimension. For this purpose, let us define the channel characteristics as follows:

for the number of lost packets,

$$P_{(i,j)} \to \min, P_{(i,j)} = \left(1 - \frac{R_{(i,j)}}{T_{(i,j)}}\right), \quad (2)$$

where $R_{(i,j)}$ is the number of received packets, $T_{(i,j)}$ is the number of transmitted packets, and $T_{(i,j)} > 0$

for the signal delay time,

$$D_{(i,j)} \to \min, D_{(i,j)} = \left(1 - \frac{t_{\min}}{t_{(i,j)}}\right), \quad (3)$$

where t_{min} is the minimum delay value in the adjacency matrix, and $t_{min}, t_{(i,j)} > 0$;

for the bandwidth,

$$G_{(i,j)} \to \min, G_{(i,j)} = \left(1 - \frac{B_{(i,j)}}{B_{\max}}\right), \quad (4)$$

where B_{max} is the maximum bandwidth in the adjacency matrix;

for the computational efficiency of the information processing node

$$CE_{(j)} \to \max, CE_{(j)} = \left(1 - \frac{L_j}{L_{j\max}}\right), \quad (5)$$

where L_{jmax} is the maximum communication node load in the adjacency matrix.

Thus, the metric based on these four parameters will be as follows:

$$W_{(i,j)} = \sqrt[4]{X_1\left(P_{i,j}\right)^2 + X_2\left(D_{i,j}\right)^2 + X_3\left(G_{i,j}\right)^2 + X_4\left(\frac{1}{CE_j}\right)^2}, \quad (6)$$

where $X_1, X_2, X_3, X_4,$ are the weighting coefficients that vary in the range of 0-1, and their sum must be equal to unity in Eq. (7):

$$\begin{cases} X_1 + X_2 + X_3 + X_4 = 1, \\ X_1 \leq 1, X_2 \leq 1, X_3 \leq 1, X_4 \leq 1 \end{cases}, \quad (7)$$

By varying the values of weighting coefficients in the metric $W_{(i,j)}$, we create an apparatus for controlling the relevance of a particular metric parameter in the final assessment of the data transmission channel from the node i to the node j.

From a mathematical point of view, the point with coordinates corresponding to t_{min}, P_{min}, B_{max}, CE_{max} (or L_{min}) for fixed weighting coefficients X_1, X_2, X_3, X_4 is selected as ideal.

In reality, given the operation dynamics of the entire communication system, weighting coefficients are selected based on the nature of priority traffic types that provide primary services.

ITU-T recommendations [2] regulate five main classes of quality of service (IP QoS), to which the communication system can be attributed. Class-0 networks are the most demanding to the performance of communication channels. As a rule, these are the networks that provide real-time service delivery, the most sensitive to latency (VoIP, video conferencing, online games, etc.) [7]. Currently, there is no single concept of the construction of systems and networks that ensure the provision of all services with the highest quality [1]. Thus, there is a need to develop a flexible traffic-routing mechanism separately from the selected service taking into account the current capacity of the communications system and requirements for its quality. The quality of service is inextricably linked to the basic parameters that appear in the metric $W_{(i,j)}$. The main idea of the developed mechanism for the effective flexible routing consists of manipulating weighting coefficients in order to achieve the best possible performance values that define the IP QoS class. In software-defined networking, the possibility of implementing such a mechanism is the most promising. A controller, a programmable controller that controls the network structure, is the core of such a network [5]. In this case, it is a device that can optimally select weighting coefficients of the metric $W_{(i,j)}$. ITU-T recommendations [2] regulate five main classes of the quality of service (IP QoS) to which the communication system can be attributed. Ranges of values inherent in the three main classes are shown in Table 1.

TABLE I.
CLASSES OF QUALITY OF SERVICE

Network operating characteristic parameter	QoS Classes		
	Class 0	Class 1	Class 2
IPTD	100 ms	100 ms	100 ms
IPDV	100 ms	100 ms	H
IPLR	1×10^{-3}	1×10^{-3}	1×10^{-3}
IPER	1×10^{-3}	1×10^{-3}	1×10^{-3}

III. ROUTING ALGORITHM

The quality of service is directly linked to the basic parameters appearing in the metric $W_{(i,j)}$. The main idea of the developed mechanism for the effective flexible routing consists of manipulating the weighting coefficients in order to achieve the best possible performance values that define the IP QoS class.

Table 2 provides a set of weighting coefficients that have a direct impact on the transmission quality of the corresponding type of traffic.

TABLE II.
IMPACT OF WEIGHTING COEFFICIENT ON A PARTICULAR TYPE OF TRAFFIC

Traffic type	X_2, X_3	X_2, X_4	X_3	X_1, X_3, X_4
	delay	jitter	band	packet loss
Real Time	+	+	+	+
Documents Exchange			+	+
Alarm/WEB				+
Video Streaming			+	

Next, let us give a block diagram of the developed algorithm (Fig. 1) and the description of its functional blocks. The algorithm begins by defining the basic values of weighting coefficients of the metric. For shared systems that simultaneously require an equal contribution of each primary parameter of the metric, the coefficients can be set equal. In the prioritization of a particular type of traffic, weighting coefficients can be selected in accordance with Table 2 taking into account their relative impact on the quality of that traffic.
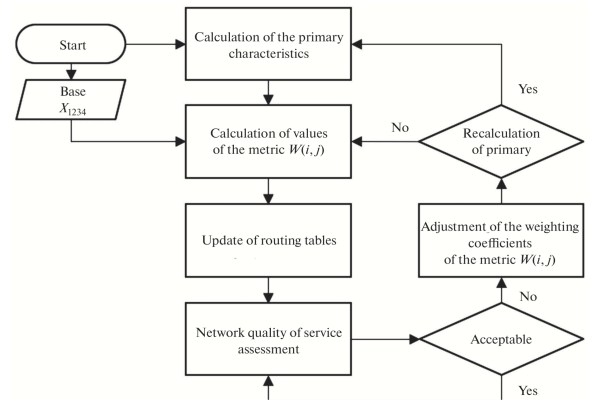

Figure 1.   Block diagram of the algorithm

At the same time, the process responsible for calculating the primary characteristics that determine the status of all existing communication channels is started. The obtained results go to the block "calculations of values of the metric $W_{(i,j)}$. Here, according to Eq. (6), corresponding values of the metric for each channel are computed. The values are recorded in the adjacency matrix A^W, which is used to determine the cost of routes of the routing tables.

The algorithm recursiveness makes it possible to achieve a continuous improvement of the network quality by checking the current values of operating network characteristics for compliance with current requirements imposed on the entire communication system. If the values of operating characteristics do not comply with given requirements to the communication system, it is possible (if necessary) to adjust weighting coefficients in order to adjust the current topology for maximum efficiency.

Given that the change in values can affect the current values of the primary characteristics of the communication channels, it is possible to recalculate metrics in order to support the relevance of the channel characteristics. Decision making on recalculating the primary network parameters and adjusting the weighting coefficients of the metric is the main task of the controller of a software-defined network. In reality, the selection of values of weighting coefficients is not a trivial task, since, given the dynamics of the operation of the IP communication systems, there are no clear rules for its control, such as in the case of emergencies. The controller is an intelligent system which, taking into account the current state of the network, can control the entire network in order to achieve the best desired results of traffic transmission. The developed algorithm provides a necessary tool for simplifying the communication system control by manipulating weighting coefficients of the metric, thereby reducing the problem to the selection of their best values.

In the next section, the process of implementing the developed algorithm will be considered, analyzed, and compared with the generally recognized equivalents.

IV. SIMULATION MODEL

A simulation model of a P2P network consisting of 18 nodes was created in the process of development (Fig. 2). Each channel is assigned to one of three types of parameters from Table 3.
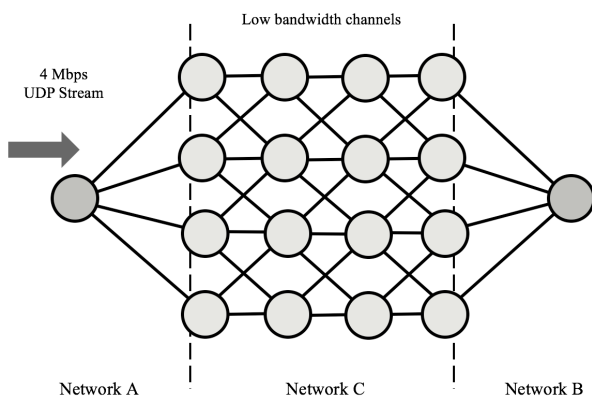
Figure 2. Simulation network

The primary parameters (Table 3) that characterize the developed metric were set with the condition that critical situations must be reached. They can be solved by the logical redistribution of data flows by multi-parametric routing algorithm. Communication system should provide the best transmission quality for 4 Mbps UDP data flow originated on network A for transmitting to network B via the transit network C that currently consists of low bandwidth channels.

TABLE III.
PRIMARY CHANNELS PARAMETERS VARIATIONS

Type	Primary Parameter			
	Interface bandwidth (static)	Interface bandwidth (current)	Delay (static)	Delay (current)
1	10 Mbit/s	2048 Kbit/s	1 ms	50 ms
2	100 Mbit/s	4096 Kbit/s	0.1 ms	100 ms
3	10 Mbit/s	8192 Kbit/s	1 ms	500 ms

The algorithms OSPF and EIGRP operating only with the numerical given static values of bandwidth and delay on communication channels.

In the course of the investigation, the values of the IPLR and jitter for reference OSPF and EIGRP algorithms were obtained. Then, in the process of establishing a connection, the adjacency matrix was compiled based on the metric $W_{(i,j)}$. The matrix describes the current status of the entire communication system under the given initial coefficients of $X_{1,2,3,4}=0.25$ that guarantee an equal contribution of each of the main parameters of the metric. During the simulation, it was found that the average delay with regard to the OSPF decreased by 34% and to EIGRP, by 20%. In turn, the IPLR decreased by 80% with regard to the OSPF and by 98%, with regard to the EIGRP (Table 4).

TABLE IV.
CALCULATED IMPACT OF WEIGHTING COEFFICIENTS ON A PARTICULAR TYPE OF TRAFFIC

Algorithm	Parameter		
	Average delay, ms	Packet loss, %	Jitter, ms
OSPF	1341.45	10.82	219.69
EIGRP	1115.45	84.60	573
$X_1=X_2=X_3=X_4=0.25$	890.93	2.14	55.46
$X_2=[0.58;0.99]$ $X_1=X_3=X_4 = (1 – X_2)/3$	612.52	84.44	570.7
$X_3=[0.3;0.35]$ $X_1=X_2=X_4 = (1 - X_3)/3$	803.71	0	12.99

During the prioritization of the parameter that characterizes the communication channel delay in the range $X_2 = [0.58;0.99]$, in the case of equal $X_1=X_3=X_4$, the average delay for the entire network operation session decreased by 54% with regard to the OSPF and by 45% with regard to EIGRP, which is 31% more efficient than the algorithm operation under equal values of the weighting coefficients. Simultaneously, the IPLR was

84%, which could adversely affect the provision of services that are sensitive to packet loss.

During the prioritization of the parameter that characterizes the bandwidth of channels in the range $X_3=[0.3;0.35]$, in the case of equal $X_1=X_2=X_4$, the average delay decreased by 40% with regard to the OSPF reference algorithm and by 28%, with regard to the EIGRP, which is 10% more efficient than the algorithm operation under equal values of $X_{1,2,3,4}$. The IPLR dropped down to zero, which indicates that the optimum was found that meets the current needs of the network. The algorithm determined the optimal route for the high-density flow, thus bypassing the low productive nodes and channels with low bandwidth and high probability of packet loss. The algorithm operation can be seen in Fig. 3.
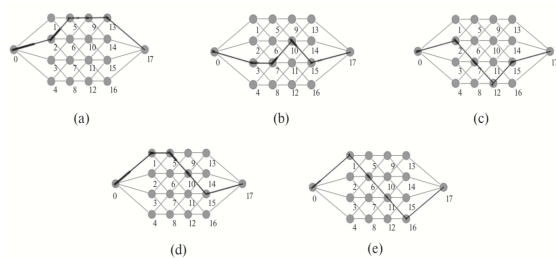
Figure 3. Rerouting of flows at different values of the metric: (a) OSPF model, (b) EIGRP model, (c) model with equal weighting coefficients, (d) model with the prioritization of the delay, and (e) model with the bandwidth prioritization.

It shows that, in various methods of assessing the cost of communication channels, the flow route also changes. On practice, the goal of the developed mechanism is to adaptively select a route that maximizes the quality characteristics of the network based on the needs of the system and the current status of the entire network.

In the system operation dynamics, it is necessary to recalculate the initial metric parameter under the current network operation conditions and, consequently, to change values of weighting coefficients $X_{1,2,3,4}$ according to the current needs of the communication system.

V. CONCLUSIONS

It was shown that, with a collection of network nodes, it is possible to increase the network efficiency by careful control of routing information. An important advantage of the proposed approach to the control of routing mechanisms is the ability to deploy it both within the current software-defined systems and within a single set of communication nodes combined by the single logic of the organization of network resources.

Future research should be directed toward the development of the intuitive decision-making mechanism that should automatically change the metric weighting coefficients in order to optimize the transmission of individual data flows based on the current capabilities of the communication system and requirements imposed on it.

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Impact of education and experiences of managers on performance of Slovak construction enterprises

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Abstract— **Education process is a first step and presumption for better performance and results of every manager. The achievement of higher level of education increases the precondition for its successful results in the management of enterprises. Knowledge and a high level of education is only one prerequisite for achieving successful results. Another prerequisite is manager´s experience and practice. This research focuses on examining the relationship between the education level of managers and the results of the construction enterprise. Another area of research is the relationship between the manager's practical experience and the company's results. The main aim of research is analysing of impact of education level and experience of managers on enterprise results, especially cost reducing and revenues of enterprise.**

I. INTRODUCTION AND PROBLEM STATEMENT

Increasing of pressure on results in strongly competitive environment increasing the level of dependence of organizations on information technology and information generally [1]. Information and communication technology has impact on productivity and development of managerial competencies [2]. But, developing of managerial competencies by information and communication technology is not one opportunity. The main approach to developing of managerial and digital competencies is education process and practice of managers [3]. New information and communication technologies increase the managerial and digital competencies, but it's not the only way and possibility to achieve them [4]. The primary role in education and acquisition of soft skills has an education system. On the other side, according to report of European Commission that alumni or managers indicate a positive impact of managerial skills and know-how developing at the higher education, although the level of application is not estimated [5]. Knowledge achieved by education process are very beneficial, however practice and experiences are another a necessary component for proper decision-making and management [6]. According to next research, university with train sheep program have better results between their alumni manager's results. The study shown increasing trend in use of training a work experience at universities with aspects on positive results in this issue [7]. Another case study highlighted on relationship between education and employability [8]. That means necessity of good education process for personal

successful increasing and enforcement. A lot of researchers and economists claim, that one of right reason for study economics it should be more than achieved knowledge about economic way and theories [9]. A lot of statement about this issue claims that actually is big need for soft skills for top level of management [10].

Based on mentioned facts, knowledge and managerial competencies by education process are very important for increasing value of manager and company and probably increasing better performance of managers and final results in company. Second point of view in real business conditions are experiences and developing managerial and soft skills by practice. One of a lot of soft skills, for example communication skills, expert knowledge and other general information is possible to achieve trough education system at universities. But a lot of soft skills like teamwork, leadership and so on is hardly developing at education environment [11]. According to these authors there are more fields of managerial competencies in industry (fig. 1).
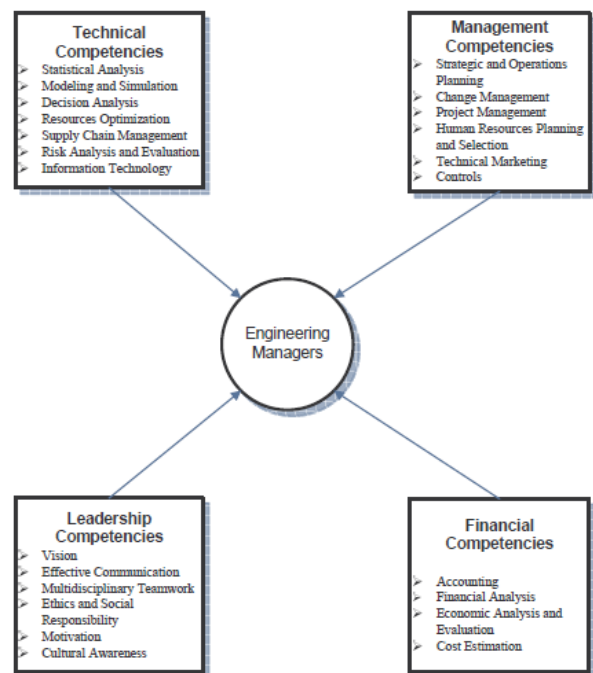

Figure 1.   Engineering management core competencies [11]

They described four main groups of engineering management core competencies. Especially, it´s a difficult issue in field of project management. Project managers need another skills. Their job is difficult and they must have range view on a lot of areas [12]. Clear example is in construction industry, where project manager discusses a lot of everyday process, not about only on buildings. All day decision-making in a different field is requiring a special experience. International labour office from International Labour Conference in 2008 in Geneva described the skills for increasing of productivity, and unemployment [13]. Based on this report, one of the education process brings cost saving in projects. But lifelong education is always needed for better results of enterprise. Acquired managerial and digital competencies trough education system can impact to the competitiveness and economic performance in every industry [14]. But, important role in competitiveness plays experiences. Headhunting with experiences and skills from practise are main value of successful and experienced managers.

Education and practice probably increase competencies which are basic for better company´s results. It´s assumption that education has impact on final results of enterprises. Question is follow, what is relationship between education of managers and results of enterprise? Is good and quality education process of managers important for better results of enterprises? What is more important, education or practise? Is it possible achieved soft skills like leadership, commination, digital competencies and so on, through education system at universities? Other side is view on practise. Do better results of companies' managers with a lot of practise? Are practices more important than education? There are a lot of questions in this topic. What is situation in Slovak construction enterprises and their managers? Based on this primary questions are set main questions of this research:

- What are the results of Slovak construction enterprises in comparison of different education level of managers?
- What are the results of Slovak construction enterprises in comparison of different practice level of managers?
- What is the impact of education process on results of Slovak construction enterprises?
- What is the impact of manager practice on results of Slovak construction enterprises?

II. METHODOLOGY OF RESEARCH

This research is focused on the issue of education and practice of managers and its impact on results of construction enterprises. Developing the managerial and soft skills are very topic issue and it´s valuable to conduct this research for construction industry. Very important for comparison and research investigation are company´s results. This research uses main economic information of enterprises. It´s focused on efficiency, that means cost saving and revenues. Every comparison of research sample divided by education level and practice level is joined to the results of enterprise as level of cost savings and level of revenues.

A. Research statement and hypotheses

Previously fact are basic for main research statements:

- Managers with high education level have better results on enterprise (cost saving level and revenues level)
- Managers with more practise have better results (cost saving level and revenues level)

Based on this statement are set hypotheses of research:

$H1_A$: Slovak construction enterprises with high education level of managers have higher cost saving level like construction enterprises with low education level of managers.

$H1_B$: Slovak construction enterprises with high education level of managers have higher revenues level like construction enterprises with low education level of managers.

$H2_A$: Slovak construction enterprises with high practice level of managers have higher cost saving level like construction enterprises with low practice level of managers.

$H2_B$: Slovak construction enterprises with high practice level of managers have higher revenues level like construction enterprises with low practice level of managers.

For analysing of this issue that´s enough only results and comparison of education and practice level of managers with results of cost savings and revenues. For better analysing and quantifying of impact is necessary following its impact, so called impact level on selected indicators. That´s reason, why another point of view in results is in research.

B. Data collection and data processing

All data were achieved by on-line questionnaire. All participants of research were asked for participation on this research by e-mail with link of questionnaire. Respondents of research were chosen by random choose and it´s representation of all size type of enterprises in Slovakia. In section of general information it was information about education level of respondent that represented construction enterprise and information about years os experiences on this job. In section of information about company it was necessary give information about their level of cost savings and revenues. All of this results were analysing and verified by statistical methods.

For this purposes it was used MS Excel and its functionality and STATICTICA software. Average value was done from all data for every research group and examined indicator. Next point of research it was verifying results by Kruskal-Wallis test on $\alpha = 0,05$. Kruskal-Wallis test shown significance of results and it was basic for acceptation or rejection of hypotheses. It was answer, if results of this research are only random, or they are significant and confirms statement.

C. Research sample

Information about research sample was first important step for comparison and rationalization of conclusion. Slovak construction companies participated on this research. Research sample includes managers from 55 Slovak construction enterprises. Participants of research represented different size of enterprise, from microenterprise to large companies operated on Slovak

construction market. This enterprise represented all type of participant of construction project, like main contractor, sub-contractor, designer and investor or developer (tab. 1). This enterprise use Slovak private equity, but some of them use foreign private equity too. Participants of research are divided by their education level of managers (fig. 2).
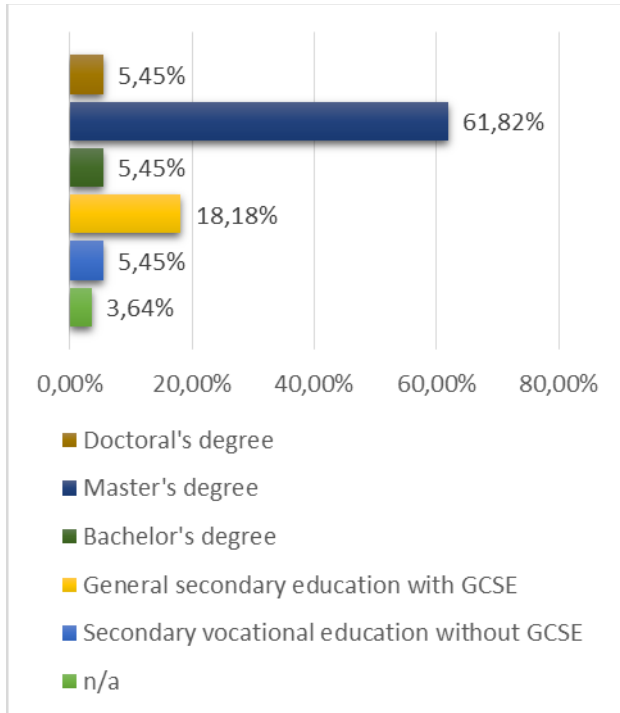
Figure 2.   Research sample divided by education level
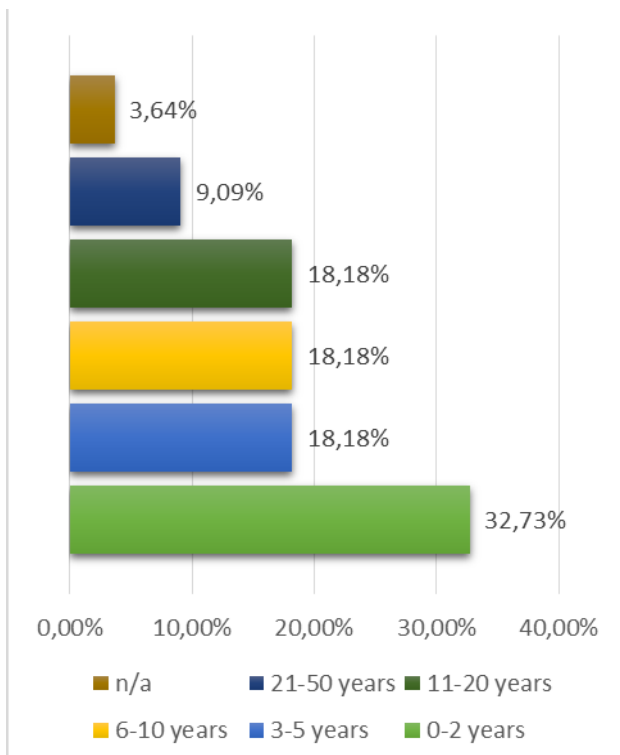
Figure 3.   Research sample divided by experience level (in years)
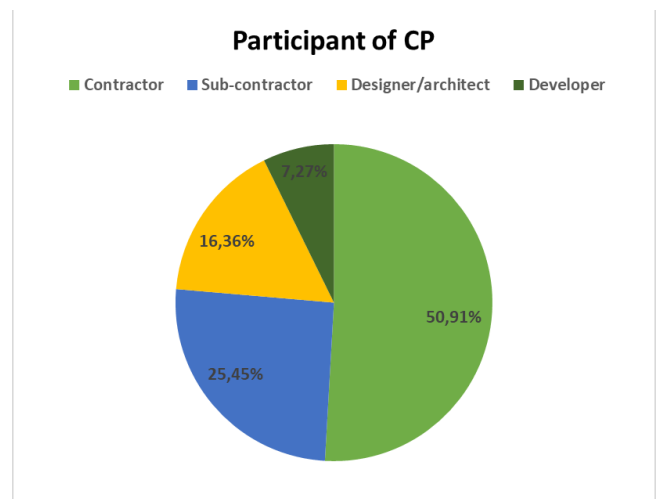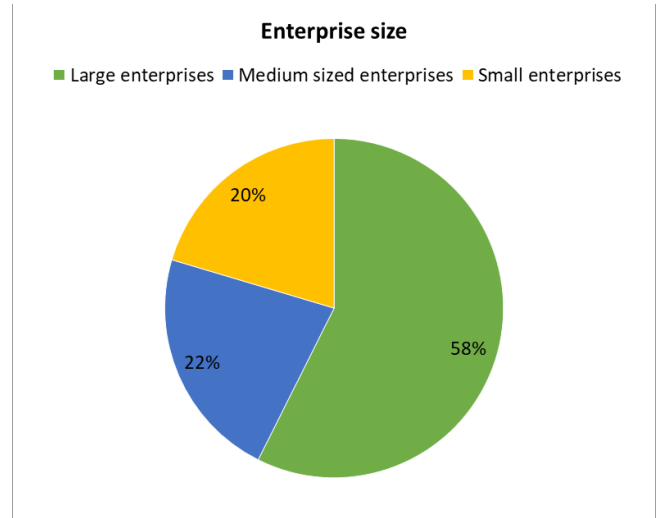
Figure 4.   Other futures of research sample (enterprise size and participant of construction project)

III.   RESULTS AND DISCUSSION

Research issue of education and practice of managers in construction industry is focused on its impact on results of enterprises in this field. First point of view on education in relationship with cost savings. It´s assumption that managers with higher level of education may achieve better results for enterprise. In this case, it´s cost savings. Results are more specified in figure 5.

Construction enterprises managed by managers with doctoral degree achieved cost savings level at 3.15. Very high cost savings level achieved managers with master´s degree. It was 3.02 value. The worst cost savings level achieved construction enterprises managed by managers with secondary vocational education without GCSE. It was only 1.83. According this results, it´s can be said, that differences between research group and cost saving level in this enterprises are measurable. Trend is clearly, but for confirmation of hypothesis 1, it´s necessary analysing of Kruskal-Wallis test and results from this.
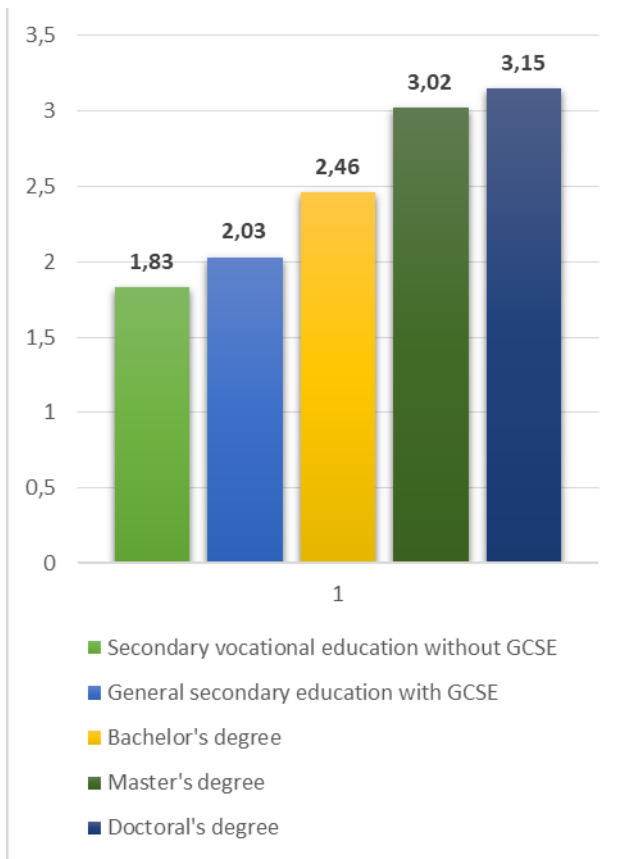
Figure 5. Relationship of cost savings level in Slovak construction enterprises with education level of managers

Next point of view is related with relationship of education level for managers and revenues of enterprises. According to this assumption, construction enterprises manage by managers with higher education level should achieve better revenues results than construction enterprises manage by managers with lower level of education (Fig. 6).

Revenues level of construction enterprises manage by managers with doctoral degree achieved 3.18. Contemporary, construction enterprises manage by managers secondary vocational education without GSCE achieved only 1.83, what means very low value. Similarly, in this case is trend relatively clear. Revenues level increasing together with education level of managers. Likewise in previously case, it´s necessary doing Kruskal-Wallis test for varication of statistical significant. Kruskal-Wallis tests for all hypotheses and assumptions are listed in table 1.

These results shown the need of increasing education process for managers that is very important part. Of course, It´s not so easy give conclusion about relationship of education level and its impact on results of enterprises. It´s only one factor. For correlation it´s necessary doing next investigation and use another statistical methods. But on the other hand, it´s trend and assumption about connection of this researched issue very probably based on facts.
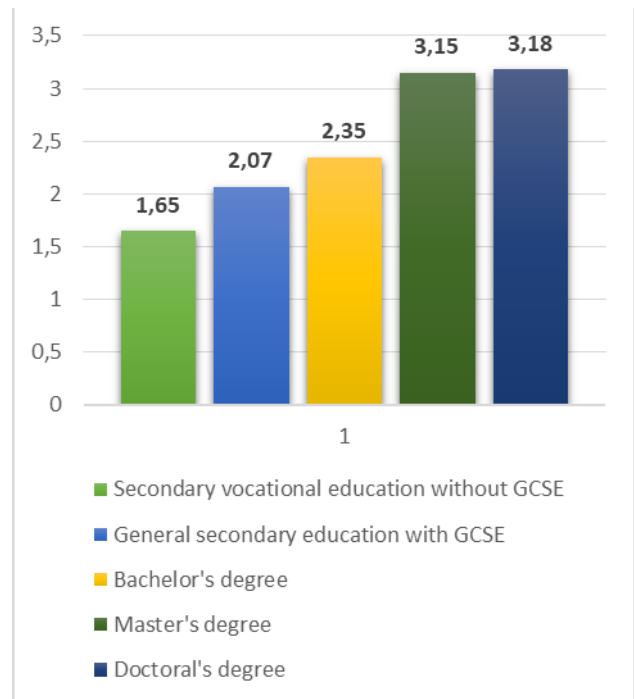
Figure 6. Relationship of revenues level in Slovak construction enterprises with education level of managers

Next point of view and another assumption it was about relationship of practice level of managers and results of enterprise. Based on hypothesis 2, it was assumption, that managers with more practice and experience achieved better results of enterprise than managers with less experience. This statement was monitored from view of revenues and cost savings level.

Results about hypothesis $H2_A$ are specified in figure 7.
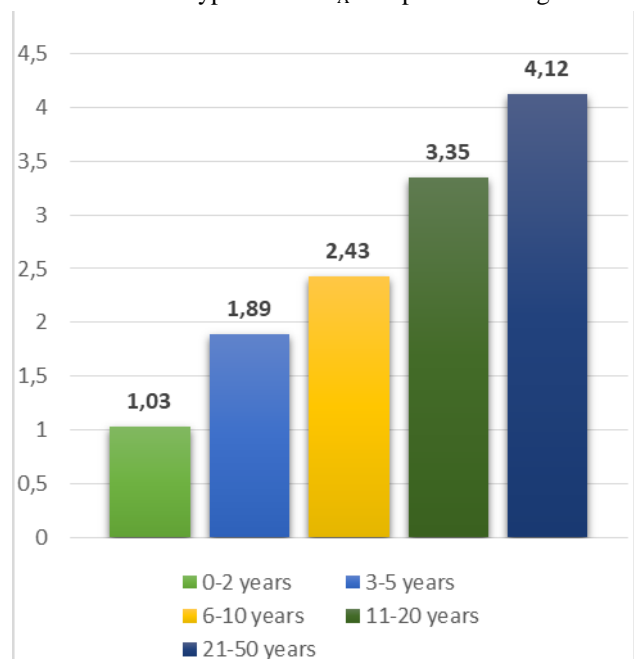
Figure 7. Relationship of cost savings level in Slovak construction enterprises with practice level of managers

According results, it seems to be important monitored practice level and experience of managers. Construction enterprises manage by managers with more experience achieve higher cost savings level like enterprises manage by managers with less experience and practice. New managers don´t have a lot of experiences and managerial competencies for decision-making requires experience. It´s cost saving level achieved very low value at 1.03. Managers with experiences to 5 years achieved value at 1.89 and managers with practice to 10 year achieved value 2.43. The highest value achieved managers with long-life practice and experience. They achieved cost savings level at value more than 4. It´s very significant value. Very high value achieved manager with practice more than 10 years generally. This results and trend is more clearly than previously about education.

Very similar situation is in case of comparison and analysing relationship of revenues level in Slovak construction enterprise and practice level of managers. The worst results achieved enterprises that are manage by managers without any practice and experiences. It´s value was only 1.21. Other research group of managers with practices to 5 years achieved revenues level value at 1.67. Trend is increasing with number of practice years. Managers with practices to 10 years achieved value 2.53 and the biggest step was recorded for another group of managers. Managers with experiences more than 10 years have very impressive results in cease of revenues. Their revenues level for their company achieved average value at 3.78. The highest revenues level achieved enterprises manage by managers with 21 and more years of practices and experiences. More results is possible see in figure 8.
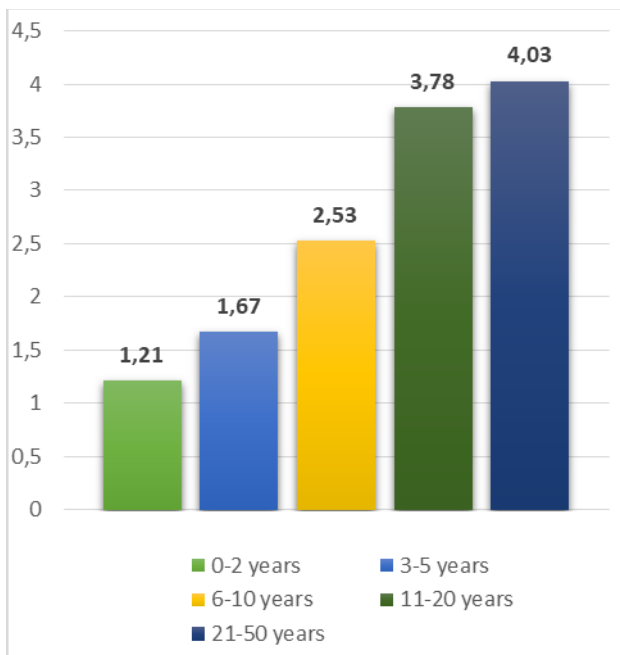
A lot of managers claim that practice and experience are more important than competencies achieved by education process. In this case, results in practice are more clearly than results in education process. This facts confirm important of practice in management of construction enterprises. Practices and experiences according a lot of managers and experts are basic for quality decision-making and complexity of manager works. For analysing of impact of education and practice is necessary complexly view of point. It´s true that previously results shown impact of education and practice of managers on final construction results. This is a question, if it possible do a conclusion prom statistical point of view. Table 1 describes final results of this research in this issue. According Kruskal-Wallis anova was set level of significance $\alpha = 0.05$, and based on this results can confirm or rejected researched hypotheses.

Based on Kruskal-Wallis test it can possible accepted hypothesis 2_A that Slovak construction enterprises with high practice level of managers have higher cost saving level like construction enterprises with low practice level of managers. Kruskal-Walis level achieved value of $p = 0.0458$, it´s statistical significance statement. Another hypothesis 2_B it can be accepted by Kruskal-Wallis anova. Slovak construction enterprises with high practice level of managers have higher revenues level like construction enterprises with low practice level of managers. Value of $p = 0.4396$ that is a statistical significance. This facts confirm importance of practice and experiences in management work, included Slovak construction enterprises.

Figure 8. Relationship of revenues level in Slovak construction enterprises with practice level of managers

TABLE I.
RESULTS OF KRUSKAL-WALLIS ANOVA

Hypotheses	Factor	K-W Anova (p)	Ecceptance / rejection
H1$_A$: Slovak construction enterprises with high education level of managers have higher cost saving level like construction enterprises with low education level of managers.	Education level	0,2356	Rejected
H1$_B$: Slovak construction enterprises with high education level of managers have higher revenues level like construction enterprises with low education level of managers.	Education level	0,3254	Rejected
H2$_A$: Slovak construction enterprises with high practice level of managers have higher cost saving level like construction enterprises with low practice level of managers.	Practice level	0,0458	**Accepted**
H2$_B$: Slovak construction enterprises with high practice level of managers have higher revenues level like construction enterprises with low practice level of managers.	Practice level	0,4396	**Accepted**

Hypotheses 1A and 1B were not confirmed. In spite of some facts and trend which is in results from this issue, itˇs not possible these statement according Kruskal-Wallis test results. Hypothesis 1A: Slovak construction enterprises with high education level of managers have higher cost saving level like construction enterprises with low education level of managers, was not confirm according Kruskal-Wallis test, where value p = 0.2356. Other hypothesis has value of Kruskal-Wallis test p = 0.3254. Based on this results itˊs not possible to accept these hypotheses.

IV. CONCLUSION

Issue of education and practice of managers is very hot topic in every field. Efficiency is one of the most important for high performance of enterprise. Managerial competencies achieved by education process and practise increase the possibility to be successful. Advantages from this can be a huge for all enterprise. From this point of view, itˊs necessary to focus on impact of education and practice of managers on global results in enterprise. Both statement and assumptions should bring better results for construction enterprise. Research shown, that this issue is relevant and objective for focusing. However all results are not clear. Both hypotheses and results for them shown the trend. Education and practice really increase managerial competencies and it means better results for enterprises. But only practices and experiences were confirmed by exact statistical methods.

In case of practice, situation is more clear. All results, that Slovak construction enterprises with high practice level of managers have higher cost saving level like construction enterprises with low practice level of managers and Slovak construction enterprises with high practice level of managers have higher revenues level like construction enterprises with low practice level of managers were confirmed by Kruskal-Wallis test. A lot of managers agree with these statement. It can be said that practice of manager's impact on construction enterprise results in Slovakia, especially indicator of cost savings and revenues.

In case of relationship between enterprise results and education of managers it is not possible to give the clear conclusion and recommendation. Itˊs true, that education process positively impact on developing of managerial competencies and itˊs assumption that it has positive impact on overall results of Slovak construction enterprises. On other side, itˊs statistical point of view. According to Kruskal-Wallis test, it is not possible to accept these hypotheses. In spite of this, itˊs very important to focus on relationship of education of managers and their results for enterprise. It might be an issue of another research problem and analys.

ACKNOWLEDGMENT

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Developing of managerial competencies trough ERP systems in Slovak construction companies

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Abstract—**Development of managerial competencies currently is an integral part of the knowledge society initiatives, social, economic but also political dimension. Managerial competencies are very important for better decision-making process and it is very closely linked to information. Relationship between enterprise resource planning systems, also known as information systems and managerial competencies is subject of this research. The main objective of the research and this paper is to confirm the statement that Enterprise Resources Planning Systems (ERP systems) supports better decision-making in Slovak construction companies, it means that ERP systems improve their managerial skills. This relationship is judged on a number of criteria, such as the size of the enterprise, the owner of the enterprise, the definition of the participant of construction project and, last but not least, the intention of the activity, so- called NACE classification.**

I. INTRODUCTION

Information is very necessary for proper decision making [1]. Currently, the value of the information represents the potential for the right decision-making [2]. However, this claim is not entirely clear. It is not just relevant information to make the right decision [3]. The right decision is based on people (managers) who know how to consider and use relevant information [4]. It can be said that the right decision is based on managerial competencies of managers in every field. The process of acquiring the managerial competencies is a long-term process supported by different technologies. Enterprise Resource Planning systems (so-called ERP systems) is a tool for planning not only enterprise resources, but for information in enterprise management process too. In addition to the tools for getting and working with information needed for business management, the ERP system should also contribute to enhancing managers' competencies. Here arises the fundamental question of whether the same is true in construction enterprises in Slovakia. Otherwise, which factors are key? Are differences between groups?

II. ENTERPRISE RESOURCE PLANNING SYSTEMS IN CONSTRUCTION INDUSTRY

The issue of ERP system is discussing by a lot of authors and researches. It's a new phenomenon for better and efficiency business management. Lot of authors try define the ERP systems. One of them claim, that ERP

TABLE I.
RESEARCHES AND CONTRIBUTIONS IN THE ISSUE OF ERP SYSTEMS IN CONSTRUCTION INDUSTRY

Year	Contribution and research	Authors	Topic
2003	Implementation of enterprise resource planning ERP) systems in the construction industry	Ahmed et al.	ERP implementation
2003	Miesto a úloha aplikácoie ERP v informačnom systéme podniku	Martiško	ERP generally
2003	Enterprise Resource Planning for Construction Business Management	Shi et al.	ERP generally
2007	Exploitation of semantic web technology in ERP systems	Anjomshoaa et al.	ERP exploitation
2008	Analyzing Enterprise Resource Planning System Implementation Success Factors in the Engineering–Construction Industry	Chung et al.	ERP critical success factors / implementation
2009	Developing ERP Systems Success Model for the Construction Industry	Chung et al.	ERP success model
2010	ERP system implementation: a case study of the construction enterprise	Tambovcevs	ERP Implementation
2012	Construction Enterprise Resource Planning Implementation: Critical Success Factors – Lesson Learning in Taiwan	Lin et al.	ERP critical success factors
2013	Impact of ERP system to the construction industry	Perera	Impact of ERP
2013	The Impact of Enterprise Resource Planning (ERP) System on the Cost and Price of Auditing–Auditor's Perspective	Azaltun et al.	Impact of ERP on cost and price
2014	Information systems for material flow management in construction processes	Mesároš and Mandičák	ERP for material flow management
2015	Factors for the acceptance of enterprise resources planning (ERP) systems and financial performance	Bazhair and Sandhu	Acceptance of ERP
2016	Enterprise resource planning systems and the effects on management control	Cuppen	Effect of ERP on management control

systems are a type of application software that enables you to manage and coordinate all your business activities and resources [5]. ERP systems are among the most popular tools in the US to help improve business processes since the adoption of the Japanese Just-Time (JIT) concept. Most Fortune 500 companies, including large construction paints, have applied ERP systems in the 1990s [6], have gradually adopted ERP systems for medium or small companies in the US, Europe. However, what is more important, there are a number of research and scientific contributions on the issue.

Martiško described tasks and functions of ERP in information system of company [7]. The issue of ERP implementation discussed Tambovcevs. It was defined the main obstacles of ERP implementation in construction industry [8]. Implementation issues are also addressed by other authors [9]. This issue of implementation of ERP in major construction contractor companies was discussed in Honk Kong by other researchers. Success factors for implementing of ERP discussed Chung et al too [10].

Next contribution discusses issue of the process of developing an ERP systems success model to guide a successful ERP implementation project and to identify success factors for ERP systems implementation [11].

In Taiwan was realized research about the issue of critical success factors for construction enterprise resource planning implementation [12]. Generally, the issue of ERP in construction business management describes in other contribution, which includes conceptual CERP architecture [13]. Very important research about impact of ERP on construction industry was realized in Sri Lanka [14].

Information systems for material flow management in construction processes was realized in 2014, where was describe basic and extended ERP system in construction industry [15]. Selected contributions and researches are in table 1.

ERP systems can be viewed from multiple angles. In short, ERP systems include the integration of specific intra-company areas such as production, logistics, finance, and last but not least human resources. In this concept of ERP as the core of the information system, it is quite difficult to apply it to the construction company or to manage construction projects [16]. For ERP systems in the construction company neither basic nor extended ERP system is often sufficient. Enhanced ERP system and other modules that support integrated data interchange and information among other participants in the construction project are required for application. Figure 1 shown ERP system in construction company. ERP system in construction industry includes lot of modules, for example specialized Supply Chain Management (SCM). There exists a lot of methodology and strategy for example for asphalt supply chain optimization and other specialized situation in construction [17]. Generally, information technology in construction are very progressive and important. For example, this BIM technology, ERP systems and other [18]. This extended model of ERP includes part project planning". It includes Integrated Project Delivery (IPD). IPD is built on collaboration and encourage parties to focus on project goals rather than their own [19].
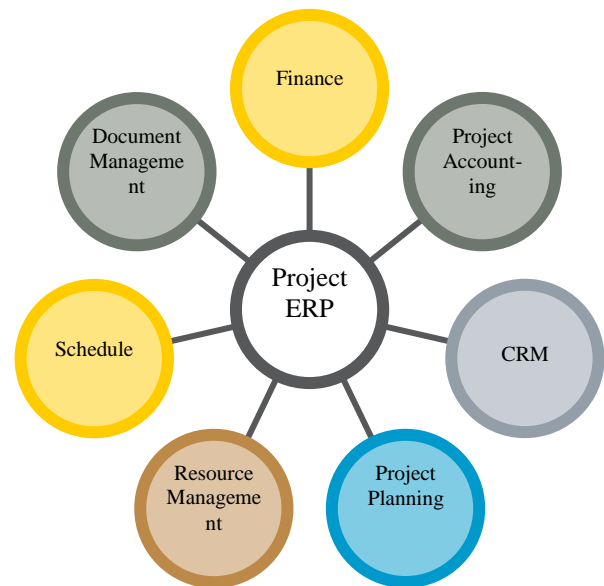
Figure 1.   ERP system in construction industry

III.   METHODOLOGY

A.   Research aims and research questions

According to literature review and researches, ERP systems are very discussed issue. A lot of research questions were answered in previously researches. However, anyone research didn´t discussed impact of ERP systems on developing of managerial competencies. ERP is not only tool for better management process. It can be tool for developing managerial competencies and other experiences of managers in every field. It follows the basic research question: Does ERP system have a significant impact on developing of managerial competencies of managers in Slovak construction companies? This main research problem supported another fundamental questions in this issue:

- What is exploitation of ERP systems in Slovak construction companies?

- What are differences in results between research groups about impact of ERP systems on developing managerial competencies (for example factors as enterprise size, enterprise owner, participant of construction project and SK NACE classification)?

There are basic questions that are basic for set of main research aim. The main research aim is to analyzing and quantifying of impact of ERP systems on developing of managerial competencies in Slovak construction companies. These results is necessary analyzing and quantifying in all research groups (divided according to construction size and more above mentioned factors).

B.   Data processing and data collection

All data in research was conducted by on-line form questionnaire. Research and data collection was realized in 2016. The research sample was approached by e-mail with the request to participate in the research to Slovak construction companies.

The research sample includes contractors, sub-constractors, designers and investors. Choose of participants of research was random from large database of companies operated in construction industry in Slovakia. All data were evaluated in software STATISTICA. For analyzing and quantifying of impact and exploitation of ERP systems on developing on managerial competencies was used Liker scale from 1 to 5 (where 1 is low use and impact and 5 maximize use and impact). The main value for research sample represents average value.

For selected research groups and analyzing of impact rate and use on choose research sample and choose factor, it was possible realized by Kruskal-Wallis test. According to into account of Kruskal-Wallis test results is possible to confirm generally results in this topic.

C. Research sample

Research sample was divided according to a few factors, especially enterprise size, use of foreign private equity (enterprise owner), participant of construction project and last one according to SK NACE classification. All represents are in table 2.

TABLE 2.
RESEARCH SAMPLE

Research group	Numbers of participants	In %
Enterprise size	**55**	**100**
Large companies	7	8.24
Medium sized enterprises	23	27.06
Small enterprises	27	31.76
Microenterprises	28	32.94
Enterprise owner (use of foreign private equity)	**55**	**100**
Use foreign private equity	44	80.00
Use only Slovak private equity	11	20.00
Participants of construction project	**55**	**100**
Contractor	28	50.91
Sub-contractor	14	23.64
Designer	9	18.18
Investor	4	7.27
SK NACE classification	**55**	**100**
Building construction	26	47.27
Engineering buildings	8	14.55
Specialized construction works	20	36.36

IV. RESULTS AND DISCUSSION

ERP systems are a support tool for managerial decision-making, and probably a tool for developing managerial skills and competencies. The extent to which the ERP systems affect to the development of managerial competencies and skills is the subject of this research. The use of ERP systems are shown in figure 2 according to enterprise size. Large enterprises use ERP systems at the level of 3.72, what is significant use.

ERP systems are used in less intent in medium sized enterprises, it achieved use rate only 3.36. Small enterprises and microenterprises achieved lowest value of use rate, especially small enterprises 2.79 and microenterprises only 1.23.

Very important is view of reason for this results. More enterprises claimed difficulty of implementation of ERP systems from finance and cost view. Complex solution is most expensive especially for small enterprise in comparison their turnover and earnings. Between other barriers was included ERP using were people's reluctance to accept change and a reluctant attitude on the part of managers.

Other point of view on results it was according to owner of construction enterprise. Figure 3 shown this results. Results clearly shown on better and more intent using of ERP systems by foreign owner of construction company. Foreign private equity or enterprises with foreign owner achieved better use level than construction companies use only Slovak private equity. Construction companies use only Slovak private equity achieved use level at 2.34 and construction companies used foreign private equity achieved 3.86, what it represents very high use level.
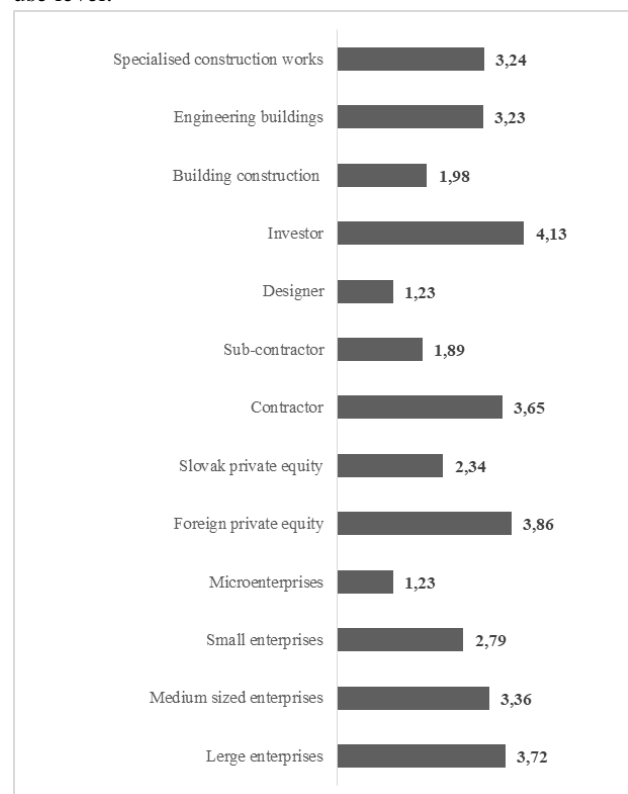
Figure 2. Use of ERP system in Slovak construction companies

According the view by participants of construction projects, results shown on the most using by investors. Investors achieved value of use rate at 4.41 that means very significant use of ERP systems. Contemporary, designers achieved value of use rate only at 1.23.

Last point of view is based on SK NACE classification. Building construction companies achieved the lowest use rate, only 1.98 that means not a significant use of ERP systems. Contemporary, engineering building companies achieved 3.23 and the highest use level achieved companies which do a specialized construction works. However, any of research group divided by SK NACE classification not achieved value more than 3.5, what means a not significant use of ERP systems. This view on use ERP systems are very important. However, use of ERP systems automatically it doesn't mean developing of managerial competencies and skills. The main research question and problem was set as impact of use of ERP systems on developing managerial competencies and skills.

Managerial competencies and skills help managers for better decision-making and do management works. Developing managerial competencies and skills is possible trough more strategy and tools. ERP systems represent efficient tool for achieving and processing a lot of information, and experience with them it can lead to an increase and developing of managerial competencies. Therefore, it is important point of view is increasing and developing managerial competencies by using ERP systems.
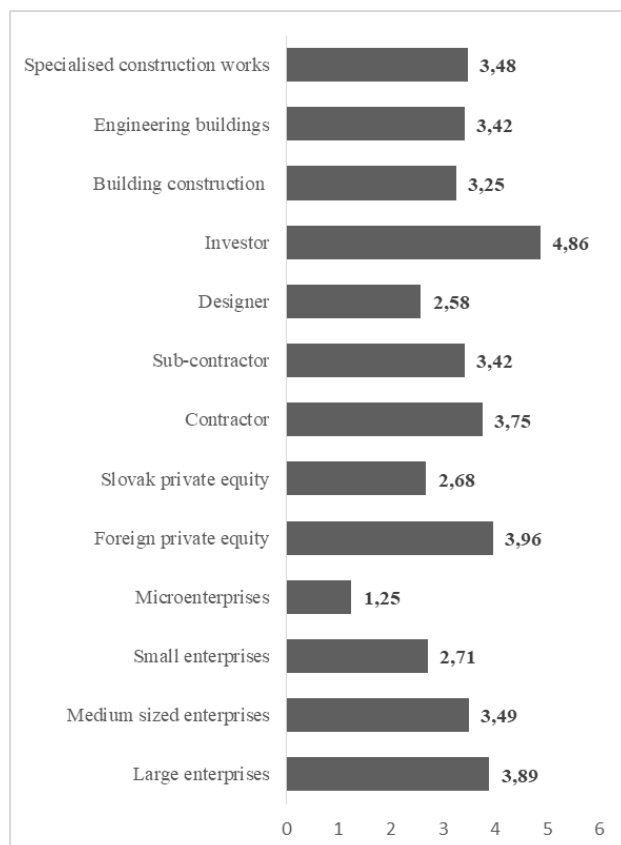
Based on a huge amount of sources it was the assumption that the use of ERP system can have a positive impact on developing managerial and digital competencies and skills for managers. Figure 3 shows results of ERP technology using impact. Based on these results that it can be say that the use of ERP system has a positive impact on the developing of managerial competencies. In spite of differences of results between research groups, this claims is confirmed generally.

One of research variable, it was **enterprise size**. According this factor and results processing in STATISTICA software. It was based on Kruskal-Wallis test. This test confirms claim, that the use of ERP systems has a positive impact on developing managerial competencies from differences of enterprise size. Large enterprises achieved the highest value at 3.89 and it means very significant impact on increasing and developing of managerial competencies. Contemporary, small and microenterprises recorded value of 2.71, respectively only 1.25. All Kruskal-Wallis test results are more specified in table 3.

Next variable or factor was set as **enterprise owner** or level of use foreign private equity. It was assumption that companies with foreign partner (know-how, management sharing or use of private equity) have more investments to the ERP systems, more using ERP systems and finally ERP systems has bigger impact on developing managerial competencies in this companies. This claims was confirmed by Kruskal-Wallis test. Companies using Slovak private equity achieved impact level at 2.68 and companies with foreign private equity achieved value 3.96. The value of p was 0.0284 (Table 4'.

Another factor in research was set as **participant of construction project**. Because of every stakeholder (participant of construction project) has a different interests, it was assumption, that these results can be different. The most impact on developing managerial competencies it was achieved by investors. Investors use ERP systems in extent level. The same is in impact results. Very significant impact achieved contractors. On the other side, designers and sub-contractors achieved very low value. In spite this results, Kruskal_wallis not confirmed clearly this results. It was value p = 0.1357. Differences between results of research groups divided by participants of construction were clear for acceptance of this claim (Table 5).

Last variable was set according to **SK NACE classification**. Companies were divided according to activities in field (building construction, engineering construction and specialized construction works). Results of ERP impact on managerial competencies based on divided according to SK NACE classification is not very significant. All value not achieved value more than 3.5. Kruskal-Wallis test shown p = 0.1826 and based on follow it is not to possible give some clear claim about results from one of this groups, generally (Table 6).

Figure 3.   Developing managerial competencies of managers trough ERP system in Slovak construction companies

TABLE 3.
KRUSKAL-WALLIS TEST , VARIABLE – ENTERPRISE SIZE

	KRUSKAL-WALLIS ANOVA BASED ON RANKING, VARIABLE – **ENTERPRISE SIZE** P=**0,0353**		
	Code	Number of valid responses	Use level
Large enterprises	1	7	3.89
Medium sized enterprises	2	12	3.49
Small enterprises	3	17	2.71
Microenterprises	4	19	1.25

Source: Own processing in STATISTICA software

TABLE 4.
KRUSKAL-WALLIS TEST, VARIABLE – ENTERPRISE OWNER (USE OF PRIVATE EQUITY)

	KRUSKAL-WALLIS ANOVA BASED ON RANKING, VARIABLE – **USE OF FOREIGN PRIVATE EQUITY** P=**0,0284**		
	Code	Number of valid responses	Exploitation level
Slovak private equity	1	44	2.68
Foreign private equity	2	11	3.96

Source: Own processing in STATISTICA software

TABLE 5.
KRUSKAL-WALLIS TEST, VARIABLE – PARTICIPANT OF CONSTRUCTION PROJECT

	KRUSKAL-WALLIS ANOVA BASED ON RANKING, VARIABLE – **PARTICIPANTS OF CONSTRUCTION PROJECT** P=**0,1357**		
	Code	Number of valid responses	Exploitation level
Contractor	1	28	3.75
Sub-constractor	2	14	3.42
Designer	3	9	2.58
Investor	4	4	4.86

Source: Own processing in STATISTICA software

TABLE 6.
KRUSKAL-WALLIS TEST, VARIABLE – SK NACE CLASSIFICATION

	KRUSKAL-WALLIS ANOVA BASED ON RANKING, VARIABLE – **SK NACE CLASSIFICATION** P=**0,1826**		
	Code	Number of valid responses	Exploitation level
Building construction	1	33	3.35
Engineering construction	2	17	3.43
Specialised construction works	3	5	2.87

Source: Own processing in STATISTICA software

Generally, research shown to developing managerial competencies in Slovak construction companies, but Kruskal-Wallis tests confirmed only variable enterprise size and owner as a significant in differences of results.

V. CONCLUSION

Actually, ERP systems are in progress generally. This research shown that this trend is in the Slovak construction companies too. Selected companies use ERP systems in Slovak construction industry, especially large companies. Very similar view on results are from divided according to owner of enterprise. Companies using foreign private equity use more ERP systems. However, in spite of large companies used ERP systems, use of ERP system is not very intent generally. Next research discussed more important research problem about developing of managerial competencies trough ERP systems. This results in this topic confirmed that ERP system has a significant impact on developing of managerial competencies of managers in Slovak construction companies. Especially, this claims was confirmed in large companies, companies with using of foreign private equity and investors. This research groups recorded very significant impact. ERP systems are very helpful in this companies. Contemporary, this big advantage and value of ERP system was not shown in small enterprises. It´s logical, because level of investment and wide of benefits is smaller in comparison with large companies.

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Mixing Augmented Reality and EEG Technology to Create an Unique Learning Tool for Construction Process

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Abstract—**The Augmented and Virtual Reality environments are proved to create excellent interactive tools for education. The development of relatively low-cost AR and VR visualization devices permitted to these technologies to form a part of educational process. By combining these immersive technologies with the EEG lecture in real-time it is possible to increase the efficiency of the digital learning tools. In the proposed study, we create an interactive immersive educational tool named "AR Constructor", which fuse the Augmented Reality and EEG technology for the purpose of further instruction in the field of building constructions.**

I. INTRODUCTION

Nowadays we can observe how the digital technologies have been able to approach all the fields of the investigation, this technology has brought with it the concept of immateriality, establishing in society new values of virtual elements.

The constant improvements in hardware and software have made available technologies of virtual reality and augmented reality to any citizen, allowing the access to these technologies regardless of degree of knowledge and computational skills. These technologies are being constantly inserted in every sphere of the society, including the educational field.

In the last decade, we have witnessed how educational institutions are being continually updated on the technological level, even the technologies of Virtual and Augmented Reality have made a great impact within the teaching field, increasing the motivation of the students through the digital interaction in real time.

In the present exist various devices that make possible the blending of real and virtual elements for the human perception, by technological enrichment of our senses, achieved in the most natural way possible. These technologies allow the extraction of data that surround the users, using different kinds of devices and sensors that transform the environment conditions into numerical values.

The data may have external character, such as the position or movement of users, but may introduce the data with internal character, such as the extraction of data from the brain activity by EEG, or muscle activity using EMG. The proliferation of such devices makes possible the exploration of new forms of education, where can be performed studies and tests based on empirical data related to the brain or motor activity of students.

In this study, we propose a combination of these technologies, combining Augmented Reality with electroencephalography, looking for the insertion of three-dimensional virtual contents adaptable to the student's brain activity and immediate cognitive response.

II. THEORETICAL FRAMEWORK

Hybridization of the virtual and the material can be perceived as an experience mediated by Augmented Reality (AR) technology. The AR allows the user to access the virtual information in the field of physical environment, which otherwise would remain invisible and imperceptible to the human senses.

AR technology blends real-world and virtual-world environments and elements, facilitating the understanding of digital information superimposed on a real-world environment. The virtual contents used in the field of AR can treat any type of digital information, image, sound, video, three-dimensional models. AR contents can be perceived by the five senses, although at present, the visual sense is prevailing in most of its applications.

The definition of Augmented Reality in many cases relies on its comparison with Virtual Reality, this phenomenon which points out to the nuances that differentiate Virtual Reality from Augmented Reality, is used very frequently to describe the true nature of this technology.

To define the AR can be used the concept that it constitutes a special case of virtual environment (EV) or, as it is often called, Virtual Reality (RV) [1]. AR and Virtual Reality contain similar features, such as the inclusion of virtual models in the field of view of the user, but while Virtual Reality represents a totally immersive environment, which is set in an entirely synthetic world, the AR allows the user´s contact with the real environment, complementing it by overlapping the virtual contents on the physical world in real time. Another very important aspect that concerns Virtual Reality, is the

difficulty of reproducing a synthetic environment, in the manner that it simulates aspects of the physical world in a truthful way.

Using the basic definitions and descriptions of AR capabilities can be highlighted three characteristics of AR technology, such as proposed Azuma [1]:

- AR combines real and virtual information.

- AR is interactive in real time.

- AR operates and is used in the three-dimensional environment.

In AR environments, these three conditions must be fulfilled at the same time. Azuma [1], provides examples of technologies that despite partially fulfill any of the conditions, cannot be considered as RA. Among such technologies it mentions the mixture of the virtual and physical that lack of interactivity like the cinema, or the possibility of adding special effects to video in real time, but without power to perform an alignment of the virtual contents within the physical environment [1].

The relationship between VR and AR was also explored in more detail by Milgram et al. [2], these authors define the degree of virtuality of AR in "Reality – Virtuality Continuum" [2], a graphic representation that contemplates several states of real and synthetic environments. In one of its extremes we find the 'Reality', understood as a completely real physical environment and without any digital content, and at its other end, can be found the totally synthetic or digital environment defined as Virtual Reality.

From left to right, the amount of digital contents generated by a computerized device increases, considering the immersive environment of Virtual Reality as a completely synthetic environment, where the real environment is completely replaced. Between these two extremes, the continuum locates the possible variations and fusions between the Real-Virtual states, depending on the amount of virtual and / or real components that are present. Here we can find the Mixed Reality, which is subdivided into two fields: Augmented Reality and Augmented Virtuality [2]. These cases depend on the amount of virtual information added, the more virtual contents, we get closer to the Augmented Virtuality, but both states must comply with the condition of being partially present in the real environment.

Xiangyu Wang [3] moved the Reality-Virtuality Continuum into the field of learning through the "Taxonomy of Mixed Reality Learning Environments". According to this adaptation of the real-virtual continuum, physical reality is related to learning in the physical environment of traditional education, the classroom, while E-learning is within the field of Virtual Reality (screens and projections).

As in the Reality-Virtuality Continuum [2], where the intermediate environments are covering the mix of the real and the virtual, this continuum shows the Mixed Reality environments in relation to the Mixed Reality Learning Environment (MRLE) [3]. Introducing virtual content in the physical world, Augmented Reality creates spaces where users can experience education and learning in a novel, interactive and intuitive way, opening the door to a wide range of educational tools that raise the level of learning.

A. Augmented Reality Process.

The creation of AR environments depends on several technological factors which had been developed and diversified over the years and has spread in numerous systems. Existing solutions implement a wide variety of hardware and software, where technical requirements may diverge, depending on the desired results, Billinghurst and Thomas summarize the process employed in the operation of AR technology into the five steps [4]:

- Construct a virtual world with a coordinate system real world.

- Determine the position and orientation of the user.

- Pose the virtual camera accordingly to the position of the user.

- Render the image of the physical environment on a device's display.

- Combine the image of the environment with the virtual contents. [4]

These five features can be gathered into three essential phases (Fig.1.) to carry out the process necessary to run AR applications:

- *Tracking:* determines the position and orientation of the user, including his point of view,
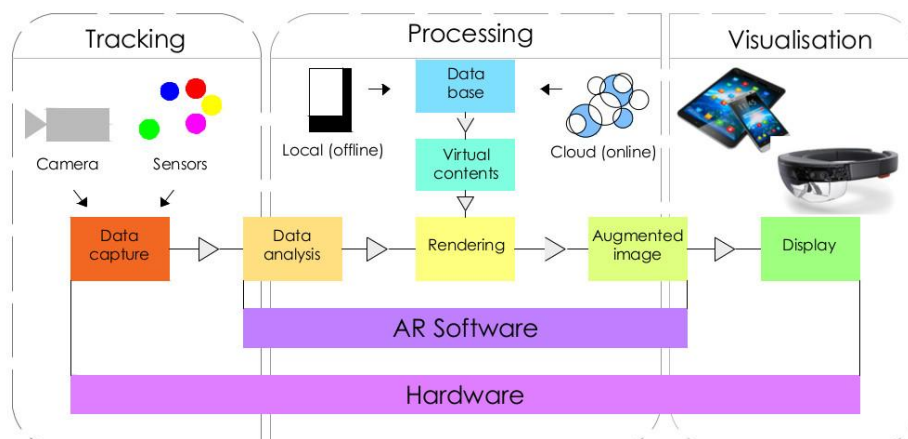

Figure 1.   AR Process

conveniently represented by a virtual camera. This phase can be based on different types of methods of tracking, which depend on the technology, software and hardware employed in this process. The input data can be collected from various types of sensors (magnetic, infrared, inertial, GPS, etc..), or captured by the camera.

- *Processing:* establishes a link between the coordinates of the physical environment and the virtual world, aligning the virtual contents with the spatial coordinates and creating an image of the augmented environment. The virtual contents can be retrieved online from the cloud or off-line from the internal repository. The efficiency of this phase is related to the performance of processing devices and the AR software used for this purpose.

- *Visualization:* facilitates to the user the vision and perception of the augmented environment. In this phase the degree of immersion is determined according to the kind of hardware employed to display the virtual content. This phase implies the utilization of different types of hardware and software to generate a convincing experience of AR environment.

B. Levels of AR.

Within the field of Augmented Reality applications, we find a classification of levels depending on the complexity of the tracking technology used [5], [6], [7], [8]:

- *Level 0*: systems that introduce hyperlinks in the physical space. This level would remain out of the definition of Augmented Reality from the point of view of the main characteristics proposed by Azuma, failing to fulfill the condition of tridimensional contents. It is based on the technology of QR codes and bar codes lecture, detected by the mobile phone camera that automatically access a web page using the predefined mobile device browser [6].

- *Level 1*: is based on the use of fiducial markers and natural feature tracking. It relies on systems of recognition of two-dimensional markers, with the ability to display three-dimensional objects. This level allows the insertion of any type of virtual content in the physical space [5].

- *Level 2:* focuses on tracking by combining GPS data with compass data, or other types of sensors, such as inclinometers or accelerometers [6].

- *Level 3:* refers to applications that use spatial tracking focused on HMD devices. According to Rice [9], it allows us to move away from the concept of a monitor or screen, transforming Augmented Reality into what it calls the Augmented Vision, where "global experience immediately becomes more relevant, contextual and personal" [9].

- *Level 4:* is based on the use of retinal devices or other devices, capable of connecting to the nervous system of the human brain, producing the integration of virtual contents with the physical environment observed. Augmented Reality This level has not been reached today, but we could

say that is much closer to the Virtual Reality than to Augmented Reality [9].

C. EEG Technology

Electroencephalography measures the electricity generated by brain structures on the scalp [10]. We will employ non-invasive techniques, capable of measuring the cortical surface to obtain specific values that reflect the electrical activity produced by the activation of neurons of the brain, provoking electric current flows [11]. The EEG allows users to control devices in their environment and is able to establish a direct communication between the computer and the user [12].

The use of EEG technology has increased significantly and has proliferated into the several fields of investigation and its employment. In combination with digital technology, EEG can create the human-machine relationship, which can be characterized as Brain Machine Interface (BMI) and Brain Computer Interface (BCI) [13].

- *BMI* focuses on the new visual perspectives, generating changes in the perception of the corporal scheme, producing experiences able to locate us in a machine or foreign body, provoking the illusion of an exchange [14], [15].

- BCI is capable to establish a communication channel between the human brain and the machine without the need of any physical interaction. The aims of BCI systems can be classified into two types [16]:

- Process control: the system directly controls the mechanical components or muscle to generate an action.

- Selection of objectives: the system identifies the intention of the user.

Through EEG technology it is possible to assess the perception of 'spatial presence' within environments such as Augmented Reality or Virtual Reality. Spatial presence can be described as "the feeling of being in an environment" [17]. This type of perception has been explored using EEG devices, studies conducted in this field have concluded that VR can generate a subjective sensation of presence [18]. Spatial presence is associated with the activation of a distributed neural network in the parietal lobe and prefrontal cortex, which is activated in the same way in both real and virtual environments [19].

The sensation of presence is conditioned by internal and external factors [20]:

- *Internal factors*: the sensation of the presence in AR and VR environments is understood as proportional to the degree of immersion. Greater immersion implies more sensation of presence, producing comparable behaviors to those generated in real environments. AR poses the ability to share information with the physical world and the virtual world at the same time, and allows the notion of events which take place in the physical environment. The inclusion of actions that require the interactivity of users, increases the degree of immersion, producing more convincing

experiences, and increasing the presence in the environments of AR and VR [21].

- *External factors:* related to the hardware and type of visualization technology used, such as screens and head mounted displays (HMD), projection and perspective [22].

  - *Screens:* In this sense, we find a proportional relationship between the size of the screen and the perception of immersion. The experience implies more immersion if the screen is larger and covers more field of the user's vision [22]. Users' angle of vision improves their successful navigation, so the use of HMD that covers the entire vision generates a very high degree of immersion, as it does not suffer interferences caused by the seams which can be generated between virtual and physical space, as it was demonstrated in experiments based on visualization of virtual content using different types of displays [23], [24].

  - *Projection and perspective:* Comparing stereoscopic vision with two-dimensional vision, we can conclude that the second one causes less understanding of depth in virtual environments [22]. This happens since the human brain is accustomed to perceiving the world by a three-dimensional image, which is generated by combining information from the left eye and the right eye. As a result, stereoscopic technologies provide a greater subjective feeling [23], capable to increase the immersion and to elevate the spatial navigation in virtual environments [24].

The AR technology helps to invoke the brain processes capable to consolidate the real and virtual dimensions, influencing the perception of the space where our own mind places us. EEG establishes two-way communication a channel between the content and the viewer, where the virtual content can be affected the user and vice-versa. This mutual influence can be perceived through neurofeedback, the process that can be understood as self-perception of patterns of the brain activity of the user using EEG, which allows users to have control of their brain activity to achieve specific mental states [25].

III. PROJECT AR CONSTRUCTOR

AR Constructor, is an educational tool that aims to introduce the combination of augmented reality technology with EEG technology. It allows us to delve into the investigation of the human-machine relationship by using cognitive systems within the augmented reality field, modifying the perceptual senses of the user by combining in real time not only the "external conditions and internal conditions" [26] that surround the subjects proposed by the discipline of Augmented cognition [27], but also by the introduction of virtual conditions.

For the purposes of this study we determine several kinds of the conditions relevant to constitute this particular BCI:

- *External conditions*: represented by the immediate experience of surrounding physical environment.

- *Internal conditions*: extracted from the physical and mental state in which the user find himself/herself at the moment of the study.

- *Virtual conditions*: deal the relationship between digital contents and physical space. In the case of employing the technology of Augmented Reality enriched with the real time EEG lectures, these conditions are affected by the relationship between external and internal factors as defined in [22].

Augmented reality in education is able to improve communication channels, breaking with some of the paradigms that are established in theoretical education, "the educational experience transcends the intellectual experience accessible through print culture to become a capable experience of being perceived through all the senses " [26], generating a relation between the contents and the student, increasing the degree of veracity through the interaction in real time.

AR makes learning more persistent through the insertion of three-dimensional virtual contents in the physical space, which can be manipulated and transformed, not only by physical action produced by interaction with AR markers, but also by brain stimulation, increasing the level of concentration generating a specific neurofeedback, which becomes perceptible through the degree of difficulty of the proposed contents.

A. Functionality

This project is based on the use of didactic contents that allow to increase the knowledge of the constructive details that are very habitual in any type of building project. The proposed virtual contents have the peculiarity of adapting their degree of difficulty in function of the student's immediate mental state, increasing or reducing the complexity of the learning content in relation to the student's attention level measured by the EEG device in real-time (Fig.2).

Students do not have always the high degree of attention, which can make learning tasks more difficult. This system facilitates a more fluid learning, visualizing the examples of high complexity that need a great capacity of attention for its correct understanding, only if the level of attention is elevated. The recognition of the student's degree of concentration in real time allows to vary the visualized content, so in certain situations, with a lack of concentration, it is more efficient to show the contents with very low complexity or introduce some more interactive tasks.
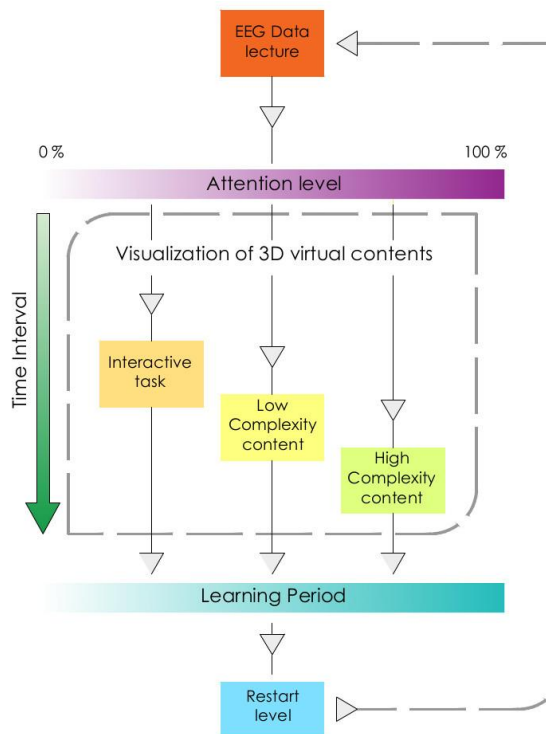
Figure 2. Operation scheme of "AR Constructor" application.

B. Technical approach

The project focuses on mixing different existing technologies to improve the metal states of concentration of students. We use traditional visualization interfaces within the field of virtual reality, that allow to mediate first-person view in the virtual environment. In this case, through a few hardware-level modifications and adding a stereoscopic camera, we transform a virtual reality viewer into an augmented reality viewer, introducing the physical environment which surrounds the user into the field of his/her vision (Fig.3).
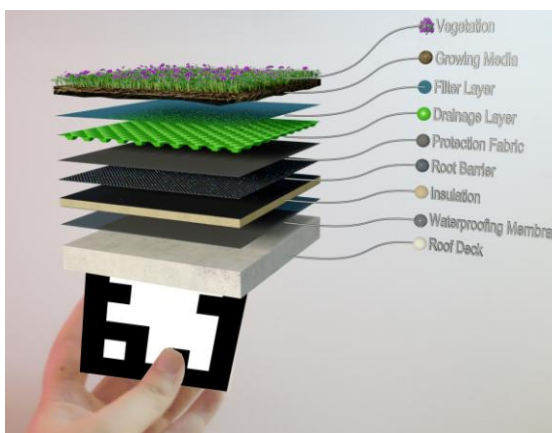
Figure 3. "AR Constructor"- first-person view- high complexity content.

Finally, we aggregate this visualization interface to a brain computer interface (BCI), conditioning the visualization of virtual contents by the data extracted from the EEG lectures. The system using the attention values of the students obtained in real time, can offer the possibility of adapting the learning contents in function of the brain activity.

The operation of the application is effectuated by the devices responsible for performing the AR process, based on the analysis of the input data, its real-time processing and the output of this data. This process uses different types of hardware and software capable to perform together, with a minimum latency, producing a convincing user experience.

C. Phases of the process and technical specification of involved components

1) Data Input:
   a) Brain data:

   • EEG *Neurosky Mind Wave*: a device that allows detecting brain activity in a single channel, uses a single dry electrode, capable of digitizing and amplifying brain signals. The device establish communication with the personal computer using Bluetooth.

   b) User's point of view:

   • *Overvision Camera*: Device composed of two cameras with low performance, the separation of these cameras correspond to the interpupillary distance of the average user, allows to generate a stereoscopic view of the environment.

   c) Correlation of visual data with physical space:

   • Fiducial markers: allow the spatial positioning of digital contents, providing real-time feedback between physical and virtual elements.

2) Data Processing:
   • Personal Computer processes input and output data using the specific application created with the help of *Unity 3D*, a game engine software capable of combining the different libraries needed for the employed hardware performance. In this case, it combines *Oculus SDK*, *Neurosky Mindwave SDK*, *Overvision SDK* and *ARtoolkit SDK*, allowing the analysis and visualization of data in real time.

3) Data Output:
   • User´s Vision:

   • *Oculus Rift II*: Head Mounted Display that allows the visualization of the contents through a screen that simulates the stereoscopic vision.

   •

The application at didactic level is divided into two parts, on the one hand it shows the constructive details and on the other offers the possibility of generating some learning exercises, where the student learns to assemble the construction details using different elements and materials.

Figure 4.   "AR Constructor"- High complexity content.
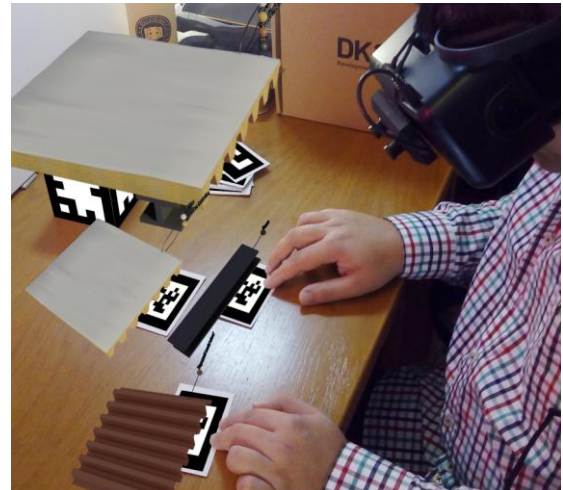
Figure 5.   "AR Constructor"- Interactive task.

To carry out these two parts uses different types of markers:

Three-dimensional markers: these are markers with cubic shape, which allow the student to visualize the constructive elements. The three-dimensional shape allows the student to manipulate these markers naturally, without interferences which would interrupt the correct function of the tracking system. This shape also permits to move the virtual contents, zoom in or out, as well as it grants the visualization from any angle, generating a better understanding of the subject (Fig.4).

The experience of being able to manipulate the Augmented reality virtual models in real time, generates an interaction that isolates the student partially from the distractions of the physical environment, and increases his/her degree of attention, which can lead to increase the degree of understanding of the functionality of each example.

Two-dimensional markers: these are markers with flat shapes, like cards, which permit partial visualization of the materials that make up the construction details. With the correct assembly of these markers the student can complete specific construction details, thus learning the correct structure and the composition of the materials involved in the construction process of each example (Fig.5).

IV.   CONCLUSIONS

The proposed system "AR Constructor" which employs the immersive environment of Augmented Reality and its combination with real-time EEG data lecture, has demonstrated the its fluid performance as a tool for the learning in a subject of constructions of the building. Although, the amount of the virtual contents was limited to small number, exists a possibility to further ampliation of the structural examples to create an efficient database of virtual models that can cover the requirements of the specific learning topic.

As well as there is a possibility of hardware improvement, which can use the other visualization devices such as smartphones or tablets in combination with low cost cardboard VR / AR viewers, to create an efficient and widely available learning tool.

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Progress in MOOC Education at Óbuda University

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Abstract—**The paper is devoted to the problem of further development of on-line education in MOOC context and its application as an advanced and effective e-learning strategy to Hungarian speaking communities in Carpathian Basin.**

I. INTRODUCTION

Education is the most powerful tool in building knowledge based societies. Through last decades, we have witnessed huge efforts done in creating new advanced tools to make the process of education more comfortable, cheaper, easier available and more effective. On-line education is one of these modern policies and on the top of this is standing MOOC, which addresses wide communities in overall the world.

In the 21st century, the need for knowledge is constantly increasing. There are new expectations of teaching and learning's every aspect. Teaching systems need reshaping, in order to facilitate every student's need. This is a massive expectation from Universities. Nowadays lifelong learning is required. The learning process is individualized, tailored to every student's needs and skills. Today's economy is based on knowledge and development. In society learning makes individuals marketable and is the most important in terms of life quality. Learning is paramount for individuals, society and economy as well.

Adult learning is useful not only to the individual, in terms of better chances in their carriers, but also in other dimensions like: health, family life, personal relationships, hobbies. This way learning is used as an active tool for development. Learning is not only beneficial in getting a good job or being able to keep their job, but also in improving life quality.

Therefore we had to combine the traditional teaching methods and the modern way of learning. We had to take into consideration the technical developments and the needs of our students [1].

Learning strategy is to be interpreted as a complex system of procedures where methods, forms and means are united in an organic relationship [2].

Online learning environments - on campus or at a distance - and the policy issues that affect them have come to the forefront of higher education. Rapid enrollment growth in e-learning courses and programs signals that students and the public at large also see online and blended options as increasingly attractive.

The grand challenge in data-intensive research and analysis in higher education is to find the means to extract knowledge from the extremely rich data sets being generated today and to distill this into usable information for students, instructors, and the public.

There are many sources describing late development of MOOC strategies, e.g. [3] - [7].

A *Massive Open Online Course* (MOOC) is a model for delivering learning content on-line to any person who wants to take a course, with no limit on attendance.

One of pregnant definitions of MOOCs is that given by Ignatia Inge deWaard in her e-book, MOOC Yourself: "A MOOC is a non-defined pedagogical format to organize learning /teaching/training on a specific topic in an informal, online, and collaborative way."

This captures the key essence of a MOOC highlighting the key differentiators between a MOOC and an online course. The confusion between a course on an LMS (Learning Management System) and a MOOC - especially now that MOOCs are all set to enter the workplace where course tracking has so far been the norm - is going to be rampant. Hence, it is essential to identify the key aspects of what makes a MOOC a MOOC.

Unlike an online course which focuses more on content, MOOCs focus more on context. Good content is a prerequisite to creating a MOOC but what keeps it going is dynamic building up of context around the content.

MOOC is an open educational system in which the participant has an unlimited and free access to online courses. There is no need of entering a given higher education institution or a preliminary registration, and there is no or very loose limitation in number of users. The topics of courses and their discussions are open to anybody. One of the goals of MOOC is to ensure accessible education for masses of people, in frame of life-long education. On the other hand, it gives tool for new credit based education for ordinary university students. MOOC in higher education context is in no way a dividing method but an alternative tool of new, advanced educational methodology. It cannot replace the teacher/lecturer but it does complete him or her in interactive way.

During recent years, MOOC has gained considerable attention and achieved significant results in English speaking part of the world. Thousands of courses have been introduced and millions of people are engaged in this form of education all over the world. The system of courses is not limited by state borders and is open and free to anybody who is on the net and can master the English texts or videos. However, there have been few attempts to adopt it in non-English languages.

This paper is to describe creation and progress of a new system of MOOC higher education courses in the Hungarian language context with cross-border effect. The

target groups are Hungarian speaking communities living in different national states in Carpathian Basin but it can be used by anybody who is on the net and can master the Hungarian texts or videos. Participants can be students of credit based university courses or individuals interested in distance life-long education.

II. EVOLUTION OF MOOC

The predecessor of MOOC was the *Open Course War* project launched by Massachusetts Institute of Technology more than 15 years ago. The goal was to extend the access to the Institute's teaching materials and make it available for wider groups of students. The number of computers in households along with access to the internet was increasing that time. This was an accelerator for the idea and application of online learning and teaching. First MOOC-like course titled *CCK/08-Learning is Binding* was open in USA in 2008 with the aim to enhance collaboration between the students through bloggs, comments and discussions on internet. Then a non-profit video provider was established by Salman Khan and named efter him *Khan Academy*.

Another predecessor of MOOC was *iTunes U* which used Apple communication system. The call for more open, free and widely accessible on-line education tool resulted in creation of first authentic MOOC courses launched first by Stanford University in 2011 and later by MIT and Harvard University. The real boom came in 2012 when, along with higher education institutions, civil organizations and foundations called for massive open on-line education methods. By now, number of well acting MOOC providers is on the scene, e.g. *Udacity*, *Coursera* and *EDX*. The first secondary school MOOC course was *Global Academy* provided by University of Miami. The biggest course, so far, has been the one announced by *Udacity* with number of registered participants of 300 000 [8].

MOOC has been developed by now such that hundreds of provider act all over the world with thousands of courses offered and the number of attendants estimated is more than twenty millions. Courses can be taken from any country in the world and many universities offer also credit based courses.

Although MOOC is most developed in **Northern America**, other parts of the world are engaged as well. The Taylor University in **Malaysia** and the Universitas Ciputra in **Indonesia** attracted students from 113 countries in the world with the biggest course attended by more than 20 thousands students.

In **Australia** there is only one provider linked with the University of New South Wales.

First university, launching MOOC courses in **Europe**, was the Helsinky University. Nowadays, more than 600 courses are active, mostly in Spain (more than 200), then UK (120), France (180) and Germany. The biggest provider is the German *Iversity*, whose course was attended by 82 000 students. Besides this, the British *Open Unirversity*, the Irish *Alison* and the French *Universite Numerique* are most well-known on the market.

According to *Open Education Europe* statistics of the European Commission, the number of free accessible MOOC courses in the world nearly doubled during year 2014 – while in January it was 1369, it increased by June up to 2625. The courses offered are diversified – along with law, economics, technical and natural sciences, new scientific and art disciplines are present in the content of MOOC education. Moreover, they offer also knowledge and skills for individual undertaking. To demonstrate the variety of teaching materials, from 325 courses, provided by *Coursera* there are 30% covering scientific problems, 28% arts and humane branches, 13% business and trade and 6% mathematics. According to the statistics, the most of the courses launched in Europe (more than 130) recently, was in the field of technical science, followed by applied science, social science and business – each branch represented by apr. 90 university courses. In international offer, one can find his or her best suitable object of study - starting with Greek mythology to up-to-date problems of bioinformatics.

In central Europe there is a big deficit in massive on-line education. Although on-line learning is being present at some of the big universities, MOOC type courses are in offer only by few higher education institutions.

In Hungary, the Mathias Corvinus College offers courses in social sciences for secondary school attendants. The 4-semester course covers modern age history, economical sciences and international relations.

III. MOOC COURSES

The term MOOC is Dave Cormier's answer to "Connectivism and Connective Knowledge" course, which started with 25 paying students. This course than has opened up to 2200 independent students, for free. The content of each course was accessible through RSS and online students were using various means of accessing the course. for example Moodle and a Second Life.

Shortly many independent MOOCs have evolved. Jim Groom (University of Mary Washington) and Michael Branson (Yorl College, City University of New York) will start an independent MOOC in collaboration with other universities. The early MOOC is mostly published as a learning management system in combination with open web base.

"The New York Times" pronounced 2012 as MOOC's year. When Harvard and the Massachusetts Institute of Technology have started an nonprofit official cause they had 370000 students. This seemed to be not much compared with Andrew Ng's Coursera, which is a profitable course series, having 1.7 million students. (Quicker increase than Facebook).

One of the biggest online courses provider company is Coursera, which is collaborating with the top 10 Universities. They offer courses for credit points through purely online courses, or accompanied by school based lessons.

In general, there are two basic types of MOOC:

a. Communicative MOOC under the teacher supervision

This is a more traditional approach to learning where the teacher is the most relevant and reliable source of knowl-edge and information. As teacher presence is "mediated", mediatisation solutions point to chunking videotaped classes, providing a set of additional resources and learning activities, and assessing through more or less automated tests. This type of MOOC privileges the

knowledge transfer and duplication. Embedded pedagogical approaches highlight behaviourism [9].

b. MOOC without communication or contact with teacher - the student plans his own learning Schedule independently

These MOOC were born before their more publicized counterparts and translate connectivist principles to the design of the course. They therefore focus on learners' networks and learners' personal learning environments. Less structured and more confident of learners' capacities for self-organizing and co-participating, they rely on content aggregation and peer evaluation. These MOOC advocate for "knowledge creation and generation" [10]. The focus of the attention in each type is on the needs of students. What can make, in this respect, an MOOC course attractive?

IV. MOOC AT ÓBUDA UNIVERSITY

The University of Óbuda has always emphasized the need of implementation of modern teaching and learning strategies. In 2012, the University founded the Office of Digital Education, which coordinates all electronic courses and their publications. Students mostly have learning needs rather than eLearning needs, this makes us believe that eLearning is not an end-solution by itself. For successful realization of this concept could be effective in meeting learning needs, however it has proven to be more difficult as we expected due to the constant change which takes place in this field.

K-MOOC was founded at Óbuda University in 2014.

Abbreviation K-MOOC stands for Hungarian name of the Centre (*Kárpát-Medencei Online Oktatási Centrum*) and as such, it refers to its MOOC activities. The founder of the Centre was prof. Imre Rudas, the former rector of Óbuda University. From the point of organisation, K-MOOC belongs to the University Research and Innovation Centre as one of the ten Knowledge Centers. K-MOOC acts as a network with tens of independent partner institutions – institutions (universities, faculties, departments) located in Carpathian Basin, in Hungary or outside Hungary, conducting education fully or partly in the Hungarian language.

Main goal was to adopt, adapt and extend the MOOC on-line education method and principles, described above and well established in English speaking context in the world, to conditions and needs of Hungarian speaking communities living in different national states in Carpathian-basin. K-MOOC launches MOOC type courses in the Hungarian language - free and accessible not only for Hungarian speaking community in this region but for anybody int he world, who can master on-line learning in Hungarian. Besides transfering new knowledge in natural, technical or social sciences, it may contribute to education in national culture and language for potential attendants who otherwise have limited access to that. Thus, it offers new opportunities also for those interested in life-long education in mother tonque and/or who are lacking sufficient knowledge of English.

Another goal is to announce credit based subjects recognized by one or more partner universities/institutions as a part of their regular curricula. Partner institutions have to provide conventional or on-line education fully or partly in Hungarian.

K-MOOC was founded having the goal to provide higher education courses for as many students as possible. The opportunity to take on our eLearning courses is open to anyone, they are not location related and the phase of learning is determined by the student.

The partners of K-MOOC are Hungarian universities and colleges, as well as Hungarian speaking higher education institutes from overseas.

The main activities of K-MOOC are:

A.

Integrates hungarian speaking higher education institutes in the Carpathian basin.

B.

Provides hungarian speaking highy professional courses, which are run in agreement with international acredition.

C.

The instututes which adhere to this network have the opportunity to start course in any subject.

D.

The courses are accesable, free of charge to anyone. Initially, there were some issues regarding MOOC, however these were associated to institutes, technology and economic aspect of this network. There were never issues regarding pedagogical methodology for running these courses. The challenge was to come up with a suitable plan for starting and running these courses. The new ways of teaching and learning motivated us to change the design of learning by making it ambitious, innovative and over all change the approach for teaching and learning.

MOOC could be and should be more than a traditional online course. From a pedagogical point of view, it is useless to pack a traditional classroom training into an online course.

MOOC is a specific tool which provides availability to rethink the well-tried online teaching strategies. This tool motivates the understanding of knowledge assimilation and learning processes which is based on high quality and innovative teaching and learning strategies.

When introducing a MOOC we have to have clear picture about the different types of MOOC.

V. THE K-MOOC NETWORK

The K-MOOC network is composed so far of 23 higher education institutions from Hungary and 14 institutions, conducting higher education fully or partly in Hungarian from abroad. The list of partner institutions can be found in [11].

VI. EVOLUTION OF K-MOOC ACTIVITIES – FROM IDEA TO TWO THOUSANDS APPLICANTS

From its beginning in 2014, K-MOOC has gone through rapid enlargement and development. Its story is the real story of success. The following numbers are to show the rapidly increasing number of courses and students involved.

TABLE I.
NUMBERS OF K-MOOC STUDENTS

Year/ Semester	Number of Courses	Number of Particip.	ÓU students	Finish
2014/15/I	4	271	170	152
2014/15/II	9	551	374	228
2015/16/I	20	1346	764	465
2015/16/II	23	1524	958	764
2016/17/I	45	2057	1476	896
2016/17/II	51	1726	1210	719
2017/18/I	59	2149		

As it is transparent from Table I., the number of K-MOOC courses and participants have gradually been increasing from the year of foundation of the network. By now, overall number of attendees of all courses announced by K-MOOC partners is 9037. This positive result has been achieved thanks to enthusiastic effort of K-MOOC staff as well as to financial support of the Hungarian Ministry of Education. This finance helped to develop new curricula of on-line subjects through projects announced with the aim to create new courses as well as to purchase modern hardware and software tools for MOOC education. Calls for tender launched in spring this year resulted in creating new courses for winter semester of 2017/18 school year.

The list of all courses launched by K-MOOC prior to last school year (2016/17) the reader can find in [12]. From that time the following new courses have been launched:

1. Anyagtechnológia alapjai (Material Technology Fundamentals)
   Műszaki tudományok, Óbudai Egyetem
2. Biztonságtechnika-történet (Safety Techniques)
   Társadalomtudomány, Óbudai Egyetem
3. Döntéselmélet és módszertan (Decision Theory and Methodology)
   Természettudomány, Óbudai Egyetem
4. Ipari technológiák gépei I. (Machines of Industrial Technologies I.)
   Műszaki tudományok, Óbudai Egyetem
5. Irányítástechnikai rendszerek (Control Systems)
   Műszaki tudományok, Óbudai Egyetem
6. Műszaki rajz és dokumentáció (Technical Drawing and Documentation)
   Műszaki tudományok, Óbudai Egyetem
7. Pénzügyek alapjai. (Financies Fundamentals)
   Gazdaság, Óbudai Egyetem
8. Robotmodellezés Matematikai és Mechanikai Alapjai (Mathematical and Mechanical Fundamentals of Robotics)
   Műszaki tudományok, Óbudai Egyetem
9. Villamosipari anyagismeret (Electrical Industrial Materials)
   Műszaki tudományok, Óbudai Egyetem
10. XX. századi művészettörténet (History of Arts of the XX. Century)
    Művészettörténet, Partiumi Keresztény Egyetem
11. Környezettan földtan, talajtan (Ecology and Geology)
    Természettudomány, Óbudai Egyetem

Besides teachers of Óbuda University, another 14 partner institutions from Hungary and abroad took part in the project financed. Altogether, 59 courses were at offer by the 2017/18 school year. The 59 courses have been launched by the partner institutions of the K-MOOC network as it is shown in Table II.

TABLE II.
NUMBER OF COURSES LAUNCHED BY K-MOOC PARTNER INSTITUTIONS

University/Institution	Number of Courses
Óbudai Egyetem	34
Eszterházy Károly Tudományegyetem	4
Budapesti Műszaki és Gazdaságtudományi Egyetem	2
Szegedi Tudományegyetem	1
Debreceni Egyetem	3
Sapientia Erdélyi Magyar Tudományegyetem	1
Partiumi Keresztény Egyetem	4
Zsigmond Király Egyetem	1
Pécsi Tudományegyetem	3
Szabadkai Műszaki Szakfőiskola	1
Apor Vilmos Katolikus Főiskola	1
Szabadkai Magyar Tanítóképző Kar	1
Kaposvári Egyetem	1
Gábor Dénes Főiskola	1
Szolnoki Főiskola	1

VII. FEEDBACK EVALUATION

Prior to establishing a new MOOC network system it is advisable to analyse and measure the possible listeners background and their motivation. After two years of successful running of K-MOOC we conducted a survey among the listeners focused mostly of their motivation, expectations, course evaluation and conclusions. Part of the numerous results we publish herein in order to help the new possible participants and/or providers in estimating market capacities.

We put questions targeting the following main areas:

A. Students motivation

a/ Have you taken the course for getting credits?
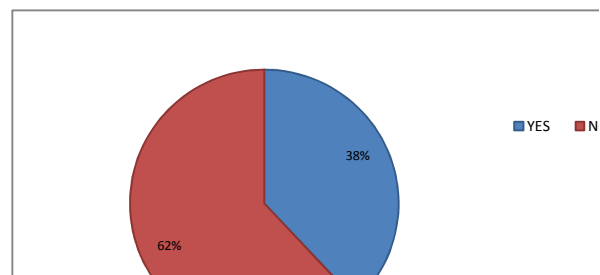
b/ Why did you choose this form of study?
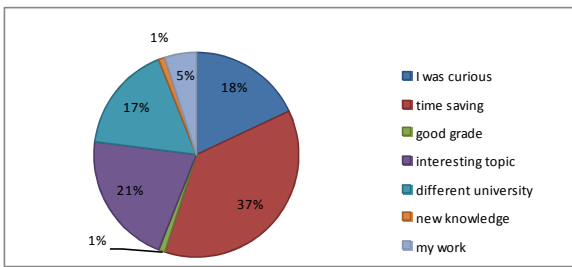
B. Difficulties during the course
a/ What caused main difficulty for you?
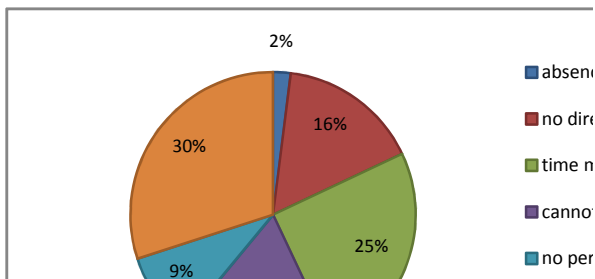
b/ Have you successfully finished the course? If not, why?
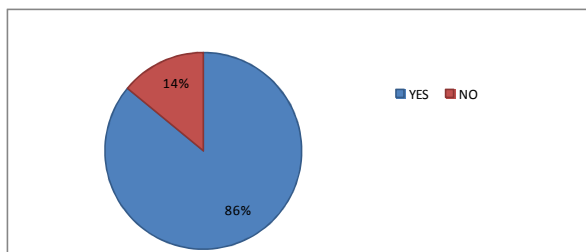
- I did not deal with it
- I did not have enough time
- I started too late

C. Advantage of Courses
What you consider the main advantage of the course?
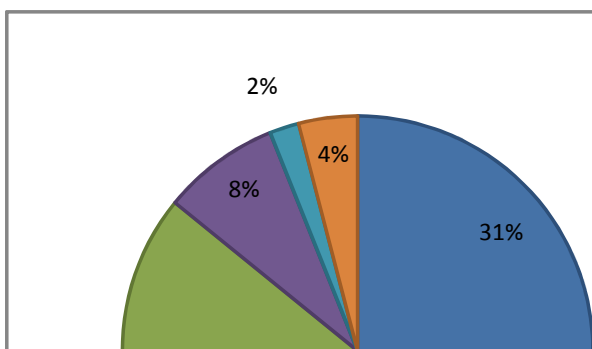
D. Fullfilment of courses
a/ How difficult/easy you find the tasks?
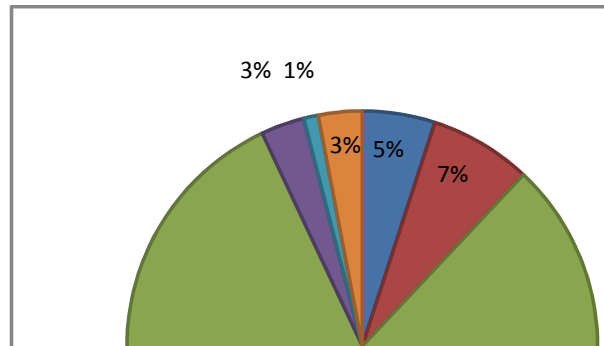
b/ How difficult/easy you find the tests?
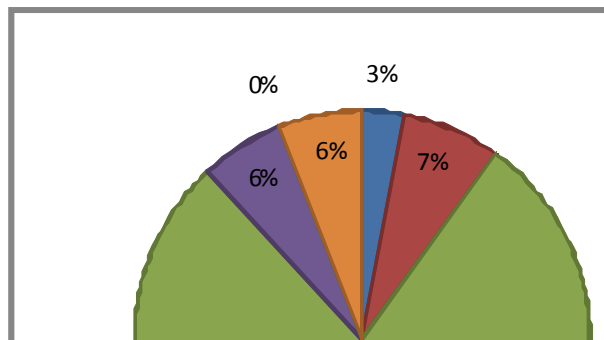
E. Usefulness of the course
a/ How can you utilize the knowledge you obtained?
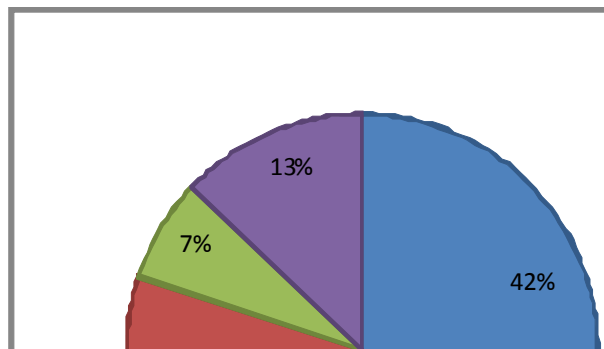
b/ Would you recommend the course for other participants?
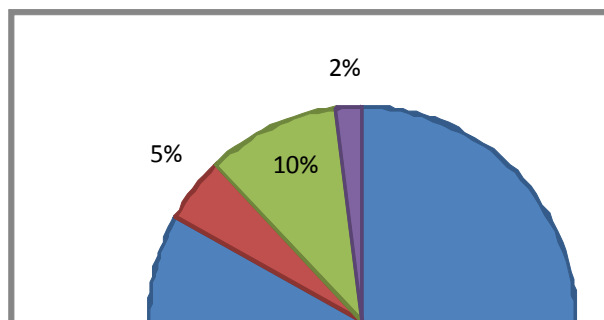
c/ What other MOOC topics would you prefer?
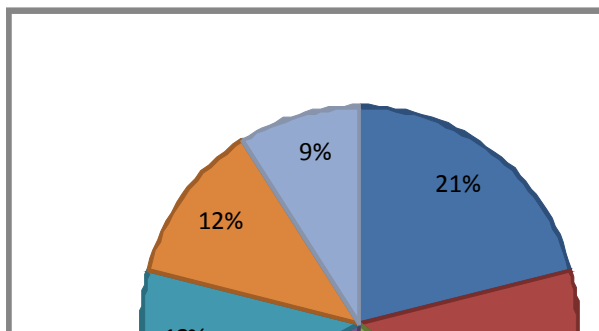
VIII. Conclusion

One of positive examples of using MOOC has been described in this paper. Creation and progress of a new system of MOOC higher education courses in the Hungarian language context with cross-border effect were discussed. The target groups are Hungarian speaking communities living in different national states in Carpathian Basin but it can be used by anybody who is on the net and can master the Hungarian texts or videos.

After two years of running a survey has been carried out on a number of participants in order to to analyze and improve the system. The results obtained confirmed the popularity and usefulness of the applied MOOC strategy.

K-MOOC will hopefully gain further space in on-line education in Carpathian Basin by launching attractive new courses by all network partner institutions. It might be followed by other countries promoting the role of national languages in on-line education.

Acknowledgment

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From the Educational Tiger Leap Program to the ICT Startup Booming in Estonia

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Abstract

Estonia has enjoyed success stories in ICT implementation in a broad field of public and private sectors for last 15-20 years. The key event for that development was the launching of the Tiger Leap program in Estonian schools, 1996. The program fully equipped schools with computers and Internet access and other ICT services. Computer science classes were provided in 84% of schools in the following eight years. Since 2014 World Economic Forum considered Estonia among innovation-driven knowledge-based societies, and some years later – being hidden entrepreneurship champion in Europe. Besides, Estonia has become one of the developed startup ecosystems where young ICT companies are booming.

These events mentioned above refer to the successful combination of educational and entrepreneurial ecosystems in Estonia. The paper aims to disclose the role of ICT as the engine of the innovation-driven development in a small society. Findings of the study show a growing importance of digital technology, ICT startups and the entrepreneurial ecosystem in the welfare of Estonian citizens.

Keywords:

ICT education, Entrepreneurial ecosystem, ICT startups, Growth engine, Knowledge economy

I. INTRODUCTION

Estonia, a small country (1.3 million residents), has earned much international attention because of its Presidency of the Council of the European Union (EU) in the second half of 2017. One of the main events organized for this period is "a digital summit for open-minded discussions about Europe's digital future" [1:19]. Many of the ideas raised at the summit come from everyday practice: Estonia has enjoyed success stories in ICT implementation in a broad field of public and private sectors for last 15-20 years. The key event for that development was the launching of the Tiger Leap program in Estonian schools, 1996. The program fully equipped schools with computers and Internet access and other ICT services. Computer science classes were provided in 84% of schools in the following eight years [2], and computer skills started to call a new literacy. An e-governance program, making Estonian Government's assemblies paper-free was launched in 2000. Many public e-services including electronic identity card and based on that authentication and digital signing of documents enabled 'one stop shop' portal (www.eesti.ee). This is a Gateway to e-Estonia where the citizen can apply practically all state services, for example, electronic voting, the Electronic Health Registry and e-Prescription, not to mention tax declaration or registering of buying-selling a car. Particular attention on international level was evoked by the e-residency system following changes to the residency legislation in 2014 [3].

In the 21-st century, Estonian leaders have reached the understanding that "[e]ntrepreneurship skills should be a part of literacy – 3rd literacy after reading and writing, and computer proficiency" [4:107]. This idea led to the wider implementation of entrepreneurship support system for welfare development in society. This also means entrepreneurship training for all the educational levels, including university [5]. Since 2014 World Economic Forum (WEF) [6] considered Estonia among innovation-driven knowledge-based societies, and two years later – being hidden entrepreneurship champion in Europe [7]. Besides, Estonia has become one of the developed startup ecosystems where young ICT companies are booming [8].

These events mentioned above refer to the successful combination of educational and entrepreneurial ecosystems in Estonia. The paper aims to disclose the role of ICT as the engine of the innovation-driven development in a small society. For that purpose (1) the concept of an ecosystem and (2) the role of ICT sector in Estonian economy are disclosed, and (3) the entrepreneurial ecosystem of ICT startups is shortly analyzed. The analysis is based on the data of Statistics Estonia (SE) and the Commercial Registry, Estonian Startups' Garage48 HUB and startup ventures' web-pages, and interviews with the actors of Estonian startup ecosystem. Findings of the study create an overview of the role of digital technology, ICT startups and the entrepreneurial ecosystem in the welfare of the Estonian citizens.

II. ICT AS A PART OF ECOSYSTEM

A. Ecosystem Approach

The concept of ecosystems originated from biology (first mentioned in 1930 by the British botanist Arthur Roy) [9], was introduced by Moore [10] in business studies already more than 20 years ago. Now, the concept is more widely used for disclosing (hi-tech) startup entrepreneurship development and research. Frequently, the ecosystem is communicated using as an example the case of Silicon Valley environment at Stanford University in California. However, Isenberg [11] warns not to emulate Silicon Valley in emerging economies despite the fact that it is the home of Intel, Oracle, Apple, and many others. Entrepreneurial ecosystems are described, but also assessed, by their performance, accessible markets, human

capital (experience, talent), the ambition of the entrepreneurs, globalization in different aspects, etc. [12]. Although, in some earlier articles [13] authors characterize universities as sources of an educated workforce and new ideas, the understanding of the importance of educational ecosystems in the broader meaning has emerged in the last couple of years [9]. That means the concept of the ecosystem could be implemented to describe different spatial, educational and industry sector communities existing simultaneously. These ecosystems are interdependent and partly overlap each other, and of course, depending on the economic development of the region and industry in the area, can be in different phases of maturity [14]. Technology and innovation are the features as well as the engines of reaching knowledge-based economy. In this context, the temporal sequence of critical events and development phases generally [6] characterizes the interdependence of ICT competencies and ICT entrepreneurship like the question about 'the chicken or the egg' dilemma.

B. ICT Education – Background Force of the Knowledge Economy

Estonia has traditionally had strong IT research since the founding of the Institute of Cybernetics in 1960. Now, the leading research and educational institutions in the field are Tallinn University of Technology and the University of Tartu. Partly, later developments of e-governance and Tiger Leap program in the 1990s are based on this tradition that only needed some impact (read: funding) at the policy level. This initiative was seeded into the fruitful soil. Despite limited resources, available that time, comprehensive framework of society from schools to universities – educational and R&D institutions were involved in ICT development.

From the computer classes of schools, launched by Tiger Leap program, has come growing share of young people starting ICT studies at universities and other HEIs. Partly, because of the demographic situation[1], the number of students of HEIs has decreased from 69 to 48 thousand in Estonia since 2006. But, the number of ICT students of all levels was growing from 3.5 to 4.2 thousand in the same period [15]. The share of new students, especially at universities is still growing – reaching 10% of all the intake in higher education level (Fig. 1).
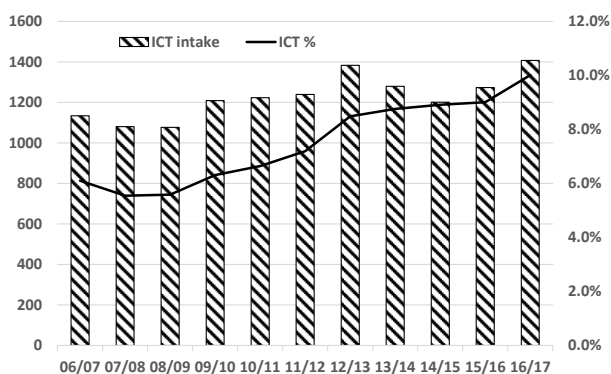
Figure 1. Figure 1. The number and share (%) of entrants to ICT studies in HEIs by study years. Source: author based on [15]

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[1] Other reasons may be saturation of the education market in some fields and changes of the funding system.

The number of graduates from HEIs is twice lower than admitted annually. Frequently, this fact is explained with the early recruitment of ICT students, before graduation, by companies. Besides HEIs, ICT specialists are prepared by vocational schools/training centers. The number of graduates from these professional schools in the field of ICT has reached 450 in last five years [15].

C. ICT – a New Growth Engine

Economic development of a small country like Estonia depends on the openness of its economy and export capabilities. The liberal economic policy has attracted foreign direct investment (FDI), which supported the fast restructuring of the industry for an extended period in Estonia from the mid of the 1990's. An inflow of FDI lasted until the crisis of 2007; since 2011, the investments started to move out [16]. That shows the need for new engines for development.

The share of services in the Estonian economy is about 66% of GDP and 25% of export [17]. 77% of the positive balance in service export is created by three sectors [17]: logistics (and transport) – 47.8%, ICT services – 16.6%, and (mainly exported wooden houses') building – 12.6%. The dynamics of the balance of main export industries are depicted in Fig. 2.
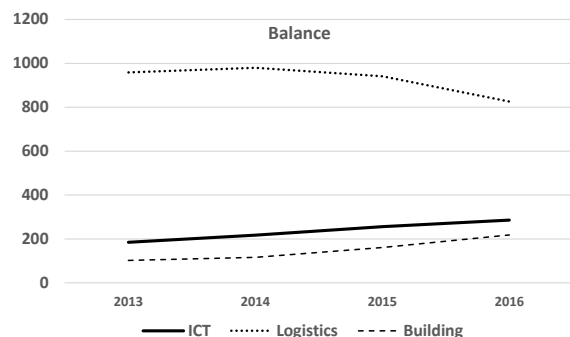
Figure 2. The export-import balance of three main sectors of Estonian service export 2013-16, million euro. Source: Author based on [18]

As could be seen, the decline of logistics starts from the sanctions to trade between the EU and Russia after Russian military intervention in Ukraine in 2014. But, the logistics sector, as well as the export of the food industry, have suffered under Russia's unpredictable policy already since the 1990s. Therefore, in the nearest future, ICT and building services, targeted to Western markets, are more perspective as are based on Estonian human (and natural) resources.

The most significant share of IT firms are producing software for different purposes; they make 83% of sales in IT services (2014). The number of people, employed in software companies (according to the Estonian Classification of Economic Activities - EMTAK, the national version of the international harmonized NACE classification), is growing fast, from about 3500 in 2005 to nearly 9000 in 2014. But, a significant number of programmers work in other sectors, which are not categorized as software businesses. For example, banks in Estonia have large ICT departments, and about 7000 Estonian firms have their ICT unit or specialist [18].

The number of software companies reporting activities has grown from 740 to 2733 making 12.2% of a total number of new active businesses of all fields in Estonia in the period from 2005 to 2015 [18]. That also means that 72.9% of ICT businesses are new ventures started in the last ten years. Dumas [19] called that a real IT startup boom. Partly, the trigger for IT startup booming are previous success stories of IT companies starting from Estonia. Among them are three 'Unicorns' – startups, valued at one billion dollars or more: Skype, Playtech and the youngest of them – TransferWise [20].

III. ENTRPRENEURIAL ECOSYSTEM OF ICT STARTUPS

An ecosystem around new ventures involves (mainly) local educational institutions, and business support structures, but also globalized businesses of ICT service sector with bigger numbers of employees. Among them should be mentioned Nortal AS (650 employees in 8 countries), Skype Technologies OÜ (~400 employees in Estonia), Playtech (~600 employees in Estonia), Cybernetica AS, and others. The share of the ICT sector in the Estonian economy reaches 7.4% [21]. Besides other business-friendly regulations and the environment in Estonia, "startups have the world's highest success rate of obtaining Visa for foreign candidates at 84.5%, more than double the success rate than the global average (41%)" [12:102].

The Estonian government has launched several programs for entrepreneurship development, and SMEs' support, entrepreneurship training of adult people, startup seed funding and other policy measures since the beginning of the 21st century. Later on, the decision was made for implementation of entrepreneurship training programs at all levels of the educational system, including for non-economic specialties at universities, 2013 [4]. A good illustration of the effect of the governmental *Start-up* program could be seen in the statistics of startups' investments (Fig. 3).

Figure 3.   Investments into Estonian startups, million euro.
Source: author based on [22]

By the initiative of Estonian Development Fund (EDF) the first investments into startups started from 100% Estonian origin capital 5.7 million euros in 2006. Now, the total funding has reached a level of €103.4 million in 2016, about 85-90% of that comes from abroad. Frequently, foreign investments into startups remain overseas because of the Estonian startups moving their headquarters into global centers. Therefore, these

investments very commonly are not included in the FDI data.

The web-page (http://hub.garage48.org/estonian-startups) of Estonian Tech Startups' garage48 HUB includes 88 startups joined the community. Sixteen biggest investments (in total €306.5 million) involve 77.2% of all startups' funding in Estonia. Among them, only two are explicitly non-ICT startups making 15% of this group funding. Just one business (Clifton.ee – semiconductor technology) has failed, three have had successful exit – sales or merge by the global player (CrabCAD, Fits.me, and PlanetOS.com).

The biggest amount, 95.6 million euros, is invested in TransferWise, which has its headquarters (HQ) in London, but the development unit with 400 employees is established in Estonia. As an innovator of banking, TransferWise currently is the only 'Unicorn' among startups of Estonian origin – value over one billion USD [20].

GrabCAD, with an 11.3 million euro investment and approximately $100 million exit value belongs to the most significant success stories after Skype. GrabCAD made a revolution in mechanical engineering integrating designers worldwide to open innovation platform (called the 'Facebook of engineers'), it was merged into global 3D technology corporation Stratasys, 2014.

AdCash (20 million euros) is a worldwide advertising platform; its network includes over 150,000 websites and mobile applications.

ZeroTurnaround (19 million euro) is a software company located in Tartu and Tallinn, Estonia, and Boston, USA. The company, founded in 2008, develops and sells a product JRebel – plugin for Java environment.

IV. DISCUSSION AND CONCLUSIONS

The ICT sector has achieved a remarkable position in Estonian economy. This development happened in the collaborative framework of public and private institutions, including educational and entrepreneurial ecosystems. As a result, the character of economic development has changed. Analysis of foreign investments in Estonia demonstrates how this type of FDI, which supported the extensive growth of the economy in the past, does not support knowledge-based economy anymore. Besides, old type investors have started to move earned capital out of Estonia – i.e., the outflow of FDI. In the last six years, a new type of investments joined to Estonian startups. The character of these seed investors is very different from the traditional FDI owners. The investment, frequently, comes to Estonian startups after moving their headquarters to global centers. The cases of GrabCAD, Fits.me and TransferWise are the proofs of that. But, this also is a feature, saying that Estonian startup ecosystem is already global.

Estonian seed funding policy has encouraged own private and foreign investors to join to new technology ventures. Frequently, these startups are merged by global companies. In some cases, we can only speculate about the price of acquisition of Estonian startups and profitability of the exit deals. From the total investment into Estonian startups, about €400 million in Sept. 2017, on an average, only 15% has come from Estonia. Considering that, this is not too high of a price for approximately 2500-3000 highly paid jobs and

competencies' development of local engineers. Besides, the jobs in high technology companies, as Moretti [23] shows, indirectly induce up to five times more jobs in other (production and service) sectors. That points that, in the socioeconomic context, Estonian startups remain a success story, not depending on the venture capitalist view.

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Utilization of IP Streaming in Identification of the Speaker

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Abstract— **In this paper, the research on the identification of a person in the video broadcast through the IP stream is presented. The software solution is created based on the analysis of face detection methods and current related researches. The crucial part is the identification of individual (university staff) in the IP stream. Training is carried out prior to the identification process. The software solution in form of the web application is created to enable live streaming. It further promotes the functionalities of discussion and voting on questions. System administrator interface is created to allow control over person identification and management of questions. Another essential part focuses on the processing and storing data from discussion or voting. The research verifies the reliability of identified persons through the series of experimental tests.**

Keywords— face recognition; IP stream; person identification

I. INTRODUCTION

The presented research is focused on the development of a system for enabling the live broadcast from assembly of Poprad city council or may be applied to any other analogous event related to education. Proposed system incorporates automatic PTZ camera system control being based on the active speaker. Broadcasting per se is to be accessible through web interface or dedicated mobile applications. These applications will allow citizens to engage in the current process through discussion and voting.

The main objective of the research is identification of objects, specifically human beings. As the object of interest, the human face is selected. The identification is to be deployed on the video streamed through the IP stream. The methods and procedures for face recognition are analyzed and also deployed in the created solution.

Another part of this research is proposal of a web solution for broadcasting of live stream from the council gathering.

II. OPENCV LIBRARY

The library called OpenCV [1] is built on a common infrastructure designed for the development of computer-based applications. Library is released under a BSD license and hence it is free for both, academic and commercial user. While utilizing over 2500 algorithms, it offers a wide range of tools for recognition of faces, identification of objects, capturing human motion in a video, recording object movement, finding similar images from an image database, eye tracking etc. Further, it implements the eigenface algorithm for face recognition.

A. Face recognition using Eigenfaces algorithm

In general, the algorithm selects the relevant information from the image and encodes it as efficiently as possible. In case of face recognition, a set of images of the same individual is evaluated for differences. The algorithm calculates eigenvectors from a covariance matrix from a set of face images [2].

Each image from the set containing the face creates an eigenvector. Vectors define the differences between the frames. A set of vectors is referred to as eigenfaces. Each face can be represented by a linear combination of these eigenfaces, where their amount can be reduced to those with the highest values and hence higher system efficiency can be achieved. The goal of the algorithm is to develop a system that does not compare the images to each other but rather their characteristic weights.

The algorithm may be implemented through the following steps:

1. Formation of a face-image database, calculation of the eigenfaces and determination of the face space.
2. Calculation of its set of weights, once a new image is found.
3. Determination if the face is present in the image.
4. Finally, checking if the image corresponds to a known face stored in database.

Let face set I1, I2, I3, …, IM, be calculated as the average of this set by:

$$\Psi = \frac{1}{M} \sum_{n=1}^{M} I_n \qquad (1)$$

The difference of each image from the average is then defined as:

$$\phi_i = I_i - \Psi \qquad (2)$$

Finally, the eigenvalues λk and eigenvectors uk of the covariance matrix are calculated:

$$C = \frac{1}{M} \sum_{n=1}^{M} \phi_n \phi_n^T \qquad (3)$$

The last step is the classification of the image containing the face. New images have to be transformed to its eigenface components. Thus, the vector of the weights has to be calculated:

$$\Omega^T = [\omega_1, \omega_2, ..., \omega_{M'}] \qquad (4)$$

where $\omega_k = u_k^T (I - \Psi)$ for $k = 1, 2, ..., M'$. M' does not represent the total number of eigenfaces but only those with larger values.

The condition that yields which image with face determines the image face class k and gives the minimum Euclidean distance is expressed as

$$\varepsilon_k = \|\Omega - \Omega_k\| \qquad (5)$$

where Ω_k is the vector that describes the face image number $\underline{k}$.

III. OPENFACE LIBRARY

Library called OpenFace implements face recognition based on the neural network using the Torch framework and a OpenCV library [3]. The library performs face recognition in four steps:

- face detection in the image using the HOG method,
- posing and projecting faces,
- comparison with available images,
- finding the name of person.

A. Face detection in the image using the HOG method

The principle of Histograms of gradients (HOG) algorithm is based on several steps [4]. The first step begins by converting any image to the black-and-white, since color is irrelevant when recognizing the face. The next step is comparison of the pixels one by one, while the main interest in put on the shade of the pixel and the pixels surrounding it. The pixel, which has a darker hue, is highlighted by the arrow. All the pixels are eventually replaced be arrows, providing this process is applied for each pixel that creates the image. These arrows are called gradients. Providing the analysis is carried out, the dark images and light images of the same person will have different pixel values. However, when considering that only the direction of brightness changes, both dark and light images end up with the same exact representation. When placing gradients for each pixel too many details
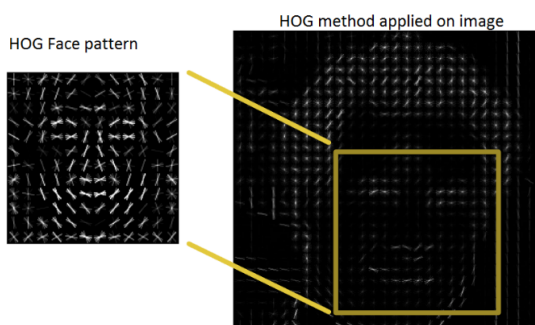
Figure 1. HOG method applied on image

are obtained. Hence, the next step is that the algorithm divides the image to squares of 16x16 pixels. Consequently, the largest number of gradients in the given direction can be calculated. These are assigned to the given square gradient. In order to find face in the HOG image, the HOG pattern has to be found, following the given set of extracted training faces (see Fig. 1).

B. Posing and projecting faces

Face recognition is a relatively uncomplicated process when the face is in the correct position. Hoverer, the issues in recognition may be introduced if the face in the image is displayed in another angle or rotated. Thus, the person in two different images can be considered as completely different person.

In order to solve above stated problem, the face landmark estimation algorithm is used. This algorithm was introduced by [5].

Algorithm is based on the concept where 68 landmarks are spread all over the face – the top of the chin, the outside edge of each eye, the inner edge of each eyebrow, etc. Then the machine learning algorithm is used to find 68 specific points on any face. When the position of eyes and mouth is detected, the simple operations such as rotation, scaling and shear are used to centralize the eyes and mouth as best as possible (see Fig. 2). No matter how the face is rotated, the algorithm is able to centralize the eyes and mouth to be roughly in the same position as in the picture. This will make next processing much more accurate.

C. Comparison with available images

This step is the main part of person identification in image. When the recognition of the face is performed, one of the most important factors is the time at which face detection is performed. Therefore, there is a need to utilize
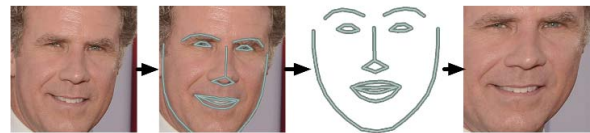
Figure 2. The face landmark estimation algorithm applied on image

the algorithm that is able to find a match within a few milliseconds. The process requires several basic calculations, such as the distance between the eyes, the mouth size, or the length of the nose.

Research carried out by the authors in [6] introduces as the most reliable way to recognize a face of an individual quickly and effectively is not with the aid of location of the nose, eye color, or similar features. But as the most effective solution is considered to enable computer itself to figure out the measurements for collection. Deep learning does a better job than humans at figuring out which parts of a face are important to measure.

Specific calculations were carried out in the research presented in [7], where the Deep Convolutional Neural Network was utilized and included 128 measurements for each face. Three images of face are considered in parallel:

- load a training face image of a known person,
- load another picture of the same known person,

- load a picture of a different person.

The neural network learns to reliably generate 128 measurements for each person, after this step is repeated for a million of times and millions of images of thousands of various people. Any then different picture of the same person should give roughly the same measurements.

D. Finding name of specific individual

The last step is actually the least difficult in the whole process. In this process, any basic machine learning classification algorithm can be used [8]. Linear SVM classifier may be selected. The classifier itself must be at the first trained, then the measurements from a new image are extracted and classifier provides information if the known person is the closest match. Running this classifier takes only milliseconds. The result of the classifier is the name of the person.

IV. SYSTEM FOR IDENTIFICATION OF PERSON AND USER ACCESS TO THE SYSTEM

The solution as proposed in this section is the part of a larger research that is to serve for gatherings of Poprad city council and as well for the citizens of this city. The system is consisted of the three parts.

The first part of system is focused on meetings of the city council. During these sessions PTZ cameras are deployed for capturing of the current events at this very meeting. Main task of this part is to create a control program for the given camera, including an automatic mode that changes the position of the camera on the active speaker. The active speaker is recognized from the output of the HER system implemented in the meeting room of the city. Camera output is used for streaming the video. This part is solved by other research presented in [9].

The second part of the system is intended for broader public, i.e. citizens of Poprad city. It focuses on the communication between the board members of Poprad and its citizens. It is to allow watching the live city meetings, using mobile applications for Android and iOS platforms. The application will include discussion and voting of signed-up citizens who are involved in the political life of their city. This part is implemented in research [10].

The last part of the system is introduced below and consists of the following components:

- module to identification of specific person,
- web application,
- module for user management and communication.

The role of module for identification of person covers recognition of person in the IP stream. Data representation is created and stored in the database. Individual person in the IP stream is identified from the group of stored people.

The web application offers to Poprad citizens the graphical interface for viewing the IP stream, discussion and voting on questions as given by the system administrator. Another part of the web application is to bring system administrator the interface to manage voting on questions and also manage identification of persons in the IP stream.

The user management module creates, updates and gets user, discussion and vote data. These parts work together through a determined communication.

A. Module for person identification

The main goal of this research is to propose a functionality of a module for identification of the person in the IP stream. The OpenFace library is utilized for this very purpose.

Prior to the identification process the person has to be known. Learning of the persons is carried out through the training. The first step is creation of some image from the IP stream. Some delay must be introduced between creating of these images.

The images are further processed. At the first, the face of a person is recognized. If no face is present, the image is discarded. However, if the human face is recognized, the image is cropped to the face area. In the next step, it is necessary to obtain the data representation from the cropped image, which can be stored in the database. Data is obtained using a Deep Convolutional Neural Network that produces 128 numerical measurements from the cropped picture.

The pictures and their numeric representations are not being saved immediately, since the information on specific individual is not yet known. Data will be saved only when the web application provides the name of the person in these pictures.

After successful processing of all images, machine learning and support vector machine analyze the numerical representations of specific person images. Model is created from the set of training data divided into categories. The categories themselves represent the names of the people. This model is used for person identification process.

Identification of person is analogous to the training of person. The picture is created from the IP stream and processed until 128 values are generated. These values are then used by SVM, which outputs the name of the identified person. This process is continually repeated.

Important part is the structure of data stored in the database system. Training functionality generates person data for future identification. This data is consisted of image of a person from which 128 numeric values are generated using the neural network. Information must be saved and thus we can use the data even when the software solution is rebooted. For this purpose, relation database system is used, where the name of the person and the generated values are stored. The image of the person is stored on the file system and only the name of the file is stored in the database.

B. Web application

The principal role of the web interface is to display all the necessary information that user can work with. For a common user, the interface offers the following features:

- sign in and sign up,
- watch IP stream,
- read and write messages in the discussion,
- vote and view the voting results on the question as given by the administrator.

In addition to common system features, more important administrator has ability to perform the following:

- enter the question for voting,
- view the input in which an individual is identified using proposed identification module,
- ability to control training mechanism for identification of specific person,
- ability to manage stored data of people in the database.

Live broadcasting is enabled using the JW player. The player requires IP address of the stream in order to be playable. Common user does not need to be logged in.

The system also enables a discussion in which the very users can engage in and discuss about what is happening on IP stream (city council gathering). Users without registration can read the discussion, however if they want to enter a new comment they must be signed in. The discussion is automatically updated with new messages. The user has access not only to the latest comments but also to the older ones.

The web solution also introduces voting. All registered users are able to vote. The question and the options for the question are shown to user, while the only one answer can be chosen and selected through the voting button. Voting can be performed only once. The number of votes is automatically displayed for each option.

In order for a common user to answer the voting question, it is necessary that the system administrator creates the question. This is only possible in a specific interface only accessible to administrator. The question is created through form in which the text, options and time of question is entered. The number of options is limited to 8. Once the voting question is created successfully, it is automatically displayed to all active users.

The system administrator interface allows tracking the status of the module for person identification. The first part is focused on recognition of the person. The system administrator can start or stop recognition. When the recognition is initiated, the image with the identified person is shown and annotation appears next to face with person's name.

Another feature introduces training of a new person. Training is started, once the start button is pressed. After training process is finished, the images of faces are displayed. The administrator is able to choose whether to create a new person or assign the new information to an existing person. He also can choose what images to save from the new images.

The last part of administrator interface is related to management of persons. Faces of individuals can be removed. At the first, the person to be edited is selected. Images of the person are shown. The administrator is then able to select which images to delete.

C. Module for managing users

The user management module is for processing of the information that the web solution works with.

The module allows creation of user. Based on the entered information, such as email, password, first name and last name, a new record is created in the system database. Registration is done by creating two tokens. A randomly generated character string represents the token.

The first token is access token. It is created to ensure that the user is uniquely identified when request from the web application is processed. Limited validity period was deployed in token creation process. The second token is refresh token. It is used to restore the access token. When it is used, two new tokens are generated to replace the old ones. Tokens are stored in the database system. Tokens are removed when the user logs off.

Some of the requests have to be uniquely identified by the user. This is accomplished by using an authentication filter that assigned request to individual user. Everything is done using an access token. The filer verifies the validity of the token. If the token is valid, the filter pairs user and request based on record in the database. The request is further processed after authorization.

The module also performs a discussion function. If the user creates a new message, the module accepts a message request. Request consists of the text and the ID of discussion. Based on this ID, the module creates a new message for the discussion. The new message is saved with a unique ID, message text, creation time, user ID and discussion ID. The user ID is obtained based on an authenticated request that contains user information. Once the message is created, it is sent to all active users.

The system needs to store IP stream information. Address of IP stream is considered as the most relevant data, which can be changed at any time, as a result of the transfer to another server. The IP stream contains information about its name and description. When creating and editing information on the IP stream, it is of course relevant whether the user has the rights to perform such operation.

The module also processes the data from the voting. The administrator makes a request to create a new question for the vote. The business logic of voting is as follows: First, it is verified whether the user who made the request is authorized to perform the operation. After this a new record of voting question is created. The record contains information about the time at which vote can be perform on question. It also contains unique string that is used for voting. When a record is created, the question is sent to all active users. When user votes on question, a request is sent to the module. The request contains ordered number of options and a unique string that identifies the question. Based on this information, a voting record is created. Individual votes are sent to active users to see the current voting progress.

V. RESULTS

Testing the reliability of the selected OpenFace library to recognize a person through a proposed research is carried out. Testing procedure is described and measurement data, as acquired from testing, are presented.

The first step was to deploy and run the system. Live streaming was recorded with specific proprietary tool, while the stream was broadcasted having the resolution of 800x600 pixels.

Recognition of persons was tested on ten respondents having the age ranging from 21 to 26 years. The obstructions such as eyeglasses or beard were examined. In the Table 1, the specific information on the respondents is shown.

TABLE I.
SAMPLE OF RESPONDENTS WITH OBSERVED PROPERTIES

Person	Age	Glasses	Beard	Sex
Person 1	25	No	Yes	Male
Person 2	25	Yes	Yes	Male
Person 3	23	No	Yes	Male
Person 4	21	No	Yes	Male
Person 5	23	No	Yes	Male
Person 6	21	No	No	Female
Person 7	26	No	No	Male
Person 8	23	Yes	No	Male
Person 9	26	No	Yes	Male
Person 10	26	Yes	No	Male

Testing was done in two phases. In the first phase, images of the respondents were uploaded to the database and trained in the web application administrator interface. Respondents sat 110 cm in front of the camera. Their faces were neutral and looked directly to the camera. For each respondent, the set of 10 images was created.

Once the training was done, the second phase of testing could begin. The respondents appeared in front of the camera, where they were identified by the identification module proposed as part of presented research. Recognition was performed on the IP stream. Respondents were asked to perform special moves. Main task was to record the number of correct identification of specific individuals. The following conditions were examined:

- direct look,
- looking down,
- looking left,
- looking up,
- looking right,
- smile,
- open mouth,
- closed eyes,
- no glasses.

No problems in the recognition of person were observed when the person was looking directly to the camera. However, the greatest concern was when the respondent looked up, having the lowest success ratio. The issues in the recognition process were not introduced even in case of smile, closed eyes or open mouth. In the Fig. 3, Fig. 4, Fig. 5, the charts represent the comparison of people with beard and without beard and comparison of people based on age. The values in these graphs are almost same, which means that the examined factor have a minimal impact on the recognition.

VI. CONCLUSION

The goal of presented research was development of a solution for identification of the person visible in the broadcast through the IP stream. The paper analyses two libraries capable of face recognition that both use different algorithm for the recognition process. Another part is considered with the identification of persons in the IP stream. This includes development of experimental software solution consisted of three separate parts. The result of this research includes also testing of the recognition reliability using the chosen solution. From the measured data, charts are formed and consider several obstructions that may appear in the overall recognition.

Figure 3. Success rate of recognition process
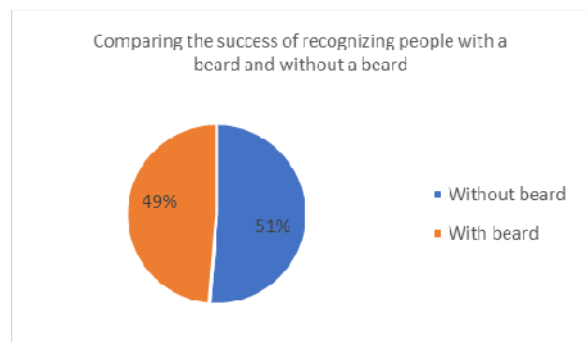
Figure 4. Comparing the success of recognizing people with a beard and without a beard
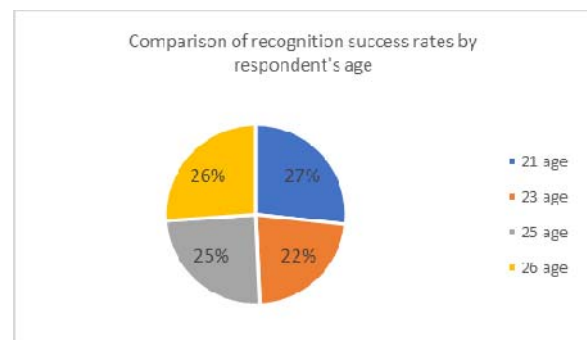
Figure 5. Comparison of recognition success rates by respondent's age

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Business Schools and RIS3 – Enterprise Architecture Perspective

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Abstract—**Industry – Research – Education, these are three phenomena impacting each other. It is important these factors are in balance and cooperate in a synergy.**

I. INTRODUCTION

What courses should be taught at Business Schools? What their content should look like? Do courses reflect real requirements of practice? Is research in alignment with the education? Do students have right skills? These few questions stay the same for ages. These questions are valid nowadays in this era of globalization driven by information and communication technologies even more than ever before.

Our paper does not to provide an exhausting view on the discussed topic. The goal of this paper is to point out that there is a possibility to involve Business Schools into RIS3. We present a view through a prism of Enterprise Architecture which recommends to map business requirements, embodied within RIS3 (Smart Specialization Strategy), into functional capabilities provided by Business Schools via offered courses. We are aware that such approach does not cover whole complexity of this topic anyway but it allows in relatively simple way to improve existing situation.

In this paper is described a research of the following question "Could Business Schools be involved into RIS3 program?

Smart specialization is a policy concept that was originally developed by a group of academic "experts" in 2008. This former concept is now a key element of the EU 2020 innovation plan [5].

The Commission has decided to build a platform of services (S3) to support regions in their efforts to devise and implement a smart specialization strategy. Discussions are currently under way about introducing smart specialization as a conditionality clause for structural fund attribution; and the OECD is launching an activity for measuring smart specialization.

Smart specialization is a topic which is widely developed and paid attention to by the three important organizations: EC, World Bank and OECD.

Into our research there were included those aspects of RIS3 which could be potentially affected by Universities and industry. It is not dealing with governmental orders, expenditures for research and development, etc.

II. METHODOLOGY

In general, Design Science Research [1, 15] (hereinafter DSR) encompasses the production of new knowledge by designing of novel innovative artifacts and/or analysis of the utilization such artifacts to improve and understand the behavior of information systems. This methodology is commonly used for the specification of knowledge or artifacts [8]. The Open Group developed TOGAF (The Open Group Architecture Framework). TOGAF is possible to utilize for research in information systems [13]. For the needs of this research TOGAF with the emphasis on the "Problem identification and motivation" and "Define the objectives for a solution" was adapted. The main preposition for design and development is entire and correct specification of business requirements. In this case our source of "business" concerns is the main document of Slovak government [16] describing deep analysis of selected factors of the Slovak economy. Applied approach can be summarized into next steps

1. Extract items of the assessment from RIS3 document
2. Specify requirements based on step 1.
3. Designate requirements relevant for universities.
4. Specify sets of topics and their aggregation into courses covering requirements from step 2.
5. Identify hot courses which could support and could be part of research and industry cooperation.

For the visualization of discovered stakeholders' concerns, identified requirements and relevant processes or services on the side of Universities we used Archimate. All discovered information was modelled into an architectural tool Sparx Enterprise Architect.

III. SMART SPECIALISATION STRATEGY IN SLOVAKIA

The Slovak Republic as an EU member elaborates The Europe 2020 strategy and the methodological recommendations of the European Commission [7] into document describing of a Strategy of Research and Innovation for Smart Specialization of the Slovak Republic (hereinafter as RIS3) [16].

The key findings is the backwardness in

1) the intensity of innovation activities on the level of enterprises

2) a potential for innovations, quality of scientific and research institutions

3) expenditures for projects of research, development and innovation resulting in practice

4) technology transfer

5) the use of cooperation potential

6) patent activities

7) cooperation of research institutions with industry

8) the use of venture capital

9) a number of aspects conditioning the effective use of human resources

10) a low level of cooperation between the institutions of science and research, education and economy

11) connection with creation of competitive innovative products, technologies and services

12) the share of knowledge-intensive services in GDP and export

13) the area of quality of education in mathematics and nature sciences (83rd position)

14) the share of the enterprise research and development in the gross domestic product

15) the innovation performance

16) quality of the system of science and research (Slovak science is considerably enclosed.)

17) inappropriate structure of PhD graduates with an insufficient share of technical and scientific fields,

18) number of excellent research teams,

19) insufficient innovation activity of SMEs

20) representation of knowledge-intensive activities in the economy

21) consideration the information from universities, public scientific and research institutions and bodies as important

List above represents assessments from the enterprise architecture point of view and hence they are the result of an analysis of the state of affairs in Slovakia.

After analysis it is straightforward to identify a set of assessments which are relevant for business schools. In other words it means that selected assessments could be handled by business schools. Before specifying business schools activities it is necessary to group selected assessments into thematic sets and identify relevant requirements. There are mappings of sets of assessments to identified particular requirements in figures 1 and 2.
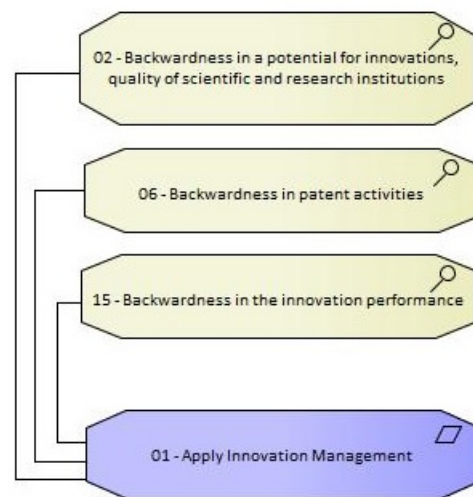
Figure 1. Mapping Assessments-Requirement relevant for Business Schools I.
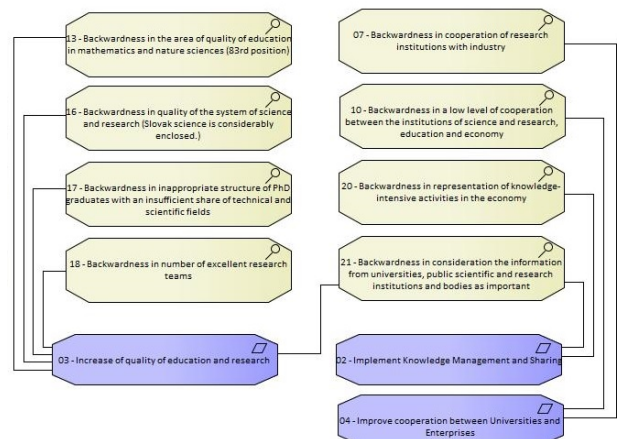
Figure 2. Mapping Assessments-Requirement relevant for Business Schools II.

When requirements are specified it is time to identify activities which should be provided by Business Schools. Relevant Business processes are defined (see figure 3).
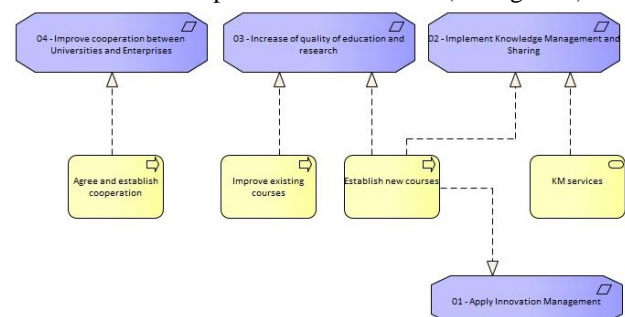
Figure 3. Mapping identified-requirements to processes and services provided by Business Schools

Specification of real processes and services is a complex process requiring the involvement of all relevant stakeholders and more iterations and discussions. It has to take into account a lot of information including analysis of current trends as well.

IV. CURRENT TRENDS

The term 'knowledge economy' was coined in the 1960s to specify a shift from existing economy to ones in which knowledge play the most important role. Our civilization is stepping into the age of the knowledge economy. The production and usage of knowledge has become critical. It is normal that academic institutions and companies engaging in research and development of knowledge are more and more prominent.

To see working knowledge management system in reality is often not possible. There is still no agreed definition of what a knowledge economy is. It is a fact that the engines of growth have changed. Data is giving rise to a new economy. Data and information is widely believed to be the future source of prosperity. Organizations mine data and getting insights from data is the main question of the day. This phenomenon is closely related to the development of ICT and new professions. In this sense, the necessity for every country is to have its own "Silicon Valley", innovative small businesses, and progressive education.

According to the World Bank, knowledge economies are defined by four pillars [17]:

1. Education & Training
2. Information Infrastructure
3. Economic Incentive & Institutional Regime
4. Innovation Systems

According to Gartner's definition of Analytic application [6] it stands to reason a tendency to customize (packaging) business intelligence capabilities from particular domain or particular business process.

In addition, the focus on the business application is gradually replaced by analytic capabilities which are source of data for more business application. In this approach there is the main focus dedicated for analytical capabilities.
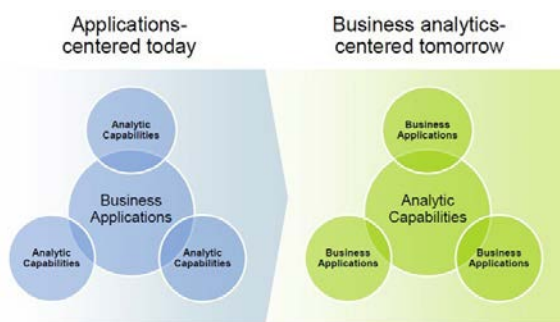
Figure 4.   Transition to Analytic Capabilities centric [2]

In the era of Social Media we can use findings in big data analytics. There is a list hottest skills of the hired people on LinkedIn. From this data we can see that up to nine from them are related with Analytics (Big Data Analytics) [10, 11].

TABLE I.
THE HOTTEST SKILLS OF 2014 AND 2015 ON LINKEDIN [10, 11]

The hottest skills	2014	2015
Statistical Analysis and DM	1	2
SEO/SEM Marketing	5	4
Business Intelligence	6	18
Web Architecture and Development Framework	8	9
Data Engineering and Data Warehousing	11	11
Marketing Campaign Management	12	3
Digital and Online Marketing	16	X
Channel Marketing	20	16
Cloud and Distributed Computing	X	1

It is seen that skills such as "Statistical Analysis and DM", "Business Intelligence", "Data Engineering and Data Warehousing", and "Cloud and Distributed Computing" are directly related with Methods and tools for Data Science and Big Data Analytics. On the other end skills related to "Marketing Campaign Management" and "Digital and Online Marketing: are data-driven and hence they require strong data science support.

Ellis and Heneghan in their survey [3] state that besides of big data/analytics and business analysis the most in-demand skill is the enterprise architecture which staged a comeback after several years of decline.
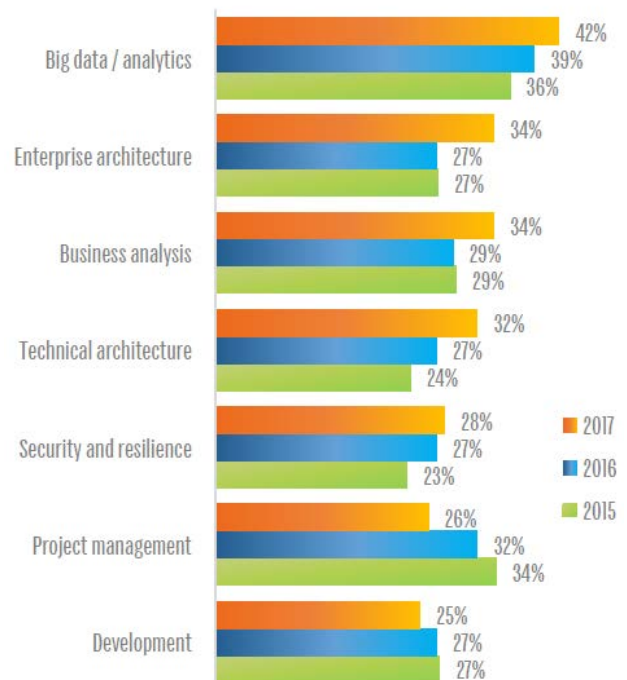
Figure 5.   Which functions do you feel suffer from a skills shortage? 2015–2017. [3]

The last inspiration comes from Denmark[1]. Danish Government developed the strategy with the goal to rank Denmark among most innovative countries with knowledge based economy.

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[1] This part is adapted from [14].

This strategy accentuates the innovation and support of education institutions, public and private sector with the emphasis on the small and medium-sized companies. Universities are motivated to make more commercially successful research. Industrial PhD programs for employees are also interesting. For development of knowledge based economy is necessary to increase of international research collaboration. Important is cooperation between education institutions and private sector mainly small and medium companies. Crucial is dissemination of research and innovation to all regions of Denmark.

History of Industrial PhD goes back to year 1970 when "Industrial Research Program" has been established. This course was two-year licentiate course. Later, in year 1989, was program changed to a three-year PhD course. We can say that Industrial PhD is innovation and research supporting initiative self-created by Denmark and its advantages and results has been proved by number of success stories.

According to report prepared by Oxford Research for the Danish Council for Technology and Innovation this initiative is extremely effective network promoter connecting private business world with universities. This programme contributes to the employment of highly educated staff, often in management positions of research and development. It also contributes growth of enterprises and creating new knowledge at universities.

From figure 7 is obvious that Industrial PhD initiative is used mainly in technical fields, then in health and nature and less in society and agriculture. There is big difference between numbers of PhD and Industrial PhD, while Industrial PhD is focused mainly on technical fields, PhD covers all fields of society including humanities or artistic.
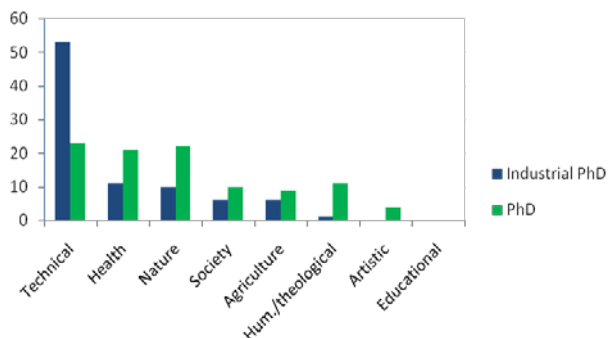
Figure 6.   Distribution of industrial PhDs and PhDs by main areas]

According to the Industrial PhD – An effective tool for innovation and knowledge sharing [9] main advantages of Industrial PhD program is:

- User-driven. Owner of the project is the enterprise. Research is based on the problem that is relevant to the enterprise. PhD student is employed by enterprise and enterprise owns the intellectual property right to the project.

- Research education at highly specialized level. Since universities are responsible for Industrial PhD education being at least on a par with traditional PhD course, they have to give academic approval to the proposed project.

- Quick case work. Only 30 days after application submission a decision on support is made. Decision is made by cross-disciplinary and independent committee.

What are advantages of Industrial PhD? There are several benefits for the Industrial PhD students. Graduates of this course do not encounter any problems in finding job. Usually they quickly find interesting job in the research areas of private enterprises and enjoy high salaries. Also synergy between research and professional experience makes Industrial PhD very attractive. For enterprises it has economical advantages of increased revenue, exports and issued patents and license sales. Also experience of network with universities helps to develop enterprise through the sharing of theoretical professional knowledge of universities and practical knowledge of enterprises. For universities is main advantage that Industrial PhD provides new knowledge and learning that can be applied on the campus. It also provides information about industry-relevant research and industry experience of collaborating enterprise.

What is the difference between traditional and Industrial PhD? Since Industrial PhD student spend half of the time at the university and second half of the time in the company he has advantage of know university's academic environment and language but enterprise's environment and language as well. Traditional PhD student knows just academic environment and language. Industrial PhD course is designed by university but it is specific for each course to meet enterprise's and student's needs, Industrial PhD student is also doing industrial-relevant research. At the other hand traditional PhD course is designed by university and also university decide what kind of research needs.

Is there any impact of Industrial PhD on society? Research confirmed that approximately 60 % of the enterprises with an Industrial PhD approved in 2002 expected an average gain in income of approximately DKK 10mil and 45 percent estimated that this project will lead to an increase in exports of approximately DKK 3-4mil. Average Industrial PhD cost including overheads for administration and research equipment is DKK 1.3-1.5mil. Estimated effects of 50 Industrial PhD projects that were approved in 2002 are 50-100 patents, DKK 250-350mil higher earnings, DKK 50-100mil increased exports and 50-100 new employees. Considering this is obvious positive socioeconomic effect of Industrial PhD.

In Denmark is number of students in particular year whose will complete research degree relatively small, it's 1% compared to Finland's 2% or Swedish 3% [4]. Danish government has decided to double the number of PhD students in coming years, primary in that areas of private sector where are PhD graduates the most important. Important fact is also that that only 20% of students of traditional PhD courses find employment in private sector and 35% are employed in private sector five years after finishing their PhD.

PhD students should have opportunity to make their education more industry-relevant. This could be done through special innovation course which would be

followed by work experience in the industry. This course should be integrated into traditional PhD program.

Another benefit of innovation this change is that some enterprises, SMEs in particular, have difficulty to enter Industrial PhD initiatives. They can be also interested in research collaboration with universities but don't have to be able or will to finance such as collaboration themselves.

Innovation pilot initiative is way how to get highly educated staff into SMEs and strengthen their collaboration with academic and research institutions. These employees are supposed to bring new experience and competencies into SMEs and contribute to promote development and innovation of SMEs existing work processes and production forms.

According to Innovation Denmark 2007-2010 [4], an innovation pilot is a highly educated person who is employed for a period to implement a development project. His goal is to create innovation in enterprise. But true is that these projects often lead to permanent employment of innovation pilot or of other highly educated person.

This kind of support is very important particularly for SMEs who can hardly compete with large enterprises to get highly educated employee with relevant knowledge and experience. In current situation of Denmark's low unemployment it might be for some of them nearly impossible.

V. ACTIVITIES OF THE BUSINESS SCHOOLS

Education, Research, and Industry implementation represent or should represent main objectives of Business Schools. Common sense says that it will be great to arrange such activities which cover all cited areas.

In addition an innovative approach and increasing of the research and education quality are monitored at every university.

A. New Courses

The main mission of universities is to provide education. It is good known finding that it is necessary many effort needed to keep high quality of provided courses. In addition it is not only about quality of existing courses. In some cases their quality is high but interest of students is low. In era when is available a lot of learning materials from different sources in different form (textual, video, podcast, etc.) is very important topicality of the offered courses.

Example of new courses and other activities which should be provided by Business Schools are displayed in the figure 7.

It is obvious that establishment of new courses is quite long term process calculating upon different opinions and many discussions. To use enterprise architecture approach and to map new courses and their topics to identified requirements could speed up this process and to bring higher relevance.

The special attention is recommended to pay to items which should be helpful for research and industry as well. To identify such items more preciously it is recommended to utilize a TOGAF's techniques Business Scenario. In this paper we sketched the process of defining new courses.
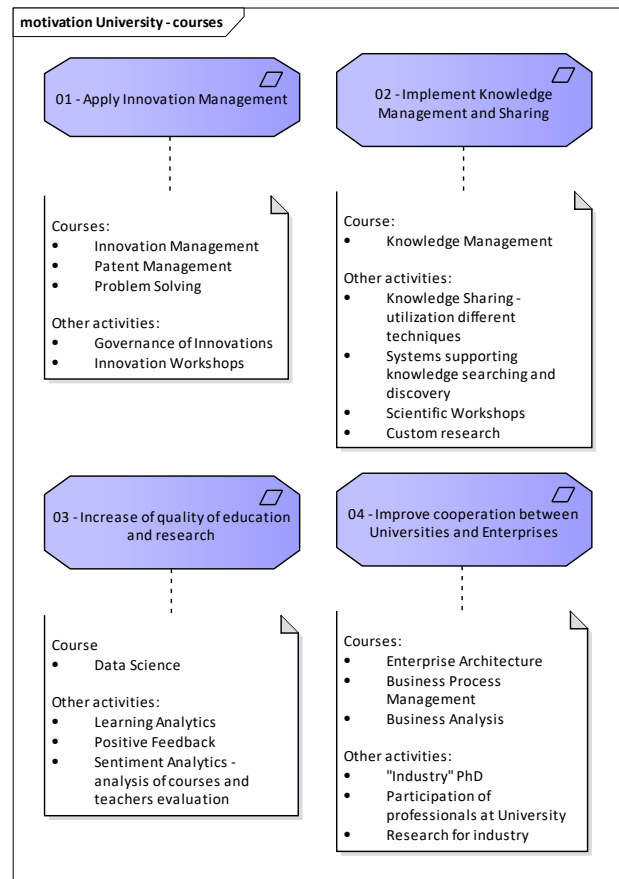
Figure 7. Mapping requirements to activities of Business School

There is proposed set of courses (in alphabetic order)

- Business Process Management including main industry framework such as eTOM, BIAN, etc.
- Data Science and Big Data Analytics including Text Analytics with highlighting of its business exploitation.
- Enterprise Architecture including architectural frameworks (TOGAF, Zachman, etc.) and architectural tools (Sparx Enterprise Architect, BiZZdesign Enterprise Studio, etc.).
- Innovation Management
- Patent Management
- Problem Solving such as Kepner-Tregoe, How to do it, Eight disciplines, etc.
- Research Methods
- Robotic Process Automation and utilization of AI in business applications

An example of utilization of Problem solving technique namely Kepner-Tregoe is service management. Usage of this method should decrease of costs, improve IT stability, and provide a better customer experience.

Another example is the Innovation and Patent Management. Although it is clear that Business Schools are not determined to develop innovations in technology they could be utilized in training how to arrange innovation, how to manage whole innovation process, etc.

Important position is occupied by the Enterprise Architecture. Enterprise Architecture not only is in line

with current trends in employee skills, but Enterprise Architecture and namely TOGAF represent effective tool for business transformation and optimization.

B. The Synergy Effect

An excellent example of synergy can be considered Data Science. There is still demand for expert from Data Science and Big Data Analytics. The equable course is fully actual, research in the area of Data Science is also fully accepted, there is still demand for solution in Data Science for different business area such as marketing, sales, logistics, etc. At least there is a possibility to utilize Data Science in Learning Analytics, Positive feedback, and sentiment analysis in education and hence in this way to contribute to its improvement [A12]. From described follow convenience such approach which can bring much higher results if it is managed properly on the one hand in cooperation inside of university or between more universities, and other hand in cooperation with industry.

In many cases these is a potential for cooperation between "technical" universities and business schools. The most suitable and obvious is the project management when students from both subjects are tough in it. It is natural that students graduated from business schools should be deeply involved into project management. In this case is participation on the same project win-win decision. Supplemental advantage is when is such project required and specified by industry organization.

VI. CONCLUSION

In this paper is demonstrated that Enterprise Architecture approach is possible to apply for more preciously identification courses and their topics which is in compliance with actual trends and demand from business. Proposal described in this paper in addition is in compliance with RIS3 initiative and with current situation in Slovakia.

Applying of the courses "Data Science and Big Data Analytics", and "Enterprise Architecture" markedly contribute to increase of knowledge and skills of students and decrease a gap which is observed in automotive industry.

Meaningful is to identify courses and topics (for example Data Science) which can be not only interesting for education but also useful for research and industry implementation.

Authors of this paper contributed to implement several arrangements in the practice. There were established courses "Research Methods" and "Data Science and Big Data Analytics" in Faculty of Management of Comenius University. Both courses are taught in English as optional courses mainly offered for Erasmus students. It is a first step in the long way. Anyway there is a need to manage and coordinate syllabus all courses because there are other courses in this faculty providing similar topics (Statistics, Machine Learning, R…) with different name. This is again challenge for applying of Enterprise Architecture to split into atomic elements (particular topics) and modelled them. In this way we can simple discover duplicates and from other site identified missing elements. But this is new topic "Utilization of Enterprise Architecture in Education" going out of the scope of this paper.

In our paper we were going to describe a possible approach to harmonize areas of research, education and industry cooperation and this way to fulfill goals and message of initiative RIS3. We demonstrated which new contemporary topics is required to teach. We also identified areas of research which could bring a synergy effect and be applied in education, research and industry. Vice versa we consider this paper as a contribution to potential discussion regarding orientation of universities in Slovakia. Such discussion needs deeper analysis and involving wider range of people from academic community and industry.

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Virtual Mine – educational model for Wider Society

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Abstract— **Education is a powerful tool not only for obtaining information and knowledge, but it is a powerful tool for creating opinions and decision making as well. Education is capable of changing views and stereotypes associated with various industrial sectors. Therefore, it was chosen as a tool to change opinions about the mining industry as an outdated sector, which is not able to keep pace with the modern sectors of economy. This article shows the possibilities of using modern presentation methods to highlight the importance of raw materials and the attractiveness of mining as a sector which uses the most up-to-date technical tools.**

I. INTRODUCTION

The decline of mining as an industry during the last decades was mostly prevalent in Europe. Such state has been caused by multiple factors including e.g. high operating costs, high degree of urbanization, local community resentment, etc [1].

The decline of mining is closely connected to the decline of educational institutions targeting mining and its related departments. This is influencing opinions of the wider public as well [2,3].

The current trend is in a direct contradiction with the reality, because the modernization of all industries incorporates modernization of the mining industry as well [4]. It is necessary to change the perception of mining by presenting it without prejudice. In general, it is well know that the negative phenomena of mining, such as fracking, can be shown as positive for the local community by means of research results [5]. It is important to show that the mining industry is a significant and safe industry and it needs to be done broadly and not only marginally. Modern trends and recommendations in education should be taken into account [6]. Success can be launched by following the trends in education at European schools [7]. Museums should represent an important platform for the introduction of changes and the modernization of history of mining education [8], in particular the specialized mining museums.

II. TARGET-ORIENTED EDUCATION

Target-oriented education is one of the possibilities to engage a wide group of people, by dividing people that we want to educate into smaller groups. We can compare this process to creating target groups in marketing. We create a group of people with similar interests, characteristics, needs, social, age or otherwise defined parameters [9].

Next we can create a suitable educational program for each group, optimized for the given group. The bigger the group of people we want to educate is, the more complicated it is to create an optimal number of target groups. The existence of too many target groups creates demanding conditions for education, because each group has its own specific needs. It is important to make historical archive documents available to the general public (see the most recent works: [10, 11, 12, 13, 14], and many other papers). The following groups for the mining education have been created according to the criteria.

Group 1: the local community - people who are directly affected by mining activities and are often a part of it, in a positive or negative meaning. This group is not very abundant, and its members do usually have a profound knowledge of mining. The most important thing to know for people of this group is to have information about how the mining is going to be developed in the future and how it will influence their life and lives of their neighbors. It is necessary to educate and to inform these people about mining and its technologies, as well as their impact on their social background and the environment.

Group 2: the business sector - people doing business in industry and mining, or certain mining sectors, which could be interesting for their future business. This group of people is small in terms of numbers but needs the most information as they are trying to enter the mining business and invest their resources. It is therefore necessary to educate them in small groups or individually.

Group 3: local governments and regional organizations - members of these organizations have bigger or smaller influence on the development of the region with mining activity. Therefore it is very important to sufficiently educate these people, so that they have all the information

needed for the decision-making processes in the development planning of the whole region.

Group 4: the general public – this group cannot be considered a target group as such because it is so extensive and so diverse that it is not possible to create specific educational tools and conditions. On the other hand, this group has one of the greatest effects on the development of mining as an industrial sector in the region. If the public does not accept mining as an industry that can represent economic and social gain and be a positive contribution to sustainable development of the region, then the mining will be condemned to extinction.

Group 5: children and students - people who have a very little knowledge about mining, despite using modern information technologies and channels. It is an abundant group of people, which can extend over time into all of the previously mentioned target groups. Therefore, this target group is the most significant in terms of long-term planning and requires sufficient attention and information about mining and its connection to human civilization and the impact on nature as well. Children need to be attracted by teaching the regional history at the basic level of education [8], and thus gradually brought closer to the history of mining itself.

TABLE 1
EDUCATION OPPORTUNITIES FOR TARGET GROUPS

Target Group	Size	Kind of information	Education
local community	middle	the future of mining	visit mines
		impact on the region	informative
		impact on the environment	regularity
business sector	small	business life	expertly
		investment opportunities	individually
self-government and regional organizations	small	Sustainable Development	expertly
		impact on the region	individually
general public	large	Sustainable Development	informative
		impact on the environment	using the media
		the future of mining	regularity
children and students	large	importance for the future	visit mines modern presentation
		job opportunities and careers	
		modern technology	activities

III. OBJECTIVES OF MINING EDUCATION

▪ to create a new entrepreneurial education approaches and the conditions to convey knowledge on raw material as key to the development of the circular knowledge-based economy in the most effective way

▪ to increase the awareness among local community about the importance of raw materials and its possible use for better development of the European regions

▪ to show attractiveness and diversity of mining through the use of customized, innovative teaching methods

▪ to strengthen the key competencies in children and students, such as practical use of obtained knowledge in the field of mining, creativity and entrepreneurship, as the skills necessary in further professional life

▪ to break stereotypes about mining, generally applicable in the society, including use of raw materials and show social utility and application of mining in everyday life as the model of sustainable development

▪ to establish cooperation between scientific and informal educational public entities to improve the attractiveness of vocational education in the faculties

▪ to popularize mining among the general public, especially children and students who start to develop their career path, as well as to show the importance of raw materials (minerals) in our modern world

▪ to convey knowledge about raw materials sector to society and implementing it to educational system in the region

▪ to create the tools and ideas to many entities, including local authorities, which will use the results in planned future action

▪ to implement the results in different locations across the Europe

IV. EDUCATION OF CHILDREN AND STUDENTS

As the most important target group, which can be found in more of the Virtual Mine objectives, children are the center of attention in education. If we want to educate children, we need to meet one of the basic goals in education, which is to attract, or rather to preoccupy the child´s mind with the subject for its entire life. To achieve this we need to create a strong emotion. It is commonly known that strong emotions are those which come together with something new in an unusual or a shocking way. Nowadays, children are accommodating to the age full of modern technology, but on the other hand they still remain to be children to which sitting without moving and learning for a long time is boring. Therefore, three basic conditions must be met for an interesting form of education:

A. Senses

Engagement of as much senses as possible during the learning process (sight, hearing, touch, active participation) in an effective way [15]. This condition is best applied in the "in situ" education. As for the mining this is best represented in a functioning surface and

underground mines with guaranteed safety conditions where the education can be provided during the full operation of the mine. Using this option, students can feel oneself into the role of miners incorporating all of their senses, which makes such education very durable. A similar form of learning can be represented by mining areas which are no longer active, but offer a trip to the mining history. It is possible to visit mining works such as underground mines in form of museums and open-air museums in these areas. The absent mining activity is on the other hand balanced by the authentic environment of such spaces, which creates a strong impression as well.

B. Activity/movement

Activity/movement – certain forms of education directly engage movement into the learning process e.g. the Montessori education. Movement is closely related to any learning. Our brains are evolving in a world in which we move and are active, and not in the world where we passively sit on the bench and think abstractly. Contemporary neurological research leads to the same conclusion, that the education to promote effective learning should largely involve movement [16]. This condition can be met with an "in situ" education. It is necessary to create educational activities inside the functioning or historical mining areas directly related to what students have experienced in the mining process or to what is directly related to the activities or processes which represent the results of the mining activities. Based on the previous experiences it can be said that the activities with a specific result are more durable. If the result of the activity can be taken away as a "souvenir", then the next step to achieve a strong and lasting impression has been accomplished. As shown by the activities done during the last 10 years at the Children University, activities such as gold-washing are overwhelmingly popular. Children are able to learn about mining technologies directly through activities, which are authentic, and have an authentic product as well – a little gold flake, which becomes their property.

C. Modern Technologies - Generation Z Toys

If we want to attract children in their school age, it is not very appropriate to show them the technology of the past in a "preserved form" without functionality. Therefore, modern technologies are more often used for the presentation of processes as well as the mining technology itself [17, 18, 19]. It is appropriate to choose modern presentational technologies for the education and presentation of the information itself. Generation Z is not interested in static models that cannot be touched, or long-lasting video presentation. It is necessary to create new unusual presentations that would create a strong impression on students. These technologies are not used in education, but are commonly used in the entertainment industry. Children get to know them through entertainment and teaching and learning using these technologies is entertaining for them. We have chosen technologies that are the most important nowadays and have the power to address the young generation.

1. Virtual Reality (VR) is a computer modeled environment simulating the reality. It can be primarily described as an environment creating a visual experience displayed on the computer screen, or through a special stereoscopic device. In more sophisticated cases, other senses are stimulated as well, e.g. hearing, smell and touch. Interaction with the user is provided either by standard computer equipment or a specially tailored devices such as three-dimensional spectacles, motion-capturing and touch stimulating clothing, multi-channel sound, etc.. Such an environment can create an image of the real world (e.g. a visit to the underground, working with machines).

2. Enhanced reality or augmented reality (AR) is a direct or indirect view of a physically real environment whose parts are enriched in digital, mostly textual or pictorial form, with additional information relevant to the object in one's view. These information are obtained from various information sources using off-line or online applications. Enhancement of reality is usually done in real time and in semantic context with the parts of the environment, such as the current activity in the mine, the closest technology, and so on.

Figure 1. An example of using of augmented reality [20]

3. 4D technology - exceeds the classic 3D projection known from cinemas. 4D technology stimulates all 5 senses with special effects, which make it possible to experience a much more intense and superior experience. Fragrance, wind, fog, light show, bubbles, water, tickling of the back or legs and, last but not least, the movement of the seats. 4D presentation offers many more possibilities and perceptions on your own skin, in addition to the traditional image, sound and 3D format.

4. Inteliglass - the use of this revolutionary product can be found in various meeting rooms where any glass wall can practically turn into an opaque white area. Such adjustment can serve as a projection surface using the front as well as the rear projection. Thanks to this unique feature, it can be used to project images on glass and create an impression of a hologram.

5. The hologram is a specific form of image recording that allows to capture its three-dimensional structure. It is a process in which the three-dimensional world around us can be recorded on a two-dimensional medium and lately reconstructs the captured three-dimensional image back to our eyes.

V. Model of education in mining – the Virtual Mine

We have created a model of education which includes all three conditions - interactivity, activity/movement and modern technologies in order to achieve the most efficient educational process. This task is not problematic when it comes to theoretical modelling, but represents a problem in the actual implementation, because of the plain fact that while interactivity and activity require an "in situ" environment, modern technologies are bound to classrooms and/or laboratories. This problem required to select and locate the technology into a suitable environment. Active mines are not suitable for the installation of these technologies because of the mining activities. Mining museums, open-air museums, and historical miming works provide the right environment for such technological installations. Moreover, the virtual technology can replace the absence of active technologies and activities natural for a fully operating mine. Even despite the choice of suitable spaces, it is not possible to use all the technology in full extent. The following table shows which spaces are suitable for various technologies.
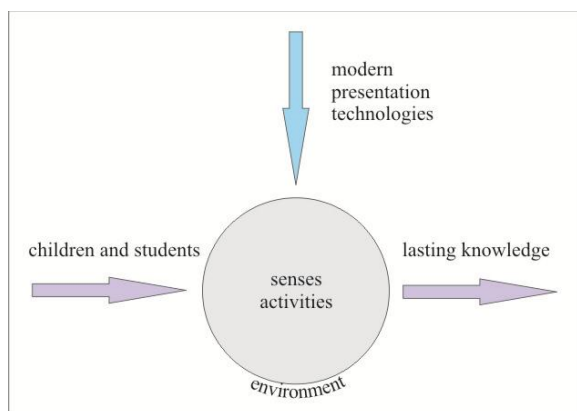

Figure 2.   Educational process with modern presentation technology

VI. Conclusion

The presentation of information using a modern technology gives the presented information itself a touch of modernity. This is true regarding the current but mostly regarding the historical mining. By installing these technologies into an authentic environment we are able to connect the history and modernity. The use of such technologies and their impact may be classified into time periods.

In the short term, the proposed actions will identify good practices, best models of conveying knowledge in terms of science education and consider the impact of this information on people who live in the mining regions. In the medium term, the results of the present action will help to better understand the effects of science education outside the regular education institutions and will increase the range of innovative products in science education that reflect societal needs. In the long term, the results should be implemented in educational systems, as a result of the wider learning of the Virtual Mine model.

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Overview of cloud computing and portability problems

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Abstract — **At the beginning, there is overview of three basic Cloud Computing services – SaaS, PaaS and IaaS. There is a definition of these services review, advantages and their security problems and effects. Next part tells about portability problems of each service, mainly the IaaS service, which has the most interoperability and portability problems.**

Keywords—**Cloud computing, Infrastructure, IaaS, Portability.**

I. Introduction

Cloud Computing (CC) has become very popular either between companies and home users. CC can be in general treated as a service. Service, where customer pays only for resources, he really uses. This feature is very often considered before customer decides to move applications and data to the cloud.

Another feature that attracts customers to CC environments is fact, that they do not have to buy expensive hardware, on which they would run applications. Not only hardware is expensive, but also its maintenance, such as housing, power supply, cooling, Internet and intranet connection, and, very important, trained staff, that would look after the hardware. All what company needs is personal computers and Internet access.

In this paper, we would like to make overview of three basic cloud services, that are quite largely used nowadays. Their description and security impact to customer and his data. In the second part, there is description of portability problem in clouds, with focus in IaaS service. Based on [7], IaaS is the mostly used service among companies and corporations.

II. Definition of Cloud Computing

There are many definitions, what is Cloud Computing. Regardless of the type of cloud deployment type (private, public, hybrid cloud) or type of provided service (SaaS, PaaS, IaaS), in general we can say, that CC is about simplicity and easiness of its management. As written in [1]: "If launching a server or grabbing a few gigabytes of storage for a VM involves (1) multiple staff or (2) staff having to get up from their chairs to manage servers, it's not cloud computing".

Many organizations refer to basic five characteristic of cloud defined by the National Institute of Standards and Testing (NIST) [2]:

1. On-demand self-service
2. Broad network access
3. Resource pooling
4. Rapid elasticity
5. Measured service

In next sections, we will explain these terms more in detail.

1) On-demand self-service

This means, that user has unified interface to whole environment. This interface should be as simple as possible, because user will operate whole CC itself, without any interaction of cloud provider. The term on-demand means, that customer can anytime modify his environment. There should be no restriction in creating and deleting of resources, because cloud providers usually use "pay as you go" method. This means, that customer is being billed only for resources, he really uses.

As an example, we can take a look at Amazon Web Service (AWS). Their customers can use web-based management console for managing and remote connecting to their networks and virtual machines.

2) Broad network access

Every cloud computing environment is being managed online, so customer should have access form any place and any device, which has Internet connectivity. Of course, customer may want to hide his topology from the Internet, or make it available only to specific locations, such as network of the customer.

3) Resource pooling

The cloud computing resources should serve to multiple customers in multiple tenants. These resources should be uniform to all customers in any tenant. So If anyone would need more resources, he will ask for more in standard way, and free resources will be assigned to him. This means, that multiple customers / tenants can use shared resources from one centralized, pooled location.

4) Rapid elasticity

For cloud customers, CC environment creates an illusion of infinite compute and storage capacity. They can

get as much, as they are able to pay. Many big companies have infrastructure counting several thousands of servers and active network components. Sometimes, these companies need on demand changes in infrastructure several times per day.

A customer should be able to get more resources, and torn them on and off as necessary. Usually, bigger cloud providers offer automated increasing and decreasing of customer's resources. This is often called "autoscaling", and by triggers, environment can automatically get bigger or smaller.

5) Measured service

Cloud is multi-customer environment, so provider should be able to monitor and measure all events, that are being done by single customer. As we mentioned earlier, many providers offer "pay as you go" method, so they need to know all steps dome by customer for proper billing him. Most cloud platforms and services are able to show this kind of information to user.

III.   CLASSIFICATION OF CLOUD SERVICES

Customer can use one single application or set of applications, which create specific platform. He can use a network infrastructure of provider and run there his own environment. Based on that, what customer use, we can divide CC to several models of services. We can split these services into five layers, as seen in the picture Figure 1.

According to [2], we divide CC into three basic layers. On the top, there are applications, followed by platform and infrastructure. Infrastructure can be internally divided into compute, storage and communication. Another layer is kernel, which we can understood as a virtualization layer. The lowest layer is hardware, which hosts all CC virtual environment.

Applications (SaaS)		
Platform (PaaS)		
Infrastructure (IaaS)		
Compute	Storage	Communication
Kernel		
Hardware		

Figure 1: CC environment

A. Software as a Service
1) Review of SaaS

On the top of the model, there is Application layer, in CC environment called SaaS. In this model, customer uses only application, or set of applications. He is not interested in updating software, creating backups and administering at all. Provider is responsible for all these tasks. Customer simply access service either via client application, or more often via web browser. This is very convenient for the customer, because from his point of view, the application is platform independent.

Another advantage of IaaS is fact, that whole application runs in the datacenter. This means, that if the customer needs to run CPU or memory intensive computations, he does not need powerful hardware in his organization [3][4].

2) Security of SaaS

Specific topic is security of customer's data. Customer has no control, where are his data stored. Usually, when customer uploads his data to cloud environment, provider multiplies copies of the data and save them in different datacenters, which can be in several countries over the world. Moreover, each country has its own legislation, so the customer does not know, which legislation will be applied to his data [6].

Best solution for the customer is to use strong encryption of his data. Considering the fact, that the customer has almost no administration power, he is usually unable modify his data otherwise, then by the application. In this case, he has no other choice then to trust to the service provider.

3) Advantages of SaaS
- Lower software license cost
- No need for complex infrastructure
- Several users can use application at same time
- Provider is responsible for maintaining and creating of backups of applications
- Multiplatform access to the application

B. Platform as a Service
1) Review of PaaS

Another layer in the CC stack is platform layer, commonly known as PaaS. It provides an environment or platform; in which can developer create applications or software. While developing an application, he does not need to install or manage the development environment.

PaaS allows the customer to use virtualized environment (servers, network, storage), but he has no control over it. The control over virtualized environment is strictly in the provider's hand.

Customer is being charged according to data transfer, CPU usage, storage usage, I/O requests and so on. Specific billing system is agreed in the contract between customer and provider before the start of the service [6].

2) Security of PaaS

In contrast with SaaS, security is not just the responsibility of the provider. It is distributed to both developer and provider. The developer is responsible for the security of his applications, while the provider is responsible for security of underlying infrastructure and communication path.

Against the SaaS model, customer, or the developer, can modify his data and adjust his application to them. So the data can be stored encrypted, while the application can still work with them. This is enormous shift in the security of customer's data because he can now manage their security and encryption procedures.

3) Advantages of PaaS
- Customer can control and adjust platform for his needs
- Customer can improve security of his data
- Customer can make backups of his data
- No need for maintaining hardware for the customer

C. Infrastructure as a Service

1) Review of IaaS

IaaS provides raw hardware and virtual infrastructure, on which can be created, managed and destroyed storage, virtual machines (VM) and virtual networks. The provider offers to customer VM with one or more CPU, optional amount of RAM and storage, connecting to custom network, and several choice of operating system.

The VM can be rent for an hour, or for as long time as needed. These resources can scale up and down according to customer's need and will be billed depending on amount of resources and duration of rented services. It is very similar than billing in the PaaS.

For the customer, it is possible to connect directly to the virtual machine, or directly to the network, in which are several VMs placed. If the networks are publicly accessible, there is usually no problem accessing the network. But if the networks are in the private range, provider have to set up VPN (Virtual Private Network), which allows customer connect to his private network. VPNs are usually encrypted, so this can be treat as a security feature. The provider is responsible for maintaining the infrastructure, to serve the client.

2) Security of IaaS

Similarly, as in PaaS, security responsibility is split between customer and provider. Customer is responsible for all systems in his environment. This includes operating systems, middleware such as java machine or database engine, up to applications, that run on virtual systems.

Provider has usually no access to customers VMs. He has to secure communication paths over network and management access to the virtualization nodes. If there is web management portal for the customer, provider should keep secure background. It means updated web server, or maintaining certificates for secure connection to the portal, usually by encrypted connection via HTTPs.

Virtual machines can be compromised from two sides. The first option is remote access to VM, such as Secure Shell (SSH), Virtual Network Computing (VNC), Remote Desktop Protocol (RDP), access to databases or web portals. There can be weak passwords or bugs in software. The second option is compromising hypervisor, and get access to VMs through it. On the other side, sometimes there is possibility to compromise VM and then get access to the hypervisor. This can be very dangerous, if compromised VM is migrated to another hypervisor, or compute node.

But in most cases, when there is compromised virtual machine or network component, it is due to customer's underestimation of security in whole virtual environment. It is either old and not updated system or firmware, but very often it is weak password and missing or default state of firewall [5].

3) Advantages of IaaS
- Customer can increase and decrease his infrastructure on demand
- Availability to automatically scale environments
- Customer can dynamically manage his networks and VMs in the networks
- Reducing costs on hardware and human resources

IV. DEPLOYMENT MODELS OF CC

All of these types of services must be hosted somewhere. Same as at services, there are also several divisions of deployment models. But the most common is model from the NIST (National Institute of Standards and Technology) organization, published in [1].There are four main models: private, community, public and hybrid cloud.

The first model is private cloud. As the name suggests, in this model is everything in administration of single organization. Not only administration of the virtual environment, but also management of servers, on which the cloud runs on. This deployment is often called as "On premise". Owner has to manage everything, that corresponds with servers: housing, power supply, cooling, redundancy in data connection, spare parts (e.g. hard drives), and last but not least qualified and trained staff. Moreover, the owner has to maintain the cloud system, installation, updating, …, and at the end virtual machines, that he wants to have in the cloud system. As an advantage of this model is, that everything is in management of the owner, so he can trust to infrastructure and save there also

confidential data. Of course under the condition, that he has secure infrastructure with strong security policies. Very strong disadvantage is, that the user has to maintain physical servers and needs trained staff. As a representative of private cloud in the enterprise deployment, the first place belongs definitely to VMware vSphere, second to VMware vCloud Suite and third to OpenStack [7]. Both VMware products are commercials, and OpenStack is open-source product.

The second model is community cloud. Same as the private cloud, it is also deployed as "On premise". The only difference against private cloud is, that community cloud is not used only by single organization, but it is used by an interest group. As an example, several universities are doing research in a single area, on one research problem. They can share computed data in the cloud, moreover, they can independently do their own computations in the cloud and then share results with other researchers.

The third and the most widely used is public cloud. According to [7], 89% of all cloud users are using public cloud in 2017. Public cloud is owned by a single organization, and it is offered to anyone. The most used is Amazon Web Service (AWS) cloud, which is being used by 59% of enterprises and 55% of small businesses among public cloud users [7]. Another very popular provider is Microsoft Azure cloud. Another noticeable provider are Google Cloud and Digital Ocean. In this model, user does not need to take care of his infrastructure at all. The only thing the customer needs to care is Internet connection, because every single server and data storage runs in provider's data center. Therefore, provider needs to take care of underlying hardware, such as redundant power supply, redundant data connection, cooling, or maintaining spare parts, for example hard drives. Time of outage is usually written in agreement called SLA (Service Level Agreement). For example, Amazon AWS says, that customer's servers will be available on 99,95% during month [8].

Fourth, and the last is hybrid cloud. This is any combination of previous ones. For example, an organization owns powerful hardware. It ca use it as private cloud for internal purposes. And redundant power can be offered to another organizations and people as public cloud

V. PORTABILITY PROBLEM

As you can see above, there are many types and providers of Cloud Computing service. And very recent problem is, that if some organization or people would like to move their applications from one provider to another. This is no such problem with SaaS or PaaS applications. A customer can ask new provider to build him the same environment. Then the customer can easily move his applications to this new environment. For example, if customer runs his java application, he will simply move java files to new virtual machines, and runs them. In the

PaaS cloud, which is example of java application, provider is responsible for maintaining all hardware, infrastructure and middleware. Therefore, java virtual machine will be running and customer looks only after his application and data, which can be exported and imported in standard format.

Bigger problem is in the IaaS cloud model. Customer is responsible also for virtual infrastructure – topology and networking, virtual machines and operating systems, and so on. So if the customer would like to migrate his environment, he needs to move his virtual machines

These environments are usually being built by scripts. In many providers, script is more powerful then web based GUI (Graphical User Interface), so this is preferred choice. Scripts are written by customers itself. Provider just offers environment to customer. So if a customer wants or needs to migrate his environment to another provider, he needs to rewrite all his deploy scripts according to the new provider's environment. Usually, this is not trivial thing, because different providers use different syntax and different philosophy of scripts. Sometimes, some providers can use proprietary or very specific functions, which other providers do not offer. If a customer uses such a feature, they are unable to move their environment to another provider. This status is often called "vendor lock-in".

As an example, we can compare two biggest public cloud providers – Amazon Web Service and Microsoft Azure. Amazon developed own syntax, which is written in JSON (JavaScript Object Notation) or YAML (YAML Ain't Markup Language) format. Microsoft Azure's scripts have no strict format; they are written as plain PowerShell scripts.

Therefore, it is not trivial to move whole environment. If there is such a need to move environment from one provider to another, there are basically two options. First is to log in to new provider's dashboard and click and create whole environment from scratch, or create scripts (if scripts are supported from new provider) that will build new environment, but also make them from scratch.

Second, and more effective option is to take old script, that built environment before, and make transformation of it into new one, that fits into new provider's system. Administrator have to think about transformation of formal syntax first. This is not so big problem, because today there are many automated tools and libraries, that can make transformations among many languages and notations, such as JSON, YAML, XML and so on.

Bigger problem is in transformation of semantic. The same component could have different name, and possibly different names for attributes. Similarly, as formal language, there would be simple substitution of key words and names, which a small shell or python script can do very quickly and effectively. Many basic word processing

programs, such as Notepad++ has 'Find and Replace' function implemented already.

However, different providers developed different logical layout of components in their cloud environments. Usually, all scripts are built from blocks. Each block belong to particular module, which cares about specific part of whole environment. Basic modules that can be found in most CC implementations are compute module (cares about virtual machines), network module and object storage module. As an example, we can state differences between Amazon Web Service (AWS) and OpenStack. Network and subnet, which belong to core components of virtual environments, are in OpenStack managed by Neutron module, which is purely network module. While in AWS, they are managed by EC2 module, which cares about networks and virtual machines as well.

Nevertheless, this is not so big deal, because the modules are internal matter of cloud engines. The biggest deal is internal logic and layout of these building blocks. We can continue in the example of AWS and OpenStack. In both, when you create subnet, which consists of some IP address space, it has to be part of network. Network is like a container, which associates subnets. In OpenStack, network has no constraints, and as required parameter, it has just a name. Whilst in AWS, network does not have parameter name, but has mandatory parameter called CIDR, which is IP address pool that all subnets in the network have to be part of. So there could be a problem during migration from OpenStack to AWS, that if subnets are from very different parts of address space, it could be difficult, if sometimes impossible, to create description of same topology in AWS, as was in OpenStack. This was just a single point of different logic arrangement of same things at different Cloud providers.

In our opinion, the problem of portability is one of the biggest problems, which Cloud users are nowadays dealing with. Since now, we have not found any automated solution for simplification of environment migration between different cloud providers.

VI. Conclusion

Cloud Computing is being widely used for many purposes. It is used by individuals, as well as by big corporations. We think, that virtual environments offered by Cloud and its providers can be variously modified for almost every need of the customer, which can use it as secure place for all his needs.

As a problem for end users, which is in our opinion very urgent, is portability problem and vendor "lock-in". For now, there are no standardized methods that can be used for migration between providers. There are several standards for interoperability between different Cloud environments, such as TOSCA [9], Cloud Data Management Interface (CDMI) [10] or Open Cloud Computing Interface (OCCI) [11]. These are just interfaces for communication between different Cloud

environments. In other words, if a customer has part of his environment at one providers cloud (for example databases in AWS) and part at another providers (computing virtual machines in Microsoft Azure),

he can use these interfaces for communication of VMs and databases, but he is not able to move databases to Azure. Customer has to have two agreements, two providers, which do not have to be always convenient for him.

On the other hand, based on actual research, there are no standards for transferring the applications between different cloud environments. However, there are studies, that suggest usage of model-driven and UML based approach how to reach portability [12], there is still no standard or reference document.

In our opinion, if this problem would be solved, it cloud be motivation for many new customers to join the cloud environments, and move there their data.

We assume that personal data of customers are securely stored in public cloud environments. At least in environments, which are in administration of leading and verified providers such as Amazon or Microsoft. Therefore, in our opinion, if there would be way, or several ways how to relative easily move applications and data between providers, more customers would consider to join Cloud Computing environments.

VII. Acknowledgment

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Teaching cloud computing in cloud computing

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Abstract—**At the beginning, this paper describes basic overview of Cloud Computing (CC) and its usage among companies. Second part describes how is Cloud Computing being taught on another schools and companies around the world. Next, there is description of our physical and logical topology, used during experiments. In the next part, there are descriptions of experiments we made during semester while teaching cloud related subjects. This is followed by results of measurements of used resources in our CC system.**

Keywords—**Cloud computing, IaaS, Teaching, OpenStack.**

I. INTRODUCTION

Cloud Computing (CC) has become very popular among either people or companies. Very popular services are online repositories, such as Google Drive, or Microsoft OneDrive.

Many people have opinion, that cloud equals online storage. But this is not true. Storage is only a tiny part of whole Cloud Computing. To be exact, it is part of Infrastructure as a Service (IaaS), what is mostly deployed among Enterprises and Small Businesses. Enterprise is company with more than 1000 employees. As a result of RightScale State of the cloud report from January 2017 [1], up to 95 % of surveyed organizations are running or experimenting with IaaS against another cloud services.

At the Department of InfoComm Networks, University of Zilina, we have been working with clouds for longer time. For research purposes, as well as for simplification purposes of our infrastructure, we have adopted OpenStack CC system. Recently, we are running fourteenth version of OpenStack, codenamed Newton. When we got more familiar with concepts and administering of CC system, we tried to use it in education on our department.

The first subject, that we fully used CC was Network Integration. In this subject, we taught basic principles of Cloud Computing and Software Defined Networking (SDN). The part of CC was also practical, on which we used our department's Cloud system OpenStack. In this system, students were administering their own virtual environment. In the section IV, there is detailed description of practical assignments for our students during semester in this subject.

In this paper, we would like to show, how can be CC used in university educational process.

II. CLOUD IN OTHER INSTITUTIONS

Recently, you can find many schools/universities, that are using Cloud Computing in their educational process. However, many of them are using it as a support to their main teaching systems, or Learning Management Systems (LMS). For example, at the University Kebangsaan in Malaysia, they are also teaching how to use cloud computing. Nevertheless, they are focused on SaaS (Software as a Service) and PaaS (Platform as a Service) [2]. Both these services offer usage of services, and platforms, that users can use without deep knowledge of underlying technologies and virtualization techniques. In fact, at this university, they are not teaching students how to program or develop software for these models, but only how to use them to simplify some processes.

There are, as well other institutions such as Cisco Systems with their Netacad program, which uses LMS as central system XXX, but nowadays (2017) they moved to Cloud environment as well. Netacad is using Amazon Web Service as hosting environments for their curricula and materials for students. It can be easily proved, because if you log in Netacad portal and open curriculum, URL in web browser is directing to Amazon's cloud.

Another example of using cloud as support is to use virtual environments to situate classes in. There are more advantages. For example, students can access their documents, homework etc. from everywhere they have Internet access. On the other hand, if student get sick, he can connect to online stream from class and can communicate with classmates while solving problem. It can also bring benefits, when student cannot go to school due to weather or in wide spread rural regions. This approach called "School in the cloud" has its supporters and opponents. However, this approach is not the scope of this paper.

At the University of Surrey, there is six weeks long course for teaching IaaS cloud computing [1]. It is based on practical training in AWS (Amazon Web Services), which is biggest IaaS public cloud provider in the world [6]. The content of the course is getting familiar with AWS environment, build simple topologies and networks, and then use orchestration based on the Eucalyptus. This is very similar to our courses, where students at the end are familiar with OpenStack environment, and are able to create and orchestrate quite complicated virtual environments.

Another examples are Khalifa University of Science, United Arab Emirates, Carnegie Mellon University, Quatar and University of Kentucky, USA, where are

teaching cybersecurity in Cloud environments [7]. Similarly, as most of schools and institutions, they are using Amazon AWS as their teaching platform. But they are teaching general principles that can be applied to another Cloud platforms, such as Google Compute Engine, Rackspace, GoGrid, HP Cloud and so on.

Nevertheless, not only schools and universities are teaching Cloud Computing and related stuff. There are many commercial organizations, at which can anybody learn how to use and administer CC environments. Very popular is CloudAcademy [8], which offers courses for both individuals and bigger groups. They are focused mainly on AWS, and offer several AWS courses with certification preparation. Moreover, they offer courses to another CC platforms, such as Google Cloud Platform, or Microsoft Azure. Interesting is course focused in DevOps techniques, where student learns how to orchestrate and effectively administer bigger cloud platform.

At our university, we are teaching specially IaaS. From installing and administration up to usage with advanced features, such as using orchestration scripts. Based on our research, at least in Slovakia we are unique in teaching IaaS cloud computing in virtualized way. In fact, that we are teaching it in our own cloud environment, it is nested virtualization. In sections below, there is description of our hardware and topology, that we use for students.

III. TOPOLOGY

In the Figure 1, you can see logical topology of our cloud system. The firewall provides security barrier, as well as routing. It is default gateway in both IPv4 and IPv6 subnets. For our networks, we use OSPFv2 (Open Shortest Path First) and OSPFv3 routing protocols.
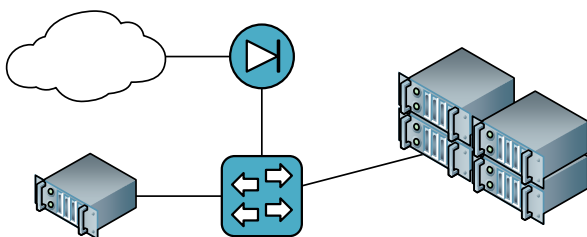

Figure 1: Physical topology

The system consists of one control node, which is responsible for delegation of commands to compute nodes, databases for internal services, virtual networks and routers, web access, and so on.

Then there are four compute nodes, which are used only for running virtual machines. These nodes are combined in "availability zones". When you are creating virtual machine, you can choose, in which availability zone will be machine deployed.

Administrator can assign several physical machines into one zone, and control node will choose, on which physical server will be machine deployed. On the other hand, if there is mapping one physical server, one availability zone, control node has no choice, so machine will be deployed exactly on the server in the zone. Therefore, administrator can explicitly choose, on which physical server will be virtual machines hosted.

In the Table 1, you can see properties of our physical cloud servers. In spite of fact, that we have three compute nodes, for our experiment, we have chosen only one physical server in one availability zone. The reason was better measuring of resources needed for running bigger virtual topologies.

Our virtualization server was Compute node 1 - Lenovo x3550 M5, which consist of two Intel® Xeon® CPU E5-2620 at frequency 2.1 GHz, each has 16 cores. RAM memory was 512 GB and altogether there was approximately 1,5 TB of hard drive space.

	Control node	Compute node 1	Compute node 2	Compute node 3
Model	Dell PE 1955	Lenovo x3550 M5	Dell PE 2950	Dell PE 2950
CPU	2x Intel Xeon E5335	2x Intel Xeon E5-2620	2x Intel Xeon E5450	2x Intel Xeon E5320
RAM	16 GB	512 GB	22 GB	32 GB
HDD	68,2 GB	14,2 TB	892,5 GB	278,9 GB
NIC	2x 1Gbps	2x 1Gbps	2x 1Gbps	2x 1Gbps

Table 1:Physical servers in our cloud

More detailed view into our department's CC system OpenStack can be seen in our previous paper [9] published on ICETA 2015 conference two years ago. Since then, there are not many dramatical changes. The most important is, that we have more powerful compute server, and the version of OpenStack system arises of five releases – from Juno to Ocata. But all settings, including physical and logical topology remains the same.

IV. EXPERIMENTS

Every student had one project in our department's OpenStack cloud. Project means, that everything in project (Virtual machines, routers, etc.) is logically separated among other projects and resources. In this environment, we have made two experiments.

In the first experiment, students installed their own virtualization platform – DevStack. In this environment, students built their own virtual instances and tried basic functionality.

In the second experiment, students administered virtual network with several machines and active network components in department's OpenStack cloud natively.

A. DevStack environment

DevStack [10] is lightweight copy of virtualization platform - OpenStack. It is aimed to unexperienced administrators, to get familiar with administering clouds and IaaS (Infrastructure as a Service). DevStack can be easily installed on one server or virtual machine, so it's deployment is very easy, in compare of OpenStack.

Every student got his own project, with single VM (Virtual Machine) Ubuntu Linux 14.04 LTS with 2 core CPU and 6 GB of RAM. This Ubuntu was directly connected to public IPv4 network, reachable from the Internet. The first task for students was to install DevStack into their VM. It can be done by few commands, that can be found in [11].

After successfully installing DevStack, students had to prepare virtual environment for their VMs. First, they had to set up network connection, and create virtual network for their projects. First of all, they needed logical router. This router was connected to public network by one interface, and the second interface was connected to private inside network. The most important feature of this router is performing Network address translation (NAT), because internal networks had private IPv4 addressing schema. This router is shared among all virtual networks in one DevStack installation.

Next step was creating virtual network, in which will be hosted virtual machines. VM can be placed directly into private network, or can be placed into separate virtual network behind another router. Each separated virtual network needs a gateway, as an exit point. So we created another logical virtual router. One interface was connected into shared private network created in previous step. But from this router's perspective, it was a public network. Second interface was connected into private local network, in which the router performed NAT once again. So VMs were NAT-ted twice.

Last step was creating virtual machines in local virtual network. We had chosen CirrOS image. CirrOS is very small Linux with almost no tools designed for testing functionality of your cloud environment. CirrOS can run on very small resources, and needs approx. 15 MB space on hard drive. Students deployed two CirrOS VM in their virtual network.

In the Figure 2, you can see topology of student's network. The green rectangle is DevStack, virtualized platform that every student installed. Inside, there is yellow rectangle. There are virtual machines and network elements, that run in the DevStack.
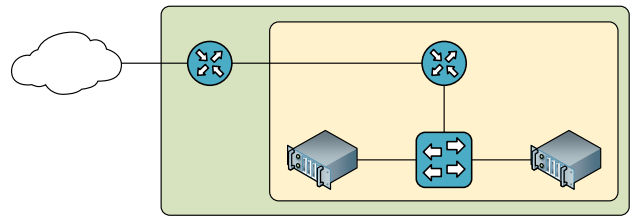
Figure 2: Logical topology in DevStack environment

We had 20 identical topologies. 18 for students, and 2 for teachers. Altogether, there were 20 Ubuntu VM running DevStack, in which were virtualized 40 CirrOS VM and 40 logical routers.

As we mentioned earlier, all these VMs were running on one physical server. On the server, there were no other virtual machines running at the time. We made measurements of used CPU and RAM. All VMs consumed 95 GB of RAM, and CPU usage was moving between 6.5 up to 9.5 %.

For measuring used amount of RAM, we used "*free*" command, and for CPU usage, we used "*top*" command.

We have to say, that all VM were idle, which means that they were just running without any memory or CPU intensive operations.

B. Basic topology

In the second experiment, students were working natively on our OpenStack environment. Every student got his own project. For protection of our physical resources, each project was limited. There was limit for at most 5 virtual machines. The project as a whole was limited to use max. 20 GB of RAM and 10 vCPU. The term vCPU (virtual CPU) can be an analogy to CPU core.

As well as DevStack experiment, there was 20 identical projects (18 for students and 2 for teachers), and everything was running on one physical server.

The topology was very similar to the DevStack experiment. There were three servers behind the router. In the picture Figure 3, you can see logical topology of one project, owned by one student. Every element in orange rectangle is maintained by student. There is one private IPv4 network behind the router.
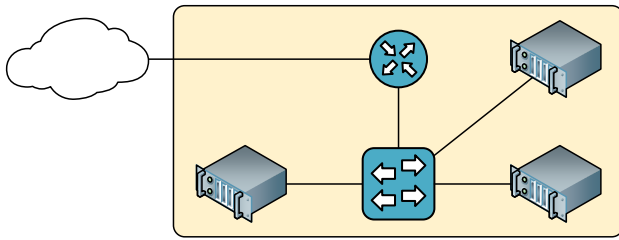
Figure 3: Logical topology of virtual network

Topology creation was divided into two parts. In first, students created topology by clicking it in web based graphical interface. In the second, the main part, students created topologies by orchestration scripts.

1) GUI topology creating

The most of OpenStack implementations offers web based GUI (Graphical user interface). In this GUI, a user can create many properties, such as network, routers, virtual machines, etc. But you cannot use all power, that OpenStack offers to you. Not all the properties are available through the GUI. Some of them are only available through CLI (command line interface) or orchestration scripts.

In the first step, students had to create network for their servers. The project they got, was blank. There was nothing, except one shared public network. The network, they had created had private IPv4 address space. For proper networking function, they had to create router with NAT capability.

Next, their task was to create three virtual machines in the private network. Every VM was Debian Linux 8.6.0, 64 bit. It had one CPU and one GB of RAM memory. HDD drive was 8 GB per virtual machine. Then, students had to connect to their VMs and update them.

2) Script topology creating

As we mentioned earlier, web based GUI does not offer all the options, you can get from OpenStack. Therefore, we taught students to use basic orchestration scripts. OpenStack use own language, called HOT (Heat Orchestration Template). Heat is one of the modules, OpenStack is built from.

Because of complexity of creating complex scripts, we had divided teaching it into several classes. But for the purpose of this paper, we will show it as one single task.

First of all, students had to create network with private IPv4 address space. Everyone could have same addressing. Despite of everyone's topology is hosted on one physical server, they are logically separated. Because of private address space, students had to create router with NAT ability. Routing and NAT-ting could be done by logical OpenStack router, or by regular virtual machine, such as some Linux distribution. We had chosen logical

virtual router, because it is much simpler to create and operate.

When we had underlying infrastructure, we could create virtual machines. In our topology, there are three VMs. One is web server, one is proxy server and one jump server. First server we needed to create was jump serer. Jump acts as SSH first hop to our topology. It is the only server, that you can SSH into and then SSH into other servers in the topology.

As you can notice, all servers are in the private address space. So the only way is to create static NAT translation for accessing server. In the cloud environment, this static record is called floating IP address. This address is assigned to virtual machine from a pool of addressees from external public network. From the point of view of Internet user, the server has public IP address. But actually, the server has private IPv4 address. According to **Error! Reference source not found.**, this is recommended approach. It is not recommended to assign VM a public IP address directly, always through floating IP. One of the reasons is, that if your server needs to be rebuild or moved to another cloud, it will get every time new private IPv4 address. With floating IP, you do not have to change anything (DNS for example), just to assign old floating IP to new virtual machine.

Another server, that we created was proxy server. Proxy is security element, that filters web traffic, in either inbound and outbound direction. We have implemented both, inbound and outbound proxy server. This means, that all traffic (HTTP requests and responses) to and from web server will go through this proxy server. Proxy is very often deployed in enterprise solutions. For this purpose, we deployed it in our topology.

Similarly, as on jump server, we used floating IP on proxy server. This has two advantages. First one is, that our real web server is not accessible directly from the Internet. For management access, we will use Jump server, and for web access, we will use Proxy server. The second advantage is, that we have three servers, but we need only two publicly accessible IPv4 addresses. In this setup, there can be several web servers, all would be "hidden" behind single proxy server.

The proxy server is intended for traffic going from inside to the public networks. This service was served by the Squid daemon. To the service doing proxy service from the Internet to internal network is referred as a reverse proxy, and usually acts as an "web firewall". This service was operated by Apache2 daemon.

Last server was web server, which hosted web pages. In our environment, there was just simple white page, just for proof, that we are accessing right web server. Our web server had very simple setup. There was just installed Apache2 web server with simple page. For security reason, we set up firewall allowing web traffic only from Proxy server. But this step is optional.

OpenStack HOT (Heat Orchestration Template) scripts allows not only build desired topology, but also

build virtual machines with predefined scripts. This means, that when is the machine spawned, it runs predefined script. So administrator can completely customize his VM right after booting. Script can be written in Linux shell or Windows PowerShell, so machine could be completely customized, including installation and setting new software. OpenStack require to write these scripts in the YAML (YAML Ain't Markup Language) format.

In the Table 2 you can see an example of a functional HOT script. This script creates web server directly connected to external network. In the part "user_data", there is simple BASH (Bourne again shell) script, that installs and then restarts Apache2 web server. This BASH script is executed only once, during first booting of VM. It is not executed during starts and restarts of VM later.

```
heat_template_version: 2016-04-08

description: Web server

parameters:
  net:
    default: net
    label: Name of external network
    description: Network for server
    type: string

resources:
  web_server:
    type: OS::Nova::Server
    properties:
      name: web_server
      image: Debian_8.8.0_amd64
      flavor: Linux
      networks:
        - network: {get_param: net}
      availability_zone: any
      user_data:
        str_replace:
          template: |
            #!/bin/bash
            apt-get install apache2 -y
            systemctl restart \
            apache2.service
          params:
            $network: {get_param: net}

      user_data_format: RAW
```

Table 2: HOT Script

The final and correct script from our students should create and set up three servers (jump, proxy and web) in private IPv4 network behind NAT router.

V. CONCLUSION

In this paper, we would like to show our approach of using Cloud Computing in the education. On one side, we were using private cloud platform, OpenStack, as a part of

education and offering it to students, so they can use it all the semester from any place with Internet connectivity. And because it is running on server which is still up, students can access their topologies 24/7 until the end of semester.

On the other side, our students learned, how to use and administer cloud environment. Lots of companies are moving their infrastructure to cloud and virtual environments. We consider this as benefit for our students, that they can get familiar with concepts of clouds during their studies.

We hope, that this paper will inspire more universities and schools for integrating clouds and virtualization into their study plans.

VI. FUTURE WORK

In the future, we would like to preserve this subject, and use clouds more intensively in education. One of candidates is our subject Network Operating Systems, in which we teach administering Windows and Linux in networking environment. On these servers run network services such as DHCP, DNS, NTP, web, e-mail, etc. Recently, we are teaching this subject on virtual machines in Oracle VirtualBox in desktop computers in our lab. But we would like to run these virtual machines in our cloud. We consider several advantages by this approach. First is, that these topologies will be running nonstop. So students would have possibility to work on their servers anytime, not only during classes. Second advantage is for teachers, that they will not be limited to classroom with specific computers, but they will be able teach subject in any classroom equipped with computers and network connectivity.

VII. ACKNOWLEDGMENT

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Analysis and Implementation of Adaptive Course in Moodle

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Abstract— **LMS Moodle is one of the most used LMS's in support of daily teaching, even as an external (combined) form of education. LMS's are focusing on support of education by utilizing ICT. The electronic educational course is the base unit. Its characteristic structure results from a pedagogical assumptions and content plans of individual subjects. In the present, these electronic educational products focus mainly on the personality of the learner. We try to find possibilities of the LMS, which enable adaptivity of the educational process according to individual characteristics of the participants of the e-course. An important aspect for a successful implementation of the e-course is to be familiar with the particular system and environment. SWOT analysis may be used for that reason. In the paper, we present some examples of utilizing adaptivity in educational process.**

I.   INTRODUCTION

In the beginnings of e-learning, several authors pointed out that in addition to its positive aspects, there are some negatives it brought along. One of the major shortcomings was disregarding the individual characteristics of the student. P. Brusilovsky [1] In his publication, this concept was named "one size fits all". As an example of this concept can be the presentation of the same study material to all participants of the e-course.

Mass education in a classroom or with the help of classic e-learning is not able to respond to individual needs of a studying individual. Some students are restrained and bored by it, other may, on the other hand, find it too quick and fail to understand everything, or the education style of the teacher might not be suitable for them. Other students are satisfied with the pace of education, but they may not be identiied with the teaching style of a teacher. Therefore, such students come to dislike the teachers and subjects they teach, which results in them having worse results [2]. The reasons stated above have led to efforts to personalize the content of e-learning courses according to individual characteristics of each specific user class. Every student is determined by a set of their individual characteristics. These characteristics include their expectations, motivations, habits, learning styles, needs etc. Based on these traits we can divide students into individual groups [3].

Personalization of education represents each student's way of learning with regards to their previous knowledge,

skills and their learning style. A set of attitudes and behaviors which determine an individual's preferred way of learning is considered a learning style [2].

The research of J. Hayes and C. W. Allinson (1996) confirmed that if a teacher uses teaching strategies that respect the student's preferred learning styles, they show more enthusiasm, display positive attitude and interest in learning [4].

Our goal is to utilize system tools that automatically help us identify the above stated individual characteristics of students. We are convinced that the more aspects we consider, the more precise personalization we can create. Prior to the implementation of the personalized course we have decided to analyze the selected LMS Moodle and create a model of an e-course utilizing a simulation tool.

Our paper is organized as follows. In Sect. 1, we present the related work we have divided into two parts. In the first part, we deal with the definitions of adaptivity and personalization. In the second part, we present solutions in the field of personalization of teaching courses. In Sect. 2 we describe the model of student transition through the personalized e-course with the support of adaptive elements. The conclusion includes a summary and discussion of further work.

II.   RELATED WORK

A.   Personalization vs. adaptivity

In scientific publications dealing with the issue of personalized systems with adaptive options, there is a certain differentiation of the meaning of concepts of adaptivity and personalization. For the average reader, therefore, it may be problematic and in some cases confusing to find out what the concepts of adaptivity and personalization mean. This may also be due to the fact that these concepts can be understood in several respects. Concepts of adaptivity and personalization are not only used in computer science, which may be another reason for their misunderstanding and, consequently, their definition by some authors. First, we need to realize that we will discuss activities that are related to teaching activities in computer science, specifically the adaptive options of the selected LMS. Our aim was to study many relevant foreign and domestic sources dealing with the issue, analyzing and selecting the definitions that best describe the nature of personalized systems with adaptive support.

According to Drlík [5] personalization means delivery, providing personalized content to a particular user. He is

of the opinion that the concepts of personalization and adaptivity are closely related. Furthermore, the personalization is seeing as "solving the problem of providing the user with the most comfort in working with the system." It follows from the assertions of Klimeš and Šamánek [6] that a personalized system can be considered as one that adapts to the requirements and needs of individual users. Bieliková and Návrat [6] state that, in addition to providing personalized information to the user, the task of personalization is to determine which information is most relevant to him and presents it in the most appropriate way. According to Basye [8] personalized learning involves the student in the creation of learning activities and relies more heavily on a student's personal interests and innate curiosity. The most effective application of true personalized learning would require one-on-one tutoring for every student based on their interests, preferences, needs and pace. Personalized learning is often conceived of as an instructional method that incorporates adaptive technology to help all students achieve high levels of learning.

According to Drlík [5], who deals with the adaptation of the user interface, he distinguishes between the concepts of adaptability and adaptivity. The main criterion is how the system customization (user interface) is implemented. Adaptive interfaces dynamically change their interface to constantly support the user in their activity, while adaptable interfaces only provide the user with various adaptation mechanisms for this change. Thus, dynamism can be considered as one of the basic attributes of an adaptive system. A lot of authors in their works draw attention to the importance of creating a user model, which is one of the tasks of adaptive systems [1]. There are several approaches leading to creation of this model. According to Kostolányová [9] an adaptive LMS monitors the behavior and characteristics of a particular student, stores this information and continually evaluates and updates the system. Based on the evaluation of this information according to Kapusta and Švec [10] adaptive systems change their structure, functionality and interface to meet the different and changing needs of an individual or group. As stated by Turčáni [10], the adaptive system also provides means for dynamically adapting the presentation, content or navigation, which, in addition to the current user characteristics, also considers the environment in which the information is provided.

These arguments therefore indicate that the system must meet certain criteria in order to be considered as adaptive. These requirements have been summed up in publications of Paramythis and Loidl-Reisinger [12], according to which an adaptive system is considered to be one that can:

- monitor the activity of their users;
- interpret these activities based on specific domain models;
- deduce user requirements and preferences from interpreted activities;
- suitably represent them based on associated models;

- respond appropriately based on available knowledge about its users to dynamically facilitate the learning process.

We will summarize the above findings to describe the mutual relationship between personalization and adaptivity. We argue that adaptivity represents the means provided by a system that allows for the collection and storage of user data and allows them to dynamically change system elements that aim to personalization.

B. Selected methods of implementation of adaptive systems in teaching

LMS's are commonly used in e-learning, but provide low level of adaptivity. By combining adaptation and personalization into LMS, a new kind of tailored learning environments which motivates learners can be built [2]. Efforts to make various modifications of personalized e-learning environments can be seen in ([2], [3], [13], [14], [15], [16], [17], [18]). Popescu developed the WELSA system which is an Adaptive Educational Hypermedia System (AEHS) that adapts educational resources to the learning styles of users [15].

Graf attempted to exploit the advantages of LMS and proposing the use of adaptation techniques in Moodle. The Felder-Silverman Learning Style Model (FSLSM) was used in this case, but its visual/verbal dimension was ignored in the development of educational resources, mainly because it is time-consuming [13]. However, this concept may lead to distorted results because the educational process is not completely personalized. Kazanidis and Satratzemi developed the ProPer system which adapts presentation and navigation according to a complex user model where learners' knowledge, educational objectives and learning style are represented [14].

Baylari et al. [16] presented a personalized multi-agents E-Learning system based on Item Response Theory, which presents adaptive tests to estimate learners' knowledge and enables it to make changes according to their needs and background.

Zhuge and Yanyan proposed the KGTutor; a Knowledge grid based intelligent system personalised E-Learning system that examines each learner requirements such as previous knowledge and the learners' targets and then provides them with a personalised course. The system can also provide the learner with progress reports, evaluations and suggestions based on their performance [17].

Yarandi et al. [18] proposed approach for developing personalised E-learning system, which use ontology for creating user model according his behavior. Moreover, they are using an ontology to build the hierarchical and navigational relations between different parts of learning materials.

Despotović-Zrakić et al. [3] developed a method for creating adaptive distance education courses in the Moodle LMS. The courses are organized and adapted to 3 clusters of students according their learning styles. Interesting thing is, that they use just default functionalities of LMS Moodle for that.

Magdin and Turčáni modified the module Book in LMS Moodle. They provided an advanced adaptive behavior of the original module and named this module as AdaptiveBook. They use Index of Learning Styles questionnaire (ILS) to match the suitable learning style to each student [2].

Karagiannis, Satratzemi decided to adapt a hybrid dynamic user model based both on learner knowledge and behavior and static modelling. The learner must answer ILS and to declare his/her objectives at the beginning of the course. Regarding dynamic modelling, data comprising the number of visits to each type of learning object and the duration of these visits, are used as input in a decision tree algorithm. Besides mining behavior data, dynamic modeling implies knowledge progress calculation [19].

In the present, there are ongoing efforts to develop more effective concepts that could be employed in applied learning adaptation systems. This clearly indicates that the issue has its own history, yet it is still relevant today. It is, however, increasingly difficult to devise a unique concept of a personalized course. Therefore, our intention is to use the knowledge from the studied literature to develop our own methodology of using a personalized e-course. Furthermore, we want to monitor the impact of adaptive properties on students' behavior from multiple perspectives when going through these courses.

III. ANALYSIS AND IMPLEMENTATION OF LMS MOODLE IN TEACHING

To determine the advantages and disadvantages of used LMS, the most appropriate method is to analyze its properties. For this purpose, we decided to use a strategic SWOT analysis to present these findings as strengths and weaknesses as well as external factors affecting the system in terms of possibilities and threats [20]. The SWOT analysis was originally created for the business sphere, where it is also primarily used today. Its use will be provided by the simultaneous linking of the analysis of the university environment with the software analysis. In the internal analysis, we consider the strengths and weaknesses of LMS Moodle in terms of implementation in the university environment, namely at The Department of Informatics (DI) UKF in Nitra. In the external environment, we identify opportunities and threats in all major areas of the organization [21]. The university environment and all elements that affect it will be considered the external factor which influences a successful implementation. All the strengths and weaknesses of LMS Moodle, along with the possibilities and threats in its implementation, are presented in Fig. 1.

Based on the results of the SWOT analysis, our goal will be to eliminate the negative factors associated with the use of LMS Moodle, respectively, to reassess the suitability of its use at the DI. After the initial analysis,

Strenghts:
- free of charge
- used at our university
- intelligibility
- multiplatform
- multilingual system including the support of Slovak language
- support of adaptive elements
- simple administration
- evaluation of students
- support of group activities
- open-source
- plug-ins
- an online community
- regular upgrades
- the most used LMS in Slovakia

Weaknesses:
- high upload limit
- surveying study materials
- limited functionality
- necessary hosting
- need to connect to the Internet

Opportunities:
- students are comfortable using it
- introduction of the subject of e-learning technology
- creation of work methodology with an adaptive LMS

Threats:
- the inexperience of students working with an e-learning course
- students not willing to cooperate in the research
- insufficient readiness of teachers to work with an adaptive system

Figure 1. SWOT analysis

however, we did not find a more serious reason to persuade us to think about changing the LMS Moodle.

Apart from the fact that LMS Moodle is free, its use brings with it many other benefits. The most important criterion for us was the support of adaptive elements for personalizing the subject matter, which the system meets either by its predefined features or plug-ins that are available at https://moodle.org/plugins/. Since we are dealing with an open source platform, we can create new functionalities and implement them directly into the system under open license.

On the other hand, one of the biggest weaknesses of the system is the limitation of uploading of the finalized assignments, specifically 128MB (at the DI), which is in some cases inadequate along with the absence of a search engine. Moodle has tool only for searching courses, but tool for searching study materials according to keywords is still missing. This tool could allow students to get a faster orientation in the study materials. We use hyperlinks in our e-course for this purpose, which we minimize this deficiency.

According to Carvalho et al. [22] the first LMS used by the student influences his future preferences towards the given system. LMS Moodle is the most widespread college LMS in Slovakia, gradually advancing in secondary and elementary schools. It has been in use for several years now at UKF in Nitra, so we expect the students to have the greatest experience working in the LMS Moodle environment.

Among the threats, we have identified a potential inexperience for incoming students to work with an e-learning course, as LMS Moodle is not as widespread at secondary schools as it is in the university environment. However, this threat could be removed by introducing a subject that would teach students to work effectively with the e-learning environment as soon as they begin their studies at the university.

This analysis is just a sketch of the initial observations. In the future, we also aim to keep it up-to-date, especially for new findings. The next step will be to eliminate identified weaknesses through the strengths of the system and the opportunities offered by the university environment.

IV.   THE METHODOLOGY OF USING THE LMS MOODLE
ADAPTIVE OPTIONS

Another point that we have set is to create the structure and content of the e-course based on adaptivity possibilities and needs. For these purposes, we have decided to use modelling methods to formalize the problem. The decision went to a graphical system with the possibility of simulation. For stated purposes, the most appropriate modelling system was the one utilizing the Petri Nets (PN). It is a graphical and mathematical tool for modelling, analysis and verification of the properties of discrete systems. [23]. We chose this tool mainly because of its clarity and a well-defined mathematical basis. The advantage of PN lies in their formal description and a detailed graphical image [24].

In order to be able to create a model of a system that we have to simulate, it is essential that we adopt the logical-mathematical rules that govern the PN and work with the simulation program. To create a model and simulation of PN, we used the TransPlaceSim program, which was developed at the DI UKF in Nitra [25]. In our case, it is a user-driven e-course model created by LMS Moodle. The content of the course is divided into study lessons per individual week in the semester. Through the adaptive elements listed below, our goal is to motivate students to study regularly. This eliminates the so-called "phenomenon of procrastination" of students during the semester which can positively affect the effectiveness of the study, the quality of knowledge and the reduction of the stress factor before examination.

The process of creation of a personalized e-learning system according to Despotović-Zrakić et al. [3] includes the following:

- Defining goals and models of personalization;
- Collection of data necessary for personalization;
- Data Analysis;
- Distribution of students into specific groups;
- Adaptation of the e-course based on defined groups;
- Implementation of teaching using an adaptive e-course;
- Evaluation of the e-course personalization.

Whereby the individual steps should not be done separately but as an integral part of the iterative and dynamic process of creating adaptive e-learning. Our efforts will follow as stated above. The specific implementation of the procedure is stated below. The next step is to create a specific questionnaire that we apply within Logical Systems (LS) and Computer Architecture (CA) subjects with the following steps according to Gavora [26]:

- setting goals,
- selecting a research file;
- specification of variables;
- construction of a questionnaire content page;
- data collection;
- computer data processing;
- interpretation of data;
- results and conclusions of the survey.

The questionnaire will collect the personal information needed to create the portfolio of the individual students. The research sample will be students of 1st and 2nd year of Applied Informatics and Teaching of Academic Subjects in Combination with Informatics, who study at the DI UKF in Nitra. We will use the tools offered by LMS Moodle to create a questionnaire. The questionnaire seeks to find information about new students with an emphasis on already acquired knowledge.

The questionnaire items will be implemented in the form of an interval scale, a dichotomous menu and a simple selection. The result will be the quantitative personalization of content for individual groups of

students according to how they assess their knowledge in the given field. To implement it, we want to use an adaptive presentation that will continuously verify the comprehension of the study material.

When transitioning through the course we address the adaptivity via functionalities based on IF-THEN rules offered by LMS Moodle. This is, for example, conditional accessibility, which restricts access to individual study materials and activities based on the rules defined by the e-course creator [27]. Restriction of access can be defined by factors:

- date and time;
- based on the results of previous activities;
- completing some of the activities;
- belonging to a specified group;
- the language used;
- profile information of the user;
- a combination of the above.

When setting the e-course conditions, we can set them to prevent the activity from being displayed during the e-course, or appear as an inactive hyperlink together with information about the conditions that need to be met to activate it.

LS and AP subjects are realized weekly in the form of lectures and exercises. At the introductory exercise, students will fill in the input questionnaire and will be divided into groups based on its results. We decided to create two experimental and two control groups. Students in the control group will have unrestricted access to all materials throughout the semester and will study according to the original e-course. In the experimental group, students will be provided with an adaptive lecture in such a way that the chapters will be followed by questions that will verify the understanding of the chapter. If a student responds correctly, he/she will continue with the lecture, otherwise he/she will be given feedback and an expanding explanation of the curriculum. The adaptive lecture will be linked to other activities and resources that will be recommended to the student based on his/her behavior while studying the subject.

Successful completion of the lecture will be a prerequisite for the student to be able to access the Quiz activity. We decided to choose this activity as the main control point of each lesson that will verify the student's knowledge and provide feedback. Upon scoring enough points in the quiz, the student will be given access to additional study materials and to the next lesson. If the student does not achieve the required number of points, he/she will have to improve their study of the issue. After completing the quiz, he/she will be aware of his/her shortcomings through feedback and will rely on the place in the course as well as the external resources where the information about the issue is located. After re-learning, he will be able to go back to the quiz activity. The deficiency of LMS Moodle is that it does not contain functionality that would reveal the actual time the student has spent on studying the issue. We partially eliminate this deficiency by using an adaptive presentation so that this activity

encourages the student to work actively with the study material. To ensure the maximum reliability of the quiz, this will be time-limited with the ability to generate questions in the quizzes taken from the file and also limited by the number of attempts. In case the student is unsuccessful in the exam more than twice, a special consultation with the teacher will be recommended to determine his / her future direction.

The sketch of the model that meets the personalized approach is shown in Fig. 2. In the next period of problem solving, we are considering using plug-ins to support adaptivity and personalization in the selected LMS Moodle.
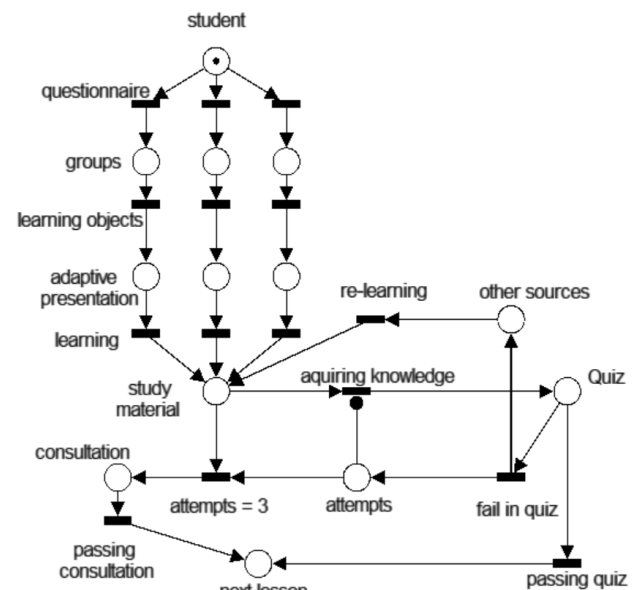

Figure 2. The model of student transition through the lesson

We aim to use the described methodology in teaching during the school year 2017/2018.

DISCUSSION AND FUTURE WORK

For a more detailed analysis of the system in the future, we would like to use the concept of quality assessment of educational technologies according to www.evaluedu.sk. The study results of the students from the experimental groups are compared with the results of the control groups as well as with the results of the students who have already completed the subjects in recent years. We obtain this information from the Academic Information System (AIS). Next, we will look at the correlations between student behavior in individual groups and their learning outcomes. We want to monitor and analyze student behavior in e-courses by using The Inspire plugin, which implements open source, transparent, next-generation learning analytics using machine learning back-ends that go beyond simple descriptive analytics to provide predictions of learner success and ultimately diagnosis and prescriptions (advisements) to learners and teachers [28]. After the analysis, we want to utilize the data obtained to create a new personalized course concept in the future.

CONCLUSION

Although the above problems have been addressed at the DI for an extended period of time, we still encounter students with their specific characteristics. Based on the above, it is necessary to thoroughly analyze the status of the learner and his / her level of knowledge and adapt his / her study to meet the study requirements. The article deals with the individual activities that accompany students in selected subjects and is part of a research project within the UGA grant agency.

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Using Virtual Reality in Education

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Abstract – The main purpose of this article is to describe and summarize experiments with creating training applications using virtual reality devices. The arrival of new and more advanced virtual reality headsets opens up more opportunities and applications. This article deals with the current state of virtual reality and its application in education. The first chapter describes basic information about virtual reality. Following chapters give a detail about some experimental applications that were developed for the virtual reality, and lastly, there are mentioned the benefits of those applications and the basic user reactions.

I. Introduction

With the increasing capabilities of modern computer hardware, more applications of these technologies are available in the field of education. Among these modern and fast developing technologies belongs virtual reality. This new trend demonstrates the enormous interest of large companies engaged in development and support. These include Google, Microsoft, HTC, etc. The interest in virtual reality is also seen in the game development when every year there are more and more titles which support virtual reality headsets.

The main purpose of this article is to describe and summarize experiments with educational applications for virtual reality, which we developed for testing and demonstration purposes of modern, widely accessible headsets.

II. Virtual Reality

First attempts at simulating complex systems came with the first 8bit computers, where users could simulate various systems through games. One such example is a game called Scram [1]. Scram (Fig. 1) is a game designed by Chris Crawford for the Atari 800 and released by Atari in 1980. Written in Atari BASIC, Scram utilized differential equations to simulate reactor behavior. In the game, the player controlled the valves and switches of a nuclear reactor directly with the joystick.

Attempts at simulating complex systems go back to the first 8bit computers, sometimes via the game media.
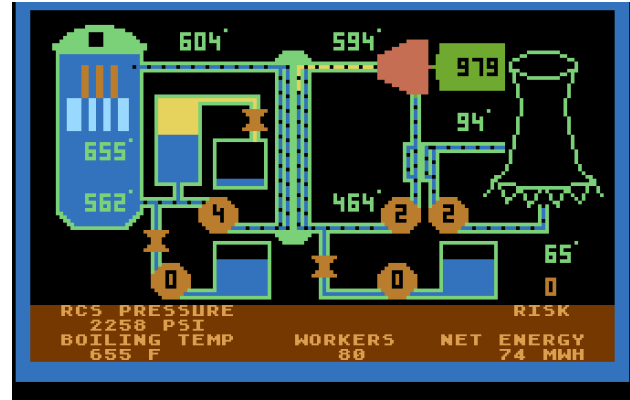

Figure 1.   Game Scram which simulate reactor behavior [1]

The computer technology has advanced quite formidably and one interesting technology is the usage of virtual reality. With the help of virtual reality [2], we can simulate an illusion of real or fictional worlds, most commonly using special virtual reality headset that is worn on the head. In the headset, the user can see a simulated environment, usually displayed on a stereoscopic display. Headset movement is tracked and the resulting image is modified depending on the position of the user relative to tracking devices.

Today's most common virtual reality devices are:

- Oculus Rift,
- HTC Vive.

Both headsets offer quite similar experience in the virtual environment.

A. Oculus Rift

Oculus Rift is considered to be the first major virtual reality headset that showed the potential of VR with using modern hardware. It is developed and manufactured by Oculus VR.

Their headset Oculus Rift DK1 was one of the first headsets available for virtual reality development. This version featured a resolution of 1280x800px, which is quite low compared to today's headsets. When wearing the headset some users had complaints about motion sickness, mostly due to low resolution and display refresh rate [3].

When using the headset, a raster grid can be could be seen, meaning the individual pixels were noticeable, which broke the immersion inside the virtual environment.

Figure 2.   Oculus Rift VR Headset [3]

With more advancement in the technology came Oculus Rift DK2 and finally Oculus Rift CV (Consumer Version) (Fig. 2). Comparison of technical features of these devices is shown in table 1.

TABLE I.
BASIC HEADSET COMPARISON

Model	Resolution	Refresh Rate
Oculus Rift DK1	1280 x 800	60Hz
Oculus Rift DK2	1920 x 1080	75Hz
Oculus Rift CV1	2160 x 1200	90Hz
HTC Vive	2160 x 1200	90Hz

Users report fewer problems with motion sickness when using headsets with higher refresh rates.

B.   HTC vive

The headset HTC Vive (Fig. 3) was made in collaboration with PC games giant Valve and works with Valve's mammoth gaming ecosystem, Steam. HTC packs in 70 sensors to offer 360-degree head-tracking as well as a 90Hz refresh rate – that's the stat that's key to keeping down latency, which is the technical term for the effect that causes motion sickness [4].

Figure 3.   Oculus Rift VR Headset [4]

The most common applications for virtual reality are video games. However, there are also available commercial applications focused on certain fields, for example, medicine. These are however expensive or difficult to access. Our goal was to examine the options of modern headsets for virtual reality and develop certain testing applications, focused on education.

The HTC Vive comes with two motion controllers. These are held in both hands by the user, while inside the virtual environment. These controllers allow him to move around or interact with certain objects.

Virtual reality is intended for everyone, however, the minimal recommended age for using the headset is at least 13 years (for the Oculus Rift). What is puzzling is the fact, that most modern arcade rooms with virtual reality allow the minimal age of 8 years or even 5 years. At this age, children are still developing their eyesight and it is not recommended for them to use the virtual reality headsets.

We used the HTC Vive device while developing our example applications, in addition to a powerful computer using Intel Core i7 processor, 16GB RAM and NVIDIA GeForce GTX1070 graphics card.

C.   Play Area for Virtual Reality

There are basically two options to set up your play area for virtual reality.

One way requires the user to have plenty of space to move around. The HTC Vive recommends an area of approximately 3.5m x 3.5m. This is due to the maximum distance between tracking base stations being 5m. The user can use this area to move around, for example, to reach for an object inside the virtual environment (Fig. 4). When the user wants to move outside of this boundary, the hand controllers mostly offer to teleport inside the virtual environment. A virtual grid is displayed to the user inside the headset when he is getting close to a boundary in the play area and thus letting him know his approximate position within the virtual environment.
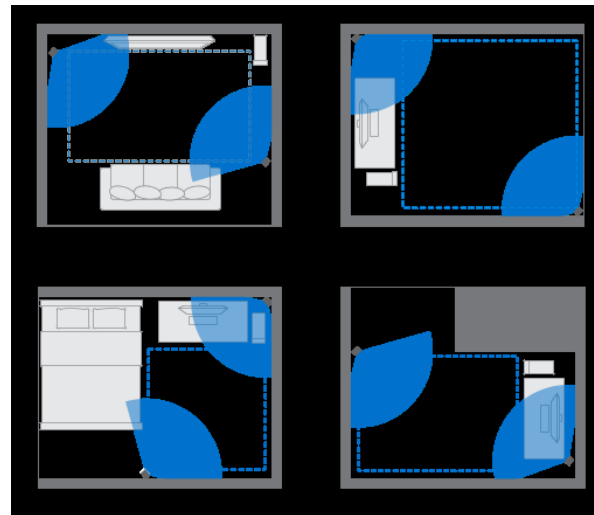

Figure 4.   Play area arrangement [4]

The second option for the user is to sit in the chair while wearing the headset. This is most common approach when there is not enough space for the user to maneuver properly. Input devices can be mouse and keyboard or a gamepad. This is how the older Oculus Rift headsets worked (for example Oculus rift DK2). The new Oculus Rift Consumer Version has already the Oculus Touch controllers available.

Both variants are commonly used, meaning that our applications should support both.

However, in our case, we focused mainly on the first option, that gives the user more freedom of movement and allows better immersion in the virtual environment. More

information about these options and setup can be found here. [2].

III. APPLICATION DEVELOPMENT

Application for virtual reality can be developed using various tools. If the goal is to achieve a realistic look, one appropriate option is to use a modern game engine. A game engine is a tool used to develop modern games 3D and 2D applications.

Most common modern engines are:

- Unity 3D [5]
- Unreal Engine 4 [6]

Both engines have their pros and cons, although for our purposes we chose Unreal Engine. Mainly because of its support for the C++ programming language and the ease of achieving a realistically looking result. An example of the development environment in Unreal Engine 4 is shown in figure 5.
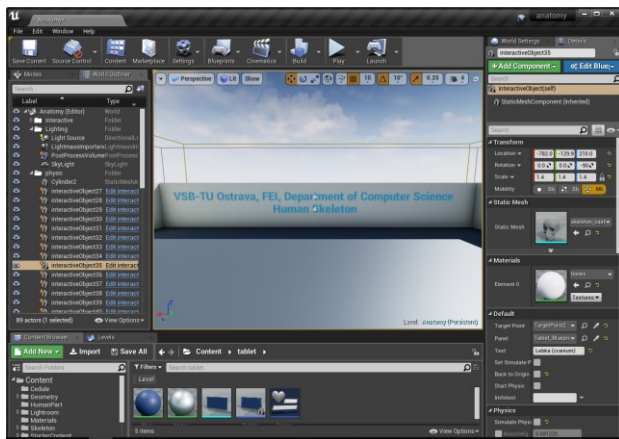
Figure 5.   Unreal Engine 4 Editor

IV. TEST APPLICATIONS

For testing and demonstration purposes, several example applications were developed focused on different disciplines. Afterwards, these applications were tested on users. The topics were chosen to be challenging to implement and visualize, testing the capabilities of chosen tools and skills of developers.

A.   Visualization of the human skeleton

The very first application was the visualization of the human skeleton. Our goal was to enable interactive inspection of individual bones that form the human body. For these purposes, a low-resolution model of the human skeleton was created.

To modify the skeleton model, we used an open-source 3D tool called Blender [7]. Individual bones were edited to suit our purposes and the final model was approximated to use roughly 500,000 triangles to form the surface of the skeleton (Fig. 6).
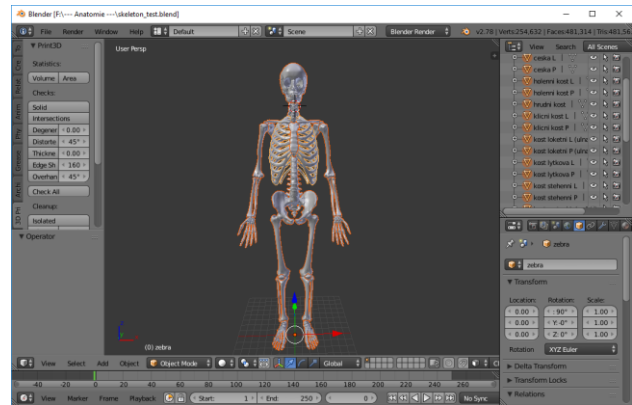
Figure 6.   Human Skeleton Modification in Blender

Afterwards, individual bones were exported from Blender [8] using the FBX file format and imported into the Unreal Engine 4 [9]. Inside the Unreal editor, appropriate materials and collision models were applied to the models and placed into the virtual scene.

Inside the virtual reality, the user can inspect the human skeleton. Using interactive HTC Vive controllers, the user can interact with the skeleton [10]. For example, he can pick up individual bones, bring those closer to the user's head and inspect them up close, see Figure 7.

Figure 7.   Practical testing with HTC Vive

For basic information about individual bones, a virtual tablet was created and placed into the scene. While holding a certain bone inside the virtual environment the user can pick up this tablet and read there some information about that bone.

For the purposes of testing, two variations of the skeleton were created. The first variation had the bones which always returned to their place after being let go, while the second skeleton had their bones stay in midair, allowing the user to disassemble the skeleton completely.

While testing this application, we encountered interesting moments. When the user found out that the second skeleton could be disassembled, the majority of the testing group immediately started creating their own version of the human skeleton.

In the next part, we tested objects that were physically simulated, meaning they could be thrown around. When the user lets go of these, physics simulation was activated and these objects behaved as if real.

Figure 8.   Virtual table with human parts

These objects were placed on a table (Fig. 8) inside the scene. Turns out that this was not the best solution. While the users wanted to pick these objects up, they found that they could not reach so far, due to space limitation of the play area. In addition to that, some users wanted to lean on the table (visible only to them inside the headset), while reaching for those objects, which could potentially result in accidents.

B. Solar System Planets in VR

Another exemplary application was the visualization of planets of our solar system. The main goal was to display the individual planets in their relative sizes to each other so that the user could see the size difference between them. Thanks to the use of virtual reality user could also grab and closely inspect every planet's surface.
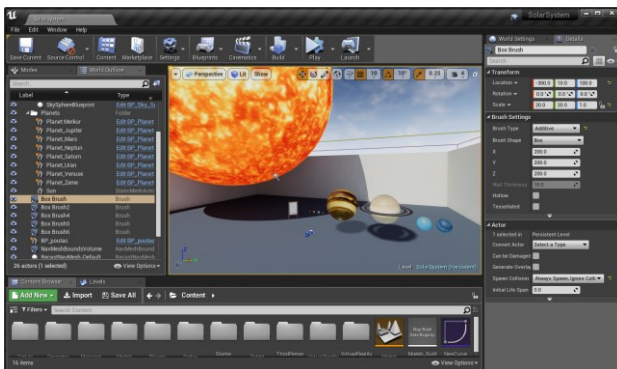

Figure 9.   Solar System Planets

Due to the selected scale of the planets, of course, the sun had to be modeled in the same scale. So, in the end, the sun occupied a very large portion of the scene. Interestingly, when looking through the monitor, the size of the sun did not surprise anyone. When using the headset, however, most users were amazed by the size of the sun compared to other planets (Fig. 9).
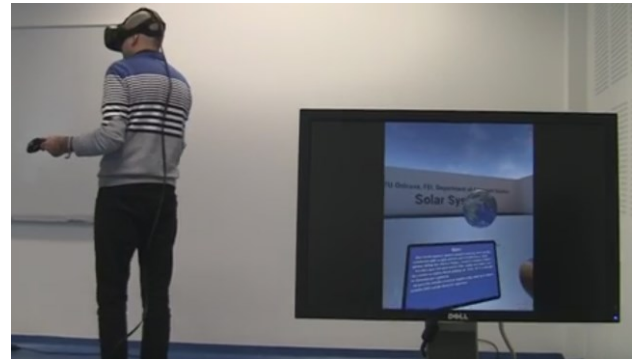

Figure 10. Solar System Planets

In the scene, there was also a virtual tablet (Fig. 10), which displayed the basic information about each planet. So, the user could grab any planet, view it, and read the basic information about it.

C. Interactive architectural visualization

Another experimental application is in the field of architecture. Our effort was to visualize the architectonic project as realistically as possible, and thus test the possibilities of realistic rendering in conjunction with virtual reality.

At the beginning, we chose the appropriate project [11], which in our case was the project of a family house in ArchiCAD (Fig. 11).

Figure 11. Family house - 3D model (ArchiCAD) [11]

First, it was necessary to remodel the entire scene (Fig 12) in a mesh-based modeling software, and then transfer the individual models to Unreal Engine (Fig. 13). Because of the number of individual objects and the complexity of the whole scene, optimization was a big part of this project.

Figure 12. Family house - 3D model (ArchiCAD) [11]

During the rendering of more demanding scenes, the refresh rate of the screen may drop from HTC Vive native 90Hz to 45Hz or less. With this drop in the rendering frequency, there is already visible tearing, which causes unpleasant feelings and motion sickness to some users (kinetosis) [12]. To avoid such problems, optimizations are inevitable, such as reducing rendering complexity and level of detail [13], [14].

Figure 13. Visualization of the family house in VR (Unreal Engine 4)

Thanks to the use of virtual reality, the user can move freely both inside and outside the house and get a better idea about sizes of individual rooms, furniture, and overall layout. The realistic look further enhances the entire experience, when walking through the building the user can feel like he is in a real house (Fig. 14).
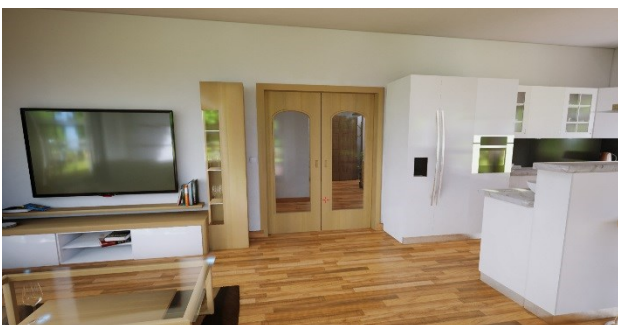

Figure 14. Interior of a family house (Unreal Engine 4)

Compared to the original project, which included only a few renderings and floor plans of the house, using virtual reality to move anywhere in the house is much more realistic and prominent.

For instance, when somebody wants to build a house and must make decisions based on a ground plan and several rendered images, he can never form a real picture of the finished house.

However, if he could walk through the planned house in virtual reality, he could create a very realistic image of what the final house will look like. He could also have remarks about individual parts before construction, which will increase the customer satisfaction.

D. The Dukovany Nuclear Power Plant

The last and the biggest project is the visualization of the Dukovany nuclear power plant [15]. Nuclear power plants are among the structures that are problematic to view. Certain parts of the nuclear power plant cannot be publicly inspected either because of security or because of health reasons. An example of such place is a nuclear reactor, as only trained employees have access there.

We used panorama imagery as a reference for modeling every individual part to gain some insight into the layout of buildings and interiors (Fig. 15 and Fig. 16).
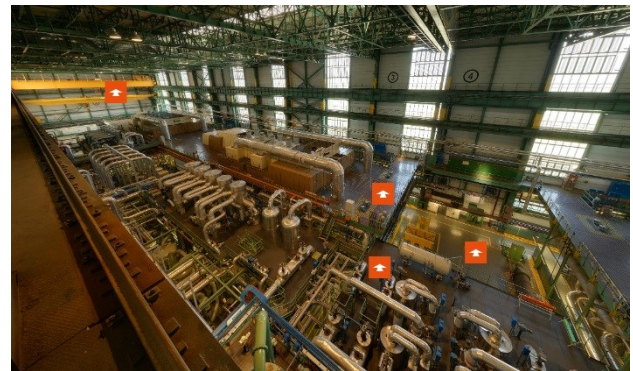
Figure 15. 360-degree panorama image of machinery room (Unreal Engine 4) [15]

Modeling according to such reference is more complicated and sometimes it is not easy to guess the right proportions and positions. Because of the complexity of the whole project we had to study basic principles and modeling only the most important parts. There was also a problem with looking up appropriate documentation and description for individual parts of the nuclear power plant, which complicated the creation process.

Figure 16. 3D visualization of the machinery room (Unreal Engine 4)

Similar problems arise when modeling the outdoor environment and the basic buildings, as the existing resources are relatively limited. Figure 17 shows a view from one of the cooling towers.

Figure 17. 3D visualization of the exterior of the Dukovany power plant (Unreal Engine 4)

V. CONCLUSION

All conducted experiments have shown that the use of virtual reality (HTC Vive) offers great opportunities for all scientific disciplines. It also offers big opportunities in the field of education, where it allows to visualize real and fictional scenes and thus allows viewing inaccessible places.

During testing, the described applications were tested on more than 1,500 people, and the results were always very positive.

ACKNOWLEDGMENT

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Preliminary evaluation of the multimodal interactive system for NAO robot

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Abstract—**The proposed paper brings a description of the pilot version of the multimodal dialogue system for NAO humanoid robot. Designed system enables multimodal interaction with the user in such manner that it takes a speech input from the user and it answers by a combination of synthetic speech and gestures. The core of the system is an external dialogue manager, which interprets VoiceXML language. A pilot speech communication application was designed and a preliminary evaluation was performed using subjective methods. Results of the preliminary evaluation highlights importance of involving gestures into communication exchange. Moreover the paper brings a discussion of usage scenarios, where designed system can be used for educational purposes.**

I. INTRODUCTION

Nowadays, we can observe a rapid involvement of speech technologies, as are automatic speech recognition, text-to-speech systems and natural language processing, into distinct types of human-machine interfaces (HMI). The importance of speech technologies grows thanks to new types of devices with new types of interfaces as are smartphones, smart watch, virtual reality (VR) devices (glasses) or other household appliances, that are designed in the concept of internet of things.

Humanoid robotics can be identified as the next very important area, where speech technologies are located. The result of undeniable effort to develop artificial human is several humanoid robots (e.g. Honda Asimo, Aldebaran NAO, Pepper) with different capabilities and with a different degree of human-like appearance [1]. With an improved appearance of humanoid robots, people tend to expect a human-like behavior, including speech production [2] and hearing capabilities.

The communication between people has a multimodal character. It means that information is usually shared through more sense (modalities). To make human-machine interaction to be more human-like, multimodal transfer of information is required.

In case of humanoid robots, gestures can be considered as a very appropriate channel for information sharing together with speech. Combination of speech and gestures supports natural and effective human-robot interaction. Moreover, gestures can convey so called "backchannel signals", which contribute to smooth communication [3], [4].

To make the process of preparing dialogue interactions with NAO robot more effective and simpler, we designed and developed the multimodal dialogue system, which enables multimodal communication with Aldebaran NAO robot. The designed system is the asymmetric multimodal dialogue system, which allows users to interact with robot by voice and robot uses speech and gestures to answer [5].

The core of the system is an external dialogue manager VoiceON [6], which manages interaction based on interpretation of VoiceXML applications.

Figure 1. Humanoid robot NAO (Aldebaran Robotics)

The proposed work is focused on the preliminary evaluation of a pilot multimodal application. Application was written in VoiceXML language. Together with VoiceXML source code, speech grammars were prepared in both XML as well as simple word list form. Configuration files for gestures generation was designed too.

To evaluate properties of the multimodal system and application, subjective evaluation experiment has been carried out. Thirty test subjects (students) performed interactions with NAO robot and they subsequently fulfill the evaluation questionnaire. Questionnaires were processed and obtained results were analyzed and will be discussed in the paper.

The paper is organized as follows: The second section describes designed multimodal dialogue system based on NAO robot and VoiceON dialogue manager. Next section introduces the pilot application and it brings results of evaluation experiment. The last section discussed possible usage scenarios, where designed system takes a role of lecturer.

II. THE MULTIMODAL DIALOGUE SYSTEM DESCRIPTION

A. NAO

Humanoid robot NAO (see Fig. 2) is an autonomous programable robot developed by Aldebaran Robotics company. NAO can be considered as a great tool to

prepare a multimodal dialogue system due to its support of vision, hearing, gesture production and body language. Moreover, an autonomous mode of the robot enhances a human-like behavior.

NAO operation system and development kit enables to prepare multimodal interactions also with built-in modules. In addition to ASR and TTS systems that supports 19 languages, NAO contains also a dialogue module, which enables to write spoken interactions. Built-in dialogue module is called ALDialog. The ALDialog module allows to endow robot with conversational skills by using a list of "rules" written and categorized in an appropriate way [7]. Despite the fact, that ALDialog module enables very natural conversations, it lacks a stronger flow management, which cannot by written directly into the rules and need to be written into the source code. Moreover, writing dialogue interactions for NAO cannot be considered as simple and effective.

These facts lead as to start think about our own dialogue unit, which can offer more simpler development of spoken dialogue with the user. Moreover, we prefer an external unit, to make possible to control several robots in the same time and to share knowledge between them through cloud.

In the proposed dialogue system, we adopt our earlier developed VoiceXML-based dialogue manager VoiceON [6], which we modified to enable multimodal interaction. VoiceON manager will be described in subsection C.

B. Architecture

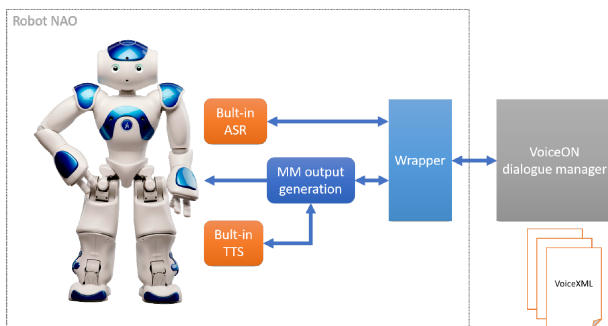The architecture of the designed multimodal dialogue system is shown in Fig. 2.

Figure 2. The architecture of the multimodal dialogue system for NAO robot.

The system consists of five components, where four of them are located directly inside the robot and the last one, VoiceON dialogue manager operates from an external server. The communication between NAO functionalities and the dialogue manager is transformed in wrapper module. The system uses built-in automatic speech recognition module and text-to-speech modules, which do not support Slovak language. To enable communication in Slovak language, we use Czech language pack installed in NAO. This cross lingual using is possible thanks to similar phonetic set of both languages. In case of speech recognition ne special changes need to be done. In case of speech synthesis, Slovak text need to be modified to overcome of differences.

To produce multimodal output of the robot the new module was designed – MultiModal output generation

module, which join synthesized speech and gestures into one output stream (see subsection D.)

C. Dialogue manager VoiceON

VoiceON dialogue manager is a server-client based engine, which manages interaction by interpretation of VoiceXML documents. VoiceON was designed in range of national project IRKR (see [8] or [9]). Manager enables system-directed interactions as well as dialogues with mixed initiative. We adopted VoiceON to manage interaction also with designed multimodal dialogue system for NAO robot. There are two main advantages of using VoiceON. Manager is a server-client system, what enables us to let the main part of VoiceON on the server. This solution makes possible dynamically change the content of interaction by generation of VoiceXML documents on the server-side.
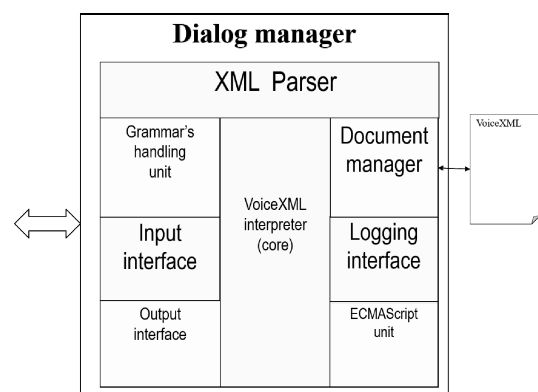
Figure 3. VoiceXML-based dialogue manager VoiceON

D. Multimodal output generation

NAO robot can generate a multimodal output in a form of speech and gestures combination. Unfortunately, this functionality is supported only for English language. Therefore, we have started to develop a new multimodal output generation module (see Fig. 4).
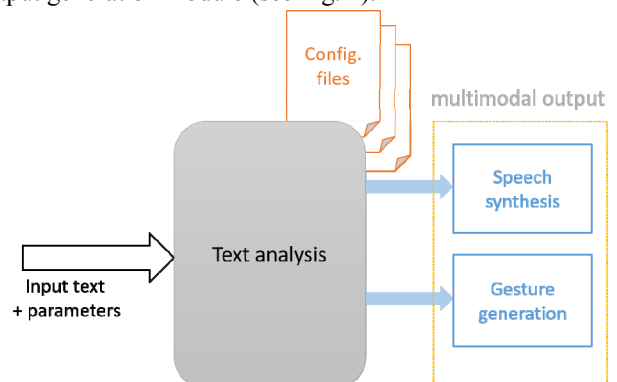
Figure 4. Multimodal output generation module

Designed module takes an input text and perform the analysis, which split the text into simple sentences and looks for keywords. Then manually written rules, stored in configuration files, are applied to add appropriate gesture marks into the output stream. The module can work in three different modes:

- **Speech only**. Output is generated without gestures.
- **RandOff**. Speech and gestures are generated. Gestures are generated as the output of the text processing. Robot random mode is switched off.
- **RandOn**. Speech and gestures are generated. Gestures and movements are produces both as the output of the text processing and as a result of Robot random behaviour.

Preliminary evaluation, which will be described later in the paper, focuses on the research of gestures impact on the interaction.

III. PRELIMINARY EVALUATION

The preliminary evaluation was carried out to assess the impact of gestures of the perception of naturalness and smoothness of the interaction. Subjective evaluation method has been selected. The pilot application was prepared, which is focused to introduce the robot. Thirty students interacted with NAO multimodal system and then they fill the evaluation questionnaire with eight questions. Questionnaire can be seen in Appendix.

A. Pilot application

The pilot application is written in VoiceXML language. Together with VoiceXML documents, also speech grammars were prepared. Each speech grammar in XML form of SRGS must have its mirror in NAO robot. The Fig. 5 shows an example of VoiceXML code of the pilot application. Expect to speech grammars and dialog documents, configuration files for generation of multimodal output were prepared, which associate keywords or keyphrases with gesture markups.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<vxml version="1.0" lang="Slovak" application="applications/ARD.vxml">

<var name="Meno"/>

<form id="steptwo">
    <field name="YourName">
        <nomatch>
            <prompt bargein="false">Uf tvoje meno je pre mňa príliš zložité. Ňevadí. </prompt>
            <goto next="#help"/>
        </nomatch>

        <grammar src="lang_resources/grammars/names.xml" type="application/grammar+xml"/>
        <prompt bargein="false"> Ahoj. Moje meno je NAO. Ako sa voláš ty? </prompt>

        <filled>
            <prompt bargein="false">Ahoj <value expr="YourName"/>. </prompt>
            <assign name="Meno" expr="YourName"/>
            <goto next="#help"/>
        </filled>

    </field>
</form>

<form id="help">
    <noinput>
        <prompt>Mohol by si zopakovať svoju odpoveď?</prompt>
        <reprompt/>
    </noinput>

    <field name="playHelp">
        <grammar src="lang_resources/grammars/yesno.xml" type="application/grammar+xml"/>
```

Figure 5. The example of VoiceXML code of the pilot application

Next figure (Fig 6.) shows an example of interaction with the robot. As we can see, system answers are written in such way, which enables to synthesize output speech correctly in the Slovak language with Czech TTS system.

```
START SESSION 09:36:12          DATE 03/27/17
_____

MESSAGE 0 : SYSTEM: Ahoj. Moje meno je NAO. Ako sa voláš ty?
MESSAGE 1 : USER: Marek (Marek)
MESSAGE 2 : SYSTEM: Ahoj Marek.
MESSAGE 3 : SYSTEM: Ak chceš môžem ti povedať niečo o sebe.
MESSAGE 4 : USER: áno (ano)
MESSAGE 5 : SYSTEM: Pochádzam z Francúzska ale teraz žijem na Slovensku.Bývam na katedre
             elektroniky a multymediálnych telekomunikácií v Košiciach.
MESSAGE 6 : SYSTEM: Ak máš trochu času poviem ťi viac.
MESSAGE 7 : USER: áno (ano)
MESSAGE 8 : SYSTEM: Keď som prišiel sem ňerozumel som po slovensky a bol som smutný.
             Teraz je to už lepšie. Kolegovia ma naučili celkom dobre rozprávať
             a už poznám aj zopár slov.
MESSAGE 9 : SYSTEM: Páči sa ti moja slovenčina?
MESSAGE 10 : USER: áno (ano)
MESSAGE 11 : SYSTEM: Ešťe musím vylepšiť svoj prízvuk.
MESSAGE 12 : SYSTEM: Áách to bol ale dlhý deň, musím si trochu oddýchnuť.
             Vďaka dobre som si s ťebou pokecal. Maj sa Marek!
```

Figure 6. Text transcription of the interaction with the NAO robot

B. Evaluation results

Evaluation was done by thirty test subjects – students, which interacted with robot. They were split into three distinct groups:

- First group of ten students interact with the robot, which produced only speech without gestures and autonomous movements (speech only mode).
- Second group (10 students) interacted with the robot, which produced speech together with gestures, but autonomous behavior was switched off (RandOff mode)
- Third group of ten students interacted with the robot in the RandOn mode, what means that the autonomous behavior was switched on and the robot produced speech and gestures, which resulted from text processing.

The goal of evaluation was to examine the impact of different modes of gesture production on the perception of naturalness and smoothness of the interaction. Subjective evaluation method was selected, where test subjects fill the questionnaire after the interaction with robot.

The most interesting results were obtained from analysis of 3rd, 4th (Fig.7), 5th and 7th (Fig.8) questions from evaluation questionnaire.
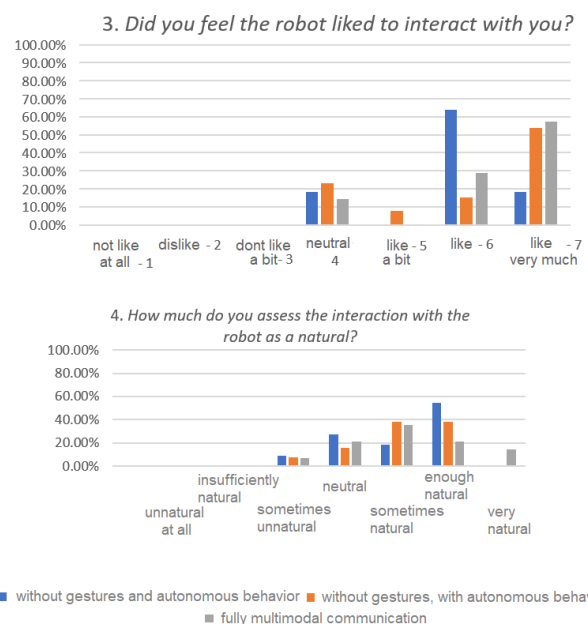

Figure 7. Results of the 3rd and 4th items of evaluation questionnaire

Answers on 3rd question

"*Did you feel the robot liked to interact with you?*"

are in range from neutral to "like very much". The most positive answer was selected most often by users, whose interact with robot, which produces gestures and also random behavior (*RandOn* mode).

Most often, the "like" option was selected surprisingly by users, whose interacts with robot without gestures. This fact can be accepted, because, people whose first time interacts with robot, usually really like such interaction due to the novelty and attractivity of robotics area itself.

In the case of the question four

"*How much do you assess the interaction with the robot as a natural?*",

the category "very natural" was selected only by users, whose interact with the robot in the *RandOn* mode, what means that robot produces speech, gestures and autonomous movements.
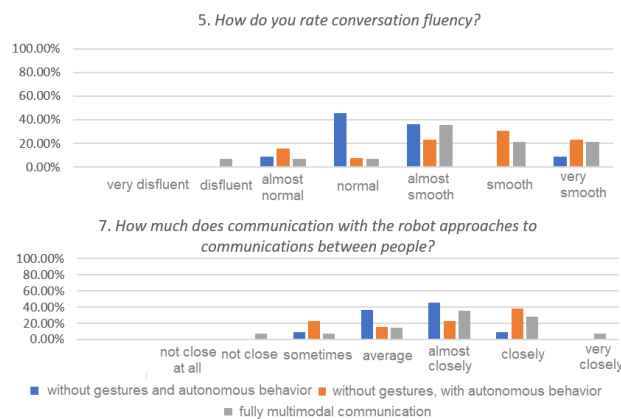

Figure 8. Results of 5th and 7th items of evaluation questionnaire

The question five

"*How do you rate conversation fluency?*"

brings interesting results. We can observe that users whose communicated with NAO in RandOn mode, selected answers in the right half of the spectrum (from "*almost smooth*" to "*very smooth*"). Users, whose communicate with NAO in other modes, assessed communication in range from "average" to "smooth".

Obtained result is interesting because the production of gestures takes a considerable time and de facto it makes interaction slower and more disfluent than without gestures. Despite that fact, users rate interaction with gestures as smoother than without gestures and movements.

In case of question seven

"*How much does communication with the robot approaches to communications between people?*"

the situation is similar as for question four. The most positive evaluation "very close" was selected only by users, whose interact with NAO in *RandOn* mode, what means that it produces speech with gestures and produces also random behavior. Users, whose interact with the system, which does not produce gestures assessed the similarity of the human-robot interaction to human-human interaction mostly as "average" or "to a certain extent".

Results of the preliminary evaluation did not bring significant differences between different modes, but they show tendencies and enable to formulate following conclusion:

- Gestures synchronized with speech and produced according the meaning of synthesized speech together with random movements positively influences perception of naturalness and smoothness of the interaction even though they make interaction longer.

IV. NAO AS LECTURER - DISCUSSION

There are many research studies, where NAO humanoid robot takes a role of teacher, e.g. [10], [11], [12] or [13]. Designed multimodal system with VoiceXML dialogue unit makes possible to prepare new interactions very quickly. These interactions can be focus also on education. One possible approach, how can NAO be a teacher is to create slides (e.g. in MS PowerPoint) with notes for each slide. Then, robot can read notes by synthetic voice, which can be supported by generation of gestures. Moreover, robot can interact with students, ask questions or record student answers.

Someone could doubt the advantage of using robots for educational purposes, but we can observe that robots are able to increase attention and motivation, as was observed e.g. in [12].

Our own observations collected during „Night of the museums 2017" supports previous finding too. During the interaction with NAO, people were asked by NAO to recite poem, after NAO recited a set of poems for children. When we prepared dialogue for the NAO, this prompt ("*And now, could you recite a poem for me?*") was designed, only to close the conversation. We were very surprised that people were willing to recite poem for the robot. They were willing to follow robot's instructions very readily and spontaneously. This fact was the most surprising in case of adult's participants. Humanoid robots have a potential to increase attention, motivation and support interaction, which are very important attributes required in education.

V. CONCLUSIONS

The proposed paper describes newly designed multimodal dialogue system for the communication with NAO robot, which uses external dialogue manager VoiceON and it describes the preliminary evaluation of the designed system.

The multimodal system extends the robot to be a dialogue participant. Users can interact with robot by speech and robot answers through the multimodal output in the form of speech and gestures.

To evaluate a perceived naturalness and smoothness of the interaction with the system the subjective evaluation was performed. Thirty participants interacted with NAO robot and then they fulfill the evaluation questionnaire with eight questions. The results of the evaluation show an importance of gestures and human-like movements for the perceived naturalness and smoothness of the interaction.

In the future we plan to focus on the more accurate synchronization of the speech and gestures, which will follow patterns from human-human interactions.

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Appendix A: Evaluation questionnaire

Technická univerzita Košice, Fakulta Elektrotechniky a Informatiky
Dotazník – Komunikácia s humanoidným robotom NAO
Rastislav Husovský, Ing. Stanislav Ondáš Phd

Ohodnoďte komunikáciu s robotom vyplnením dotazníka krížikmi - ☒

	vôbec 1	2	3	neviem 4	5	6	určite 7
1. Mali ste pocit, že vám robot rozumie?	☐	☐	☐	☐	☐	☐	☐

	veľmi nepríjemne 1	2	3	normálne 4	5	6	veľmi príjemne 7
2. Ako ste sa cítili počas komunikácie s robotom?	☐	☐	☐	☐	☐	☐	☐

	Vôbec nepáčila 1	2	3	neutrálne 4	5	6	veľmi páčila 7
3. Mali ste pocit, že sa robotovi interakcia s vami páčila?	☐	☐	☐	☐	☐	☐	☐

	vôbec 1	2	3	neutrálne 4	5	6	veľmi 7
4. Na koľko hodnotíte komunikáciu s robotom ako prirodzenú?	☐	☐	☐	☐	☐	☐	☐

	veľmi pomalá 1	2	3	normálna 4	5	6	veľmi plynulá 7
5. Ako hodnotíte plynulosť konverzácie?	☐	☐	☐	☐	☐	☐	☐

	Uplne nepravdepodobná 1	2	3	neviem 4	5	6	veľmi pravdepodobná 7
6. Ak by s te mali na výber medzi získaním informácie z webu alebo cez komunikáciu s robotom, aká je pravdepodobnosť, že by ste si vybrali komunikáciu s robotom?	☐	☐	☐	☐	☐	☐	☐

	vôbec Nepribližuje 1	2	3	neutrálne 4	5	6	veľmi približuje 7
7. Ako veľmi sa komunikácia s robotom približuje ku komunikácii s ľudmi?	☐	☐	☐	☐	☐	☐	☐

	určite nie 1	2	3	neviem 4	5	6	rozhodne áno 7
8. Myslíte si, že komunikácia medzi človekom a strojom dokáže nahradiť medziľudskú komunikáciu?	☐	☐	☐	☐	☐	☐	☐

Existing Mechanisms of IP Fast Reroute

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Abstract— **The slow convergence of existing routing protocols after link or node failure became a problem. As a solution IP fast Reroute mechanisms have been developed. IP Fast Reroute mechanisms offer rapid network recovery after link or node failure. The basic idea of the IP Fast Reroute is to pre-calculate alternative backup path in advance. In the case of failure IP Fast Reroute Mechanism will use pre-calculated backup path to bypass failed link or node.**

In this paper we focus on description of well-known IP Fast Reroute mechanisms that are currently being used in real ISP networks but also describe IP Fast Reroute mechanisms that are under investigation and offer new approach. We test LFA IPFRR mechanism in simulator GNS3. Results proof, that IPFRR technology has significant impact on time of network recovery.

Keywords: IP Fast Reroute; LFA; RLFA; TI-LFA; Segment Routing; BIER-TE FRR.

I. INTRODUCTION

Current IP networks are used to transfer various data streams. Modern IP networks also have to handle data with more complex transmission requirements, such as: VoIP, online computer games, Internet TV (IPTV), online exchange, virtual private network (VPN), and more. These services can be classified under the category of real-time services which means, that they require specific requirements for delay, throughput and reliability.

A variety of network unintentional failures may occur, such as natural disasters (earthquakes, fire, flood), traffic congestion, software errors and failures due to maintenance or sabotage. The impact of failures on network devices affects services of specific users.

When a link or router failure in the IP network occurs, all routers affected by the failure must respond by sending new routing information and all routers must update their routing tables. This process of network recovery after link or router failure is called the network convergence. The time of the network convergence depends on many factors as used network protocol, its timers and the topology of the network itself.

Average IGP convergence time within an autonomous system (large corporate network) is several hundreds of milliseconds [1] [2] [3].

A. IP Fast Reroute

For real-time services, especially voice and video, achieving recovery time in the order of several tens of milliseconds after the link or node failure is important for maintaining transmission quality [1] [4]. The IPFRR technology, which provides fast local repair, takes care of this problem until the convergence process is completed in

the network. IPFRR mechanism reduces the time that a router needs to respond in the event of network failure. IPFRR mechanism provides redirection of data flow around the failed element in the network. The router using this IPFRR mechanism has a precalculated alternate path in the case of link specific failure [5] [6] [7] [8].

IP Fast Reroute technology uses fast failure detection to minimize time for network recovery [9].

In the event of failure, the data flow is redirected to the precalculated alternate path in tens of seconds without having to wait for the competition of the network convergence (Figure 1.).
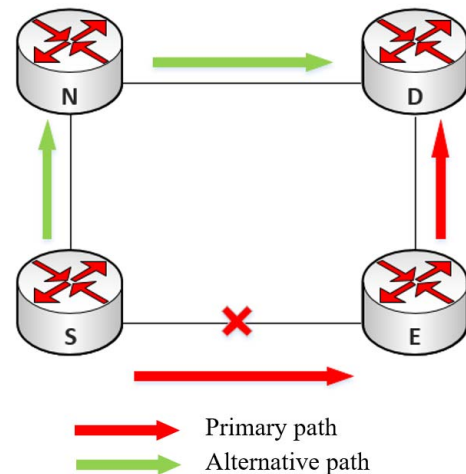
Figure 1.   IPFRR mechanism

For better understanding of IPFRR, we explain basic terminology [1] [3] [3]:

- Router S – known as a source router, alternate pre-calculated path is calculated on this router.
- Router D – known as a destination router.
- N (N1, N2) – an alternative next-hop router for the specific destination. This router is used, when the Router S reroutes traffic to bypass failed link or node.
- Router E – it is the primary next-hop router for the specific destination. This is the router for which IPFRR mechanism provides protection. The link between router S and E is called as protected link.

The IPFRR mechanism implemented in the router can provide two functions, link protection or node protection. Both cases are showed on Figure 2.
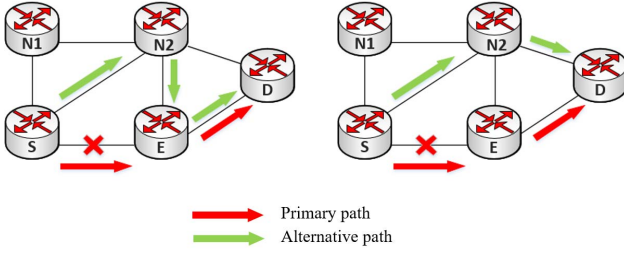
Figure 2. The link protection and the node protection

The left side of the picture shows an example where the S router protects the link S-E, referred as the link-protection. The router E is still part of the alternative path.

The right side of the figure shows example where N2 provides the node protection of router E. In the case of the node E failure, the alternative path traverses via the router N2 and the router E is not part of the alternative path.

B. Repair coverage

The term repair coverage describes in IPFRR area efficiency of the individual IPFRR mechanism and it is one of the main parameters in comparison of these mechanisms. If the IPFRR mechanism is capable of repairing all possible network failures, then this mechanism reaches 100% repair coverage [1] [3].

II. ANALYSIS OF EXISTING IPFRR MECHANISMS

In the following sections we will describe well-known IPFRR mechanisms such as LFA or Remote LFA and relatively new mechanisms TI-LFA and BIER-TE FRR. Many other FRR solutions have been developed so far [10] [11] [12] [13] [14] [15].

A. LFA

The Loop-free alternates IPFRR mechanism is one of the mostly used mechanisms [1] [3]. The LFA IPFRR mechanism does not provide signalization between adjacent routers and provides the local repair for affected data after the link or the node failure. The LFA mechanism can be enabled on one, group or all routers in the network.

The topology shows (Figure 3.) a link failure between R1 and R2. The router R1 has activated LFA FRR mechanism and immediately after failure detection redirects the data stream to router R3 without waiting for the network to converge.

The LFA FRR minimizes the recovery time by not waiting for IGP to send info messages between routers in the network and calculate the shortest route.
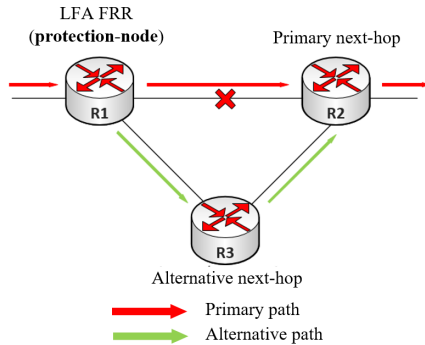
Figure 3. The LFA IPFRR mechanism

For the source router (protection-node) to calculate the alternate path, certain conditions must be met. Also, a network with multiple redundant links does not meet the criteria for calculating the alternative path.

There are three main criteria for the potential alternative next-hop of LFA IPFRR mechanism. The more conditions are met by the calculation of the alternative path, the more potential failures in the network are protected. When describing the criteria, the expression v(X, Y) represents the shortest distance from X to Y.

Condition 1 (*loop free*):
$$v(N,D) < v(N,S) + v(S,D) \qquad (1)$$

The first condition is the minimum requirement for the router to calculate the alternative path and find the correct LFA neighbor. In the left part of Figure 4. , the N router meets the first condition, and on the right side first condition is not met, due to the metric between routers N and D. This metric prevents the router S from using the neighbor N as an alternate next-hop without creating a temporary routing loop. When the first condition S is met, the next-hop router can provide the link protection.
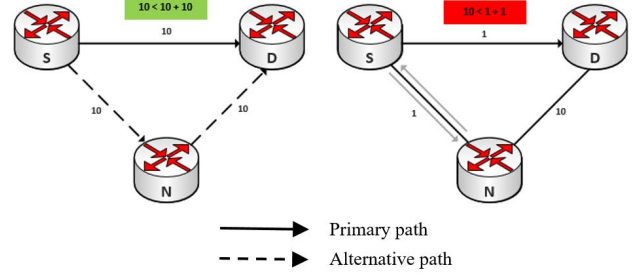
Figure 4. LFA 1. condition

Condition 2 (downstream path):
$$v(N,D) < v(S,D) \qquad (2)$$

The next-hop router N is closer to destinations than a source router (see Figure 5.). This condition ensures that in case of multiple failures, router N does not send packets back to router S, so no micro loop can occur.
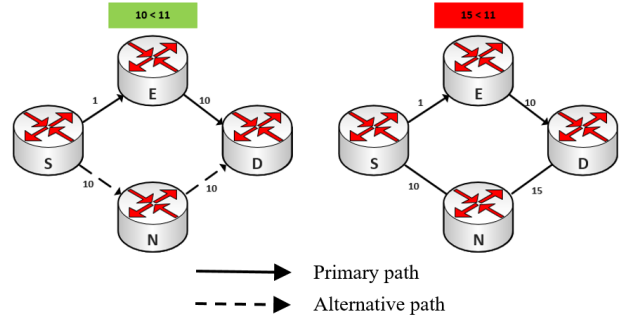
Figure 5. LFA 2. Condition

Condition 3 (node-protection LFA):
$$v(N,D) < v(N,E) + v(E,D) \qquad (2)$$

The primary path from the router S to the D traverse via the router E. This condition ensures that if the E router fails, data flow forwarded to the router N will not traverse via router E (see Figure 6.).

Figure 6.   LFA 3. condition
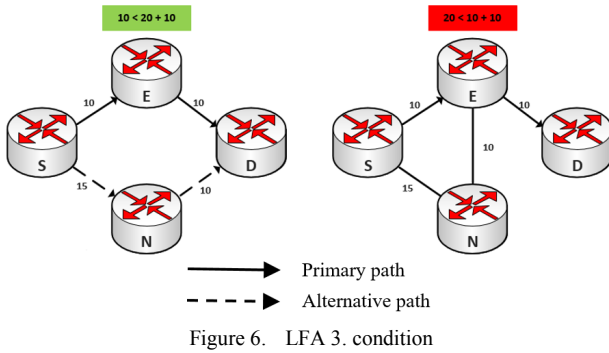
The LFA IPFRR mechanism can calculate the alternative next-hop in two ways: per-link and per-prefix. For a per-link, all destinations reachable through the primary (protected) S-E link share a common alternative path.

For a per-prefix, for each destination, an alternate next-hop is calculated separately. The calculation of the alternative path for a given destination may differ from link [2].

Per-link LFA candidate requires fewer calculations but also provides minor repair coverage. The per-prefix increases repair coverage but is more demanding for the calculations.

The repair coverage of LFA is very good for some networks (many redundant links between routers). The LFA IPFRR mechanism has been tested on the 11 most widely used ISP topologies, RFC 6571 [16]. The results indicate that the per-link LFA provides an average of 67% repair coverage and the LFA per-prefix reaches up to 89% repair coverage.

In general, the LFA per-prefix provides the best LFA coverage and is recommended to use this method in IP networks [1].

B.   Remote LFA

This mechanism is described in RFC 7490 [17]. Remote LFA represents the extension of the classic LFA IPFRR and it increases repair coverage in the networks where LFA cannot provide protection [18].

The basic idea behind Remote LFA is to use tunnel technology to achieve a remote router. Such a router is a LFA candidate for a specific destination D.

The basic terminology of Remote LFA IPFRR mechanism:

- P-space: The P-space of a node S is the set of nodes, which can be reachable from node S not traversing via protected link.
- Extended P-space of node S: The set of neighbors of a node S protecting a specific link, without a next-hop router, which can be accessed via protected link.
- Q-space: The Q-Space of a node S, is the set of the nodes, from which can be accessed node E not traversing via protected link.
- PQ node: PQ node of node S is a node, that belongs to P-Space of node S and the Q-space of node S.

The Figure 7. shows an example of Remote LFA operation. The protected link is located between the router S and E. When the S router detects link failure with the primary next-hop for destination D it performs local repair with Remote LFA IPFRR mechanism [17].

Figure 7.   Remote LFA IPFRR mechanism
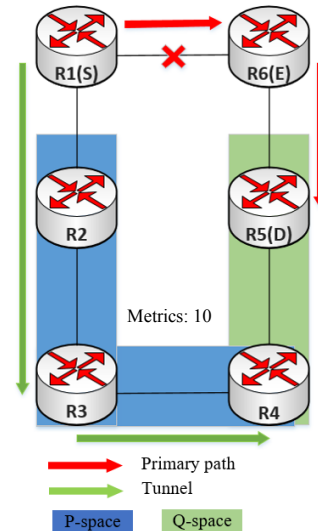
The shortest (primary) path from router R1 (S) to router R5 (D) traverse via routers R1-R6-R5. The routers that are reachable from the router R1 (S) via shortest paths and meet conditions of P-space are routers R2, R3 and R4.

The conditions of P-space meet routers R5 and R4. Thus, the router R4 will be chosen as the tunnel endpoint (PQ node). In other words, the router R4 is the Remote LFA of router R1 (S) for destination (D).

The classic LFA and Remote LFA mechanisms are both dependent on network topology and link metrics.

The Remote LFA is not always able to find the PQ router, which means the Remote LFA mechanism cannot provide protection.

The Remote LFA IPFRR mechanism is the enhanced version if the classic LFA, and achieves better repair coverage.

The document RFC 7490 [17] in section 9 contains information where both LFA and RLFA have been compared in 14 real networks and this test proofed that RLFA has significantly better repair coverage. It is important to remember that the RLFA mechanism is dependent on topology and network metrics and it is very difficult to achieve a 100% repair coverage.

C.   Topology Independent LFA (TI-LFA)

The TI-LFA IPFRR mechanism can use segment routing technology in specific situations to send packets around failed link or node. Topology Independent LFA (TI-LFA) IPFRR mechanism provides link and node protection.

This IPFRR mechanism is based on verified LFA and RLFA IPFRR mechanisms. Segment routing technology allows TI-LFA to use custom alternative path but also allows shortest/optimal alternative path. The TI-LFA uses terminology PQ space described in [17].

Figure 8. shows topology, where link failure between R1 and R2 occurs. The TI-LFA in this case will not use segment routing technlogy, because there is no need for it [19].
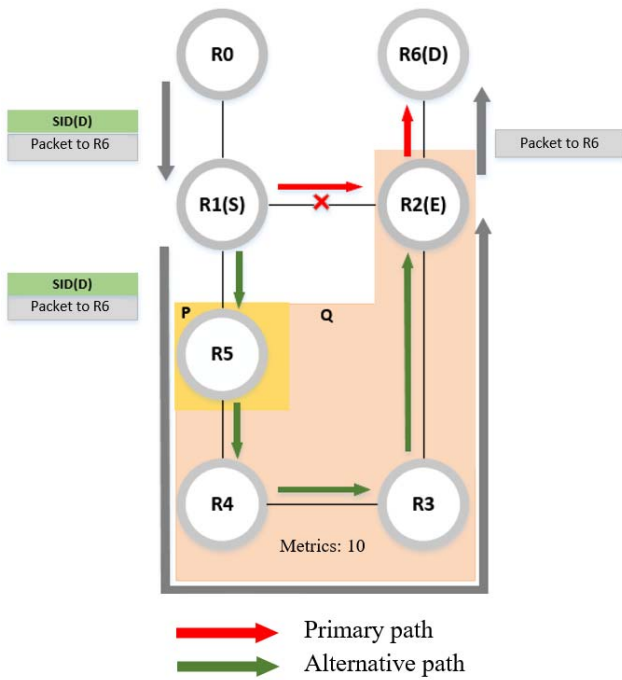
Figure 8.   Example of zero segment TI-LFA

From the perspective of router R1 the primary link to reach destination router R6 is R1-R2.

The process of calculation TI-LFS from the perspective of R1 begins with deletion of primary link for destination R6 (R1-R2) and calculation of SPF tree of new created topology. Post-convergence path from R1 to R6 in this topology is via routers R5-R4-R3-R2.

The router R5 in the P-space of router S (R1), which means R1 is able to send packet to R5 without receiving it back, so no micro-loop can occur.

The router R5 also belongs to Q-space of the router S (R1) and can send packet to R2 without receiving it back. The packet will not traverse via protected link R1-R2. The router R5 is PQ node, meaning there is no need to use segment routing technology to reach router R6 [19].

Figure 9. shows the case where double segment has been used to send packets around the failed link R1-R2. Router R4 belongs to the P-space of R1 and router R3 belongs to Q-space of the R1. In this case we have to use two segments to direct packet to R6. First segment is to reach router R4 and second segment for link R4-R3.
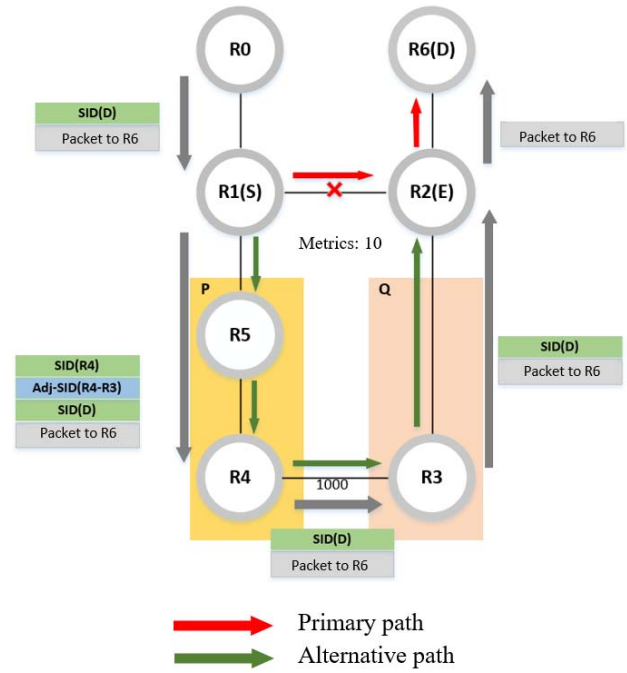
Figure 9.   Example of double segment TI-LFA

TI-LFA IPFRR mechanism guarantees 100 % repair coverage for link and node protection. This mechanism can be used for LDP and IP traffic. Tunnel is created using segment routing technology. This technology creates possibility to set custom alternative path [19].

D. BIER-TE Fast Reroute (BIER-TE FRR)

The Bit Indexed Explicit Replication (BIER) protocol is also known as "stateless multicast", because the amount of "state" information within the multi-cast [20] [21] network is reduced. In BIER protocol, information about destination is stored in a packet rather than searched in the routing tables for the individual routes, via packets traverse.

More specifically, destination information is encoded as a bit string (BitString) that is transmitted along with the packet (BIER header). In general, each router in a BIER domain that is associated with a destination node or a BFER has an assigned bit in the BitString.

The bit value at the given bit position determines whether the router corresponding to that bit position is the destination of the packet with this bit relay. The BIER is described in the document [22].

The BIER-TE is based on the BIER architecture, the BIER packet format is unchanged. The BIER-TE directs and replicates packets as well as BIER, based on the BitString in the header of the packet but does not require IGP.

The BIER-TE supports TE based on explicit hop-by-hop and loose hop packet forwarding. The BIER-TE protocol is described in detail in the document [23].

The BIER-TE FRR mechanism is an extension of the BIER-TE architecture and supports link and router protection [24].

In order to operate this FRR mechanism in the BIER-TE network, it is necessary for the FRR mechanism to support BIER-TE controller and BFR routers. The BIER-TE FRR

does not have to be supported in the entire BIER-TE network but only by BFR routers that are directly connected to the link/router for which FRR protection is required.

The BIER-TE architecture and BIER-TE tables do not require any change, but the BIER-TE adjacency table (BTAFT) will be added.

The BIER-TE controller calculates alternative paths in case of the link or node failure in BIER-TE network. This information is after calculation installed in to BTAFT table of BFR routers and BTAFT of this router controls the FRR process.

The basic principle of BIER-TE FRR mechanism is modification of the BIER header (BitString), which ensures that affected traffic traverses around the failed link or node.

In the next section we will show the concept of the BIER-TE FRR mechanism.

Figure 10. shows a multicast tree from node A to B, F, and H. Every link has specific bit in the BitString. The AD link represents bit 1, the AE link represents bit 2, the DC link represents bit 3 and so on.

The path from A to B is represented by bits {1, 3, 4, 12}, the path from node A to F {1, 6, 7, 13} and path from node A to H {2, 8, 14}. Bit positions 12, 13, 14 represent local_decap.
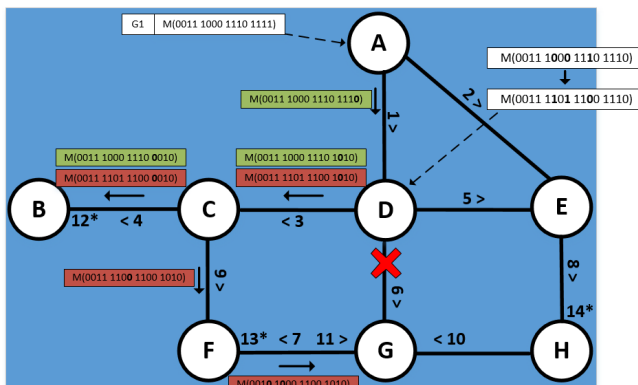
Figure 10. BIER-TE FRR link protection

We expect a link failure between routers D a G. The link between routers D and G can be protected via backup paths C-F-G with bit positions {3, 9, 11} or backup path E-H-G {5, 8, 10}. Figure 10. shows link protection of the link DG via backup path C-F-G via router D.

The packet enters the BIER-TE network via router A with the BitString corresponding to the tree {0011 1000 1110 1111}.

The Router D, after link D-G failure detection, modifies BitString, removes the failed DG bit (6) and inserts bits of alternative path CF (9) and FG (11). The backup path C-F-G does not duplicate packet.

We now assume the failure of router G. The backup patch must send the packet to all routers of the multicast tree behind the router G (downstream next hops). Router D is able to identify the downstream routers through the BTFT table of failed router G. In our example (see Figure 11.) only the router F is downstream because bit 7 is set in the link GF. Router H is not downstream router because link GH does not have specific bit in the BitString.

When router D detects router G failure modifies BitString, it removes bit of the link DG (6) and inserts bits of backup links CF (9).
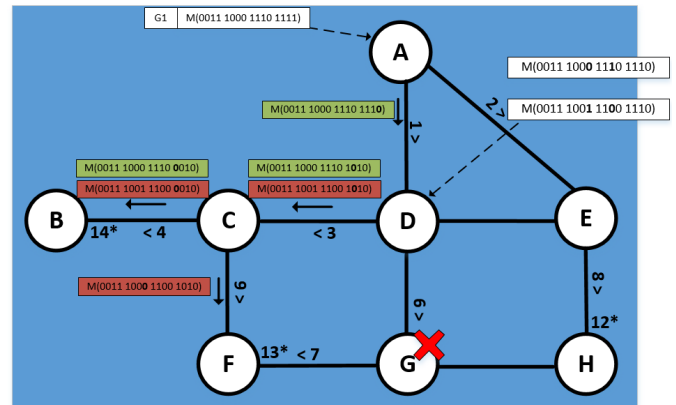
Figure 11. BIER-TE FRR link protection

The link protection requires to know router on the other side of the link. The node protection requires to know all downstream routers.

The BIER-TE FRR is relatively new approach in FRR area and is in the development stage.

III. TESTING OF LFA IPFRR MECHANISM

According to our research [25] [26] [27], we decided to test LFA IPFRR mechanism. The IPFRR mechanism is one of mostly used mechanisms in current ISP networks [1].

To test the LFA mechanism, we have used the GNS3 simulator (See Figure 12.). The topology in GNS3 includes three c7200 emulated routers and a CSR1000v router that runs through VirtualBox on a local computer and it was imported into GNS3.
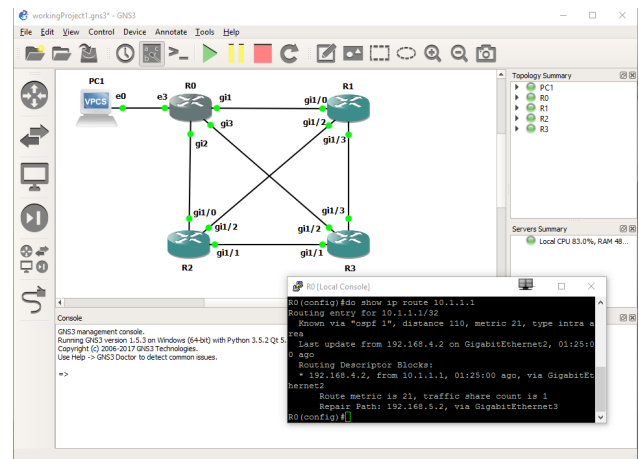
Figure 12. GNS3

The configuration of LFA IPFRR mechanism was configured on the router R0 with following commands (See Figure 13.). The first command activates the FFA per-prefix for area 0 and sets the prefix priority.
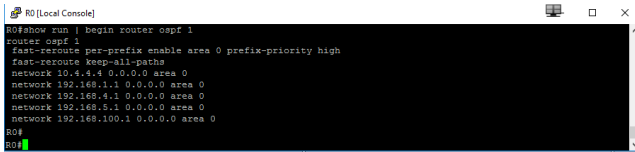
Figure 13. The LFA configuration

The primary path according to the metrics for generated data flow is R0-R1-R3. Alternative path according to the metrics is R0-R2-R3 (See Figure 14.).

The data flow is generated using Scapy 2.3.1. The Scapy tool was installed on Linux (Ubuntu) using VirtualBox and connected to the network in GNS3.
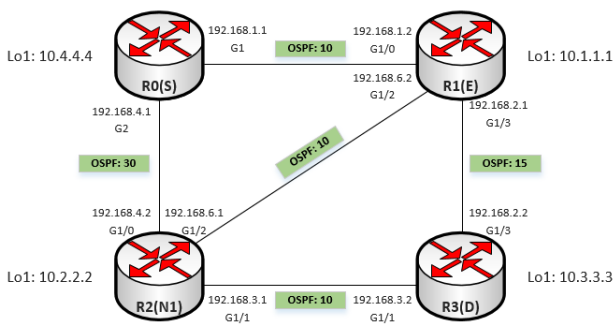
Figure 14. The LFA testing topology

First, we tested how many packets our network can handle, that is, the amount of packets that will be generated after the tool is generated to the selected router. It turned out that GNS3 and our network can successfully transfer approximately 100 packets per second. The generated test flow rate was 1000 bits, 100 packets per second. We used this data stream for three scenarios and compared the results with Wireshark.

In all scenarios, the flow of data enters the network on router R0 and passes through the network to destination R3 (lo1 10.3.3.3). We repeated each scenario five times and in the Tab. 1 are average results of these tests.

The first scenario serves to verify the generated data stream, and without any failure within the network. Our tool generates the correct number of packets. The number of successful packets was detected using Wireshark on the R1-R3 link. Tab. 1 contains the measurement results.

In the second scenario, we simulated the failure of the R0-R1 link without using the LFA mechanism. Only the routing protocol OSPF was enabled for re-routing the traffic via alternate path.

In the simulation scenario 2. we generated data flow and then we executed the shutdown command on the GigabitEthernet1 interface of router R0. We simulated link failure with primary next-hop R1 for destination D.

The number of successful packets was determined by the sum of Wireshark's results on R1-R3 (primary path) and R2-R3 (alternative path). According the results, we found out that more than half of the packets were lost until network reconvergence.

The third scenario is the same as the other, but we have used the LFA IPFRR mechanism. The results in Tab. 1 clearly show that the LFA mechanism was much better performing while link failure within the network occurs.

TABLE I.
AVERAGE RESULTS OF LFA IPFRR TEST

	Failure	LFA FRR	Received packets / Sent packets
Scenario 1	No	-----	1002 / 1002
Scenario 2	Yes	No	434 / 1002
Scenario 3	Yes	Yes	989 / 1002

Based on these tests, we have been able to verify the functioning of the LFA IPFRR mechanism on our emulated network topology.

IV. CONCLUSION

IPFRR technology is becoming very important in today's IP networks. Real-time services are becoming more and more important and requirements on ISPs networks grow each day. ISPs will need a solution to this problem.

IPFRR technology is a possible solution, some of the IPFRR mechanisms are already implementable in real networks such as LFA or Remote LFA and others are in the development and testing phase.

The content of this paper is a description of the principle of IPFRR technology and a more detailed view of selected IPFRR mechanisms.

The LFA IPFRR mechanism provides basic link and node protection. The enhanced version of the LFA IPFRR mechanism is Remote LFA. The remote LFA IPFRR mechanism provides better repair coverage. Even LFA cannot provide 100% repair coverage. In some topologies with specific metric is impossible to find Remote LFA candidate.

TI-LFA and BIER-TE FRR are new approaches in IPFRR area. Both concepts provide high repair coverage. The BIER-TE FRR uses BitString to signalize alternative back up path. The BitString provides very flexible way how to set alternative backup path.

At the end of the paper, we provide test of the LFA IPFRR mechanism on emulated routers from Cisco in GNS3. This test proved that IPFRR mechanism can provide significantly faster network reconvergence than classic IGP routing protocol. In the future we will focus on research in the IPFRR area and the testing of more IPFRR mechanisms.

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Digital Literacy or Computer Science: Where do Information Technology Related Primary Education Models Focus on?

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Abstract— **The present deep impact of information technology on society results in an increasing number of countries starting to introduce information technology related topics even in primary schools. However, the resulting curricula, educational standards and competence models differ in several aspects like in their structure or competence focus, making them hard to assess and to compare. This contribution presents a graph-based approach that eases the comparison and that can be used to exemplify different focal points easily. In order to do so, we looked at several educational models and used a graph-based representation form to display the emphasis on either Digital Literacy and/or Computer Science concepts.**

I.   INTRODUCTION

The information technology's deep impact on present society has also high influence on developments in education. So, countries all over the world increase their effort to establish reasonable education in related areas already in primary schools. For this purpose, different curricula, educational standards or competence models were developed and implemented. A report from the European Schoolnet in 2015 [1] points out that in most cases, information technology related content is part of curricula or educational standards for *Computer Science*, *Computing* or *Informatics*. It further shows that in 19 of 21 participating countries *Digital Competence* or *Digital Literacy* is focused, whereas only 10 countries set their focal points on "Computing and Coding skills" [1], with other words *Computer Science*.

Based on the idea of classifying the focus of curricula, this contribution aims at, in a first step, analyzing and, in a second step, comparing different curricula and competence models. For the categorization nine experts participated in a survey and rated elements of curricula and competence models to be part of either *Digital Literacy* and/or *Computer science*. A graph-based representation form presented by Pasterk and Bollin [2] is used to display an overview of the priorities within three selected educational models.

This contribution is structured as follows: chapter two gives an overview of related literature and in chapter three the selected educational models are described. Chapter four presents the graph-based approach used in this paper and chapter five defines the two categories as well as the process of categorization. In chapter six the results are presented and discussed.

II.   RELATED WORK

The increasing number of published literature concerning *Computer Science* in primary education reflects the fact that the research interest for this field of study rose during the last years. A lot of these articles present new best practices or the development of a new educational model [3].

Only a few works include an analysis and comparison of different educational models. On their way to develop a Computer Science and Programming course for primary education, Duncan and Bell [4] studied four English-language curricula for primary school, including the Australian "Digital Technologies" curriculum [5]. Duncan and Bell defined the following six categories of themes: *Algorithms*, *Programming*, *Data representation*, *Digital devices and infrastructure*, *Digital applications*, and *Humans and computers*. In a further step they classified the single elements of the selected curricula among these new themes and compared the topics for different school grades, resulting in a list of differences and similarities [4].

An additional example for a analysis of curricula for K-9 Computer Science education based on categorization is the work of Barendsen et al. [6]. Besides teacher interviews and the investigation of assessment, the article also contains a classification of Computer Science subjects into knowledge categories, based on the knowledge areas from the *ACM/IEEE Computer Science Curricula* [7]. They define the following list of knowledge categories: *Algorithms*, *Architecture*, *Modeling*, *Data*, *Engineering*, *Intelligence*, *Mathematics*, *Networking*, *Programming*, *Security*, *Society*, and *Usability*.

To identify the focus of four selected curricula the occurrences of special codes defined for each knowledge category are counted. These numbers indicate the relative importance of individual categories within a curriculum. Results show that *Algorithms* is considered in all analyzed documents as a major concept [6].

Looking over the borders of primary education more approaches of curriculum analysis and comparison are to be found. Most of them focus on undergraduate degree programs or academic courses. A promising example based on graph theory comes from Lightfoot [8]. His article focuses on the improvement of the structure and the correct placement of assessment within a Bachelor degree curriculum. For this purpose the curriculum is mapped to a simple acyclic directed graph, in which courses correspond to vectors, and prerequisite requirements

display the edges, and basic graph-theoretic metrics are calculated and visualized. With the help of the selected metrics (like degree, structural centrality, and clustering density) interesting vertices and good positions for topic introduction or assessments are determined [8].

A further graph-theoretic approach is presented by Marshall [9], aiming at identifying major changes of three undergraduate degree Computer Science curricula from 2001, 2008 and 2013, including the ACM/IEEE Computer Science Curriculum from 2013 [7]. The topics, knowledge areas, knowledge units or modules are mapped to vertices and the connecting edges represent dependencies between these vertices. The comparison of the directed graphs of the three curricula is conducted visually, to get a quick overview of the differences, as well as algorithmically, for a quantification of differences and similarities. Results of this analysis show that the content of Computer Science curricula changed from 2001 to 2013 significantly [9].

In this contribution and different to the above mentioned we present an approach for Computer Science in primary education that uses ideas from analysis and comparison based on graph theory combined with the categorization of curricula based on an expert rating. As supporting technology we chose the graph database neo4j to store and represent the single elements of the curricula as graphs.

III.   EDUCATIONAL MODELS

As a preparation for this contribution three educational models had to be selected for analysis and comparison. We chose one of the main English-language curricula, the curriculum from Australia [5], and two German-language models, the curriculum from Switzerland [10] and the Austrian Digital Competence model "digikomp" [11], because of their local importance. Parts of the German-language educational models cited in this contribution were translated into English by the authors.

A.   Curriculum from Australia (AC)

The Australian curriculum for the learning area "Technologies" was implemented in 2014 [12]. In 2015 and 2016 the version 8.3 of the curriculum was established. The learning area is part of the curriculum from Foundation (F), which represents the first school year, and ends at the tenth grade as an elective subject. It combines the two subjects "Design and Technologies" and "Digital Technologies", which are described as being "distinct but related" [5]. Where "Digital Technologies" focuses on use and technical background of digital technology, "Design and Technologies" deals with topics related to design and technology's impact on society. In this contribution, the curriculum for the subject "Digital Technologies" is considered. The levels of this curriculum start as mentioned with F and contain two school grades, so F-2, 3-4, 5-6, 7-8, and 9-10. For this contribution, the first three levels are of interest, because they cover the school grades of primary education. Two major themes, "Knowledge and understanding" and "Processes and production skills", divide the content of the curriculum and are further subdivided into the following sub-strands: Digital systems, Representation of data, Collecting, managing and analyzing data, Creating digital solutions by investigating and defining, Creating digital solutions by generating and designing, Creating digital solutions by producing and implementing, Creating digital solutions by

evaluating, and Creating digital solutions by collaborating and managing [5].

B.   Curriculum from Switzerland (Curriculum 21)

The curriculum for primary and lower secondary school in Switzerland called "Lehrplan 21" was presented in 2014 and established by 21 of the 26 cantons with individual adaptations. The subject "Media and informatics (Medien und Informatik)" is part of it from first year at school. The "media" part deals with the understanding and responsible use of different media, whereas the "informatics" part focuses on problem solving and basic concepts of Computer Science [10]. Additionally, the other subjects have to foster their individually required application competence. So called "cycles" represent the level system and contain three to four school grades. Cycle one covers kindergarten and school grade one and two, cycle two grades three to six, and cycle three grades seven to nine. In this contribution cycles one and two are considered, because they cover primary school grades. Seven major competences are defined in the curriculum, which are reached step by step by passing competence levels assigned to a specific cycle. Each major competence deals with one of the following content areas: Life in media society, Understand media and media products, Produce media and media products, Communicate and cooperate with media, Data structures, Algorithms, and Informatics systems [10].

C.   Digital Competence Model from Austria (digiKomp)

In Austria, a new curriculum for "Basic Digital Education (Digitale Grundbildung)" is under development at this time. Therefore, the competence model, which can be seen as a building block of the new curriculum [13], is analyzed and compared in this contribution. This model called "digikomp" is no national curriculum yet, but can give interested teachers some information and suggestions what can be taught in Computer Science. There are versions of this model for primary ("digikomp4"), lower secondary ("digikomp8") and higher secondary education ("digikomp12"), which contain similar content areas but with more details in higher levels. The competence model for primary education was presented in 2013 by Mulley and Zuliani [14] and focuses on the responsible use of digital technology including some concepts of Computer Science. The following four content areas are defined in the "digikomp4" competence model: Informationtechnology, humans and society, Informaticssystems - Usage of digital devices and networks, Applications - Digital tools in everyday life, and Informaticsconcepts - First steps in informatics [11].

IV.   A GRAPH-BASED APPROACH

As mentioned in the introduction, the two objectives of this contribution are firstly to analyze and secondly to compare curricula and competence models using a graph-based representation form. This idea is not new but has never been done for Computer Science related curricula in primary education. Our approach uses labeled and typed edges and vertices, which enables the inclusion of additional attributes for edges and vertices, and maps them to a graph database [2]. In this section, the steps for this process are described and the advantages and technical opportunities of this approach are illustrated.

A. Extraction of Competences

As a first step, the documents of the curricula, educational standards, and competence models are analyzed to identify small and comparable key elements. Possible comparable elements are the content and the learning outcomes. But it has to be considered that these learning outcomes are often formulated similarly and denoted differently in the curriculum documents. As in Austria and neighboring countries competence-orientation is an important topic in the development of curricula, in our approach, we define competences as our comparable key elements and understand them following Weinert as "the cognitive abilities and skills possessed by or able to be learned by individuals that enable them to solve particular problems, as well as the motivational, volitional and social readiness and capacity to use the solutions successfully and responsibly in variable situations." [15]

An example of a competence from the Austrian Digital Competence model shows, how they are formulated:

"I can understand and execute easy instructions." [11]

It defines, from the perspective of a student, what she or he should be able to do. Whenever a curriculum is competence-oriented (like in Switzerland) comparable key elements can easily be extracted. But not all of the selected educational models are competence-oriented. This is the case for the Australian curriculum, which uses the term "learning objectives" [12] to describe the expected learning outcomes. The following example objective shows, how they are formulated:

"Follow, describe and represent a sequence of steps and decisions (algorithms) needed to solve simple problems." [5]

Although the formulation is different to the previous two examples, the content is either similar or at least mappable.

Now, to represent the selected curricula and competence models as graphs, those content specific competences or learning objectives were extracted based on the rating of experts and labeled with a unique ID number, the original text, and attributes like the related curriculum, the level, minimum and maximum age, or keywords. They are displayed as the vertices in the graphs.

B. Relations

The edges of the graph-based representation of the educational models were added in form of relations between the extracted competences or learning outcomes within one curriculum. We classified the two relation types "required by", meaning one vertex is required by another one, and "expanded by", representing either a generalization or a specialization relationship. This step resulted in one simple, acyclic and directed graph for each curriculum, which were in a first step evaluated and revised by two experts.

Please note, the results shown in this contribution focus on the categorization and not on the types of relations. Therefore, the figures show graphs with directed edges, but without type-labels.

C. Graph Database

As supportive technology, the graph database *neo4j* [16] was selected. The graph-based representations of the educational models are mapped to this NoSQL database, which differs in several aspects from relational databases. Data and connections are not stored in tables but as vertices and edges of a graph [17]. Neo4j uses the own query language *cypher* to calculate several graph-theoretic metrics or retrieve needed information.

V. CATEGORIZATION

The main questions during our efforts was to find out, if and to what extend the focal points of curricula and competence models differ. We decided to start with two categories first: either a focus on *Computer Science* or on *Digital Literacy*. This section provides a definition for both categories and further describes how the categorization process was executed.

A. Computer Science and Digital Literacy

Defining the term *Computer Science* needs an additional clarification of the used terminology. Whereas *Computer Science* is a common term in US, in Europe the term *Informatics* is broadly used and also *Computing Science* can be found [18]. Formerly also \textit{Information and Communication Technology (ICT)} was a common term in education, with the varying meaning from "teaching basic concepts" to "application of systems" [19].

In the report of the joint Informatics Europe and ACM Europe Working Group on Informatics Education from 2013 [18] the terms *Informatics* and *Computer Science* are used synonymously and are defined as follows:

"Informatics covers the science behind information technology. Informatics is a distinct science, characterized by its own concepts, methods, body of knowledge and open issues." [18]

In this contribution, we build up on this definition of *Computer Science* and use the abbreviation *CS*.

A detailed definition of *Digital Competence* was presented in connection with the DIGCOMP framework for Developing and Understanding Digital Competence in Europe [20]:

"Digital Competence can be broadly defined as the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society." [20]

For this contribution, we use *Digital Competence* and *Digital Literacy* synonymously and refer to it with *DL*.

B. The Process of Categorization

As mentioned in section II, there are different ways to categorize the elements of a curriculum. Most of them focus on the content and the learning outcomes [4, 6] and classify these element by using specific codes for each knowledge categories. For our contribution nine experts (three females, six male), four of them were Informatics teachers and five were researchers in the field of Informatics didactics, participated in a survey to categorize the competences and learning objectives. Each of them completed a questionnaire including all competences and learning objectives of the three selected models in a random order with the possibility to classify them into *CS*, *DL*, *Both* or *None*. From the results of this survey enough data could be collected, to represent the

focus of each of the analyzed educational model in graphs, which are discussed in the following section.

VI.   RESULTS AND DISCUSSION

To accomplish our goal of giving an overview of the focus of the selected educational models, we represent the results from the expert survey as graphs with different colored vertices. For each curriculum or competence model three graphs with different coloring are presented.

The first and the second graphs show the separate numbers of votes for *CS* and *DL*. So, the colors of the vertices in the first graph represent how many experts chose *CS* or *Both* for each of the corresponding competence or learning objective, and the second graph does the same for *DL*. This is of interest because the two categories are often related together, so it can occur that even if more experts chose one category for one competence or learning objective some would classify it to the other category. Similar cases can be identified by a comparison of the first and the second graph.

The third graph divides the vertices into "CS", "Rather CS", "Draw", "Rather DL" or "DL". A vertex is classified as "CS" or "DL", if more than 75 percent of the experts chose CS or DL for the corresponding competence or learning objective. If more than 50 but less than 75 percent of the experts chose CS or DL, the vertex is classified as "Rather CS" or "Rather DL". If exactly the half of the experts voted for CS and the other half for DL, then the vertex is displayed to be "Draw". With nine experts this can only happen, if at least one expert voted with Both at the corresponding competence or learning objective, because it is counted for CS and DL. In this section, the results for each analyzed educational model are presented and discussed.

The separate results for each of the two categories *CS* and *DL* of the Australian curriculum are presented in Fig. 1 and 2. Fig. 1 shows that at least eight experts voted for ten learning objectives to belong to *CS*. Further one learning objective was classified by at least six experts into *CS*, four learning objectives by at least four experts, three learning objectives by at least two experts, and two learning objectives by one expert. Only two learning objectives have not been classified into *CS* by any expert. In comparison to Fig. 2 six learning objectives were never classified to belong to *DL*. Four learning objectives were classified by at least eight experts into *DL*, six learning objectives by at least six experts, three learning objectives by at least four experts, one learning objective by at least two experts, and two learning objectives by one expert. These results don't indicate a focus on one of the two categories, but it seems that the experts agreed on the classification of learning objectives into *CS*, whereas their opinions concerning *DL* were a bit more divided.

For this comparison has to be considered that some vertices are classified by at least eight experts into one category, but have also e.g. four votes for the other category. An example for this case is indicated in Fig. 1 and 2 by a green cycle. That can occur, if several experts chose *Both* for the corresponding learning objectives and several others chose one of the categories "CS" or "DL".

Figure 1. The distribution for CS of experts' choices for the learning objectives from the Australian curriculum

Fig. 3 shows an overall comparison of the Australian curriculum. Exactly the same amount of the learning objectives (ten) were classified into *CS* and into *DL* by the majority of the experts. For *CS* nine learning objectives were classified into "CS", because over 75 percent of the experts chose *CS* for the corresponding learning objectives, and only one into "Rather CS", what means, that between 50 and 75 percent of the experts chose *CS*. On the other hand, only three learning objectives are classified into "DL", because over 75 percent of the experts voted for *DL*, and seven into "Rather DL", because between 50 and 75 percent of the experts voted for *DL*. For two vertices both categories got the same number of votes, that is why they are classified as "Draw". These results show that the Australian curriculum as a balanced number of learning objectives of each category and has no clear focus.
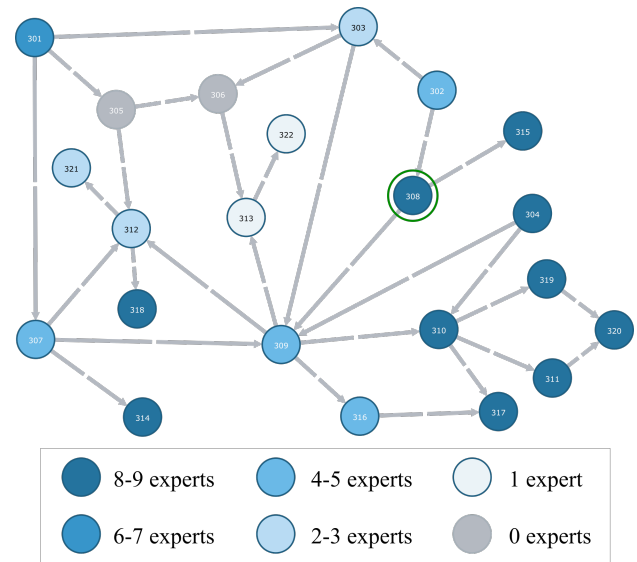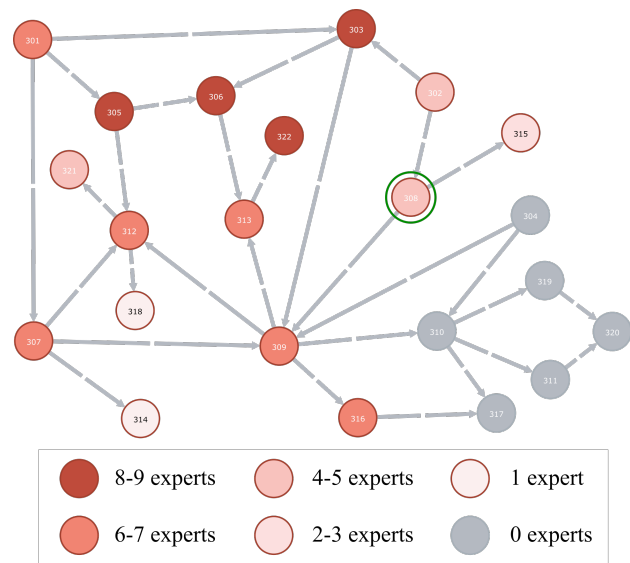

Figure 2. The distribution for DL of experts' choices for the learning objectives from the Australian curriculum
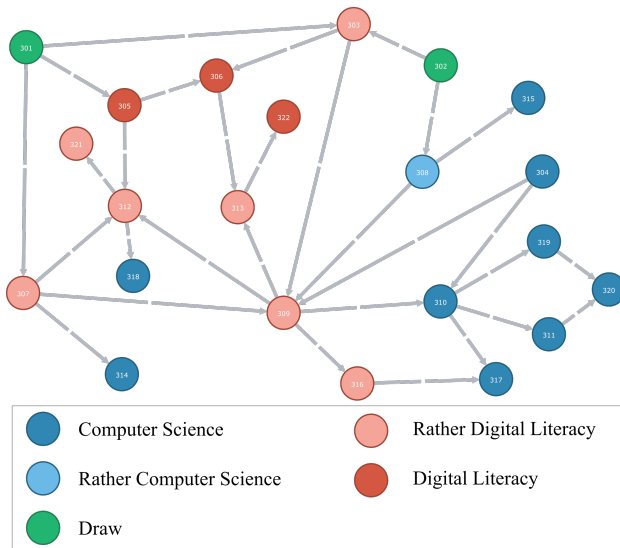
Figure 3. A comparison of learning objectives related to CS or DL from the Australian curriculum

Figure 5. The distribution for DL of experts' choices for the competence levels from the curriculum in Switzerland

For the curriculum from Switzerland the separate results are presented in Fig. 4 and 5. Fig. 4 shows that the distribution of choices for *CS* is limited to a few vertices. Nine vertices were classified by at least eight experts into *CS*. On the other hand, there are 17 vertices, that don't have any vote for *CS*. Fig. 5 shows also a clear focus on DL, because 25 vertices are classified by at least eight experts into *DL*, whereas only three vertices include no vote for *DL*.

The overall comparison in Fig. 6 shows only five vertices are classified to "CS" and six to "Rather CS", whereas 22 vertices belong to "DL" and ten to "Rather DL". And one vertex is classified into "Draw". Following the decisions of the experts the focus of the curriculum from Switzerland is on *DL*.

The separate results for the Austrian Digital Competence model are presented in Fig. 7 and 8. Fig. 7 shows that only one competence was classified into CS by at least eight experts. On the other hand, 25 competences had no single vote for CS by any expert. Fig. 8 shows the dominance of DL in this model. From overall 49 competences 43 were classified by at least eight experts into DL.

The overall comparison of the Austrian model presented in Fig. 9 shows that there are only two vertices classified into "Rather CS" and two into "Draw". The rest belongs with 38 vertices to "DL" and with seven vertices to "Rather DL". As the Austrian model is a model for Digital Competence it has a strong focus on *DL*.

Figure 4. The distribution for CS of experts' choices for the competence levels from the curriculum in Switzerland

Figure 6. A comparison of competence levels related to CS or DL from the curriculum from Switzerland

Figure 7. The distribution for CS of experts' choices for the competences from the Austrian competence model

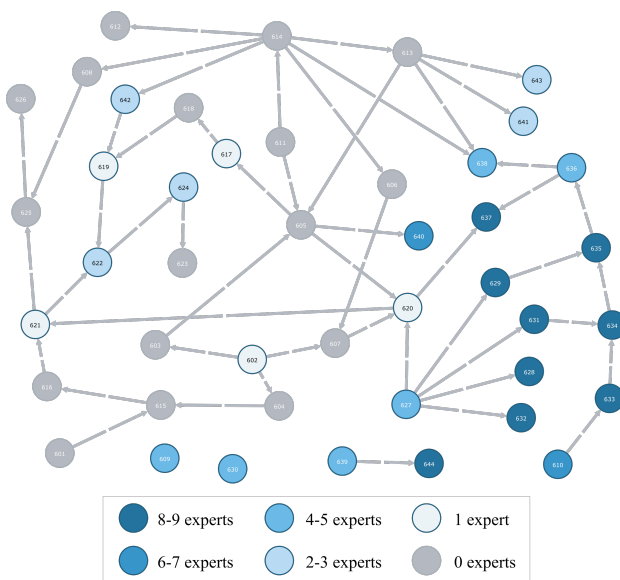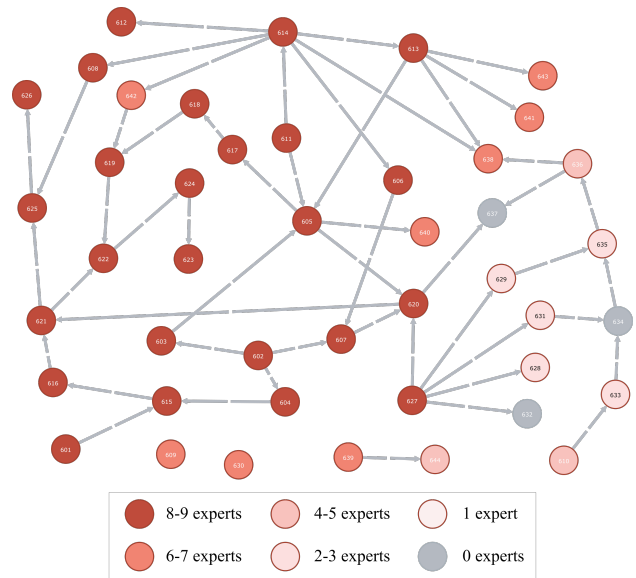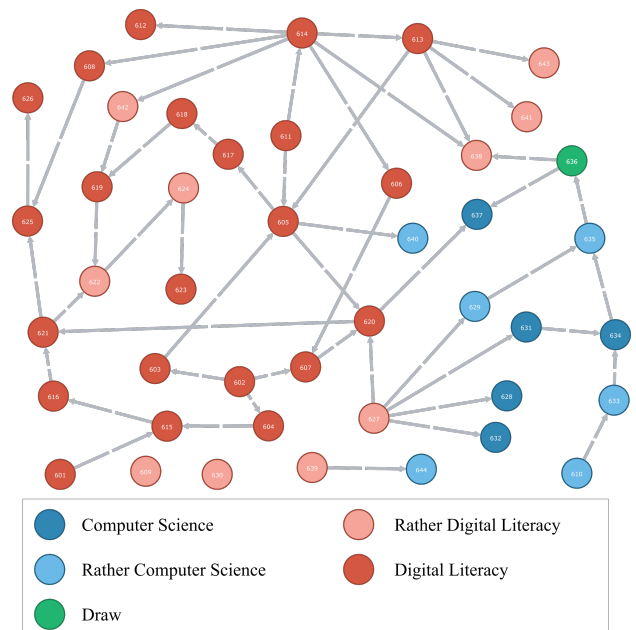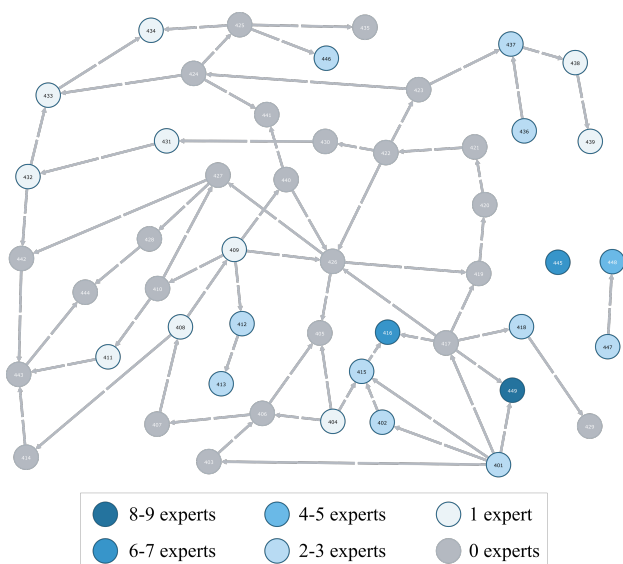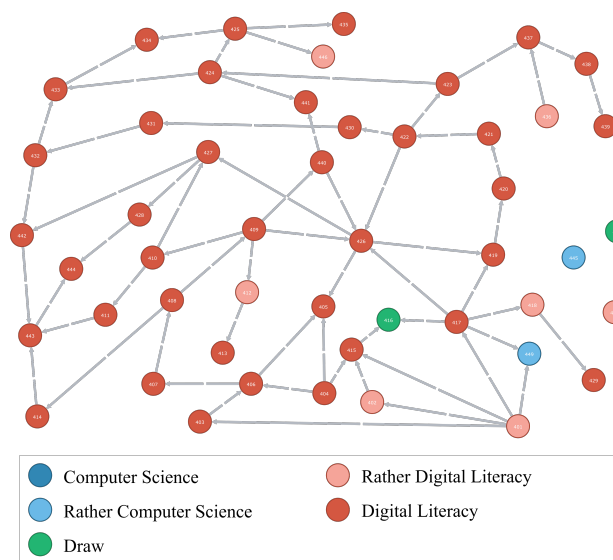Figure 9. A comparison of competences related to CS or DL from the Austrian competence model

VII. CONCLUSION AND FUTURE WORK

This contribution aims at giving an overview of the focus of three selected educational models using a graph-based representation form. For this purpose, nine experts classified the competences and learning objectives into *Computer Science (CS)* or *Digital Literacy (DL)*. In the resulting graphs, these rated competences and learning objectives were represented by the vertices and the different colors displayed their classification. The graphs for the Australian curriculum for "Digital Technology" show a balanced distribution, which indicates that this curriculum has no obvious focus in one of the two categories. In contrast, the resulting graphs for the curriculum 21 for "Media and Informatics" from Switzerland indicate a prioritization of *Digital Literacy*. And, the Austrian Digital Competence model "digikomp" is dominated by competences focusing *Digital Literacy*.
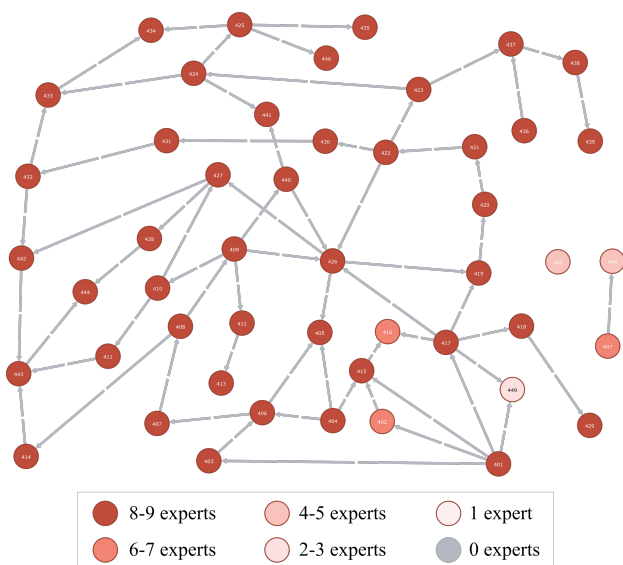
As future work additional curricula, educational standards and competence models for primary and also secondary education will be represented as graphs and mapped to our graph database. Further, a more detailed categorization system will be implemented, based on e.g. the knowledge areas of the ACM/IEEE curriculum. To enable collaborative work and evaluation of the relations within the graphs and the classification of the competences, we are working on an online platform, based on the graph database neo4j. It will offer experts the possibility to evaluate the relations of an existing graph and give suggestions about missing relations. Users like teachers will be able to plan their own learning paths and develop individual curricula based on competences from existing educational models.

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Figure 8. The distribution for DL of experts' choices for the competences from the Austrian competence model

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THE SUGGESTION FOR NEWSPAPERS APPLICATION IMPROVEMENT

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Abstract— **The main aim of the submitted paper is to propose recommendations for the newspapers application improvement for smartphones and tablets used by wide range of users. The first part of the paper contains the explanation, advantages and disadvantages of using digital versions of newspapers for better understanding of the dealing issue. The second part of the paper describes the authors survey, the sources and ways of the data gaining for the questionnaire. The results of the survey among users or potential users of the newspapers smartphone and tablet application are presented in the section Results of the survey. The discussion part of the paper summarizes the results of the survey and contains suggestions for possible ways of newspapers application improvement.**

Key words: application, smartphone, tablet, innovation, newspaper, online

I. THEORETICAL BACKGROUND

The applications for smartphones and tablets are one of the latest innovations in print media. Some of the applications are able only to show issues, offer the subscriptions which are convenient for the reader. The application contains database of previous issues and electronic version saves environment.

The first newspapers were published in Europe in the seventeenth century. Evolving technology has brought changes to the newspaper business. The web has given to newspapers the new opportunities to update the news rapidly and fresh ways to deliver the news [1].

Five advantages of the online media can be defined: time reality, interactivity, direct competition comparison, linking information via hypertext and format blending [2].

In addition to offering a Web edition of newspapers customized for computers, papers are also delivered either by application or mobile Web sites tailored to work with smartphones, tablets and other mobile devices.

Advantages of using digital version of newspapers compared to print ones are following [3][4]:

- The content can be organized in any way the author wants. The software can imitate a codex, a scroll or even a clay tablet.
- It can support a linear path through a book like a codex or scroll, or it can provide hypertexting that allows a multitude of paths through the content.
- The reader can look up words and dig deeper for information in an instant.

- There is no need for costs of a printing press, paper, ink or electricity, lubricants, cleaners, and labour to rub the printing process.
- There is no cost for the shipment and storage of books, and people to sell the books. Vans, drivers, warehouses are not needed as well as salary for book sellers, inventory and real estate costs are not necessary.
- The purchasing process is faster and easier for customers. A book can be purchased anywhere and at any time.
- Timing and always fresh news. Update can be done anytime as there is no deadline for printing the newspapers.
- Interactivity. Newspapers can not only merely shift its print media content to its online version or mobile app: it can be changed to a cool, value-added experience. Larger graphics, added videos, interactive comments add value that print cannot offer.
- Social sharing and community. Users increasingly expect to interact with the content they consume.
- Ad-serving flexibility. The advantage of using digital media advertising is not only that multiple ads in one advertising space can be published but some of the latest advertising technologies can be used, too. Digital media advertising enables readers to engage with ads whether banner ads or more intensive sponsored content.
- Tracking and analytics. The clearest benefit to digital publishing is the feedback that helps to optimize content and interface of the application. That information can be used especially to grow and maintain readership and attract viable revenue streams through sponsored content and ad revenues.
- Readership feedback. Readers can be asked directly about their experience and opinions through well-formulated surveys. This valuable insight can be used to improve content of the digital version.
- Access to free marketing channels. Digital media provides access to social networks where the newspapers can distribute news and promote themselves.

But digital editions of newspapers give publishers another issues to deal with, including [1][5]:

- Getting paid for online content. Newspapers and other media outlets have long given away their

product for free online. Once you have started doing that, it is hard to get people to start paying.

- Online plagiarism. Digital media publishers need to take additional steps to protect their written content, photos, videos, and other original works.

- Shorter attention spans. As people get older, they understand and remember less, and they have greater difficulty transferring their learning to new contexts. Digital media have to work extra hard to keep its attention-deficit readers engaged.

- Time limit. Online content can be available for only some time or can be deleted by owner without reader´s knowledge. The information is not available anymore.

- Sensory experience. The studies show that person retains knowledge and experience better through physical interaction.

This paper is focused on Slovak newspapers. SME newspapers is the first Slovak newspapers that registered internet domain. In 1996 SME became online on www.sme.sk. Since 1998 Pravda and Hospodárske noviny started online versions of the newspapers [6].

Later, applications became popular. Plus jeden deň, Denník N, Hospodárske Noviny, Šport are examples of applications that offer printed issues in electronic form. On the other hand, some newspapers applications do not offer full issues but the articles are shown individually the way they are available also on the internet website of the newspapers, for instance newspapers Nový čas, SME and Pravda. The biggest advantage is that they can add latest news even in the evening and night hours.

II. METHODS AND AIMS

To reach the main aim of the submitted paper, to propose recommendations for the newspapers application improvement for smartphones and tablets used by wide range of users, 5 partial aims are stated: First, collection, study and sorting of the theoretical data of solved issue. Second, setting methods and aims of the survey. Third, collection of the data for the analysis of the current state of newspaper applications usage. Fourth, the suggestion for newspapers application improvement. Fifth, conclusions and a summary of the findings.

For collecting data for this paper was used the questionnaire method. The questionnaire contained twelve questions. The questions were constructed from data obtained by studying theoretical resources. The structure of the questionnaire is shown in Fig. 1.
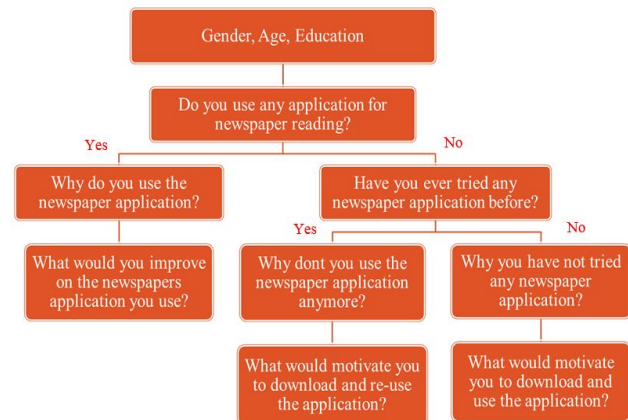
Figure 1. Questionnaire scheme

The first three questions are sociodemographic questions – gender, age and education. Next question asks the respondent whether he/she uses newspapers application. If the answer is yes, questions about satisfaction and improvement suggestions of the used application follows. If the answer is negative question whether the respondent used to use any newspapers application follows joined by questions with checkboxes for multiple choices about what would make users to install and use the newspapers application again. The questionnaire also contains questions for respondents who have never used any newspapers application. The questionnaire contained space for the respondent to add some notes. The survey questionnaire was distributed via Google Documents and available from October 8th to October 18th 2016. The survey questionnaire was answered by 130 respondents from Slovakia. 10 questionnaires were excluded from the survey because of incorrect answers of the respondents.

III. RESULTS OF THE SURVEY

The first three questions reveal that the questionnaire was answered by 61 % female and 39 % male (Fig. 2). The biggest age group was composed of the 19-30 years old respondents (82 %) (Fig. 3) and 64 % achieved university grade (Fig. 4).
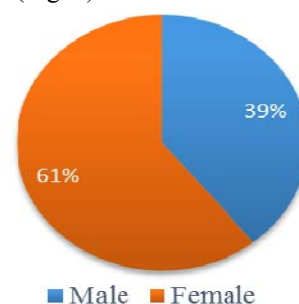
Figure 2. Gender – Sex
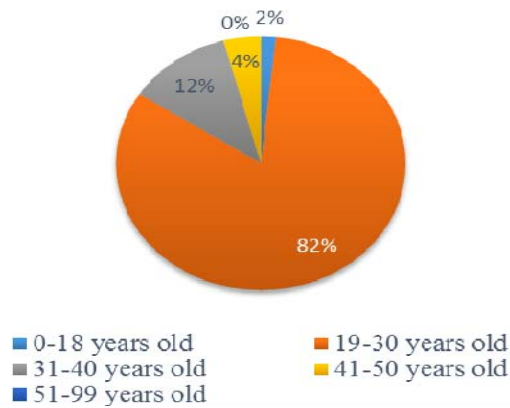
Figure 3. Age
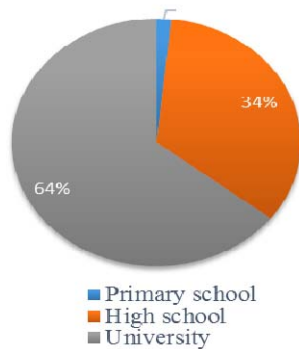
Figure 4. The highest level of achieved education

After these socio-demographic questions, another section followed. Firstly, respondents were asked whether they use any newspaper application. 22 % of respondents answered positive, 78 % of respondents do not use any newspapers application.

The results of the survey questions are shown in absolute frequency of respondent's answers. The most important reason why respondents use newspapers application was quick access to the content without need of opening Internet browser (11 respondents), easier orientation in the content (7 respondents) and notifications about important news on the screen (7 respondents). Answer „there are good recipes" was added (Fig. 5).
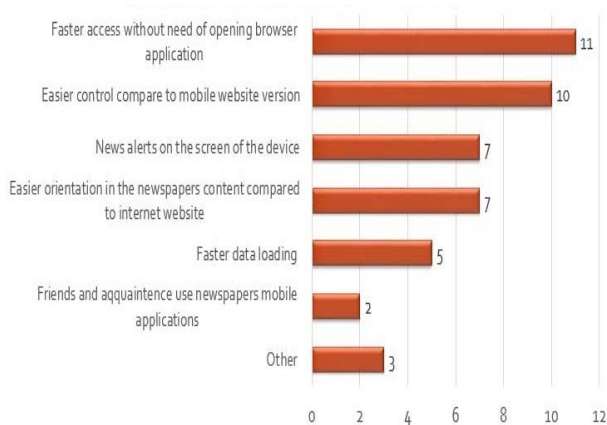
Figure 5. Why do users use newspaper´s application instead of mobile website version?

The following question discusses the suggestions what would the users improve on the newspaper application they use. The chart below (Fig. 6) shows that two most popular suggestions are the posibility to choose preferred content (12 respondents) and the possibility to create a free account for saving preferences (10 respondetns).
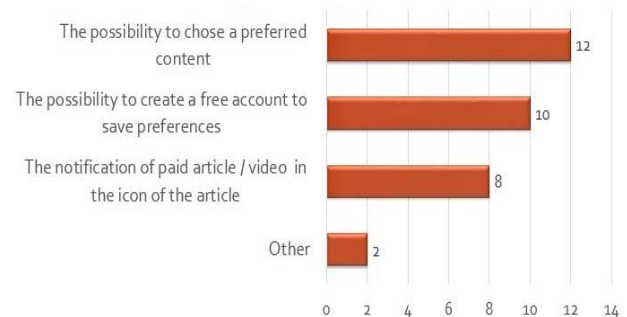
Figure 6. What would you improve on the newspaper application you use?

The respondents who do not use newspaper application were asked about their previous experience with it. The biggest group of total respondents are those who do not use newspapers application and had never used any newspapers application (65 %). Group of 13 % of total respondents had tried newspaper application but either stopped using it or uninstalled it from device for various reasons.

The group of the respondents who had experiences with newspapers applications (13 %) uninstalled the application for more reasons. The chosen application either did not fulfill their expectations as functionality, content or price of the service they had to pay for using the application (9 respodents), or they were not satisfied with the control of the application (2 respondetns). Three respondents prefer reading news online. Other answers contained complaints about updates and hardware problems (Fig. 7).
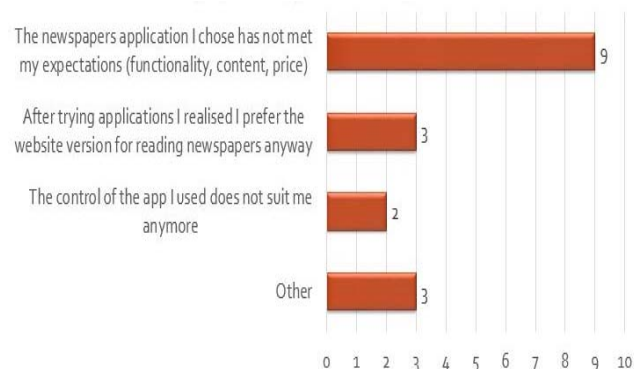
Figure 7. What is the main reason why you do not use the newspaper application anymore?

The respondents who had used the newspaper applications would consider installing the application back, if the navigation through the content of the application was more user-friendly (4 respondents), better marketing of the application as without promotion they will not know about the updates, changes and improvements in the application (3 respondents). The

respondents would consider reusing the application if features such as notification of paid article/video (2 respondents), possibility to customize the content (2 respondents) and to display chosen content on other devices by logging to private free account with saved personal preferences (2 respondents) are added. Flawless operation (2 respondents) and faster loading of the site (2 respondents) are the most important aspects of their decision to install the newspapers application again. More interesting content and new device are answers which respondents added to Other (Fig. 8).
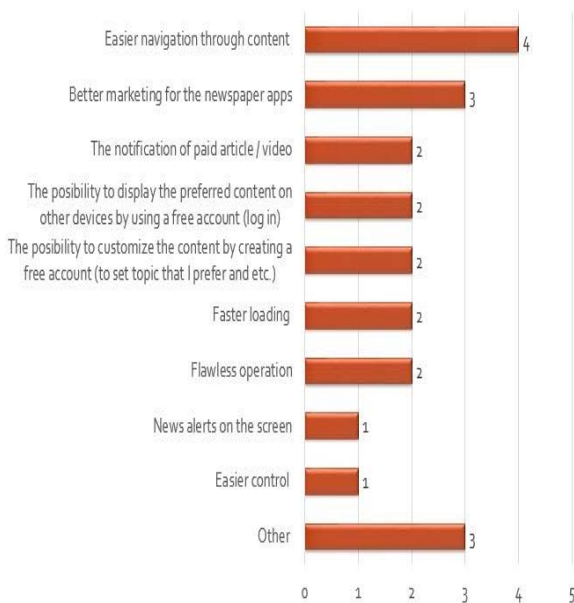
Figure 8. What would motivate you to download and re-use the application?

The respondents of the biggest group of 65 % who have never tried any newspapers application were asked why they have never tried any newspapers application. The most frequent reason was that they had not heard about any newspaper application (44 respondents) or they are not interested in the application because they prefer online version of the newspaper (41 respondents). Five of the respondents are not interested in any applications as they do not have suitable device for the application and as they pointed out in answer Other mostly because of the full memory of their device (3 respondents) (Fig. 9).
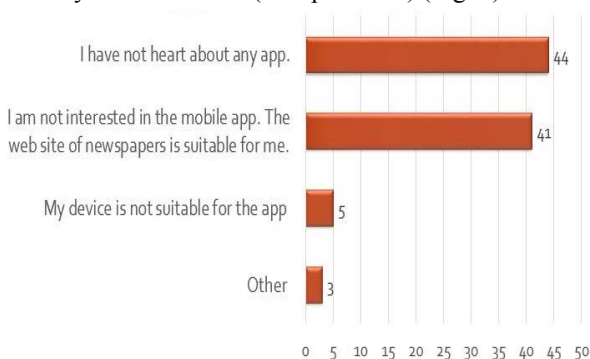
Figure 9. What is the main reason why you have not tried the newspapers application?

The respondents of the 65 % group require from the newspapers application easy navigation through the content and the faster loading of the content compared to the online version (20 respondents) and easier way of control of the application (19 respondents). 16 respondents require flawless operation. Four respondents added that nothing would persuade them to use newspapers application, two are satisfied with website version and one respondent would download the application if the content was free. (Fig. 10)
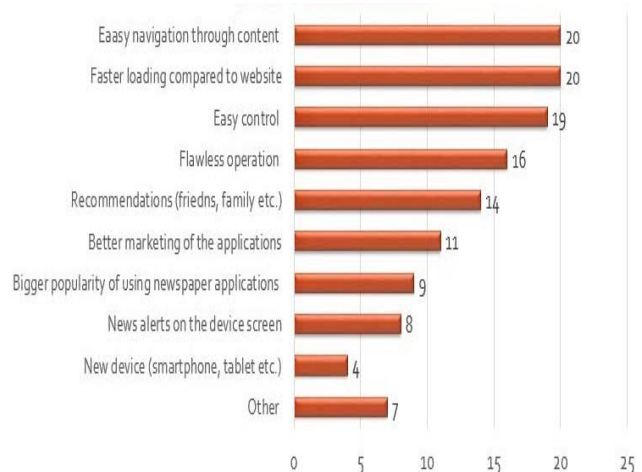
Figure 10. What would motivate you to download and use the application?

Last question was not compulsory. The respondents had space to add their thoughts on discussed topic. The most common are following: "I avoid using similar applications. They require many private information about the user, take system memory, they are slower...; I prefer reading news on PC or mobile via the browser.; Lately, newspapers become tabloids, I am tired of having to dig through the information to find something useful. I gave up." Newspapers applications respondents use: Teraz application, Sme.sk, Denník N.

IV. CONCLUSION

The results which are presented above can be summarized as:

- 22 % of total number of respondents use smartphone or tablet newspapers application. The main reasons why they prefer the application to the website are that it is faster, has easier control, offers alerts about news and they have positive recommendations. However, there are areas to improve: possibility to customize content, possibility to create free account for saving customized content and notification of paid content so the user is warned before opening the article.
- 13 % of total respondents who have tried the newspapers application stated that the reason why they did so, was that it did not work properly, content was not interesting for them, they were not willing to pay the price and the application did not suit their needs. They would consider re-using of the application if the navigation was easier, there is possibility to customize content and saving the customization

by creating free account, screen alerts about the latest news and the loading of the application was faster. All this needs better marketing to let people know about these updates.

- 65 % of total number of respondents have not tried newspapers application. There are two most important reasons. They either have never heard about any smartphone or tablet newspapers application or they are not interested in any newspapers application. Some of them have not tried newspapers applications because they do not have a suitable device. Their conditions for downloading some newspapers application on their device were numerous: easy navigation, fast loading, easy control, flawless operation, recommendations from friends. Few respondents would not be persuaded by anything to download such application.

According of the survey results, following recommendations can be suggested:

- Firstly, the application should have user friendly navigation, flawless operation, fast loading, interesting content and good look. These aspects would make users satisfied and they would share positive feedback among people. "Word of mouth" is one of the most powerful marketing tool for spreading information.
- Secondly, the most effective way for keeping actual users is to innovate. New features, such as possibility to personalize application for individual user, creating free account for saving this personalization, are welcome. Space for users' feedback, especially for getting suggestions for improvement, should be provided.
- Old users could be persuaded to start using the newspapers application again by easier navigation, application personalization, more interesting content and marketing to let them know about the updates.
- People who never used any smartphone or tablet newspapers application should be aware of the newspapers application existence. Good marketing plan should be prepared for promoting the application as well as for those who do not use any newspapers application either because they are not interested or they lost interest in it. Advertisements in different applications with direct link to the download site are effective.

Realization of further research is planned on a larger sample of the respondents. The research would be implemented also in further research in cooperation with several newspapers publishers. Consequently, the results will be compared with the results of this paper.

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Open Educational Resources Development and its Infancy in Slovak eLearning

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Abstract—**2017 marks 15 years since the worldwide push for Open Education Resources (OER) started. Recent studies (for instance [1]) claim, that OER movement has reached its adolescence. We have a feeling, that in Slovak academic context, the movement is still in its infancy. This article briefly summarizes 15 years of development and advocacy of Open Educational Resources (OER) and looks at the barriers to its use and at a recent situation state of using of OER in Slovak academia, using Comenius University as an example. Analysis of possible incentives and ways to overcome barriers in the Slovak context is included.**

I. Introduction

The concepts of Open Education and Open Educational Resources (OER) have been introduced and spread around the world some 15 years ago. This started as an experiment of few scientists, but it has evolved into a movement accepted and promoted by academia, non-profit organizations, companies and governments. There are many who say that this has been more of an evolution rather than predicted revolution [1], but there are no doubts, that OER experienced a massive growth, global acceptance, promotion and use.

Of course, openness in education as a general concept has much longer history [2]. It is tied to belief, that education and knowledge is a public good. David Wiley [3] likes to use an example of lit candle in order to explain the concept. If you use your lit candle in order to light up a candle of somebody else, it does not mean your own candle will go out. Actually, with two lit candles, you will both have more light. This is the same concept public libraries are based on. Later, the main focus of openness of education was on open entry to study. This lead to raise of public schools and later concepts of open universities. New options appeared with arrival of the Internet.

The term Open Education Resources was first used at UNESCO's 2002 Forum on Open Courseware (for instance [4]). There are numerous definitions of OER, one of those used very often is the one by The Hewlett Foundation:

"OER are: Teaching, learning and research resources that reside in the public domain or have been released under an intellectual property license that permits their free use of re-purposing by others" [5]

Permissions for using open educational resources are based on four basic principles (so called "4Rs Framework:"[3]

1. Reuse - the right to use the content again in its original form (for instance make a backup copy of the material)

2. Revise - the right to edit, adjust, modify, or change the content itself (for instance, translate the content into another language, or adding few paragraphs)

3. Remix - the right to combine the original material or altered content with some other materials to create something new (for instance, incorporate the material into a mashup, or record a video presentation that includes this and other materials)

4. Redistribute - the right to share copies of the original material, your revisions, or your remixes with other people (for instance, give a copy of the content to a friend, or place it into your online course).

There was a need to create licenses that would enable authors to give permissions to others to use their materials. Creative Commons [6] licenses are the most common tool. Creative Commons licenses include different options for authors to state permissions and limitations for others.

Basically, the limitations are:

Attribution

All CC licenses require others who use your work to give you credit in the way you request, and not in a way that suggests endorsement on your part.

NoDerivatives

You allow others to copy, distribute, and otherwise use only original copies of your work without modification.

NonCommercial

You allow others to copy, distribute, and otherwise use your work for non-commercial purposes.

ShareAlike

You allow others to copy, distribute, modify, and otherwise use your work, as long as they distribute the modified work under the same terms of license.

II. Development of OER

Creation and use of OER gained world-wide support from academic institutions, governments and international organizations. According to Guttenplan [7], it was the 2002 MIT Open Courseware Project, by which MIT published their whole course catalog and large parts of materials on the web for free, that sparked the massiveness of the movement.

In 2007 the Open Society Institute and the Shuttleworth Foundation invited thirty leading proponents of open education to a meeting in Cape Town to collaborate in a

common manifest [8]. In January 2008, they issued the Cape Town Open Education Declaration, which was appealing to governments and publishers to provide funding making materials openly available.

Years 2007 and 2008 are also years, when another significant massive movement based on the same principles started. David Wiley in Utah and George Siemens and Stephen Downes in Canada decided to open the courses they taught online at their universities for free for everybody who was interested. They did not offer university credits to people who did not pay tuition, only the course participation. Thousands of people participated in these courses. When in 2011 Stanford University opened up one of their courses, they got over 160,000 people signed up. Today there are hundreds of institutions offering free participation in Massive Open Online Courses (MOOC) and thousands of courses to choose from.

III. OER DEVELOPMENT IN EUROPE

The beginning what is now known as the Open Educational Resources (OER) in the context of the European Union (EU) finds its *de iure* roots in the Treaty of the Functioning of the EU (its 2016 consolidated version), in the articles 165-166[1] and more notably through the articles 179-190.[2]   Although the legal framework existed, the EU had made little consolidated and coordinated effort in order to establish OER. Promoted by the so-called knowledge triangle, where education, research and innovation closely interlink and, therefore significantly contribute to creation of jobs and growth, a giant leap towards OER in the EU was made when European Institute of Innovation and Technology (EIT) was founded. In the following excerpt from Regulation (EC) No. 294/2008 of the European Parliament and of the Council of the EU from 11 March 2008 a legal framework for establishing the EIT was set almost a decade ago.

"A new initiative at Community level, the European Institute of Innovation and Technology should be established to complement existing Community and national policies and initiatives by fostering the integration of the knowledge triangle — higher education, research and innovation — across the European Union. [...] contribute to sustainable European economic growth and competitiveness by reinforcing the innovation capacity of the Member States and the Community. It shall do this by

promoting and integrating higher education, research and innovation of the highest standards."[9]

EIT represents one of the tools used by Barroso Commission[3] in 2008 to tackle fast-growing financial and economic crisis and decreasing competitiveness of the EU Member States (MSs), that was taking its toll in severe loss of jobs and decrease of economic growth on the EU territory, with negative effect dramatically expressed in economic, political, social and other aspects of life of the EU citizens. Institutionalized within the EU, European Institute of Innovation and Technology can be seen as an executive force in the triangle of education, research and innovation known as the *knowledge triangle*. The Juncker Commission[4] continued with promoting and investing in the knowledge triangle, enriching it with the recent shift in the direction of open innovation. That has led to further enhancing its international attractiveness where new forms of cooperation between education/research institutions and businesses were introduced. These cooperations, with their international structure, represent the so-called *Knowledge and Innovation Communities* whose main tasks are to develop innovative products and services. They also establish new companies and develop entrepreneurs for the innovative age, since the goals of EIT and knowledge triangle remained the same – giving new impetus to innovation, competitiveness and entrepreneurship in the EU.

When in September 2013 the (former) Vice-President of the European Commission Neelie Kroes[5] and the (former) Commission Member Androulla Vassiliou[6] launched an initiative titled Opening Up Education it has *de facto* opened up the front door for coordinated actions with an aim of developing Open Educational Resources in the EU. Although OER were not unknown to the EU MSs it did not have open advocacy on behalf of the EU in such a manner nor the consolidated and coordinated efforts including funding. With the Opening Up Education initiative OER has for the first time gained not only strong

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[1]*"The Union shall contribute to the development of quality education by encouraging cooperation between Member States and, if necessary, by supporting and supplementing their action [...] Union action shall be aimed at: [...], promoting cooperation between educational establishments, [...] encouraging the development of distance education, [...]."*

[2] *"The Union shall have the objective of strengthening its scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely, [...]. [...] permitting researchers to cooperate freely across borders and at enabling undertakings to exploit the internal market potential to the full, in particular through the opening-up of national public contracts, the definition of common standards and the removal of legal and fiscal obstacles to that cooperation."*

[3]The Barroso Commission represents the term for the College of the European Commission (26 and, post-2013 enlargement, 27 Commissioners and president) in the periods 2004-2009 and 2009-2014 where the whole composition was named after its president Juan Manuel Durão Barroso.

[4]The Juncker Commission represents the term for the College of the European Commission (27 Commissioners and president) in the period 2014-2019 where the whole composition is named after its president Jean-Claude Juncker.

[5]Neelie Kroes was a member as well as a Vice-President of the College of the European Commission responsible for the Digital Agenda in the period 2010-2014 (Barroso Commission).

[6]Androulla Vassiliou was a member of the College of the European Commission responsible for the Education, Culture, Multilingualism and Youth in the period 2010-2014 (Barroso Commission).

support by the EU "motor"[7] but also stout wind in the back to flourish and develop.

Opening Up Education seeks the way to raise the usage of digital technologies in the process of learning and teaching, therefore giving impetus for serious advancement of OER and their respective supportive policies in the EU. In order to achieve so, the European Commission used the already existing programs, such as Erasmus+, both as object and example of OER. In this sense, Commission ensured that all the educational material supported by Erasmus+ is available to the public under open licenses. This practice served as a test case and is to be promoted and spread to similar EU programs. Inspired and motivated teachers, IT companies, publishers, and other stakeholders should/are expected to enable high quality OER and other digital educational material, as well as new IT solutions and business models in variety of languages[8] via Erasmus+ and Horizon 2020 programs. The Commission was aware that such actions require clear and available information on copyrights as well as open licenses to OER users. In order to achieve communication between teachers, learners and researchers but also use and connect all the other already obtainable OER repositories in different languages, Kroes and Vassiliou have also and on behalf of the European Commission launched a common portal – Open Education Europa. The portal encompasses high quality OER in different languages but it also serves as a promoter and inspiration for the EU MSs to create policies in the context of open access resources. Such policies are to ensure publicly funded educational materials and persuade formal institutions for education and training to incorporate digital content into educational material for learners, regardless of their educational level. They should also be fostering creation of high quality OERs where copyrights would be owned by public authorities.

The OER narrative in the context of the EU would be incomplete if we failed to mention one of the major European Commission's priorities: the Digital Single Market. The Juncker Commission is trying to achieve a digital single market, which will provide the fundamental four freedoms of the EU – the free movement of goods, persons, services and capital. In this context, the four freedoms are being enriched by their fifth counterpart – data as the free movement of data is perceived crucial in forming fully integrated digital single market. At that point the digital single market will offer (further) boost of EU economy – new jobs, growth, competitiveness, investment, innovation, market expansion, with possibility for the EU to position itself as the digital economy world leader. Modernizing the EU copyright rules to fit the digital era therefore freeing the potential of the European data economy with a framework for the boundless flow of non-personal data in the EU are the two of seven objectives the Commission has set in order to achieve digital single market, that are of particular interest for OER development in the EU. It also encompasses an additional objective to ensure the so-called "connectivity for a European gigabit society" that aims to enable everyone in the EU the best

possible internet connection. So far, the European Commission has proposed several legislative novelties regarding copyright rules as well as renewal of regulation and directive on copyright law. New proposals seek to find and ensure balance between copyright and relevant public policies and their target goals in the field of education, research, innovation and needs of disabled citizens of the EU. This is the reason why they include, amongst others, increased options for use of copyrighted materials in education and research, as well as cultural heritage. Furthermore, the proposal was made to implement the Marrakesh Treaty[9] according to which people with disabilities, such as visual and other print impairment, will be provided with more books and texts in format that meets their needs.

As a part of the EU Digital Single Market strategy, the Commission has adopted a Communication on "Building a European data economy" in January 2017 that has tackled the obstacles of the free flow of data on the one hand, but also promoted the use of digital data and unlocking its full potential that could bring numerous advantages to both, the economy and the society, on the other. Additionally, a public consultation has also been launched regarding the review of the Directive on the reuse of Public Sector Information[10] with an aim to reuse public and publicly funded data and development of their respective policies. At the current moment, we take the role of observers awaiting information on renewed directive and how it will be transposed to national laws and how the situation concerning the OER development will unfold within the EU, with more focus towards Central and Eastern European Countries as they strive to overcome the OER development gap between not only OER developed EU Member States, but also countries in the world with OER in more advanced phase, especially bearing in mind the EU's ambition in becoming the world's leader in digital economy.

IV. BARRIERS TO OER DEVELOPMENT

Annand [10] provides a detailed list of potential obstacles for OER development, such as: doubts concerning the quality of educational material, potential damage to authors' good name and loss of control regarding intellectual property especially if the intellectual property is considered as top intellectual produce [11]; location and evaluation of the material is too time-consuming [12]; inadequate and/or lack of technical skills of teaching faculty [13]; financial constraints [14]; providing on-going and sustainable resources of educational material in the long run [15]. Krelja Kurelović [16] takes copyright as an important obstacle but she also stresses the challenge of adapting the OER material into concrete pedagogic context as well as country's cultural

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[7]"Motor of integration process" or "Daily initiator of integration process" are commonly used metaphors that reflect the function of the European Commission, which has a role of legislative initiator and proposal maker, mediator and broker, but also executive force of EU policies' implementation.

[8]There are 24 official languages in the European Union.

[9]Marrakesh Treaty to Facilitate Access to Published Works for Persons Who Are Blind, Visually Impaired, or Otherwise Print Disabled (MVT) or simply Marrakesh Treaty was adopted on 27 June 2013 in Marrakesh (Morocco) with an aim to provide a set of mandatory limitations and exceptions for the benefit of the blind, visually impaired and otherwise print disabled (VIPs). It is administered by the World Intellectual Property Organization (WIPO).

[10]Directive 2003/98/EC - Directive on the reuse of Public Sector Information.

context also pointed out in the Paris OER Declaration (2012) that does not only consider cultural context of educational material, but also included variety of languages. Additional things that Krelja Kurelović indicates is the reality of OER development in small countries1[11]that continuously fail to set OER implementation policy on either national or institutional level; lack substantial financial support; lack upgrading their teaching and learning practices from traditional teacher-centred teaching and learning; lack the appropriate digital and information literacy; feel the constraint of language and different cultural context. As expressed by [16], there are very similar obstacles to OER development in Latvia and the Slovak Republic, additionally limited by the lack of stronger marketing activities and supporting instruments.

There have been numerous studies conducted on use and perceptions of faculty and students towards OER [17], [18], [19] Most mentioned barriers in literature can be summarized as follows:

1. Lack of information on OER.

Large surveys conducted at universities in US and around Europe [17], [18] show that only small percentages of faculty know what OER are and where to look for them. One of the US studies [20] claims, that only 18% of faculty at a large US university had sufficient information to look for OER, in a study conducted accross Europe [18], 80% of faculty claimed they need more information.

2. Quality of Resources

Faculty often perceive OER as materials of dubious origin and low quality [18]. Teachers argue, that there are quality controls and quality standards for classic textbooks, but no rules for OER, so they have no way to know to trust the quality.

3. Language issues

Of course, the OER needs to be in the language that the course is taught in, but need for translation is not the only problem [18]. Very often OER use also cultural references and are based in the context of particular country they were created in.

4. Lack of discoverability

Large number of survey participants [17], [18] insisted, that it was not possible for them to locate suitable OER materials. They complain that since OER repositories let people mark and tag their own materials as they upload them for sharing, the tagging system is in-comprehensive and makes finding suitable materials close to impossible.

V. OER Development in Slovakia

In line with the EU policies, Slovak Government proposed an Action Plan for the Initiative for Open Governance for Years 2015-2019 [21]. Main goals concerning OER in this Action Plan were focused on mapping situation in OER in Slovakia. The efforts discovered few repositories, mostly focused on high school level.

The Slovak Government then approved a new adjusted Action Plan on March 1, 2017 as the Action Plan for Open Governance for years 2017-2019 [22].

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[11]In this particular case it is the case of Croatia, but the reality can easily be transposed to the case of Slovak Republic.

In the part concerning Open Education Resources, the Action Plan presents the Minister of Education with with particular tasks and deadlines (website):

Create and run an OER repository where OER can be kept accessible for a long term (deadline: June 30, 2018)

After the repository is created, continue to publish resources there under the Creative Commons (CC) simple Attribution license (continuously)

Contact partner organizations that have been supplying educational resources for the Ministry of Education in the past and propose to have all future resources supplied with CC Attribution license (deadline: July 31, 2017)

Ensure, that all new contracts made by the Ministry of Education for educational materials will include a condition, that the materials need to be released under Attribution CC license (continuously, starting on March 1, 2017)

Support translation of appropriate OER (mainly videos and short movies) into the state or minority languages of Slovakia (deadline: June 30, 2018)

Create and pilot-test a policy for making accessible university textbooks and materials as well as scientific journals under the Attribution CC license (deadline: December 31, 2018)

Suggest legislative that will introduce clear rules for open publishing and that will introduce an obligation for open publishing of materials supported by public funds. (deadline: December 31, 2018)

Analyze option to make all final and qualification theses that are registered in the Central Registry accessible under the Attribution CC license (deadline: December 31, 2018)

Continue to increase knowledge of teachers, other employees in teaching process and students on OER (continuously)

Publish information on selection process for support of educational resources on the Ministry of Education website (continuously)

VI. OER Use at Comenius University

Most universities in Slovakia use open source learning management system Moodle as their main system for elearning. However, it seems like what establishing system and policies the main focus was on technical aspects. The university of Zilina makes provides Moodle and technical support to use it for all their teachers. There is a technical department that provides technical support for teachers as well as students using Moodle. [24], [23]. On the other hand, the university does not provide any incentives for teachers to transfer their courses into online form, and it also does not provide instructional design support. A similar situation exists at the Slovak Technical University, which also uses Moodle as a Learning Management System [25], or Constantin Philosopher University in Nitra [26], [27], University of Presov [28], University of Economics in Bratislava [29] and the Technical University of Kosice, which developed a Learning Management System of their own [30] and is also using Moodle [31].

Comenius University in Slovakia uses Moodle as its Learning Management System since 2006. Just like the others, for many years, it was left up to the teachers whether and how they decided to use Moodle. Only in the

last few years, also some instructional design support and training is available. But incentives are still missing.

In September 2017, the Moodle of Comenius University, contains 525 active courses. If we discount a few exceptions, there are no full online courses, but just spaces set to support classes, that meet for regular classroom sessions. Mostly Moodle spaces are used for providing materials to students, collecting assignments and/or using tests for assessment of students.

We searched through the courses to determine how often open educational resources are used and we interviewed three teachers who have used OER and three teachers who have not in order to get at least some picture on how often teachers at Comenius University use OER and what are their reasons for using them or for not using them.

For the purpose of this study we defined OER as materials, where it is clearly stated, that their author approves others to use their materials (in most cases Creative Commons licenses), or that the materials are in public domain and hence without any copyright restrictions. Out of 525 courses, we only found OER in 10 of them. This amounts up to 1.9% of courses.

Out of the three teachers who used OER in their courses that we interviewed, only one could be considered an OER advocate, a person who has information on OER movement, knows what Creative Commons licenses mean, believes in the idea and tries to promote wider use of OER at his department. He also posted online some of his own work under creative commons license. However, he complain how hard it is to find OER of decent quality that would fit his curricula.

The second teacher was using materials with Creative Commons license because a colleague told him, that "the ones with these icons are OK to upload into the course". He did not know what the "icons" mean or why it is OK to upload those into the course. The third teacher did not know what we were talking about, since she somehow ended using Creative Commons licensed material somehow accidentally. He found it online, liked it and used it without much concern for copyright and the fact that it happened to be an OER with Creative Commons license was just pure luck.

With the exception of the first teacher, who has already published some of his work under Creative Commons license, the other two teachers declared that they would hesitate to publish their work with permission for others to use it for free, even though one of them admitted, that he used some copyrighted material without permission in the past. As reasons for hesitation, they listed feelings of lack of appreciation for their hard work in creating materials, uncertainty of not knowing who uses their materials and for what, as well as handing unfair advantage for their competitors (departments of the same specialization is theirs at other Slovak universities).

At the end one of the half-jokingly added: "And also there is the humiliation if we post something online for free and then nobody will be interested to steal it at all".

We also interviewed three teachers, who have not used OER in their courses. One of them has heard about OER movement and Creative Commons licenses, but did not have much interest or trust towards the concept. He claimed, he spent a "short time" looking into OER and he was not impressed by selection and quality. The other two

teachers have never heard about OER. But after getting an explanation on the concept, they showed some interest. One of them even became very enthusiastic eager to improve his courses right away.

However, search through materials in Moodle courses at Comenius University unearthed an additional problem. We found numerous cases of copyright breach where teachers simply posted copyrighted materials into their courses. All six interviewed teachers agreed, that reason for this is most probably the fact, that teachers don't realize, that copyright laws are applicable in online courses just as much as everywhere else. They know it is illegal to download a movie or a music CD for free instead of buying a disk, or download an electronic version of a textbook without paying for it. But for some strange reason they thought that if their online course in Moodle is password protected it is perfectly fine to share copyrighted materials with students.

VII. Analysis and Conclusion

Our little study into use of OER at Comenius University cannot be generalized easily. In order to select teachers to interview we randomly choose courses on the Moodle server and contacted lead teachers on those courses. Not every person we contacted we available for an interview in the short time frame we have, so we move onto another course. Selection of interviewed teachers can not be considered representative. There is also the fact, that both authors of this article have personal enthusiasm towards OER movement, which could be infectious during a longer interview.

However, the fact that we found use of OER in only 1.9% of all courses at Comenius University is telling. The interviewees lead to impression, that the reasons for low use of OER at Comenius University seem to be very similar to the reasons for slow adoption of OER at other places as described in literature:

1. Low level of information about OER (teachers never heard about it)

2. Lack of discoverability (teachers have trouble find suitable OER)

3. Concerns about Quality of OER (materials that have not been "blessed" by appropriate institution probably don't reach required quality)

In order to overcome these issues we can only issue the same recommendations that are offered in literature [17], [18]:

1. Information campaign on OER, spreading information via university newsletter, boards etc...

2. Training and information for teachers on where and how to search for OER in suitable quality.

3. Information and Training for teachers on purpose and using of Creative Common licenses.

There are chances, that as the new Action Plan for Open Governance works itself slowly from theory into practice, there will be legislative frame and support for open publishing of materials.

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IP Networks Diagnostic Communication Generator

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Abstract—**Generation of diagnostic communication (GDC) is an important task in the area of computer networks that is used in various circumstances. For example, it is used for the purpose of testing networking hardware, such as routers or switches, for analyzing and benchmarking of networking systems or web services. Although there are various solutions using GDC, typically, they are specialized for generation of either general network traffic, network communication for diagnosis of anomalies in the network, or aimed on analysis of the captured network packets. Therefore, these solutions are not suitable for functional verification of network devices. In this work, we concentrate our research on the functional verification of software routers. We introduce the GDC diagnostic tool for IP networks that is dedicated to validation of software routers' functional correctness. This tool is based on GDC, driven by a configuration file and it provides also the response communication capturing and evaluation of the executed tests in a visual form. Although it was mainly intended to simplify the basic functionality validation of the software routers implemented by students during the coursework, it can also be useful to verify the functionality of the real network devices.**

Keywords—**ARP; diagnostic communication generation; IP networks; software routers functional verification; RIP**

I. INTRODUCTION

At the Faculty of Informatics and Information Technology, there are many courses in which one or more hands-on assignments are required to complete for students to get the necessary knowledge and practical experience. The work of the teachers in these courses is to check the correctness of these assignments, which is often very demanding, especially in terms of time. Also, students do not have an easy access to the hardware devices and therefore cannot adequately verify the functionality of their solutions outside the laboratory.

WAN technologies course is no exception. One of the hands-on assignments in this course is the design and implementation of a software router that is able to create an ARP (Address Resolution Protocol) table and a routing table, it can perform static paths routing, as well as routing using RIP (Routing Information Protocol). Testing for the correctness of the assignment solution therefore consists of several activities or scenarios for each of these functions, which need to be evaluated.

The aim of our research is to speed up and streamline the process of evaluating these tasks and to develop a tool that will automate this testing. Based on the scenarios to

be performed, the instrument should carry out tests, gain and then display the results of the tests that demonstrate the success of these tests.

However, active networking devices, such as routers or switches, represent essential elements of almost every computer network. With the expansion of the Internet, the demands of network hardware market were substantially increased and the new vendors came along. Some of these vendors are focused on modular networking hardware development. It means, the networking hardware is composed of a generic motherboard with several network interfaces and the required functionalities of this networking hardware are obtained by a suitable software solution installed on the motherboard.

This configuration of the networking hardware enabled to create several open source projects, such as DD-WRT, Tomato, OpenWRT, M0n0wall, PfSense, Vyatta [1] etc. The main focus of the mentioned projects is to allow a user to adjust the networking hardware to user-specific, most detailed requirements.

A great amount of testing comes with the adjusting or creating of the new software for this networking hardware. Therefore, in order to support this emerging configurable networking hardware, the proposed tool should also be utilizable for testing real hardware routers. When changing configuration parameters or minor changing of the implementation, the tool should also be used to test other network elements (e.g. switches).

As a result, we are introducing a tool for generation of diagnostic communication (GDC), which allows an automatization of validation of the router's functionality. This tool will be also available for students, who are implementing the software router.

The paper is organized as follows. In Section 2, the existing GDC methods and tools are summarized. The proposed new automatization tool is introduced in Section 3. The proposed solution verification and testing is discussed in Section 4. Finally, the results are summarized and the plans for future work are provided in the concluding section.

II. RELATED WORK

Concerning network traffic there are plenty of solutions available [2] that are able either to generate network traffic or to capture and analyze the network communication. Some of them represent open-source solutions (e.g. [3] or [4]), the others are either closed or commercial tools (e.g. [5]). Five of the available tools were selected and they are shortly summarized in Table 1.

Tool	Description
Harpoon [3]	Flow-level traffic generator. Harpoon can be used to generate representative background traffic for application or protocol testing, or for testing network switching hardware.
KaTaLyzer [6]	Network traffic analyzer for Linux based operating systems (routers, servers and desktops). It supports widely used protocols (Ethernet, IP, TCP, UDP, HTTP, SSH, SIP, etc.).
NetScanTools ® Pro [5]	Tool for generating TCP, UDP, ICMP, ARP and RAW protocols packets with option of modifying headers.
OSTINATO [4]	Open-source, cross-platform network packet crafter/traffic generator and analyzer with a friendly GUI. It crafts and sends packets of several streams with different protocols at different rates.
Wireshark [7]	Wireshark is the world's foremost and widely-used network protocol analyzer.

These were used as an inspiration and they helped us to specify the requirements for the novel GDC tool that would be suitable for the intended usage.

The most interesting features of Harpoon [3] are the client-server architecture and the configuration file, which provides scenarios for the traffic generation process. Another interesting feature is its self-configure function, which means the TCP (Transmission Control Protocol) communication generation can be configured automatically based on the captured traffic analysis. However, for the intended usage, this feature would not be very useful. In multiplatform commercial tool called OSTINATO [4], the Protocol Builder is internally used along with exclusive Ethernet port privileges, which enables to check the whole data flow through the ports. On the other hand, only the basic statistics about the network ports traffic are implemented in this tool, which is not sufficient for our purpose. In terms of modularity, NetScanTools ® Pro [5] consist of modules, which can be also modified. It is an interesting solution where a module represents the type of scenario and a configuration file represents the scenario set-up. Analysis tools (Wireshark [7], KaTaLyzer [6], and a part of NetScanTools® Pro) have the most relevant features concerning visualization, filtering, and a graphical user interface.

Despite of all the interesting features of these tools, they have not been designed for the network devices validation purpose. Therefore, it will still be difficult to adopt them for this purpose. In addition, the available tools are typically quite robust and complicated, and thus less suitable for education purpose. These were the reasons why we have concentrated our work on novel GDC tool development that will be focused mainly on parts with the most significant asset for the intended usage. However, the analyzed and tested solutions inspired some of the features of the newly proposed tool, concerning architecture, language selection, user interface and other aspects. For better understanding of GDC, it was appropriate to divide the whole problem into two sub-problems, namely network traffic generation and network traffic analysis.

III. THE NOVEL GDC TOOL DESIGN

This section summarizes the novel GDC tool design, specified requirements for the tool, its architecture, and the graphical user interface.

A. Requirements specification

Based on the analysis of available solutions and consequent testing of selected subset of them, the following requirements for the novel GDC tool development have been specified. They are divided into two groups: functional and non-functional requirements. These requirements have to be met during the tool development process for correct functionality of the proposed solution.

Functional requirements for the GDC tool include:

- handling the configuration file,
- generating packets based on the configuration file,
- selection of the two network interfaces,
- generating of and replying to ICMP (Internet Control Message Protocol) messages,
- generating of and replying to ARP requests,
- generating of RIP messages,
- visualizing the traffic statistics, captured packets, and passed tests.

Non-functional requirements for the GDC tool include:

- simplicity,
- effectiveness,
- modularity, and
- usability.

B. Architecture

The proposed architecture of the new GDC tool consists of two main modules: client and server. These modules operate on the same machine (e.g. a personal computer) with two Ethernet interfaces as shown in Fig. 1.

The server side, representing the generation part (GP), is mainly in charge of handling configuration files and creating packet streams. Packets are sent through one of the interfaces afterwards.

The client side, representing the analysis part (AP), receives packets (going through the network including
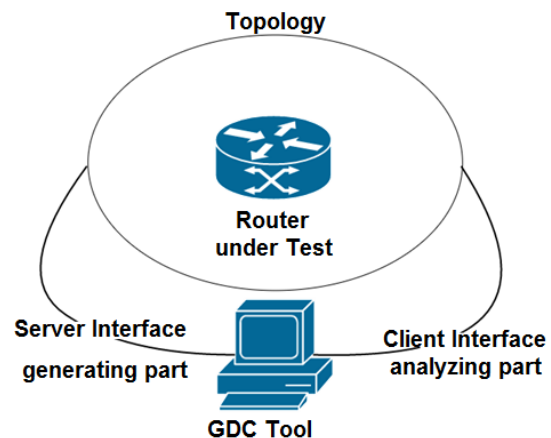

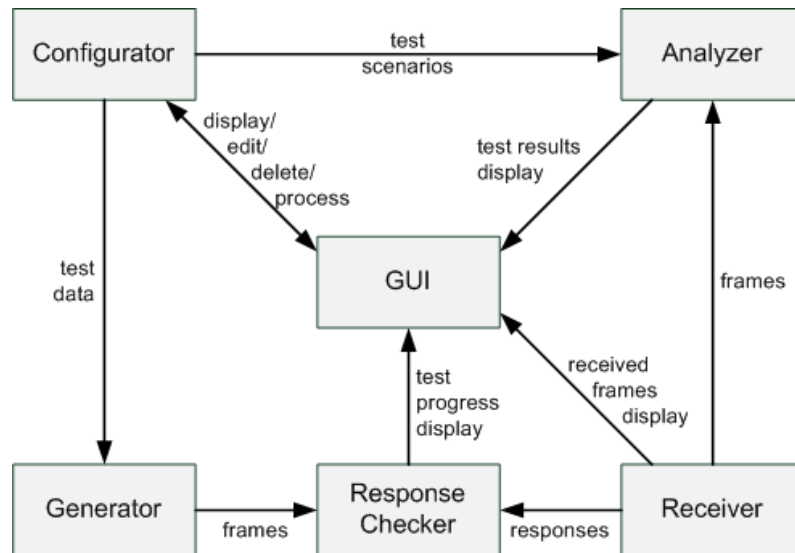
Figure 1. The adopted testing scheme

Figure 2.   The System Architecture

device under test) on the second interface of the machine, analyses the received packets, and evaluates the results of testing.

Both parts consist of several modules. The module that covers both GP and AP is a graphical user interface (GUI) that displays information from individual modules and contains tool controls. The co-operation of the individual tool modules is summarized in Fig. 2.

The solution of a single-machine client-server application has been selected in order to simplify the diagnostic access. The user does not need to dispose with several machines; instead, he/she can operate with both parts easily. However, client and server use separated network interfaces that are dedicated and strictly controlled by one of them. The modular solution meets the criterion listed in the non-functional requirements, which is the modularity of the tool and also its simple extensibility. Let us introduce the two parts modules in more detail.

GP modules:

- Configurator – enables creating, editing and deleting configuration files, and performing the tests listed in a specific configuration file. This module is also sending the test data to the analyzer so that it can evaluate the tests within the tool.

- Generator – its task is to create the frames, based on the configuration file, using the PacketBuilder for this purpose. Generator is also sending the generated traffic into the network.

AP modules:

- Receiver – this module receives the frames on the other side of the topology, transfers the frames to the user interface for viewing and also responds to the traffic.

- Analyzer – its task is to evaluate the received frames and to check if the received traffic is in the accordance with the test scenarios.

- Response Checker – this module is checking the response based on the type of protocol, used for testing, and it provides the results to the AP.

C. Configuration file

The scenarios for testing the networking hardware are represented by a configuration file (CF) loaded to the tool and then executed. The server side is building the packets stream according to the CF and the client side validates the traffic, incoming from the other side of the topology, based on the CF.

The CF is represented as an XML (eXtensible Markup Language) file with a custom suffix (e.g. gdct – GDC tool) for simple recognition by the tool. The XML form is used due to simplicity and modularity. XML files are easy to edit with various tools. A very simple example of CF is shown in Fig. 3.

The example illustrates the CF format. Each scenario has a name and contains several tests, distinguished by a description that represents the test type (i.e. targeted functionality). Inside the test hierarchical level of the XML structure, there are the actual test options. In the

```
<scenario name = "sc1">
  <test description = "arp">
    <sip>10.10.10.2</sip>
    <dip>10.10.10.1</dip>
    <wait>200</wait>
  </test>
  <test description = "ICMP">
    <dmac>c2:00:25:f0:00:00</dmac>
    <sip>10.10.10.2</sip>
    <dip>20.20.20.2</dip>
    <count>4</count>
    <inttl>128</inttl>
    <outttl>127</outttl>
    <routing>true</routing>
    <wait>200</wait>
  </test>
</scenario>
```

Figure 3.   Configuration file example
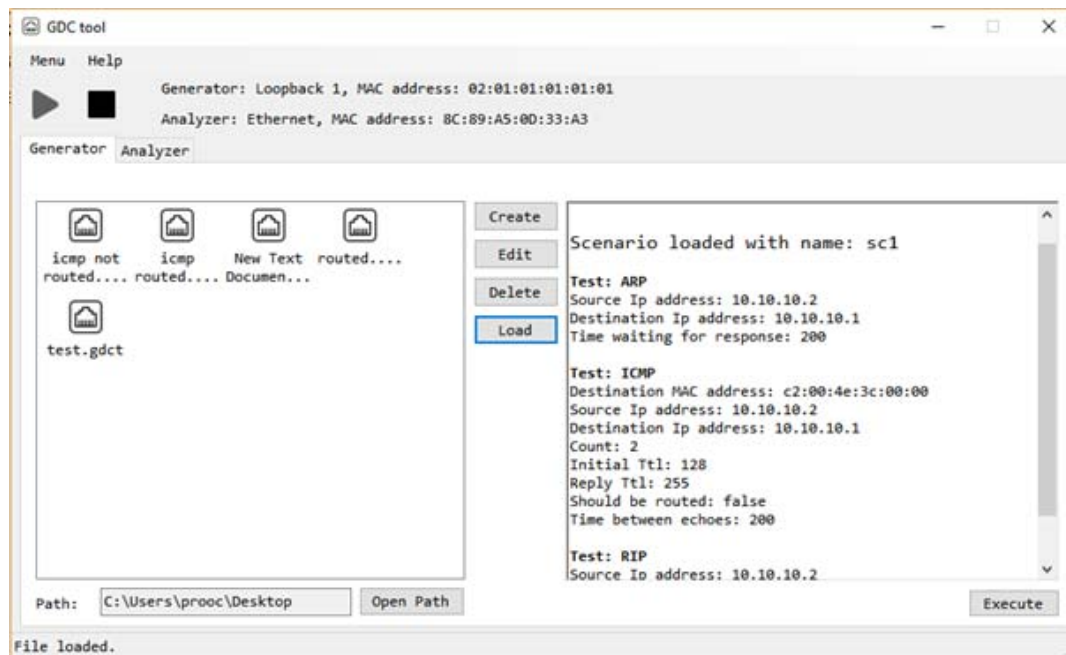
Figure 4.   The GDC tool – the main window of the graphical user interface with Generator screen displayed

example of *arp* test, there are specified the source IP (Internet Protocol) address (*sip*), the destination IP address (*dip*), and how much time the tool will wait for the response (*wait*). There are even more options for the *ICMP* test.

D.   Graphical User Interface

The usability requirement of our solution is accomplished by the use of GUI. Fig. 4 illustrates the main window of the GUI with the Generator screen displayed.

The Generator screen contains the CF control elements with the available CFs displayed on the left-hand side and the content of the loaded CF displayed on the right-hand side text field. Based on loaded CF the tests can be initiated using the Execute button. However, prior to this the devices to be tested have to be selected and switched on. The connected devices can be accessed by means of Menu, available in the upper part of the main window. The pop-up window is invoked, illustrated in Fig. 5, enabling to display and select the devices.

After the tests initiation the main window is automatically switched to the Analyzer screen, illustrated

in Fig. 6, displaying the actual state of the initiated tests. The results of tests are also saved into a text file.

The list of filtered received packets can be tracked in the receiver window of Analyzer, illustrated in Fig. 7 (available by means of Menu). The filter area extracts the protocol type and the exact IP address to the packet list.

IV.   THE SOLUTION VERIFICATION AND TESTING

As a development environment, Microsoft Visual Studio Enterprise 2015 and Visual C# 2015 were used to implement the proposed tool. The C# language was extended by Pcap.net library [8], which is taking care of communication with network interfaces and it is capable to access frames and network interfaces at the higher level. The Pcap.net library supports all the protocols needed to implement this tool except for the RIP protocol that had to be implemented manually.

The proposed and implemented tool was verified in two phases. The first phase was the continuous testing during the design and implementation of the individual solution modules. The next phase was the overall testing of the whole solution.
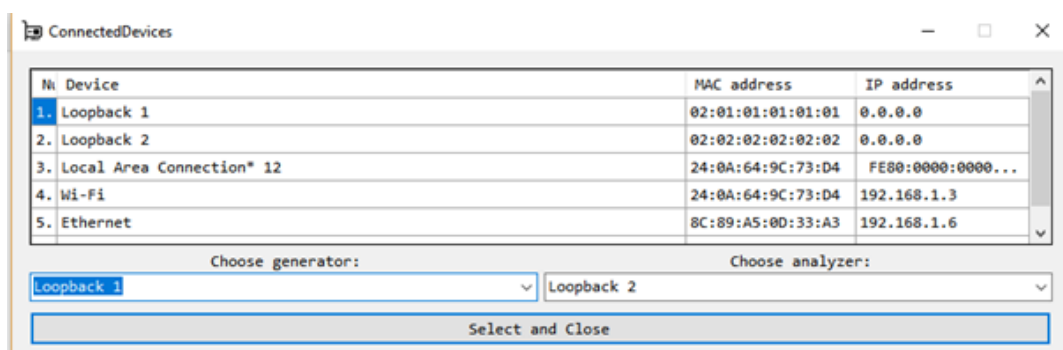
Figure 5.   The GDC tool – connected devices selection

Figure 6.   The GDC tool – the Analyzer screen of the main window

Figure 7.   The GDC tool – Analyzer receiver window

For the frames capturing and displaying, Wireshark version 2.2.5 was used, which also captures the network traffic in promiscuous mode. For test purposes, the GNS3 in version 0.8.7 was also used, in which the virtual router implementation tool was attached.

Different methods were used to verify the accuracy of the test during the continuous testing. Their form differed from module to module.

The configuration module was tested during each function implementation using the debugging mode in the development environment. For this module implementation the functions directly implemented in Visual C# libraries have been used, therefore their testing was not crucial. However, it was always checked whether the implemented feature provided the desired result. During these tests, several possible erroneous inputs, which could have occurred, were always been treated.

The generator was tested using Wireshark. Firstly, a frame was generated according to the requirements, and then, it was compared to the captured frames on the interface. The frame fields' validity was also checked. Thus, the functionality of the frame creation functions was also tested.

When testing the receiver, again the Wireshark was used, this time to compare the received and displayed frames in both tools. The receiver was tested using the already implemented generator.

For verification of the implemented analyzer, the already verified generator and receiver modules were used. The input argument for this test was the configuration file from which the generator generated and sent the frames, the receiver received them, and the analyzer output was the information displayed in the GUI. This result was checked based on the changes in the CF and changes in the test topology.

The overall solution testing was performed when all the modules were already implemented and verified separately. Firstly, the overall solution was tested using GNS3 with a router attached to each network interface. The router was connected using the Microsoft Loopback virtual network interfaces. The tests were performed using fully functional router, as well as the software router implemented by a student. During the overall solution testing the compliance with the specified requirements was also verified.

V. CONCLUSIONS AND FURTHER WORK

In this paper, we have proposed a tool for generation of a diagnostic communication. The analyzed existing tools are primarily focused on general diagnostics of a network traffic (e.g. as a prevention of attacks) and it is too difficult to use them to test a specific functionality of a network element. The proposed tool can generate a network traffic based on the specified test scenario in the configuration file, it captures responses of the devices in the tested network, and evaluates the test. This way, the proposed tool can be used to verify the functional aspects of the connected network devices in the tested network.

Although it was mainly intended for students to verify their implementations of software routers (i.e. a coursework assignment during the university study) during development, it can be also used by teachers to quickly evaluate the correctness of the final implemented solutions. Moreover, it can be used to test the functionality of real hardware network devices.

The implemented prototype of the proposed tool was verified on the selected testing scenarios. These tests showed that the tool is useful and it speeds up the checking of correct functionality of the tested network device. The tool has its limitations regarding general usage (e.g. support of the limited number of network protocols); however, due to its modular architecture, it can be easily extended and the limitations eliminated.

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Generation of Structure Function Based on Ambiguous and Incompletely Specified Data Using the Fuzzy Decision Trees

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Abstract— **The informatics is extremely fast development area that is based on interdisciplinary knowledge. University education for students of this specialisation must include interdisciplinary subjects to illustrate modern trends in researches and technologies. The reliability engineering or reliability analysis is one of typical areas of knowledge that based on principles of interdisciplinary. One of important problem in reliability engineering is development of mathematical model of investigated system. There are a lot methods and algorithms for elaboration of system mathematical model for completely specified information about investigated system. But numerous applied problem must be decided implemented if the initial information is incompletely specified and uncertain. In this case, new methods and algorithms must be developed for the construction of mathematical model. One of possible way for such methods development is based on application of approaches of Data Mining that are focused on the decision of analysis of uncertain and incompletely specified data. New method for mathematical model construction in reliability analysis by Fuzzy Decision Tree is considered in this paper.**

I. INTRODUCTION

The interdisciplinary knowledge is typical paradigms of the present time that must be took into account in education process. One of the subjects that require considerable knowledge of other areas is the Reliability Engineering or Reliability Analysis [1]. The tasks of reliability theory that is often solved by methods of other subjects are focused on analysis of the system reliability based on uncertain data. It extends typical methods of Reliability Analysis by fuzzy logic and methods of Data Mining.

The system reliability examination includes some steps and one of them is construction of system mathematical model for analysis. Depending on the number of the system performance levels and its components states, the system mathematical models are divided into [1]:

- Binary-state system (BSS) – each component and system performance levels have exactly two states, eq. full functioning and fatal failure.
- Multi-state system (MSS) – each component and system can be described by more than two states, eq. full functioning, functioning good, functioning bad, fatal failure.

BSS allows to a system and its components to be only in two extreme states. Nevertheless, in practice, numerous of systems can show different performance levels between extreme states of full functioning and fatal failure [2], [3].

At present time, there are different mathematical approaches, which allows creating mathematical models of a system. Typical mathematical approaches are, for example, Markov models, fault trees, block diagrams, structure function and others [4]. The structure function is often used as mathematical model that allows us to represent system with any structure complexity. Using the structural function, it is possible to analyze the reliability of both BSS and MSS.

Structure function captures relationships between the system components and the system itself, in such a way that the state of the system is known based on the states of its components. The structure function must capture all possible states of the system components that are reflected in system performance level. Consider a system of n components. Assume that it is in stationary state or is considered in fixed time point. This assumption allows defining MSS structure function as a time-independent function [1], [4]. The concept of the structure function associates the space of component states and system performance levels. In general, the structure function is defined as $L_1 \times \ldots \times L_n \to L$ (n is the number of system components).

Let i-th system component state is x_i ($i = 1, 2, \ldots, n$). Each system component state is defined by the vector states $x = (x_1, x_2, \ldots, x_n)$. State of each component can be denoted by a random variable, x_i, that takes on the value $x_i = 0$ if the component fails in a stationary state and $x_i = 1, \ldots, m_{i-1}$ if the component is functioning. Denote $\phi(x)$ as the structure function, then:

$$\phi(x_1, \ldots, x_n) =$$
$$= \{0, \ldots, m_1 - 1\} \times \ldots \times \{0, \ldots, m_n - 1\} \quad (1)$$
$$\to \{0, \ldots, M - 1\}$$

where $\phi(x)$ is the system state (performance level) from failure ($\phi(x) = 0$) to perfect functioning ($\phi(x) = M$ -1); $x = (x_1, \ldots, x_n)$ is the state vector; x_i is the i-th component state that changes from failure ($x_i = 0$) to perfect functioning ($x_i = m_i$ - 1).

The structure function can be constructed only if all possible states of components and system performance levels can be defined. According to (1) the structure function can be interpreted as classification structure that splits all possible combination of components states into M group. These groups agree with the system performance levels.

Need to note that initial information about real-world system behavior is incompletely specified and uncertain.

Therefore this information can not be sufficient to construct the structure function for reliability evaluation of system. Special methods must be developed for structure function construction based on uncertain data. One of possible way to decide this problem is application of methods of Data Mining [5], [6]. One of these methods for the structure function construction has been proposed in the paper [5], [7]. The principal approach used in this method is *Fuzzy Decision Trees* (FDT), which is used to transform uncertain data about system to the structure function.

Decision trees are popular method in Machine Learning and Data Mining that are used in classification problem typically. The objective of classification is to assign new instances into known classes based on acquired, learned experience. FDT is one of types of classical decision trees, which is inducted and operated with fuzzy data. As a rule the algorithms for FDT induction are developed as generalizations of traditional algorithms such as ID3, C4.5 or CART for fuzzy data [8]–[10]. In this paper, the induction of FDT is provided based on the algorithm introduced in [9] in which the conception of the summary mutual information is used for the selection of expandable attributes.

In this paper, the method for construction of a structure function based on uncertain an incompletely specified data is considered. The method is demonstrated on public available dataset for *Evaluations of Teaching Performance* from repository of Machine Learning [11].

This paper is structured as follows. The principal steps of the method are represented in section II. In section III, the specifics and requirements of dataset representation for proposed method is discussed. These specifics and requirements are caused by the application of FDT for which the initial data must be defined as fuzzy data. The induction of FDT is considered is section IV. In this section, the theoretical background for FDT induction is presented and illustrated by the induction of FDT based on typical dataset from Machine Learning repository (*Evaluations of Teaching Performance*). The construction of the structure function based on FDT is discussed in section V. The example of the structure function construction for dataset of *Evaluations of Teaching Performance* is illustrate the proposed method.

II. Principal steps

Nowadays, systems are mostly composed of large number of components which are non-homogeneous and vague. Therefore, reliability analysis requires to create a mathematical model of real system based on the uncertain data very often. The uncertainty can be caused by a lot of factors, but two of them are took into account in this paper. The first factor is ambiguity and vagueness of collected data values. This type of ambiguity can be caused by an inaccuracy or error of measurement, expert subjective evaluation etc. The second factor is incomplete specification of data, because some values of system components states or performance levels cannot be obtained.

Therefore, the structure function construction must address two aspects. The first is structure function definition as a classification structure of components states according to the system performance levels. The second is uncertainty of initial data. In other words, this problem can be interpreted as a classification problem of uncertain data that is a typical problem of Data Mining. FDT is typical approach that used for decision of this problem [12]. Therefore the construction of structure function based on uncertain data includes three of three principal steps (Fig.1):

- Collection of data into the repository – Monitoring of the states of system components and the corresponding performance level of investigated system
- Mathematical representation of a system in form of fuzzy decision tree
- Construction of a structure function derived from a fuzzy decision tree

Figure 1. Principal steps for structural function generation

Many times, induction of fuzzy decision tree from collected data requires additional transformation, eq. in case of numerical attributes. These attributes must be transformed into linguistic fuzzy terms. The possible way to perform such transformation is experts evaluations or another is fuzzy clustering described in [13], [14]. When a decision tree is built, the construction to the structural functions requires creation of decision table, or decision rules. The structure function is constructed as a decision table that classifies the system performance level based on each possible profile of components states. The decision table is formed based on FDT that provides the mapping for all possible components states (input data) in *M* performance levels. FDT is inducted by uncertain data that is presented in form of specified repository. These steps are considered and studied in detail in next parts of this paper.

III. Data and repository

The induction of FDT is based on the data that are presented in the repository, which has the form of a table. It consists of $n+1$ columns associated with n input attributes and 1 output attribute. The i-th column, for $i = 1,…, n +1$, is divided into m_i sub-columns. The j_i-th sub-column, for $j_i = 1,…, m_i$, agrees with the j-th value of the attribute represented by the i-th column. Each row of the repository corresponds to one instance of collected data. The classification algorithm used in this paper works with fuzzy attributes. Each fuzzy attribute A_i is a linguistic attribute, which means that A_i can take fuzzy values $A_{i,j}, j = 1,2…, m_i$. Every value $A_{i,j}$ of fuzzy attribute A_i can be considered as a fuzzy set. Each value of each instance $\mu_{A_{i,j}}(e) \in [0,1]$ and $\sum_{j=1}^{m_i} \mu_{A_{i,j}}(e) = 1$ where e represents an instance of the repository. These restrictions on

representation of initial data are caused by the strategy for FDT induction.

TABLE 1.
REPOSITORY (DATA COLLECTION) FOR FDT INDUCTION

| Input attributes, A_i | | | | | | | | Output attribute, B | | |
| A_1 | | | A_2 | | | A_n | | | | |
A_{1_1}	A_{1_2}	A_{1_3}	A_{2_1}	A_{2_2}	. . . .	A_{n_1}	A_{n_2}	B_1	B_2	B_3
0.1	0.5	0.4	0.6	0.4	. . .	0.5	0.5	0.0	0.0	1.0
0.2	0.1	0.7	0.1	0.9	. . .	0.8	0.2	0.4	0.4	0.2
0.0	0.1	0.9	0.7	0.3	. . .	0.1	0.9	0.1	0.1	0.8
. . .			. . .		. . .	. . .		. . .		
0.3	0.3	0.4	0.0	1.0	. . .	0.4	0.6	0.1	0.4	0.5

If the collected data contains numeric attributes, then the transformation, which provides a mapping of numeric attributes into fuzzy attributes, is required. This transformation is called fuzzification. The fuzzification is the process of transforming precise (crisp) values into degrees of membership for linguistic terms of fuzzy sets [12], [15]. The task of fuzzification can be accomplished manually by a specialist in a researched field or it can be done automatically by specific algorithms. In this paper, simple method for fuzzification based on fuzzy clustering is proposed. In contrast with traditional clustering algorithms (eq. K-means), each instance is assigned to more than one cluster with partition degree. One of the most commonly used fuzzy clustering algorithms is the *Fuzzy C-means clustering* (FCM) proposed in [13], [16]. In this paper, the customized version of FCM is used, where the number of resulting clusters is determined by conditional entropy between clusters and the output attribute. The algorithm is iterative process, which starts with two clusters. On the finish of each iteration, new cluster is added and conditional entropy between the clusters and the output attribute is calculated. The algorithm continues, while entropy does not start to rise. It is important to say that partition degrees to the cluster represent the values of the fuzzy attribute.

This algorithm can be described as follows. Let A_i is the numerical attribute, which is defined by vector of real numbers as $a = \{a_1, .. a_l, ..., a_k\}$. Firstly, algorithm defines m_i clusters where $m_i \geq 2$. Number of clusters corresponds with the number of values of fuzzy attribute. Every cluster contains center c_j initialized to a random value. Algorithm assigns the partition degree $u_{l,j}$ for each value a_l, such that $0 \leq u_{l,j} \leq 1$. Partition degree $u_{l,j}$ indicates the grade of membership of the a_l to the j-th cluster. Fuzzy C-means is aimed to minimize following objective function:

$$\text{minimize} \sum_{j=1}^{m_i} \sum_{l=1}^{k} (u_{l,j})^2 d(a_l, c_j)^2, \quad (2)$$

where $d(a_l, c_i)$ is an arbitrary distance function. The sum of partitions to each cluster for a_l must be equal to 1. The mathematical notation of this obligation has the following form:

$$\sum_{i=1}^{m_i} u_{l,j} = 1, \text{ for } l = 1, ..., k. \quad (3)$$

The minimization of (2) is done by iterative procedure. Each iteration starts with measurement of distances $d(a_l, c_i)$. When the distances are known, the portions u_{lj} are computed by following equation:

$$u_{l,j} = \frac{\frac{1}{d(a_l, c_j)^2}}{\sum_{t=1}^{m_i} \frac{1}{d(a_l, c_t)^2}}. \quad (4)$$

Centers are recalculated at the end of each iteration when each $a_l \in a$ are assigned to the clusters. Then, the center of each cluster is recomputed.

$$c_j = \frac{\sum_{j=1}^{k} (u_{l,j})^2 a_l}{\sum_{j=1}^{k} (u_{l,j})^2}. \quad (5)$$

The equation (4) represents membership functions, which provides required mapping of real values to degree of membership to fuzzy sets. The fuzzification of each numerical input attribute takes into consideration the output attribute B. Proposed algorithm tries to reduce conditional entropy between input attributes and the output attribute B with m_n values. This is also iterative procedure which starts $m_i = 2$. Notice, that m_i is the number of values of A_i and it corresponds with the number of clusters. The number of values m_i is gradually increasing by one until the conditional entropy $H(B|A_i)$ starts rising. Conditional entropy $H(B|A_i)$ is defined as:

$$H(B|A_i) = -\sum_{j=1}^{m_i} p(A_{i,j}) \sum_{s=1}^{m_n} p(B_s|A_{i,j})$$
$$* \log_2 p(B_s|A_{i,j})$$
$$= -\sum_{j=1}^{m_A} \sum_{s=1}^{m_B} p(B_s, A_{i,j}) \quad (6)$$
$$* \log_2 p(B_s|A_{i,j})$$

where $p(B_q|A_{i,j})$ is the conditional probability, which is computed as:

$$p(B_q|A_{i,j}) = \frac{p(B_q, A_{i,j})}{p(A_{i,j})} = \frac{\frac{M(B_q \times A_{i,j})}{k}}{\frac{M(A_{i,j})}{k}}$$
$$= \frac{M(B_q \times A_{i,j})}{M(A_{i,j})} \quad (7)$$

IV. FUZZY DECISION TREES

Decision trees are the popular technique of machine learning designed for classification and prediction. The principle of classification is in the learning function that maps (classifies) data records into one of the several predefined classes.

There are various kinds of decision trees and algorithms for their induction such ID3, C4.5, CHAID, CART [17] or fuzzy decision trees based on cumulative mutual information [9].

Decision trees are independent on a investigated problem and usable for large scale of applications. There are many reasons why we could use decision trees. One reason is that they are easy to interpret and understandable for people. Decision trees allow to finds interesting data segments and important attributes. Nevertheless, decision trees are considered as unstable classifiers, which are sensitive to the deviations of training data. The introduction of fuzzy logic to the decision trees improving this aspect [18]. It can be demonstrated on C4.5 algorithm, which handling numerical data by choosing a split point based on learning examples. It can lead to decrease of the classification accuracy for values close to the border of intervals after numerical data splitting [13], [17]. The fuzzy decision trees are one of the possible types of decision trees. It permits operating on fuzzy data (attributes).

Decision tree generally consists of nodes, where the top-level node is denoted as a root. Each internal node stands for a classification test on individual input attribute (the root node is also a test) and outcome edges of internal nodes mean a possible test result. External nodes are denoted as leaves which represents target classes of classification. Classification of unknown instance starts in the root node of the tree. If this node is a test, the outcome for the instance is determined, then the instance passes decision tree from top to bottom according to this outcome. When a leaf is finally encountered, its label gives the predicted class of the instance. In case of fuzzy decision tree, the instance can go through more than one branches during classification. Therefore, is necessary to take a decision based on a set of leaves. Hence, it is common that tree is transformed into the classification rules which allow such classification in an effective way. The usage of classification rules is described in [9].

Input attributes associated with internal nodes can be selected by several types of criteria. The main focus is on choosing an attribute that can split the instances with a maximal reduction of uncertainty. In this paper *Un-ordered Fuzzy Decision Tree* (UFDT) is used, which has been proposed in [8], [20]. The splitting criterion for UFDT induction is the *Summary Mutual Information* (SMI), which has the following form: $\mathbf{I}(B; A_{i1,j1},…,A_{iq-1, j\,q-1}, A_{iq})$ [9], [19] where $A_{i1,j1},…,A_{iq-1, j\,q-1}$ is the sequence of attribute values from the root to the investigated node and q is the level of the investigated node. The attribute with the greatest value of SMI is chosen to associate with investigated node at q-th level according to

$$\arg\max\left(\frac{\mathbf{I}\left(B; A_{i_1,j_1}, …, A_{i_{q-1},j_{q-1}}, A_{i_q,j_q}\right)}{H(A_q)}\right), \qquad (8)$$

where the entropy of attribute A_{i_q} is computed as

$$H\left(A_{i_q}\right) = \sum_{j=1}^{m_i} M\left(A_{i_q,j_q}\right) * \left[\log_2 k - \log_2 M\left(A_{i_q,j_q}\right)\right] \qquad (9)$$

where k is the count of instances in repository.

To increase the performance of decision trees the pruning technique is used. The purpose of pruning tasks is to remove leaves or subtrees of decision trees, which provide insufficient quality of classification. UFDT uses the pruning technique that takes place during tree induction. Techniques that are performed during tree induction are referred to as pre-pruning. The pruning method in this work uses two specific conditions to decide if a node will be established as a leaf or not. These conditions are determined by threshold values α and β. Threshold α reflects the minimal frequency of occurrences in an investigated node. It is a percentage of instances, which belongs to the that node. It is important to say, that one instance can belong to more than one nodes with partition degree. Parameter β reflects the maximal confidence level computed in a certain node and it reflects the likelihood of the taken decision. Each node of the tree is established as a leaf if at least one of the succeeding conditions is satisfied:

$$\alpha \geq \frac{M\left(A_{i_1 j_1} \times … \times A_{i_q j_q}\right)}{k} \qquad (10)$$

$$\beta \leq 2^{-\mathbf{I}\left(B_j | A_{i_1 j_1}, …, A_{i_q j_q}\right)} \qquad (11)$$

where $A_{i_1 j_1}, …, A_{i_q j_q}$ is the sequence of specific values of attributes $A_{i_1}, …, A_{i_q}$ (this sequence agrees with a path from the root A_{i_1} to node A_{i_q}), B_j represents the j-th value of output attribute B, where $j = 1,2, …, m_B$, and $\left(B_j | A_{i_1 j_1}, …, A_{i_q j_q}\right)$ is computed as:

$$\mathbf{I}\left(B_j | A_{i_1 j_1}, …, A_{i_z j_z}\right)$$
$$= \frac{M\left(A_{i_1 j_1} \times … \times A_{i_q j_q}\right)}{\log_2 M\left(A_{i_1 j_1} \times … \times A_{i_q j_q} \times B_j\right)} \qquad (12)$$

Each of these thresholds has significant impact on the resulting tree level and the depth of branches (length of paths from the root to a specific leaf). Increasing of value β result in growing of the depth of tree branches. Value of parameter α also affects the tree level and depth of its branches. In this case, bigger α causes the smaller depth of branches. Thresholds should be set to values that ensure the most accurate classification. If $\alpha = 0$ and $\beta = 1$, the classification is extremely accurate very often, but just for training instances. Smaller branch frequencies will lead to errors in the classification of instances that are not involved in the training process [5], [19], [20].

In this work, the simple process to determinate threshold values is used. The modification of α and β values is done by repetitive training of UFDT with different mixtures of the thresholds. When the process is finished, the best obtained mixture is chosen. The process is shown in the diagram below.
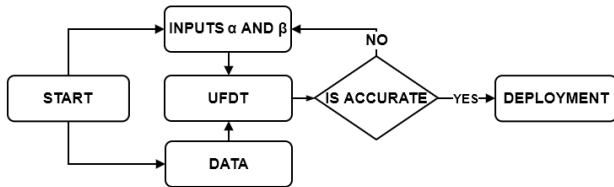

Figure 2.The diagram for assessment of thresholds α and β

A. Fuzzy decision tree induction on dataset "Evaluations of Teaching Performance"

This section contains the demonstration of the method, which is described above, on *Evaluations of Teaching Performance* (TAE) dataset [11]. The dataset consists of evaluations of teaching performance over three regular semesters and two summer semesters of 151 teaching assistant assignments at the Statistics Department of the University of Wisconsin-Madison. The examples are separated into three approximately equal-sized classes ("Low", "Middle" and "High") to form the output variable, where the target of classification is to predict teaching performance of teaching assistants. The original version of these dataset consists of 5 input attributes. The used version works with 3 input attributes because attributes for the identification numbers of teachers and courses are not used. The description of used attributes is in Table 2.

TABLE 2.
DESCRIPTION OF THE ATTRIBUTES IN EVALUATION OF TEACHING PERFORMANCE DATASET

Name	Description	Type	Values
native speaker	is the TA a native English speaker	binary	yes no
summer or regular	Semester period	binary	Summer Regular
class size	Size of class	numerical	from 3 to 66
performance	Performance of teaching assistant	categorical	Low Middle High

It was necessary to perform fuzzification of attribute *class size*, because this attribute is numerical. The result of fuzzification was the new attribute for *class size* that contains 3 fuzzy values. After fuzzification the UFDT has been inducted according to the description of the dataset. The threshold values for pruning was chosen as follows: the minimal frequency $\alpha = 0.099$, maximal confidence level $\beta = 0.603$. These parameters have been acquired according to the TAE dataset, where 20 percent of instances were randomly selected for testing and the remaining 80 percent was used for training of UFDT. The best obtained results are in Table 3.

TABLE 3.
BEST RESULTS OF EXPERIMENTS FOR VARIOUS VALUES OF α AND β THRESHOLD PARAMETERS

α	β	Accuracy
0.011	0.780	68.418
0.080	0.602	65.640
0.030	0.610	67.029
0.099	0.603	68.721
0.010	0.610	67.723
0.080	0.610	66.335

This section contains a simple example of UFDT induction. The induction starts by choosing an attribute which will be associated with root node. It is necessary to select this attribute from all input attributes, which are described in table 1. Algorithm for FDT induction computes the mutual information between input attributes and output attribute according to the (8) and then the input attribute with the biggest value is chosen for association with root node. The biggest value of this criterion has attribute *SUMMER OR REGULAR*. Then the confidence levels are computed. These levels are computed by (11), and it corresponds with degree of belief to the output classes. In the root, the confidence levels have the following values: *Low*: 0.257, *Middle*: 0.359, *High*: 0.366. The frequencies are calculated by (10), but in the root, the frequency is equal to 1. When the node is created, it is necessary to check if it is a leaf or not. Minimal frequency is 0.099, and maximal β is 0.603. In the root, the maximal β is 0.366 and the frequency is equal to 1. Hence, the root is not a leaf and tree expansion will continue. Attribute *SUMMER OR REGULAR* according to the Table 2 has two values *Summer* and *Regular*, therefore the root will have two outcoming edges. The first level of the UFDT is shown on the picture below.
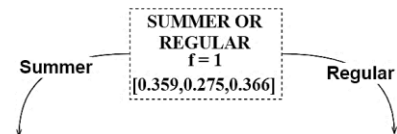
Figure 3.The first level of UFDT

At the end of the branches that outcome from the root of the tree new nodes, are created. The first node has input branch *Summer* and its frequency according to (9) is equal to 0.36 and confidence levels are *Low*: 0.09, *Middle*: 0.366, *High*: 0.714. In this case, the maximal confidence level has value *High* which is bigger than threshold parameter β, therefore this node is established as a leaf. In case of the second node at this tree level, the frequency is equal to o.84 and the maximal value of confidence level is 0.409, therefore this node is not established as a leaf, and tree expansion will continue with this branch. Algorithm needs to choose associative attribute, which is not used at given tree branch. The best value of splitting criterion (8) has the attribute *NATIVE SPEAKER*, which has two values. Therefore, this node is associated with this attribute and it has two outcoming

edges. The second level of the tree is shown on the figure below.
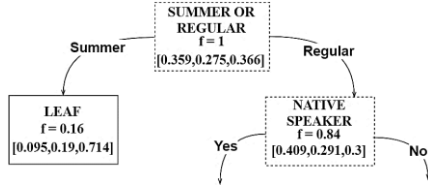
Figure 4. The first level of UFDT

In a similar way, it is possible to continue in tree induction at next level. At next level, all nodes are leaves. The resulting decision tree is shown on Figure 5.
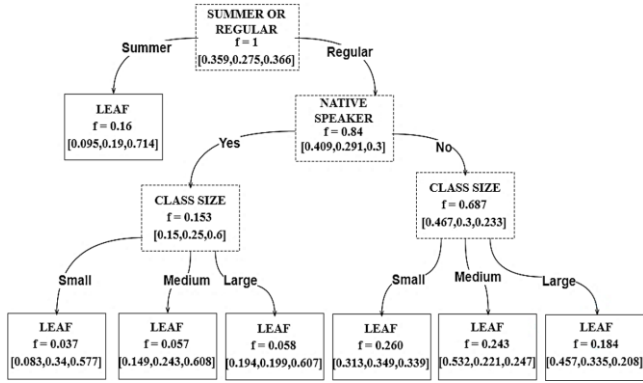
Figure 5. The resulting UFDT

V. STRUCTURE FUNCTION CONSTRUCTION BASED ON FUZZY DECISION TREE

In this section, the construction of structure function using FDT is described. Task of structure function construction is closely related to the creating the decision table, or decision rules. Both of this techniques are simply acquirable by the FDTs according to [5], [21]. The decision table contains all possible combinations of input attributes which corresponding with target class which is determined by the classification using decision tree. There is the analogy between decision table and structure function. Input attributes can be considered as the system components and the output class corresponds to the system performance levels [5], [7]. Then the decision table is equivalent to structure function. More formally the analogy can be described as follows. Each internal node of the tree is associated with one of the input attributes. In the notation of the reliability theory, each internal node is associated with the component. Every input attribute A_i has exactly m_i values, where each of these values agrees with one of the component states. The path from the leaf to the root of the tree indicates the state vector of the structure function that is determined by the values of the association attributes and the corresponding performance level. If any attribute is not present in this path, all possible values of states are defined for the associated component. The decision table derived from the trained UFDT displayed in Figure 5.

| NATIVE SPEAKER		SUMMER OR REGULAR		CLASS SIZE			PERFORMANCE		
1	0	1	0	2	1	0	0	1	2
1	0	1	0	1	0	0	0.095	0.19	0.714
1	0	1	0	0	1	0	0.095	0.19	0.714
1	0	1	0	0	0	1	0.095	0.19	0.714
1	0	0	1	1	0	0	0.083	0.34	0.577
1	0	0	1	0	1	0	0.149	0.243	0.608
1	0	0	1	0	0	1	0.194	0.199	0.607
0	1	1	0	1	0	0	0.095	0.19	0.714
0	1	1	0	0	1	0	0.095	0.19	0.714
0	1	1	0	0	0	1	0.095	0.19	0.714
0	1	0	1	1	0	0	0.313	0.349	0.339
0	1	0	1	0	1	0	0.532	0.221	0.247
0	1	0	1	0	0	1	0.457	0.335	0.208

Figure 6. decision table for TAE dataset

According to the decision table, the structure function can be constructed as follows. Each input attribute corresponds with the component. The *NATIVE SPEAKER* represents the first component x_1, which has two states according to the number of values attribute values. The value *Yes* corresponds with the component state 1 and the value *No* corresponds with the state 0. In case of *SUMMER REGULAR,* it represents component x_2 and the value *Summer* is representation of component state 1, while *Regular* indicates component state 0. The attribute *CLASS SIZE* is component x_3 and it has after fuzzification three values labeled as *Small, Medium, Large*. In case of *Small,* the component state is 2, for *Medium* is 1 and for *Large* the value of component state is 0. The system performance level based on state on its components is noted as $\phi(\boldsymbol{x})$. Then the structure function based on UFDT from the Figure 5 is following.

Component states	x_1	1	1	1	1	1	1	0	0	0	0	0	0
	x_2	1	1	1	0	0	0	1	1	1	0	0	0
	x_3	2	1	0	2	1	0	2	1	0	2	1	0
$\phi(\boldsymbol{x})$		2	2	2	2	2	2	2	2	2	1	0	0

Figure 7. Structure function of TAE dataset

The representation of system in form of the structure function permits to estimate various reliability indices and measures of the system reliability. For example, importance measurements according to [2] or probability of system performance levels can be calculated by typical method of reliability [3, 4].

Consider the calculation some of indices for reliability evaluation of the system. The evaluation is provided for coherent systems will be considered. This means: (a) the system structure function is monotone: $\phi(x_i, \boldsymbol{x}) \leq \phi(x_j, \boldsymbol{x})$ for any $x_i \leq x_j$; and (b) there are not irrelevant components in the system.

The evaluation based on the structure function supposes knowledge of the probabilities of individual states for every system component:

$$p_{i,s} = \Pr\{x_i = s\}, s = 0, \dots, m_i - 1. \qquad (13)$$

The structure function (1) allows calculating the boundary system states [22], minimal cut/path sets [23] and importance

measures [2]. One of basic indices is the probability of system performance level that is calculated as [3]:

$$A_j = \Pr\{\phi(x) = j\}, j = 0, \ldots, m_i - 1. \qquad (14)$$

According to (14) and the structure function in Fig. 7, the probabilities of the system performance levels are defined as:

$$A_0 = p_{1,0} * p_{2,0} * (p_{3,0} + p_{3,1})$$
$$A_1 = p_{1,0} * p_{2,0} * p_{2,1}$$
$$A_2 = p_{1,1} * p_{1,0} * p_{2,1}$$

Suppose that the probabilities of the components states (or attributes in the initial data) have values shown in Table 4. In this case, the probabilities of the system performance levels are: $A_0 = 0.098$, $A_1 = 0.042$, and $A_2 = 0.86$. These values shows that the most possible level of teaching performance is *Low*, because the probabilities of this level is most for indicated conditions in Table 4.

TABLE 4.
COMPONENTS STATES PROBABILITIES

Component state, s	Probabilities		
	$p_{1,s}$	$p_{2,s}$	$p_{3,s}$
0	0.2	0.7	0.3
1	0.8	0.3	0.4
2	–	–	0.3

VI. CONCLUSION

In this paper, the method for construction of structure function based on uncertain and ambiguous data is considered. This method consists of three principal steps, specifically collecting data into the repository, FDT induction and structure function construction based on decision table obtained from resulting FDT. These steps are explained on examples, which are based on the publicly available dataset. This method has been extended by a process of fuzzification, which makes the considered method applicable to numerical data. The fuzzification was performed using fuzzy clustering.

The publicly available dataset, which is used to show the considered method, contains data about teaching assistant performance evaluation. The induction of fuzzy decision tree has been demonstrated according to this data. Next part of the paper is focused on construction of structure function based on inducted FDT. Decision table has been derived from resulting FDT. The process of transformation of decision table into the structure function is described in section V.

In future research, it is possible to analyze the impact of different kind of decision trees on resulting structure function. The representation of system by the structure function can be used to estimate various reliability indices and measures to analyze system reliability.

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Analysis of Bulk-Driven Technique for Low-Voltage IC Design in 130 nm CMOS Technology

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Abstract—**Nowadays, increased demand for ubiquitous wireless devices caused growing effort to development of design techniques for low-voltage (LV) analog integrated circuits (IC) in standard CMOS process, in order to avoid circuits to be limiting factor of the overall power supply voltage. These techniques, which meets modern integrated circuit requirements, appears as the key towards achievement of enhanced performance of designed circuits. In this paper, an analysis of bulk-driven design technique was performed with focus on the comparison of this techniques to a conventional approach in terms of main properties. Test circuits were designed and analyzed in 130 nm CMOS technology using the supply voltage of 0.6 V and fabricated on an ASIC test-chip. Fabricated circuits were characterized and their characteristics are compared to the simulation results.**

Index Terms—**bulk-driven, current mirrors, low-voltage, low-power analog circuits**

I. INTRODUCTION

Low-voltage along with low-power design is a rather difficult challenge taking into account todays technology parameter fluctuations and customer requirements. The power supply voltage downscales in a similar fashion with the reduction of transistor channel length over the years. Otherwise, the robustness and reliability of devices would deteriorate due to time-dependent dielectric breakdown and hot electron effect. However, unlike the shrinkage of the power supply voltage V_{DD}, the MOS transistor threshold voltage V_{TH} reduces much less aggressively (Fig. 1) to maintain on/off characteristics of a MOS transistors [1].
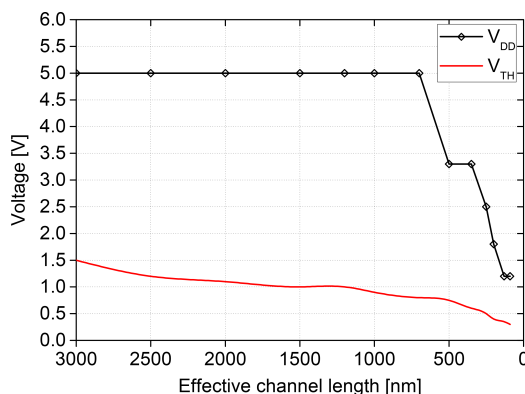
Fig. 1. V_{DD} and V_{TH} versus the effective channel length downscaling [1]

Analog circuits without employing any LV design techniques limit their power supplies to the value given by a sum of the turn-on voltage of MOSFET V_{GS} and the required signal swing. For a standard $130~nm$ CMOS process, the $V_{GS} \approx 0.3~V$ is quite normal for an NMOS device biased in strong inversion. Thus, a small voltage headroom is left for analog circuits targeting LV applications with the supply voltage of $0.6~V$. There are several design techniques used in low-voltage analog ICs. One of the most suitable for targeted $130~nm$ standard CMOS technology is technique using bulk-driven MOS transistors [2].

II. BULK-DRIVEN MOS TRANSISTOR

Drain current I_D is usually controlled by the gate-source voltage V_{GS}. Bulk-source voltage V_{BS} can also affect this current, which is usually considered as a parasitic effect and may introduce unwanted body transconductance g_{mb}. But if constant V_{GS} is kept as a bias voltage, and the input signal is applied to the bulk terminal, a JFET-like transistor can be obtained [3][4]. Schematics of basic bulk-driven (BD) MOS transistor is shown in Fig. 2.
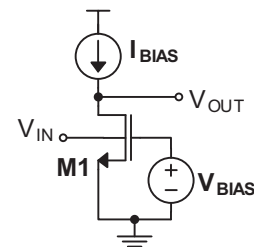
Fig. 2. Schematics of a BD transistor

Principle of this technique is in MOS transistor structure itself, which consists of four electrodes gate, drain, source and bulk. As mentioned above, the BD technique uses bulk as the signal input, which implies significantly reduced need to overcome the threshold voltage at the MOS transistor input. Advantages of the BD design technique include [5]:

- BD transistor depletion characteristics significantly reduce the need to overcome the threshold voltage V_{TH}

at the transistor input and increase the voltage headroom for low-voltage applications,

- Possibility to operate with low-voltage power supply,
- Use in a standard CMOS technology.

Unfortunately, BD technique has also the following disadvantages:

- Body transconductance g_{mb} of BD transistor is 3-4 times lower than the gate transconductance g_m, which can lead to lower gain band-width (GBW) and worse frequency response,
- Input capacitance of BD transistor is increased to the value of $C_{B,sub}+C_{BS}$ in comparison to the against input capacitance of conventional MOS transistor that is given by $C_{GS} + C_{BG}$,
- Input noise of BD transistor is increased,
- BD transistors are prone to turn-on parasitic bipolar transistors in substrate, which can lead to unwanted latch-up effect.

A. Body Transconductance

The body transconductance g_{mb} is a small-signal parameter of MOS transistor which describes the dependence of the drain current I_D on the body-source voltage V_{BS} [6]. It represents gain of a voltage-controlled current source, which is controlled by V_{BS} and situated between drain and source terminals in well-known MOS transistor equivalent circuit (Fig. 3).
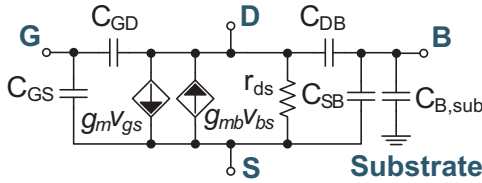
Fig. 3.   BD transistor equivalent circuit

Body transconductance is the secondary effect of a MOS transistor, and is given by a partial derivative of the drain current with respect to V_{BS} with constant values of V_{GS} and V_{DS}. The final product is equation 1, where g_m is transconductance of the classic gate-driven (GD) MOS transistor, γ is body effect constant, ϕ_F is the bulk Fermi potential and η is the ratio from g_{mb} to g_m. Parameter η is in the range from 0.2 to 0.4, depending on V_{BS} and specific process parameters.

$$g_{mb} = \frac{\gamma g_m}{2\sqrt{-2\phi_F - V_{BS}}} = g_m \cdot \eta \qquad (1)$$

Considering the fact that the body transconductance of BD MOS transistor is lower than the gate transconductance of a conventional MOS transistor, the maximum transit frequency $f_{t(BD)}$ of the BD transistor (equation 2) is significantly lower than the maximum transit frequency $f_{t(GD)}$ of a gate-driven equivalent (equation 3).

$$f_{t(BD)} = \frac{g_{mb}}{2\pi(C_{SB} + C_{BD} + C_{B,sub})} \qquad (2)$$

$$f_{t(GD)} = \frac{g_m}{2\pi C_{GS}} \qquad (3)$$

B. Latch-Up

Development of CMOS technology was motivated mainly by low power consumption in a static state at the cost of more layout masks, technology steps and total costs. Another drawback which came to existence along with CMOS technology is a parasitic effect called latch-up [6][7]. The parasitic bipolar transistors are created in n-well and p-well of MOS transistors with collectors connected to the bulks. Their mutual interconnection creates a positive feed-back loop, which can result into a current leakage from the supply voltage source to the ground.

The initial parasitic current can be caused by different sources in ICs. It can be, for example, coupling between the bases of the parasitic bipolar transistors and drains of CMOS structure. A high voltage swing can also excite a parasitic current into n-well or substrate, which can be the beginning of the latch-up effect. This problem can be avoided by several techniques. One of these techniques uses suitable doping profiles of individual layers and very strict follows the layout rules to minimize the substrate and well resistance. Another technique to minimize the latch-up risk uses a triple-well technology. In the triple-well process, p-well is insulated from p-substrate with a buried n-well, which ensures significantly reduced signal coupling. Cross-section of a CMOS structure in triple-well technology is depicted in Fig. 4.
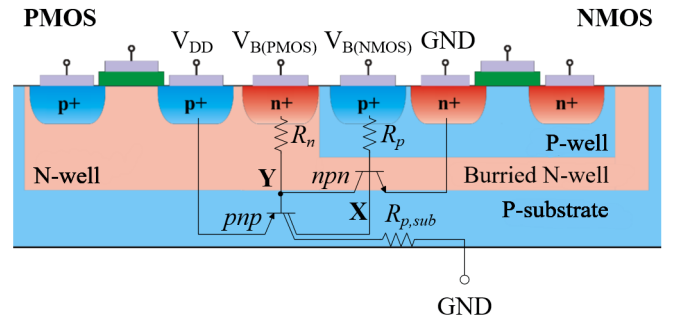
Fig. 4.   BD transistor equivalent circuit

Another effective technique to reduce the risk of triggering the latch-up effect uses guard rings created from n-well and p-well structures between individual transistors along with triple-well technology (Fig. 5). Connecting n-wells to the highest potential and p-wells to the lowest potential of the circuit creates reverse-polarized diodes between NMOS and PMOS transistor, which effectively prevents latch-up.

BD transistors are prone to other type of unwanted effect. MOSFET driven through the well (bulk) increases the risk of turning on a parasitic diode between the source and bulk as seen in Fig. 5. In NMOS transistor, if the voltage difference between the bulk and source grows to a value greater than the built-in barrier potential of the PN junction, a leakage current
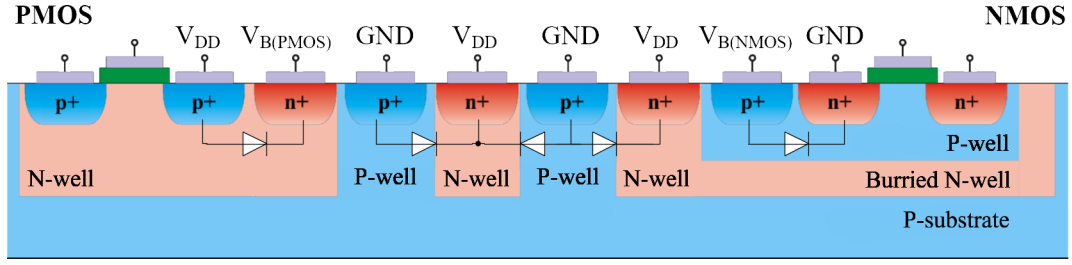
Fig. 5. BD transistor equivalent circuit

starts flowing from the well to the ground. The same principle works for PMOS transistor. A prevention action for this kind of problem is the voltage supply limitation to the value lower than the barrier potential of the PN junction between these terminals. Unfortunately, still a sub-threshold current will flow through this barrier.

C. Application of a BD technique on basic IC building blocks

The BD technique has been applied to design selected basic building blocks for analog ICs in order to analyze and evaluate the technique in low-voltage applications. The following circuits were designed and analyzed:

1) BD differential pair amplifier: Fig. 6 shows one of the most frequently used topologies based on BD transistors an input differential pair. The gates of transistors M1 and M2 are connected to a negative supply potential to ensure their right operation in saturation.
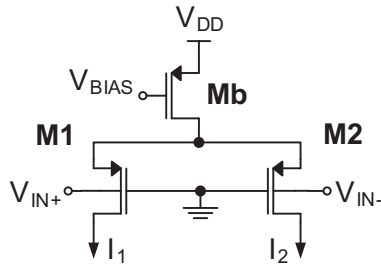
Fig. 6. BD input differential pair

The input voltage range V_{CM} of a conventional transistor pair is limited by high threshold voltages. This voltage range can be described by equation 4:

$$V_{CM} = V_{DD} - V_{DS(sat),Mb} - V_{TH} \qquad (4)$$

Input BD transistors are used to obtain the rail-to-rail input voltage range, which is important for achieving a sufficient voltage swing when $0.6\ V$ supply voltage is used. In addition, BT technique appreciably improves the input common mode range (ICMR). Another advantage of using a bulk-driven differential pair over gate-driven differential pair is the linear transconductance with respect to the differential input. The drawback of the BD differential pair is that grounded gates of the input transistors do not catch any noise generated by

the negative supply potential, which leads to a lower power supply rejection ratio (PSRR) values [8]. An example of using the BD differential pair was published in [9] as an input pair of variable gain amplifier (VGA).

2) BD current mirrors: Current Mirrors (CM) are one of the most frequently used IC building blocks. The current mirror is a two-port device that accepts current I_{REF} at the input branch and produces current I_{OUT} at the output branch according to equation $I_{OUT} = k \cdot I_{REF}$, where k is an amplifying coefficient. If we apply the BD technique to a simple current mirror, the circuit shown is Fig. 7 is obtained. Using the same principle, more difficult CM topologies can be designed.
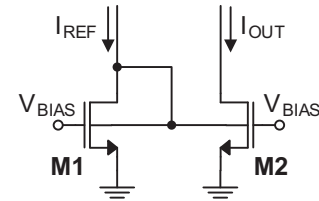
Fig. 7. BD simple current mirror

The bulks of transistors M1 and M2 in both branches are tight together and the gates are connected to the bias voltage V_{BIAS}. The input current brought into the input branch creates voltage V_{BS} between the bulks and sources of both transistors. By this voltage, the threshold voltage V_{TH} can be modulated and decreased according to equation 5, where V_{T0} is the threshold voltage when $V_{BS} = 0\ V$.

$$V_{TH} = V_{T0} + \gamma(\sqrt{|2\phi_F| - V_{BS}} - \sqrt{|2\phi_F|}) \qquad (5)$$

III. Experimental Results

A. Simulations

As mentioned before, body transconductance g_{mb} of a BD transistor is multiple times lower than the gate transconductance g_m, which can lead to lower gain band-width (GBW) and worse frequency response. However, this statement is valid only for situation when the MOS transistor is turned on. In the sub-threshold region ($V_{GS} < 0.5\ V$), gate transconductance is almost zero and body transconductance takes its advantage. The curves for g_m and g_{mb} are shown in Fig. 8 and Fig. 9, respectively.
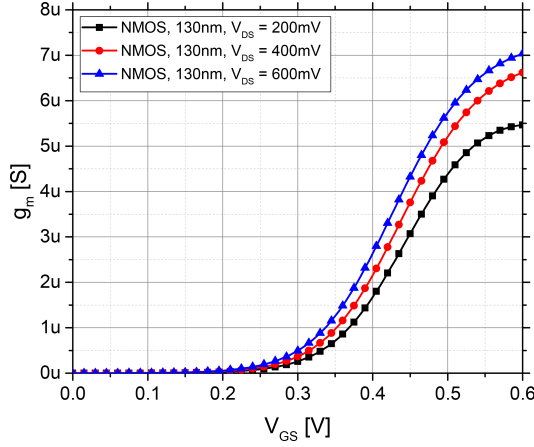
Fig. 8.   Gate transconductance vs gate-source voltage
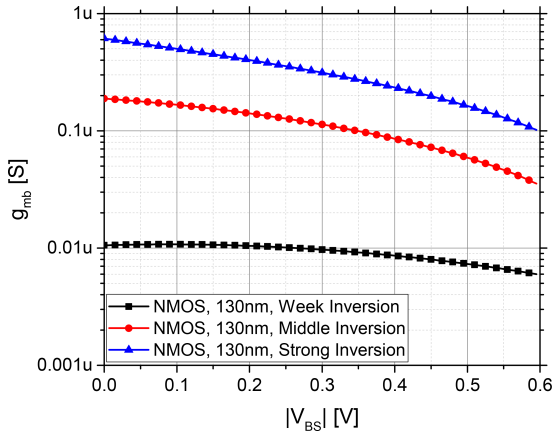
Fig. 9.   Body transconductance vs bulk-source voltage

Risk of turning on the parasitic diode between bulk and source is one of the unwanted effects. Nevertheless, simulation of the body-biased transfer characteristic shows (Fig. 10) that if the supply voltage is kept under $0.8\ V$, there is practically no risk of turning on the parasitic diode. Even though there is always a small diffusion current flowing through this PN barrier but it varies in the range of nA.
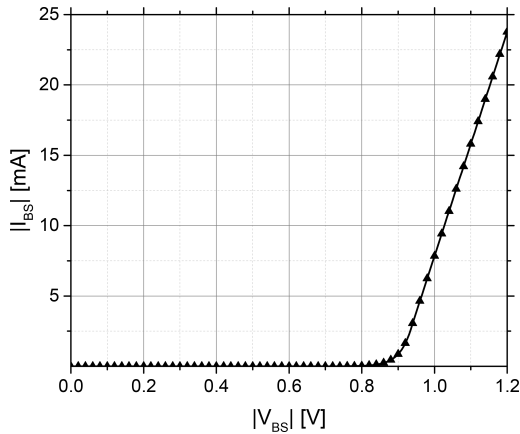
Fig. 10.   Bulk-source current vs bulk-source voltage

In our analysis, three basic topologies of current mirrors designed using the BD technique are compared in terms of main characteristics. Simulations of CM circuits were run for 130 nm standard CMOS technology. Dimensions of transistors were L = 2 m and W = 6 m for a simple CM (Fig. 7), and W = 14 m for improved Wilson and cascode current mirrors (shown in Fig. 11). Gates of all BD transistors are biased by voltage $V_{BIAS} = 300\ mV$.
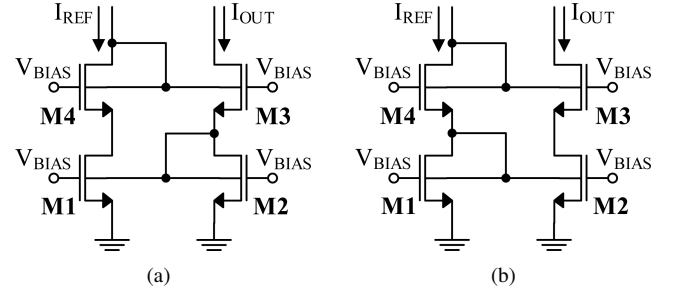
(a)   (b)
Fig. 11.   Schematics of BD CM: (a) improved Wilson; (b) cascode

TABLE I summarizes the results obtained from simulations of three basic CM topologies designed by GD and BD technique [10]. Achieved results prove the main advantages and importance of BD technique for low-voltage analog design and IC applications. Using the bulk electrode as the signal input terminal can minimize the threshold voltage of a MOS device (that has to be overcome) but at the cost of output impedance due to the fact that $g_{mb} < g_m$. The proposed CM topologies were laid out on an ASIC chip and fabricated.

TABLE I
COMPARISON OF GD AND BD DESIGN TECHNIQUES ON SELECTED
CURRENT MIRROR TOPOLOGIES

Topology	GD		BD	
	V_{MIN} [mV]	r_{out} [MΩ]	V_{MIN} [mV]	r_{out} [MΩ]
Simple	118	0.96	114	0.97
Im. Wilson	286	14.2	131	1.74
Cascode	372	35.6	131	1.75

B. Measurements

The designed CMs were manufactured and the prototyped chips were evaluated. In this section, the measured output characteristics are compared to simulation results.

The minimum output voltage $V_{MIN} = V_{DS,sat}$ of a simple CM does not depend on the threshold voltage V_{TH} or transconductance and thus, the output characteristics and the output resistance $r_{out} = r_{ds}$ of both mirrors are similar. It means that a simple GD CM is suitable for design of LV ICs but its drawback is in a low output resistance (in order of hundreds $k\Omega$). Simulated and measured output characteristics are shown in Fig. 12. Poor output resistance can be observed in the slope of the output characteristics for $V_{OUT} > V_{MIN}$, which is not fully horizontal as the reference current is. Measured characteristics shows even lower output resistance with similar V_{MIN} compared to the simulated characteristics.
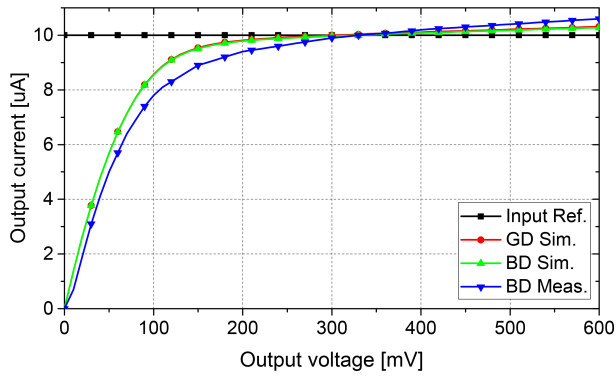
Fig. 12. Output characteristics of a simple CM

Improved Wilson CM can improve the output impedance by a negative serial feedback added to the circuit. From Fig. 13 one can observe that BD technique reduces the V_{MIN} voltage from $300\ mV$ to approximately $120\ mV$, which is similar to the simple CM but with much higher output resistance (in order of $M\Omega$).
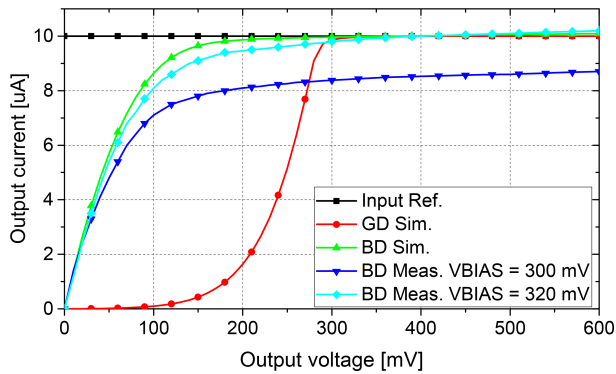
Fig. 13. Output characteristics of improved Wilson CM

Similar situation is with the cascode CM (Fig. 14). The minimum output voltage is significantly reduced using BD technique to the value about $150\ mV$. Measurements of both topologies approved simulated results with slight inaccuracy. Thus, DC biasing conditions had to be slightly modified from $300\ mV$ to $320\ mV$ to achieve the required CM accuracy.
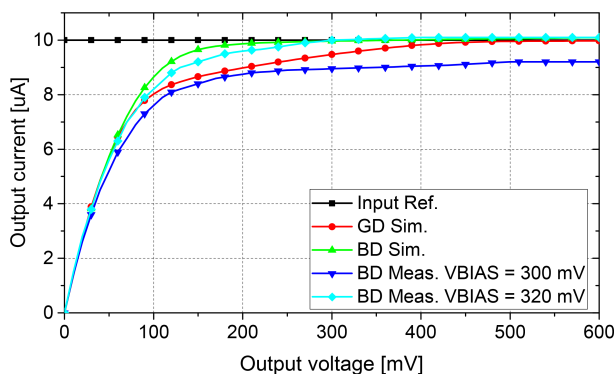
Fig. 14. Output characteristics of a cascode CM

Simulations of the designed current mirrors prove that the BD design approach can increase the signal swing by reducing the MOS transistor dependence on the threshold voltage. This can be the key towards modern low-voltage IC design, especially when cascode current mirror topologies are used (due to their simplicity and good characteristics). Output parameters of different CM topologies that were obtained from simulations are summarized in Table II.

TABLE II
COMPARISON BETWEEN SIMULATED AND MEASURED VALUES
$V_{MIN}\ [mV]$

CM topology	Simulation		Measurement	
	GD	BD	BD 300 mV	BD 320 mV
simple	118	114	109	-
improved Wil.	286	131	97	137
cascode	372	131	127	16

C. Layout

From the layout point of view, BD transistors have higher area consumption compared to standard GD MOS transistors. It is caused by that BD transistors has to be placed in separated wells, which are usually surrounded by guard rings in order to prevent the structure from the risk of unwanted latch-up. Some of transistors can be placed in the same well if their bulks are driven with the same signal (i.e. transistors M1 and M2 in Fig. 7), which can save rather considerable chip area, as can be observed in Fig 15.

(a)   (b)

(c)
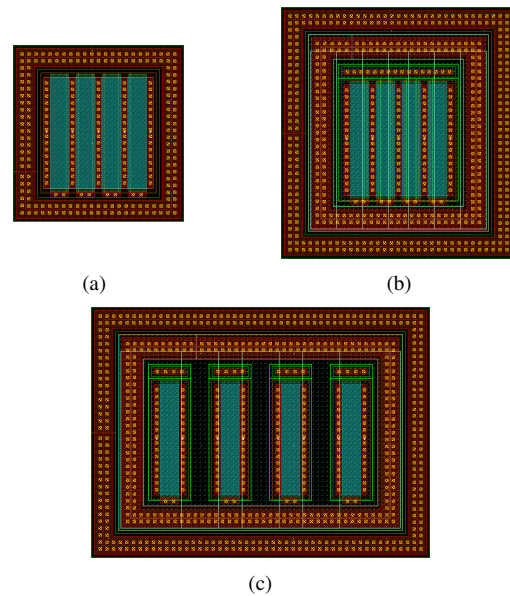
Fig. 15. Layout of four transistors: (a) GD; (b) BD in the same well; (c) BD in separated wells

In this comparison, area consumption of multiple NMOS transistors with all necessary rings and contacts was compared and results are summarized in Fig. 16.
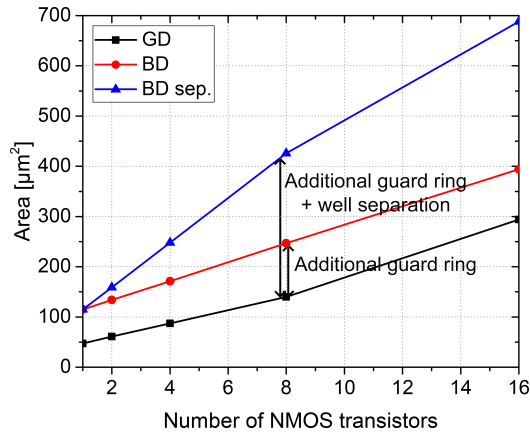
Fig. 16. Chip area vs number of NMOS transistors

Proposed CM topologies were laid out on an ASIC chip with some other test structures implemented. Layout examples of the selected current mirror circuits are depicted in Fig. 17. Current mirrors have common-centroid cross-coupled layouts with dummy structures on their sides for better MOS transistor correlation and temperature gradient immunity.

(a)   (b)
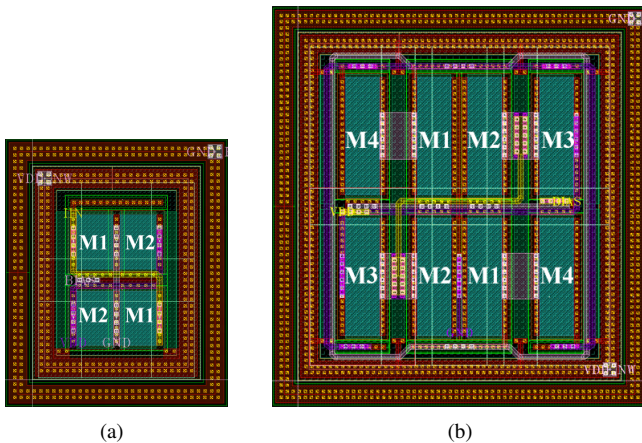
Fig. 17. Layout of: (a) simple BD CM; (b) cascode BD CM

IV. CONCLUSION

In this paper, bulk-driven design technique related to low-voltage analog ICs is presented. Since current mirrors belong among the fundamental analog building blocks, three different BD CM topologies in 130 nm standard CMOS technology were analyzed, fabricated, characterized and compared. Simulations show that bulk-driven technique can reduce the minimum output voltage of the improved Wilson and cascode CM down to 30% with respect to the gate-driven equivalent. The bulk-driven technique may eliminate limitations associated with the threshold voltage and thereby, reduce the supply voltage value required by the circuit or system. Measurements uncovered that accuracy of simulation models is lower when BD transistors are used. That is why DC biasing conditions had to be slightly modified during measurements. The research carried out and the results presented in this paper have proven

that the bulk-driven technique could be the approach to design of low-voltage analog ICs.

Further measurements and analysis of another bulk-driven test structures and circuits will follow-up to better character-ization of bulk-driven design technique in 130 nm CMOS technology, in terms of reliability, temperature stability and process stability.

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Utilization of voluntary pro-environmentally oriented instruments in the educational process

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Abstract— In the last decades, there is rising importance of standardisation in the field of systems of environmental management, auditing, environmental labelling, evaluation of environmental performance and life cycle of the product, environmental communication, and integration of environmental aspects into product design and development, and greenhouse gas emissions. Sustainable development which meets the basic present requirements without compromising the ability of future generations to meet their own personal requirements. It also includes investment in general infrastructures and social services along with necessary regulatory, technical and financial tools, all of them contribute to enriching the living standard of the local population whereas Innovation is the successful production, integration and exploitation of novelty in the socio-economic and environmental spheres. The implementation of voluntary instruments of environmental policy should be given support in the area of information and educational tools, i.e. pro-environmentally oriented edification, education and training. In this study the researcher is intended to identify various challenges and opportunities evolved in context to develop a sustainable environment. For this purpose, researcher will conduct an empirical study with the help of a questionnaire and will further extract data on secondary basis.

I. INTRODUCTION

The society is currently exposed to serious environmental problems resulting from non-sensitive access to the eco-systems, to renewable and non-renewable resources. Topically, there is discussed in particular the issue of climate change, of unsustainable drawing of natural resources, loss of biodiversity, increasing the volume of waste, excessive use of chemicals, increased greenhouse gas emissions.

To the priority areas of research – development – innovations, training, employment and business environment there were added the themes of climate change and energetics, and greatly was increased an emphasis on sustainable development. For these reasons, close attention require, in particular, new technologies coming to market.

To contribute to sustainable development as regards not only the humanity but also all life forms on the planet means to reassess the system of our priorities. It is necessary to limit the excessive polluting of the environment, reduce the population growth, in particular in developing countries, and to limit the excessive

consumption in industrialized countries. Over-consumption in industrialized countries and under-consumption in developing countries (dialectically related to over-production and lagging-behind) is the main source of the global instability.[2], [10], [11], [13] In general, sustainable development recognized as a function of all those human oriented activities that are using resources in regions, concentrating upon increasing socio-economic and environmental development initiatives.[14] From the system point of view, the consistent or sustainable system has components as productivity,resilience, vulnerability and adaptability.[12] In order to preserve the natural world, socioeconomic and environmental factors must be considered and harmonized.[6]

The Brundtland Commission defined sustainable development as a pattern of resource use that "meets the needs of the present without compromising the ability of future generations to meet their own needs." In order to preserve the natural world, economic, social and environmental factors must be jointly considered and harmonised. Formal and informal learning, through raising awareness and influencing behaviour, has a pivotal function if sustainable development is to be achieved. This role is especially pronounced in the realm of higher education because at this level students are being prepared to enter the labour market and emerge with skills to support green economies and as messengers of ideas.

Elliott J.A. has outlined the challenges in building sustainability where he has highlighted poverty as a major barrier in sustainable development due to its complex linkages with environment. [4] Winkler et al, has suggested that there should be equitable access to the sustainable development policies, technological and financial transfers so that people within poverty line can also avail the benefits of such opportunities.[1] Application of the sustainable development strategy calls for the implementation of various instruments of environmental policy. A major benefit is the implementation of voluntary instruments of environmental policy, which should have the support in the field of educational tools, i.e. pro-environmentally edification, education and training.

II. INSTRUMENTS OF ENVIRONMENTAL POLICY

Politics is a broad and general instruction on the procedure, which defines the boundaries within which it directs and regulates the activity of entities in the implementation of the strategy. The concepts of tool and means are not clearly defined and they are not used in the

same manner and under the same conditions. A certain change of the importance of the tool/means can occur at any given time, depending on the situation and perspectives of the action, respectively.

Environmental policy in the strict sense of the word has available a variety of tools to influence economic subjects to ensure the protection of the environment. Instruments of environmental policy can be divided into several groups.

According to the number of voluntary pro-environmentally oriented instruments applicable in an organization, we can recognize:

• application of a generic systemic environmental voluntary instrument (EMS, or EMAS) and, subsequently, of other pro-environmentally oriented voluntary instruments,

• application of a single voluntary pro-environmentally oriented instrument without prejudice to the organisation was implemented a generic systemic environmental tool EMS or EMAS, resp.,

• application of a tool mix of pro-environmentally oriented voluntary instruments, without a generic system environmental tool, or the application of EMS or EMAS, resp. was implemented to the organisation,

• application of a tool mix of voluntary instruments oriented on quality, environment and safety (the introduction the integrated system, or the ability to integrate of the singly implemented systems).

III. INSTRUMENTS OF ENVIRONMENTAL POLICY OF THE EU

In the EU we can talk about four main categories of tools, i.e., of legislative, market, horizontal, financial ones. [15] The EU legislation is a dynamic process and it is subject to continuous development. It is therefore important to monitor development in this field. [5]

The environmental policy of the EU originated in the originally exclusively economically focused European communities from the need to synchronize the environmental policies of member countries, which act as protectionist barriers to the internal market. Therefore, also environmental measures have mostly the nature of the standards for the products and technological processes. Later, when the scope of the EC has extended to other areas such as economic, also the environmental policy has been broaden, there were introduced some new regulation areas and some new instruments in order to ensure the high quality of the environment in the EU as a whole.

The current EU mandate in the environmental area is defined in the Treaty of Lisbon. Policy in the field of the environment is outgoing from the basic document of the EU and the EC. In article 191, there it is written that the Union policy in the environment area shall contribute to pursuit of the following objectives:

• preserving, protecting and improving the quality of the environment,

• protecting human health,

• responsible and rational utilisation of natural resources,

• promoting measures at international level to deal with regional or worldwide environmental problems, and combating climate change in particular.

The Union´s environmental policy is aimed at a high level of its protection taking into account the diversity of situations in various regions of the Union. It is based on the damages precautionary principle and prevention, on the principle of environment damages remedy should be taken just at their source, and on the principle that the polluter should pay for damages compensatory. In this context, harmonisation measures answering environmental protection requirements shall include, where appropriate, a safeguard clause allowing member states to take provisional measures, for environmental and non-economic reasons, subject to a procedure of inspection by the Union.

In preparing its policy on the environment area, the Union shall take account of:

• available scientific and technical data,

• environmental conditions in various regions of the Union,

• potential benefits and costs of action or lack of action,

• economic and social development of the Union as a whole and the balanced development of its regions.[3]

Management of some enterprises understood the context and introduced a system of responsible care and programmes of product stewardship which lead to openness and dialogue with employees and the public; they carry out environmental audit and evaluate fulfilment of individual programmes. A growing number of such management members voluntarily and at their own initiative take over the responsibility and manage their activities so as to minimise their impact on human health and the environment. The situation was helped by regulation measures adopted by individual countries, such as higher awareness of consumers and the public, and awareness of the management in business and industry. A positive approach of business and industry to sustainable development can be increased by economic tools such as free-market mechanisms which allow for the product and service prices to reflect the environmental costs of their inputs, production, use, recycling and final disposal in a growing degree and in compliance with the specific conditions in individual countries. [9]

A company has to define what sustainability means for its business (from the environmental, economic, social as well as ethical point of view) because its approach to the product issues will depend on its vision, obligations and type of business, i.e. the area of products or services. [7]

IV. COOPERATION PROGRAMMES

There is a wide scope to build on current development cooperation programmes for skills development. Fruitful avenues could include engaging national institutions in:

• Further exchange of experience, promotion of the training strategy for strong, sustainable and balanced growth;

• Integrating skills into national and sectoral development strategies through the UN Common Development Framework system;

• Providing capacity-building and financial help to expand the coverage and the quality of education and training available to disadvantaged groups;

- Upgrading the informal apprenticeship systems which are the only means of acquiring skills available to most young people;
- Building skills into current "aid for trade" initiatives.
- This in turn requires good-quality education in childhood;
- Good information on changes in demand for skills;
- Education and training systems that are responsive to structural changes in economy and society; and
- Recognition of skills and competencies, and their greater utilization in the workplace.

V. EDUCATION AND THE IMPLEMENTATION OF VOLUNTARY INSTRUMENTS OF ENVIRONMENTAL POLICY

Raising of public awareness about the issue of environmental protection is leading the public not only to a greater awareness of the environmental context of the economic and social life of the society, but also to increasing the quality of decision making by consumers, to raising the legal awareness of citizens and, consequently, to increasing the protection of the environment and quality of life.

Progressively, universities and other higher education institutions have been incorporating sustainable development values and practices into their core activities of teaching and research, institutional management and operational systems. However, the debate thus far has focused primarily on the rationale and reasoning for why sustainable development needs broad adoption. The international discussion, however, has failed to specify the various actions that higher education institutions can adopt. [6]

In the field of education, the activities of the European Union (Treaty of Lisbon, article 166) aim at:

- facilitation of adaptation to industrial changes, in particular the vocational training and retraining,
- improvement of initial and continuing vocational training in order to facilitate professional integration and reintegration into the labour market,
- facilitation of access to professional training and encouraging of mobility of instructors and trainees, particularly of young people,
- stimulation of cooperation in the area of training between educational and training facilities and firms,
- development of exchanges of information and experience on common issues concerning the vocational training systems of the member states.

The implementation of voluntary instruments of environmental policy should be given support in the field of:

- educational tools (pro-environmentally oriented awareness-raising, education and training),
- information instruments,
- legal, economic, planning, institutional and administrative tools.

VI. ENVIRONMENTAL MANAGEMENT SYSTEMS

In the global context, there is clear an evolution towards an effective environmental management. The issue of environmental management creation and of implementation of environmental management systems, in practice, was dealt with many of the authors. Environmental management systems are based particularly on the following principles:

- formulation and implementation of environmental policy in manufacturing practices and implementation of projects (programs) to achieve environmental objectives in the manufacturing plants,
- realization of an objective and periodical assessment of the environmental efficiency of these systems,
- public information on the site (locality) of the implementation of production (industrial) activity on their environmental performance (environmental reporting),
- securing of certified compliance with environmental requirements at the implementation of this policy and management system with the requirements of the standards in the form of the certificate (verification) by an independent, certified (accredited) environmental verifier (so called the third person).
- The ISO 14000 series of standards provide a guide to the development and application of an effective environmental management system. The main purpose of these standards is to promote the protection of the environment and prevention of pollution. In the year 2015 there was adopted the revised standard ISO 14001: 2015.[16]
- At the implementation of ISO 14001: 2015, or STN EN ISO 14001:2016, it is necessary that the organization match the questions below (question to them can contribute to a better orientation on the level of readiness of the organization for the application of ISO 14001: 2015):
- While the VEGA 1/0990/15 project has been carried out a survey on the readiness of industrial enterprises to implement the requirements of standards for quality management systems ISO 9001:2015 and environmental management systems ISO 14001: 2014.

Some organizations were consulted in the form of questionnaire. 123 respondents have replied provisionally and their answers are currently under analysis. We present some of the queries:

- has the organization identified the stakeholders and their needs with respect to SME (Environmental management systems)?
- has the organization addressed the subject of SME which is documented and made available to interested parties?
- has the organization identified the risks and opportunities associated with environmental aspects, with binding and other requirements?
- has the organization created any environmental objectives at the relevant functions and levels?

- how the organization ensures increasing environmental awareness among employees?
- does the organisation carry out at regular intervals the assessment of compliance with its mandatory requirements?

Questions relating to environmental policy were focused on the following topics:

- does it correspond to the focus, scale and environmental impacts of the organisation?
- does it provide a framework for the setting of environmental objectives?
- does it include a commitment to protection of the environment, including pollution prevention and more specific commitment?
- does it include a commitment to continual SME improvement?
- is it documented and communicated across the organization and made available to interested parties?

Questions about top management were focused on themes – see Table 1

Table 1: Top management in the context of the application of the ISO 14001: 2015

Top management demonstrates leadership role with respect to the:	♦ acceptance of responsibility for the SME effectiveness, ♦ creating of the environmental policy and the objectives that are in accordance with the strategy by the organisation, ♦ ensuring the integration of the SME requirements to the business processes of the organization, ♦ ensuring the availability of resources required for SME, ♦ communication, involvement and supporting of the staff in order to promote their participation and effectiveness of SME ♦ to promote continual improvement in order to achieving the intended outputs?
Has the top management defined the following issues:	♦ the responsibilities and powers to ensure SME, ♦ the responsibilities and powers to inform the top management on the SME efficiency and on environmental performance of the organisation?
Has the organisation's management documented information about the:	♦ risks and opportunities, ♦ environmental aspects and their environmental impacts, ♦ criteria for the determination of the environmental aspects, ♦ environmental objectives, ♦ competence of persons which affect the environmental behavior of the organization,
	♦ results of the review by the management?
Has the organisation defined competence relating to:	♦ identifying competence of persons affecting the environmental performance of the organisation, ♦ ensuring the necessary education or training of persons, ♦ evaluation of the effectiveness of the adopted activities relating to the competence of individuals?

The survey carried out in the framework of the VEGA 1/0990/15 project showed that for organizations already using ISO 14001: 2004 there is recommended when application of the ISO 14001: 2015 among other things:

- to specify responsible employees and their responsibilities for transition of management system under the revised standard,
- to communicate with the certification authorities the process of audit performance confirming compliance of the management system with the requirements of new standards,
- to ensure training for stakeholders (top executives, senior managers, internal auditors, determined staff, etc.),
- to carry out an analysis of the differences in the established management system over to the new requirements of ISO 14001: 2015,
- to carry out a review of the readiness of management system to transition to the revised standard,
- to draw up a timetable of activities for the transition to the new standard,
- to update the introduced management system to meet the specified requirements of the revised standard and requirements of their own organization to management system.
- For organizations that are applying for the first time to obtain a certificate pursuant to the revised ISO 14001: 2015 the deadline, conditions, procedure of the certification audit will be negotiated with the certification authority.
- For organizations that have issued a certificate according to the previous ISO 14001: 2004– these can apply for confirmation of the implementation of these standards in the context of the re-certificated/refresher or within the first or second supervisory audit of the three-year the certification cycle.
- Publishing the ISO 14001: 2015 counts with a transitional three-year period. This means that the certificates ISO 14001: 2004 may be valid until 15.9.2018.

The methods of documentation and attestation of conformity in the context of the individual management systems, i.e. according to the ISO 9001: 2015, ISO14001: 2015 and OHSAS 18001:2009 standards are promoting the integration of multiple individual systems into one integrated management system.

VII. CONCLUSION

Organizations expect from their suppliers more responsible approach to the environment, and such a business ethics in many cases resulted in a requirement for contractors had as a part of their business, introduced a system of environmental management. Environmental management means a systematic approach to the protection of the environment in all aspects of business, through which the organisation have integrated the care for the environment into its business strategy and current operation. This approach consists in the creation, introduction and maintenance of a properly structured system of environmental management, which is a part of the overall management system and is associated with all elements of the environmental performance of the organisation.

The readiness of the industrial enterprises to implement the requirements of the revised standard for environmental management systems ISO 14001:2014 depends on whether the organisation is applying for the first time to obtain a certificate pursuant to the revised ISO 14001:2015, or already has a certificate as per previous ISO 14001:2004. The results of the review represent a whole series of significant changes, which must be implemented within established or implemented management systems in organizations.

Acknowledgements

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[10] Note: For instance rich industrialised countries (20% of the world population) consume as much as 86% of the global resources, the rich fifth of the world population consumes 45% of all produced meat, 84% of paper, owns 74% of phones, etc.

[11] Note: the expression „industrialised countries" and „developing countries" includes the categories used by UN to express developer market economies or developing countries with market economic and Asian socialist countries

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The Software Library used in Teaching of Multiple-Valued Logic and Logic Function

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Abstract—**Multiple-valued logic (MVL) is used in various fields of knowledge such as logic, philosophy, logic circuits design, reliability engineering or artificial intelligence. MVL is generalization of well-known binary logic and unlike binary logic MVL allows operating with a larger number of truth degrees and provides numerous tools for problem formalizing and solving. In order to describe relationships between inputs and the result of certain phenomena in the MVL a mapping of *n* multi-valued inputs into *m*-valued output called MVL-function is needed. The MVL-function can be used for example in electrical engineering, computer engineering, logic or reliability engineering. MVL-function is a fundamental element of MVL. Therefore a software library for working with MVL and MVL-functions is needed for implementation of numerous applied problems. The software implementation of demanding process such as symbolic calculations with MVL-functions is hard. New software library for working with MVL and logic functions is introduced in this paper. This software library is programmed in C++ for fast and efficient performance. It can be used for helping student with symbolic calculations of MVL-function or as a support library for complex programs, which need to work with logic function.**

Keywords – software library, multiple-valued logic, logic function, direct partial logic derivative

I. INTRODUCTION

In the last time, classical algebra logic has undergone significant changes that cause intensive development of new types of logics [1]. One of these logics is MVL [1, 2]. MVL is a non-classical logic. It is similar to classical logic because MVL is basically constructed as truth-functional calculi, just like classical logic: the degree of truth of a formula can be calculated from the degrees of truth of its components [2]. But it differs from classical logic by the fundamental fact that it does not restrict the number of truth values to only two: it allows defining a larger set of truth degrees.

The use of MVL instead of classical logic has numerous advantages and it offers wider opportunities for implementation of algorithms [3]. MVL application simplifies computational processes and reduces the total number of operations. This logic can be used to find alternative computational methods, more easily formalize and better understand the problem to be solved [3, 4]. MVL is used in different areas of knowledge as philosophical [5], linguistics [6], logic and mathematics [1, 7, 8] and technic [3, 9]. MVL applications in technical areas are most developed in last time. There are a lot of examples of successful applications of this logic in technical area and, first of all, in computer science. MVL is used for development of new methods, algorithms and

approaches in logic design [3, 4], artificial intelligence [6] and system evaluation, in particular, for reliability analysis [10].

Logic design is actually the most promising field of MVL applications. There are three main directions of MVL applications in logic design. The pressure of attempting to reduce interconnection complexity and reduce chip area on VLSI is giving impetus to the investigation of many different hardware implementations of multivalued systems [11, 12]. The largest commercial use of MVL is in the area of multivalued memories [13, 14]. The second area concerns the use of MVL to assist in the analysis of problems in two-valued digital systems, such as the design of fault simulators [4, 15]. Finally, there is still ongoing work in the general area of switching theory to yield the best methodologies for the design of multivalued systems [16]. Application of MVL in logic design allows us to eliminate serious difficulties with limitations on the number of connections of an integrated circuit with the external world (pinout problem) as well as on the number of connection inside the circuit. It is possible for some VLSI synthesis if signals in the circuit are allowed to assume more states rather than only two. In addition, the MVL application has opportunities to reduce the number of ripple-through carriers used in the process of realization of arithmetic operations (normal binary addition or subtraction).

Artificial intelligence is promising field of MVL applications too. This logic is used in representation of vague notions and commonsense reasoning, e.g. in expert systems [6]. Also, this logic is useful in databases and in knowledge-based systems to represent and store vague information [17]. MVL is also used in data mining and knowledge discovering. For example, the mathematical approach of MVL is applied for clustering methods [6, 18]. In this context, one is also interested in automated theorem proving techniques for systems of MVL, as well as in methods of logic programming for systems of MVL [18].

The most interesting and successful application of MVL among problems of system's representation and evaluation is the use of this logic in reliability analysis [9, 19]. MVL is used for the mathematical representation of analyzed system. This type of mathematical representation is known as *Multi-State System* (MSS). According to [19], MSSs are one of the prospective mathematical representations in reliability engineering. MSSs have been introduced in reliability engineering since 1975 [20]. Their main advantage lies in the fact that they allow introducing more than two states in system/components performance [9, 19], i.e. from perfectly functioning, through functioning with restrictions, etc. to complete failure. This

indicates that they are very suitable for modeling of complex systems. Mathematical approaches of MVL, such as Logical Calculus [21] and Multi-Valued Decision Diagram [22, 23] represents useful tools for the evaluation of system reliability behavior. These tools allow developing methods and algorithms for calculation of reliability's indices [24] and critical measures [25].

The analysis of MVL application shows that it is promising mathematical approach for different areas in computer science. Therefore MVL as a part of algebra of logic can be included in educational program for students of specialization in computer science. The introduction of MVL in educational program requires development of special software that can be used in practical class. There are some initiative developments in MVL for educational purpose. One of them is sets of benchmark for different types of multivalued circuits [26]. The second is software for Multi-Valued Decision Diagram [27, 28]. In this paper, new software library of MVL-function is represented. The software library is written in the C++ programming language. This library permits to perform symbolic calculations of logic functions and to define own algebraic systems or own operations. This library can help student with mostly symbolic calculations of logic function that can have applications in some areas of computer science, particularly, in reliability analysis according to methods and algorithms discussed in [10, 21, 25, 26].

II. MULTIPLE-VALUED LOGIC

MVL is a generalization of Boolean logic in the sense that the level of truth is not only binary-valued but *m*-valued or infinite-valued [29]. The first indication that this type of logic is needed has been mentioned by Aristotle, who came up with the paradox of the truth of future claims. In his work *On Interpretation*, he noted that the phrase *"sea battle tomorrow will not be held,"* cannot be clearly labeled as true or false, until the battle will not or will take place tomorrow [30]. However, he did not create a system in which he would solve this problem.

The idea of creating a system for MVL re-emerged in the twentieth century. In 1920, Polish logic and philosopher Jan Łukasiewicz came up with a system of ternary logic, using the third value *"indeterminate"* to solve the paradox of the truth of future claims. This system is based on the set $\mathbb{M} = \{0 = false, 1 = indeterminate, 2 = true\}$, and it has two basic operations: the complement operation and the two-place operation implication [29]. However, this system does not create a complete functional algebra, which means that it is impossible to express all the logic functions using basic operations [31]. But if we add a unary operation, known as *"T-function"*, then it is possible to formulate a functionally complete algebra. Definition of the operations can be seen in Fig. 1. Although this system is built for three values, it is possible to generalize this system to finite and even infinite multiple-valued system [29].

There are many ternary logic systems, which were introduced after Łukasiewic system, such as Bochvar logic, which is similar to Lukasiewicz's logic, but with the difference of the schematic implementation of the third value. In this system the third value is known as *"undecidable"*, which changes the definition of the two-place operations [32]. Another example is Kleene logic, which is another ternary logic system, where the third value is known as simply *"unknown"* [29]. Definition of the changed operations for Bochvar and Kleene logics can be seen in Fig. 2. Ternary logics are typically used in electronics or in the database structural query language SQL in order to handle comparisons with NULL values, e.g., temporal databases studied in [33].

Another multiple-valued system was introduced in 1921 by Emil Leon Post. This system is functionally complete and it is defined over a linear ordered set $\mathbb{M} = \{x_0, x_1, \ldots, x_{m-1}\}$, $x_i < x_j$ if $i < j$ [29]. Two basic operations are defined in this system. The first is 1-cycle inversion, which is defined as follows:

$$\hat{x}^1 = x + 1 \ (\mathrm{mod}\ m),$$

where $x \in \mathbb{M}$. The second operation is two-place operation maximum, which is defined as follows:

$$\mathrm{MAX}(x_1, x_2) = x_1 \vee x_2 = \begin{cases} x_1 & \text{if } x_1 \geq x_2 \\ x_2 & \text{otherwise} \end{cases},$$

where $x_1, x_2 \in \mathbb{M}$ [16]. For $m = 2$ Post logic corresponds to binary logic with operations negation and disjunction, which is also functionally complete.

MVL developed by Allen and Givon in 1968 mainly in order to build mathematical foundations to support MVL circuits is functionally completed and defined over a linear ordered set $\mathbb{M} = \{x_0, x_1, \ldots, x_{m-1}\}$, $x_i < x_j$ if $i < j$ [16]. In this system, basic operations are two-place (term binary for operation with two operands is not used, because it can be misunderstood with operation in Boolean algebra) operation MAX, which corresponds to basic operation in Post logic, two-place operation minimum, which is defined as follows:

$$\mathrm{MIN}(x_1, x_2) = x_1 \wedge x_2 = \begin{cases} x_1 & \text{if } x_1 \leq x_2 \\ x_2 & \text{otherwise} \end{cases},$$

where $x_1, x_2 \in \mathbb{M}$ and the window literal operation, which is defined as follows:

$$^a x^b = \begin{cases} m - 1 & \text{if } a \leq x \leq b \\ 0 & \text{otherwise} \end{cases},$$

where $a, b, x \in \mathbb{M}$ and $a < b$ [16].

MVL can be used in many scientific fields, for example in linguistic for modeling natural language phenomena [34], in logic for solving problems with multiple possible values of truth [16], in philosophy for solving old

x	$\bar{x}$	$T(x)$		$x{\Rightarrow}y$	0	1	2
0	2	1		0	2	2	2
1	1	1		1	1	2	2
2	0	1		2	0	1	2

Figure 1.   Operations in Łukasiewicz functionally completed algebra

Bochvar

$x{\Rightarrow}y$	0	1	2
0	2	1	2
1	1	1	1
2	0	1	2

Kleene

$x{\Rightarrow}y$	0	1	2
0	2	2	2
1	1	1	2
2	0	1	2

Figure 2.   Differences in implications in Bochvar and Kleene logic

paradoxes such as *Sorites* or *falakros* [30], in electrical engineering when working with circuits, which have more voltage levels [16] and in data mining when working with multiple attributes [6].

III. LOGIC FUNCTION

In order to describe, express relationships between inputs and the result of certain phenomena in the MVL a logic function is needed. The m-valued logic function $f_m(x_1, x_2, \ldots, x_n)$ of n multiple-valued variables $x_1, x_2, \ldots, x_n$ is defined as mapping:

$$f_m: \mathbb{M}^n \to \mathbb{M}$$

where set $\mathbb{M} = \{0,1,\ldots,m-1\}$, $n \in \mathbb{N}$ and $\mathbb{N}$ is the natural number set [16]. If $m = 2$, then the two-valued logic function represents Boolean function in Boolean algebra. From the definition, it can be inferred that exists m^{m^n} possible m-valued logic functions for $n, m \in \mathbb{N}$. For example for $n = 2$ in three-valued logic $3^{3^2} = 729$ different three-valued logic functions of 2 three-valued variables exists [16]. Also all the operations, which were mentioned in multiple-valued systems are logic functions. Other well-known operations are also used in, for example m-ary operations of multiplication or addition modulo m, which are defined as follows:

$$\text{MOD} - \text{PROD}(x_1, x_2, \ldots, x_n) = x_1 * x_2 * \ldots * x_n \mod m,$$

$$\text{MOD} - \text{SUM}(x_1, x_2, \ldots, x_n) = x_1 + x_2 + \cdots + x_n \mod m.$$

The m-valued logic functions can be represented in several ways, which can be seen in Fig. 3. One of the easiest ways to represent the m-valued logic function is by a truth table. Each row of this table consists of output value from the m-valued logic function and a combination of values of input variables which generates that output value. The truth table contains all possible combinations of input variables and associated outputs, which means that for large-scale logic functions with large m or a large number of input variables, they are not very used. But for reasonable m and a reasonable number of input variables the truth table can be clear, fast and easy way to describe a logic function [3].

Another way to represent the m-valued logic function is by using a logic expression. Logic expression was derived from propositional logic and allows express the logic function in algebraic form. For the specified finite collection of multiple-valued variables $x_1, x_2, \ldots, x_n$, logic expression $\phi(x_1, x_2, \ldots, x_n)$ is defined as follows [16]:

I. constants $0, 1, \ldots, m-1$ and multiple-valued variables $x_1, x_2, \ldots, x_n$ are logic expression;

II. if ϕ and ψ are logic expressions for the multiple-valued variables $x_1, x_2, \ldots, x_n$, then using the defined operations of a multiple-valued system, which have as operands φ and ψ, we obtain the logic expression;

III. each logic expression for inter-variable variables is created by the final number of rules I and II.

It is needed to point out, that a logic expression represents only one logic function, but one logic function can be represented by many different logic expressions. Logic expression can be used to effectively describe large logic
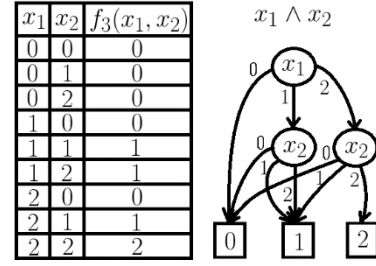
Figure 3. Different forms of representation for three-valued function MIN

functions, but it is harder to work with logic expression on a computer [16].

The last way to represent the m-valued logic function, which will be presented in this paper, is by using decisions diagrams. A multiple-valued decision diagram (MDD) is an acyclic oriented graph. This graph consists of two types of nodes, namely decision nodes, which represent variables, and terminal nodes, which represent possible values of a function output. Nodes are connected by oriented edges, which are pointing from decision node to another decision node or terminal node. Each edge represents one value of the variable represented by the decision node, from which the edge comes out [29]. Using MDD to represent a m-valued logic function is intelligible and can be easily used for analysis and computation. Problem with MDD is in choosing the order of variables, because bad ordering may result in large MDD [16].

Logic functions are used to describe the phenomena that produce output based on the values of inputs. However, when analyzing the logic function, it is necessary to determine the dependency of the change of the output of the logical function by changing the input of one or a group of inputs. For this purpose, a mathematical tool is used called a Direct Partial Logic Derivative (DPLD) is used. DPLD is defined as follows:

$$\frac{\partial f_m(j \to h)}{\partial x_i(s \to r)} = \{f_m(x_1, \ldots, s, \ldots, x_n) \leftrightarrow j\}$$
$$\wedge \{f_m(x_1, \ldots, r, \ldots, x_n) \leftrightarrow h\},$$

where $s, r, j, h \in \{0, 1, \ldots, m-1\}$, $s \neq r$, $j \neq h$ [16]. DPLD expresses how the change of the value of multiple-valued variable x_i from s to r changes the output of logic function f_m from j to k. The result of this derivation is therefore either 0 or $m - 1$, since operation ∧ represents operation MIN and operation ↔ represents an operation equivalence in the MVL, which can be defined in the following way:

$$x \leftrightarrow y = \begin{cases} m-1 & \text{if } x = y \\ 0 & \text{otherwise} \end{cases}, x, y \in \mathbb{M}.$$

The usage of DPLDs is mainly in electrical engineering in analysis of logic circuits, especially since DPLDs have been developed mainly for this purpose [16]. However, it is possible to use DPLDs in other disciplines, such as in analysis of discrete event systems, where it supports their modeling, testing and synthesis [35] or reliability theory, where it is necessary to determine whether a failure of one component of the system can cause a system failure [21].

The usage of logic functions is closely related to the use of MVL in which the logical function is defined. Logic function is used to describe behavior of the logic circuit in electrical engineering and computer engineering [16], to express the statement and evaluate its veracity in logic [34], to describe a behavior of a system for the purpose of investigating reliability in the reliability engineering [21] and in many other disciplines.

IV. SOFTWARE LIBRARY FOR LOGIC FUNCTION PROCESSING

Working with MVL and logic function is important in many fields. Therefore, it is important to teach students how to work with MVL and logic function. However, doing symbolic calculations with logic functions can be a time-consuming and computationally demanding process. Therefore, it is advisable to perform these tasks quickly and efficiently using the software library, which was developed in order to help student with mostly symbolic calculations of logic function not only for reliability analysis and will be presented in this paper.

The software library is written in the C++ programming language, as this language is powerful, time-tested, and provides all the tools needed to develop an object-oriented software library [36]. In the design and development of software library all functional requirements and minimization of time and memory complexity of used algorithms were taken into account. Software library allows performing mostly symbolic calculations of logic functions. This means that it is necessary to process the logic function in a form of logic expression because this form is more suitable for symbolic calculation than truth table or decision diagram. In development was also focus on the possibility for users to define own algebraic systems or own operations because this library was designed in such a way that it can be used to work not only with MVL but also with other types of discrete systems that are based on pseudo-logic functions, function based on Galois fields or other integer functions [16].

All classes in software library are divided into two namespaces, namely algebra and parsing_and_processing. In namespace algebra are classes for creating algebraic systems and classes to work with them and namespace parsing_and_processing contains classes used to parse all tokens of logic function from text input, to build a tree represents logic function and classes for working with logic function.
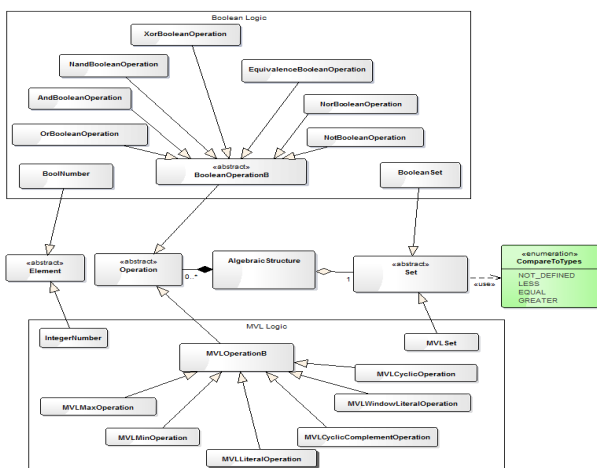
A. Namespace algebra

This namespace contains classes that allow us to create algebraic systems. There are also already defined classes, which represent operations and set in Boolean algebra and MVL. All the created classes and the relationships between them can be seen in Fig. 4, where all classes relating exclusively to Boolean algebra or MVL are placed in the respective boundaries. In this paper, we will not focus on the Boolean part.

Abstract class Element serves as a template for classes representing values in an algebraic system and one of the implementations of this class is the class IntegerNumber that is used to represent integer numbers. Since the algebra is defined on a given set, it is necessary to have an abstract class to represent it. Therefore, the abstract class Set and also MVLset, which is implementation of class Set in MVL, is defined in the namespace algebra. In order to define our own operations, it is necessary to have an abstract class Operation. For each defined MVL operation, there is a superclass MVLOperationB that implements the Operation superclass and implements the basic common methods for each operation in MVL. The last class that will be introduced in this namespace is AlgebraicStructure. This class represents the algebraic structure, which means that there is an attribute that represents the set, at which the algebraic structure is built, and also the attribute representing the list of operations that are defined in the algebraic structure.

B. Namespace parsing_and_processing

All classes in this namespace are used to parse the text input, to create a multiway tree by processing the parsing result and to work with logical function. All the classes created in this namespace and the relationships between them can be seen in Fig. 5. But before those classes will be introduced, algorithms for parsing and processing will be introduced and explained.

It is necessary to choose an algorithm for parsing and processing that can work with logical functions written in a form of a logical expression effectively. Based on these requirements, we chose to use the slight variation of *shunting-yard algorithm* introduced by Edsger Dijkstra [37]. Main principle of the shunting-yard algorithm is that it transforms logical expression from a text input (e.g. x1 + x2) into a reversed polish notation (RPN), (e.g. x2 x1 +) [38]. In order to obtain RPN, two stacks are needed. The first stack, which will be called the output stack, will store the output tokens and the second stack called the

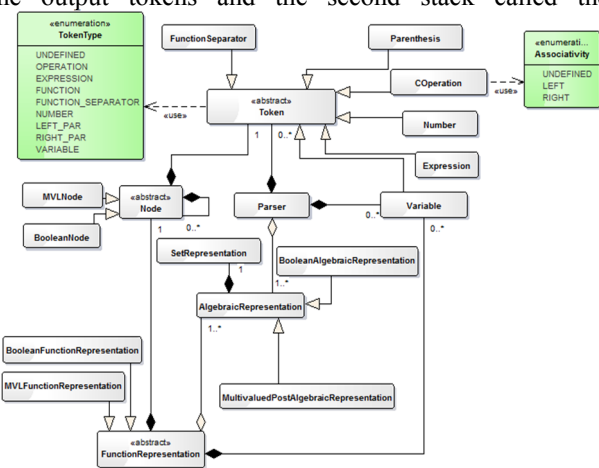Figure 4. Classes in namespace algebra and their relationships

Figure 5. Classes in namespace parsing_and_processing and their relationships

temporary stack will temporary store operations, brackets, and functional separators to maintain the priority of the operators. The term token used in this algorithm is understood as a text representation with a certain meaning [39]. This means that, for example, the token "var2" is understood to be a variable, the token "3" is understood as a number or token "*" is understood as an operation.

The shunting-yard algorithm works by sequentially recognizing the tokens in the text input and inserting them into one of the two stacks according to the following rules.

I. If the token is a number or a variable, put that token into the output stack.

II. If the token is an operation, put it in the temporary stack. However, before doing so, check the priority of the top token in the temporary stack. If there is an operation with higher or the same priority and the inserting operation is left-associative or inserting operation is right-associative and at the top of the temporary stack is operation with higher priority, then select the operation from the top of the temporary stack and insert it into the output stack. Repeat this procedure until the temporary stack is empty or the condition for removal from the top of the temporary stack is not valid.

III. If the token is a function, insert it into the output stack and insert the token representing the start of the function into the stack. However, if the token is a functional separator, then consecutively remove the tokens from the temporary stack and insert them into the output stack until you find the beginning of the function. If the beginning of the function is not found, then declare the function invalid and thus the text input is invalid.

IV. If the token is a left bracket, insert it into the temporary stack. However, if the token is a right bracket, then remove tokens from the temporary stack and insert them into the output stack until there is a left parenthesis on the top of the temporary stack. Then pop out the left bracket from the temporary stack. If you cannot find the left parenthesis, then the brackets in the text input are incorrectly entered and the text input is invalid.

If all the tokens are already processed from the text input, then the tokens in the temporary stack are moved to the output stack. Also when algorithm processes a token, this token is tested whether it can have a given token type in front of it, or whether the text input can start or end with him. In Fig. 6 we can see the sequential processing of the input string x + 3 = y * 1, which is a 4-valued logic function in which operation * is the operation MIN with priority 2, operation + is operation MAX with priority 3, operation = is operation of equivalence with priority 4 and each operation is left associative. We choose to use *, + and = for operations instead of ∧, ∨ and ↔, because it is much easier to type those symbols on the computer. However, in the software library, it is possible to choose custom representations for every operation.

After successful parsing, the text input is transformed into RPN stored in the output stack. However, such a representation is not the most appropriate for performing symbolic calculations. Therefore, it is necessary to transform RPN in the output stack into a multi-way tree. The construction of the multi-way tree is done by execution of an algorithm whose example is shown in Fig. 7. The algorithm starts by first checking whether the output stack is empty. If it is empty, the algorithm ends. However, if the output stack is not empty, the following procedure is performed.

1. Create the node and set this node as the root.

2. Perform these actions recursively until you build a multi-way tree.

2.1. Select the token from the output stack and put it to the node. If there is no token in the output stack, declare the tree to be invalid and end.

2.2. If the token has no arguments, then end.

2.3. If the token has k arguments, then repeat the following steps k times.

2.3.1. Create new node.

2.3.2. Set this node as the son of a node, which contains the token from step 2.3.

2.3.3. Run recursive the algorithm from step 2.1. over the son.

When the algorithm finishes, it will either create a multi-way tree representing logic function or declare the created tree as invalid if the number of tokens in output stack is smaller or larger than the number required to build a multi-way tree. It is then possible to perform various necessary symbolic operations above the created multi-way tree representing logic function.

One of the symbolic calculations, which can be done on the logic function stored in the multi-way tree, is DPLD. Algorithm for calculation of DPLD first makes two copies of a logic function (in the form of multi-way tree). Then it
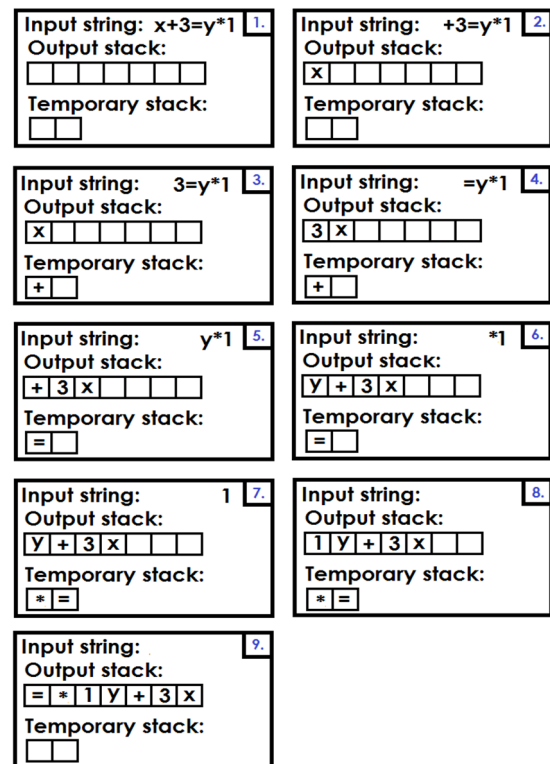

Figure 6. Example of shunting-yard algorithm

changes the changing variable for a given value before change in the first copy and after change in the second copy. Also it altered both copies in a way that it adds two-placed operation of equivalence to the root of the multi-way tree representation of the first or second copy of the logic function, which will have as a one operand first or second copy and as a second operand given value of the logic function before change in the first copy and after change in the second copy. Lastly, it creates a new logic operation representing DPLD that will be composed of operation MIN with both altered copies as operands.

In order to implement those algorithms, we choose to create following classes. Abstract class Token represents token and all descendants represent certain type of token, for example, class Number represents numerical value, class Parenthesis represent left or right parenthesis, class Variable represents variable, etc. The SetRepresentation class represents the superstructure over the abstract class Set, which means that it provides some tools needed in parsing or calculation, for example to determine if a specific element belongs to a specific set. Class AlgebraicRepresentation is the basis for all algebraic representations defined in this namespace (for example MultivaluedPostAlgebraicRepresentation), and it contains all of the objects needed for the proper functioning of the algebraic system and also provides basic methods for working with the algebraic system. One of the main classes of this namespace is the class Parser, whose main task is to perform parsing by the shunting-yard algorithm. In this class, it is possible to set algebraic system in which the function is defined or to define representations for dot, comma, and parenthesis or function separator. Abstract class Node represents the node of a multi-way tree that is built from the specified output stack according to the algorithm and for MVL, there is defined a descendent

class MVLNode. The Abstract FunctionRepresentation class is used to represent the function, which means this class implements an algorithm for creating a multi-way tree and all general operations for manipulation with function. The MVLFunctionRepresentation class is a descendant of the FunctionRepresentation class and represents a logic function, therefore in this class all the symbolic and numerical calculations of the logic function are defined.

V. CONCLUSION

In recent years, the MVL have found its purpose in many fields, such as linguistics, logic design, artificial intelligence, system evaluation, in particular, for reliability analysis and for different areas in computer science. Right now, the MVL is used even more and as a mathematical approach, it is more established and provides many tools for working with ternary, m-valued or endless-valued logic. Therefore it is needed to teach students of computer science about MVL and to provide software tools to help them with working in MVL in practical class.

In this paper, new software library of MVL-function is presented. The software library is written in the C++ programming language, and it allows to perform symbolic calculations of logic functions and to define own algebraic systems or own operations. This software library will help students with mostly symbolic calculations of logic function that can have applications in several areas of computer science, particularly, in reliability analysis.

In future development, it is considered to extend the software library for new algebras and their operations, for example, discrete systems that are based on pseudo-logic functions, function based on Galois fields or other integer functions. This software library will be then used as a supporting tool in practical class for students learning about MVL and logic function. Also, this library should be used in complex software tool for reliability analysis to handle logic function and symbolic calculations.

Figure 7. Example of building a multi-way tree

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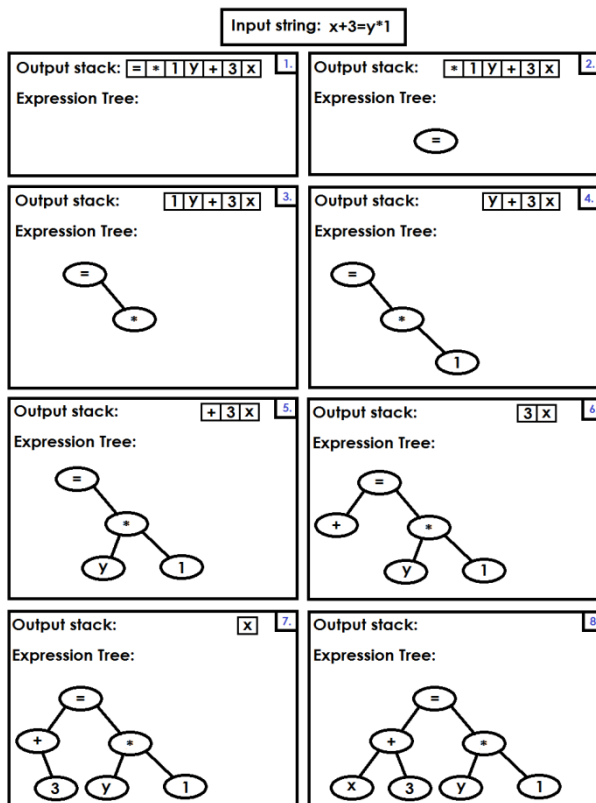[7] D. Scott, Outline of a Mathematical Theory of Computation, Univ.Oxford Computing Lab, 1970.

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Securing SIP infrastructures with PKI – the analysis

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Abstract—**The communication environment of present IP networks offers wide options of multimedia real-time communication (RTC) possibilities. RTC is a type of communication service provided over IP, which introduced its specific security threats and security related problems that may disturb a RTC communication environment. RTC communication consists of two parts – signalization and multimedia data transfer. Within the signalization part, the SIP (Session Initialization Protocol) protocol became dominant. In the data transfer part, there is the RTP (Real-time Transport Protocol) protocol. From the security point of view, on one side both of these protocols use several built-in security mechanisms. On the other side, there exists a whole autonomous infrastructure specially built for the provisioning and support of secure communication. The infrastructure is known as the Public Key Infrastructure (PKI). The article focuses on the present state analysis of use and cooperation of RTC and PKI in order to provide forms of better and more complex RTC security.**

I. INTRODUCTION

IP networks changed significantly for the last period and extend their types of deployment (data networks, telco networks, IoT, mobile networks, industrial networks). Actually, IP networks offer many kinds of services that have great impact on forms and ways how we communicate. One of developing areas that significantly influenced the usage of IP networks as a converged and unified communication medium used in our daily lives is the area of multimedia and real time communication (RTC - Real Time Communication). RTC integrates many different and various internet protocols and services into one concept. Therefore, the RTC in overall is very wide and complex. Thanks to its very dynamic development is RTC complicated in many ways. Because of reasons of extension, complexity and possibilities of RTC service abuse and its impacts, one of the most important feature of the technology is the possibility of its security. This paper therefore especially focuses on issues regarding of the security of RTC environment. However, areas of RTC and security of internet communication are vast topics of their own. Therefore, the paper focuses only on specific part of present RTC, the communication systems that are using one of relatively new, but a key protocol for the session management of multimedia relations – the SIP (Session Initiation Protocol) protocol. We focus our analysis on ways how to secure the RTC infrastructure with the use of a PKI (Public Key Infrastructure) infrastructure. As a basis for our research, we are considering the fact that the implementation and expansion of the SIP protocol and its solutions reveal a whole set of specific security issues and risks. The security of SIP architectures is therefore challenging and complex task. It includes securing a SIP based signalization stream and media stream on one side, as well as securing the set of support systems on the other side. Achieving it requires the use of a whole set of available security mechanisms be able to provide confidentiality, authenticity and integrity of communication. These techniques in many situations are focusing on the usage of simple, build-in SIP security mechanisms. They usually work on the principle of shared password. The need to build and maintain a PKI infrastructure and the distribution of certificates themselves prevent the ability to use advanced techniques, which work with user's certificates (authentication) and public keys (encryption). However, such PKI infrastructures are nowadays being built or are already available in many countries, and are integrated into electronic ID cards for example. In this paper, we analyze issues of the security improvements of SIP and VoIP communication regarding the use of PKI techniques (for example suitable for eCert, eID cards). The article focuses on possibilities, how the SIP protocol cooperates and may reuse a PKI infrastructure to provide a higher level of security. In principle, we would like to know the answer on following questions: What is the state of using certificates for mutual authentication and encryption of SIP protocol and what is the actual state of distribution process? Do already exist, or is there a need for the solution extending the architecture regarding of the certificates distribution process? Is there possibility to use the DNS (Domain Name System) for the distribution of certificates or for the authentication of SIP entities? Regarding of distribution process we preferably think on the distribution between SIP infrastructure users placed on the open internet and within different SIP domains, not in closed private corporate deployments.

The structure of this article is as follows. Next chapter focuses on the explanation of a PKI infrastructure concept. Consequently, we analyze the current state and knowledge regarding the security, but the focus is mainly on the SIP environment. The chapter III briefly introduce SIP security threats. Within of chapter IV we provide the analysis of built-in and external security mechanisms focusing on those, which use PKI. The chapter also provides the security feature analysis of actually available open source SIP clients. Finally, in chapter V we analyze the state of PKI integration in the field of SIP security. Primarily, we focus on the possibility of certificates usage (PKI) as well as on the way of certificates distribution realized within of RTC communications.

II. PUBLIC KEY INFRASTRUCTURE

Under the term of the Public Key Infrastructure (PKI) we understood a publicly accessible database of available public keys and certificates [1]. We distinguish two pair of keys, known as a public and a private key, usually used for the asymmetric cryptography of a communication. The communication is on one way encrypted by one of keys (usually the public one), and the other key is used for the decryption of data (usually the private one), and vice versa. Except of encryption, keys are used for the verification of the authenticity of users, messages or documents (digital signatures) too. Public keys are part of a publicly available certificate of a holder; a private key of the pair the owner should keep in secret. A certificate, in addition to a public key, also contain the whole chain of certification authorities (CA), validity timestamps, and a reference to Certificate Revocation List (CRL) of a domain. Certificates can be organized into a database, which usually take a form of a tree, where users' and devices' certificates are its leafs. Each valid certificates have to be signed to validate the content of a certificate, which as was mentioned is the public key of the certificate owner.

Actually there exist two ways, how to sign a certificate. The first one is a community based signing of certificates, where certificates are directly signed among communication parties themselves. This concept practically ignores the idea behind of PKI as it does not create an organized structure of certificates. Typical representative of this concept is the Pretty Good Privacy (PGP) created by Phil Zimmermann [2].

The second method expects of hierarchically build tree (trees) of certificates signed by superior entities, called the certification authority (CA). CA can be a superior authority for several subtrees. A certification authority has its own certificate signed by another superior CA, or the CA signs its certificate itself. The certificate signed only by the owner, is so-called as self-signed. CA which has self-signed certificate only and does not have the superior CA, is called the Root CA. Root CA is usually on the top of the domain, and it creates its own tree of trust CA. Many CAs offer certificates as commercial (Comodo, Verisign, Digicert…) or free of charge (TrueCrypt, CAcert…) service.

The concept of PKI works optionally with the Registration Authority (RA), which part is to receive a request of certificate signing, authenticate and authorize the user. While is the user successfully authenticated, RA resends request to CA, which signs the certificate. Validating authority (VA) is also optional. VA is the authority of independent third party, which has access to all signed certificates, and once the certificate is used, VA checks, if it is still valid based on copy of all certificates gained from CA [3].

In practice, PKI has developed as a forest of several certification trees with own root CAs, which are not mutually interconnected. Therefore, there is problem of trust ("*Who do we trust, and for what?*"). If users from different domains should communicate with each other, there is no join line among trees. That is a problem as end users by default trust just to another user, whom they can reach through their own tree of trust.

Nowadays, we can commonly see the deployment of PKI in enterprise networks, either from the point of view of identities or communication security. However, the expansion of PKI to the public internet is quite problematic, and got stuck by many reasons. As examples, we can state the difficulty and robustness of the whole PKI infrastructure, or user unfriendliness (mainly from the point of view of IT inconvenient user). As another point in this field is lack of the automation of generating and signing of certificates, what could significantly help to increase the PKI popularity. Last, but not least reason is the fact, that root certification authorities, that guarantee certificates and integration into existing trees of trust, are often offered as commercial services.

The importance of secure communication on public internet together with the requirement of secure using of many progressive services could have an impact on the expansion of PKI into ordinary life. One of examples where such standalone PKI tree of trust is build are electronic ID cards issued in Slovak republic [4]. The eID card stores certificates on their chip and together with freely provided card readers are used for secure access and use of e-services provided by the government. According to [5], the certificate can issue only an authority signed by National Bureau of Security (NBÚ - Národný Bezpečnostný Úrad) of Slovak republic. NBÚ than becomes an isolated root authority and establishes its own tree of trust.

Looking around the world, we are able to provide more examples of such isolated trees of trust. Commercial or public trees of trust, there still appear principled problem. Is impossible to verify an arbitrary user, if they do not become members of the same tree of trust. The solution could be the creation of central root CA, which would sign every root CAs, and therefore, it would be an intersection between all existing trees of trust. We can see an analogy in the Domain Name System (DNS), where there exist such intersection of domains at the top-level domain, which is called "." (dot). However, such general solution of this principal PKI problem is not available now. We suppose that it is mainly political-administrative problem, more than technical.

III. SIP SECURITY THREATS

SIP is a signalization protocol standardized by IETF (Internet Engineering Task Force) in RFC3261. SIP works on the application layer of the TCP/IP model. SIP is a text-based protocol developed for the management of multimedia sessions. It is designed as a client-server protocol, where a SIP entity can act as the client and server at once [6]. From the security point of view, there is identified a set of security threats and attacks on the SIP protocol in [7][8][9][11], that may lead to the disruption of its communication environment. The most common and easiest are attacks on denial of service (DoS). DoS focuses on the overloading of victim or service resources by generating an great amount of messages [12][13]. There are also other types of SIP attacks, such as eavesdropping, stealing or manipulation of identity, manipulation with relation, frauds, spam, and so on [14]. Attacks can be driven not only from the external environment, but also from the internal environment [11].

RTC consists of two parts, the signalization and the media transport. Both of them have their own vulnerabilities. From the simplified perspective, just the media are valuable for attackers. If an attacker intention is

not a service unavailability, he is interested in medial content. For the transport of unencrypted media the RTP (Real-time Transport Protocol) protocol has been developed. RTP in its basic implementation [15] does not offer any kind of data protection. Whilst the RTP transports its data utilizing a transport protocol (usually UDP), similarly as SIP, is RTP indirectly influenced by every attack on lower layers of TCP/IP stack.

Securing of RTC infrastructures based on SIP protocol is therefore a necessary condition. However, here is important to note that SIP also uses or relies on services of other protocols of the TCP/IP stack. Therefore, the vulnerability of any of used protocol from the stack also indirectly compromises the SIP signaling. For the complexity of the topic, the paper does not cover these other threats.

IV. SIP SECURITY MECHANISMS

From the security point of view, the SIP safety may be enhanced by using of several built-in or external security mechanisms now.

A. SIP built-in security mechanisms

Between built-in mechanisms, we include a challenge-based authentication mechanism, secure Multi-Purpose Internet Mail Extension (S/MIME) mechanism, and a secured SIP schema (SIPS) with the transport layer security (TLS) [6][16]. These mechanisms provide functionalities for authentication, data integrity, and confidentiality.

The SIP authentication mechanism reutilize the authentication mechanism of HTTP (HyperText Transfer Protocol). There are two versions of HTTP authentication, the HTTP basic and the HTTP digest authentication. The HTTP basic authentication isn't supported by SIP version 2. The HTTP digest authentication is a challenge-response MD5 hashing mechanism of username and password, which takes place between the UA (User Agent) and a SIP server. We may consider as an advantage of the HTTP digest algorithm its simplicity and wide support among either SIP clients, servers or SIP service providers. HTTP digest authentication is a minimal required protection mechanism, whose common purpose is to validate the user authenticity but is contingent on use of strong passwords. To provide integrity protection and confidentiality of SIP messages, we have to consider the use of S/MIME and TLS.

MIME is in its origin, a standard that extends the support of e-mail messages for more character sets, support of message attachments and so on [17]. MIME, and its security improvement S/MIME, has been originally designed for the e-mail service, but actually are used by other text based internet application protocols too. S/MIME is actually de-facto standard for securing emails by using a PKI infrastructure and X.509 certificates. The usage of certificates does not require any other transport mechanisms, as the certificate is transferred in the „application/pkcs7-signature" header field. Using S/MIME, a sender is able to either encrypt (using the public key of a recipient) or digitally sign a message (using the private key). These features are also reutilize within the SIP protocol, where the S/MIME provides end-to-end confidentiality for the transfer of SIP messages. S/MIME partially provides confidentiality for SIP headers, integrity protection for the body and identity authentication for a sender of the message [16][18]. In present days, the S/MIME is not widely deployed, as there are identified several problems with practical exploitation of S/MIME in real infrastructures. For the clarity let's suppose following situation, where we want to have entire SIP messages to be encrypted by the public key of a recipient on the entire end-to-end path. The decryption of encrypted messages is possible only on the recipient site, because only he owns appropriate private key. However as the whole message is encrypted a problem arise here, as every intermediate SIP entities (i.e. SIP servers) have difficulties to read parts of such encrypted SIP message and then have a problem with their proper processing. An example is a SIP proxy server, which for proper SIP routing need to read message headers. Another example are SIP servers (SBC, application, media server...), which need to analyze SIP headers (or SIP message bodies) to be able to offer their services.

The second option to provide the integrity and confidentiality in SIP is the use of TLS (transport layer security) [21] at the transport layer. Inside of a SIP architecture, TLS works on the hop-by-hop (HBH) basis securing the communication of SIP neighbors. To establish a secure encrypted channel between two entities, the TLS Handshake protocol (a TLS component) first establishes a connection. During the establishment, TLS verifies the credibility of SIP entities. This is assured by using a signed certificate (PKI or self-signed). For the transport of certificates, TLS does not use another protocol, but TLS transports the certificate directly during the connection establishment phase. A SIP server first sends to a user its certificate, which contains server's public key (one-way authentication). In some cases, the SIP server could request the certificate of an end user for the mutual authentication. Provide its functions; TLS relies on reliable transport features of connection-oriented protocols such as TCP. TLS does not work over connectionless UDP protocol, as the lost or reordering of datagrams breaks TLS handshaking and TLS record layer functionalities. Therefore, when UDP is preferred as a transport protocol of SIP messages, the datagram TLS (DTLS) have to be used.

Regarding of the usage of TLS in SIP we have identified several issues. From the point of known vulnerabilities, in the [22] is identified the opportunity to realize a "Man-in-the-Middle" (MitM) attack on the TLS Handshake protocol. In the case of this attack, the first message of the protocol contains a list of supported encryption protocols. An attacker can reduce the list only to NULL algorithm (without encryption). The Null algorithm means, that SIP messages will be send unencrypted in the plain-text format. Receiving SIP entity will react on the reception of such modified proposal by adapting an offer send back to sender (the initiator). The offer will contain the only one shared encryption protocol – the NULL.

Similar to S/MIME, the TLS has identified several problems, which limits its practical exploitation on providing a secured communication channel over the whole end-to-end (E2E) path. One of limitations could be the deployment requirements. Once we need to place into middle of the secured communication path other SIP entity to process the flow of SIP messages, we cannot use TLS or we need to split TLS secured communication

channel [23]. Another example is a situation, where is a need to communicate over several, intermediate SIP entities, and one of them does not support the TLS. This part of the communication chain then would not be encrypted [23].

B. External SIP security mechanisms

The SIP protocol, as well as protocols transporting multimedia, as the protocols of the TCP/IP stack do not have to rely only on their own security mechanisms. They may use other available mechanisms offered by lower layer's protocols of the stack, such as the DTLS and IPSec.

DTLS [24] is a protocol, which has been designed for the communication privacy of datagram protocols such as UDP, DCCP (Datagram Congestion Control Protocol), SCTP (Stream Control Transmission Protocol) and others. DTLS comes from the TLS protocol, and it provides equivalent security guarantees. DTLS similarly like TLS may cooperate with a PKI infrastructure. As well as TLS, DTLS uses two phases of connection establishment. Apart from TLS, it offers additional functions that TLS cannot ensure and that are required for unreliable transport protocols. For example, by usage of datagram protocols, a datagram can get lost, while the layer of transport protocol does not offer the retransmission service. DTLS, apart from TLS, which offers cipher chaining through several datagrams, offers encryption/decryption of single datagram without the need to receive previous datagrams. Nowadays, DTLS is often used in WebRTC, which mandatory requires for transport of signaling and media streams support of encrypted and secured transport mechanisms, such as DTLS/UDP or TLS/TCP protocol stack [25]. This is an interesting fact, as some publication sources do not recommend the use of DTLS at all, as there are available attacks that are able to break it. As an example, we can mention the "*Padding oracle attack*", published in [26].

Finally, for securing of signaling message flows we are able to use the IPSec (IP Security) security mechanism, which work at the internet layer. IPSec is a well know umbrella of secure technology standards [27], which offers confidentiality, integrity, authentication, and session anti-replay protection. IPSec, through its components IKEv1/v2 (Internet Key Exchange), is able to use for authentication of communication' parties, among others, digital signatures with public-key certificates too. The IPv6 stack of present operating systems (OS) supports the IPSec natively and the integration of IPSec into a SIP software is not usually required. However, in the IPv4 world, the IPSec is not natively supported. Therefore, the IPSec service usually provides third party IPSec software clients. The aspect of SIP and IPSec client collaboration is here questionable and we think, that for the smooth IPSec user experience the integration of IPSec into a SIP client is very suitable. IPSec supports UDP, TCP, and SCTP based SIP signaling. IPSec for SIP is usually applied on the hop-by-hop basis, as the reading of SIP headers is required on intermediary SIP entities at least [16].

The IPSec deployment scenarios within of RTC supports the hop-by-hop as well as end-to-end deployment. There is a possibility create secured tunnels between neighbor SIP entities, as well as through several intermediate devices. However, from the point of practical deployment, the IPSec as the mechanisms of securing RTC almost is never used in real life. Our analysis (Table 1) also shows there is no open-source SIP client, neither SIP server that have native support for IPSec protocol family.

C. Securing media streams

Media streams are one part of RTC communication (voice, video, chat, file sharing or desktop sharing). Therefore, there is the requirement to secure not only signaling messages but also the media traffic. Actually, there are available only several media encryption mechanisms. Some of mentioned mechanisms, as for example DTLS and IPSec, are able to use for securing both of them, the signaling and media.

Main mechanism that has been developed to protect media streams is the RTP media profile (RTP/SAVP) of the Real-time transport protocols (RTP) [28]. The profile is known as the Secure Real-time Transport Protocol (SRTP) [29]. SRTP is an efficient security protocol with low computational cost, memory and bandwidth requirements with good interoperability results, and it provides the encryption, message integrity, authentication and replay protection of a RTP stream. To cipher media streams, SRTP is using the concept of one master key, from which temporary session encryption keys are derived. SRTP does not define how the master key is exchanged. Therefore, it expects an external key management solution. To realize this there exists several key exchange protocols, for example, the SDP Security Descriptions (SDES) protocol, Datagram TLS (DTLS), Multimedia Internet KEYing (MIKEY), and ZRTP protocol. Some of them for the exchange of master key may use Diffie-Hellman method (MIKEY, ZRTP). However, the DH has identified a vulnerability that allows the Man-in-the-Middle attack [31]. Therefore, alternative solutions as for example ZRTP are recommended. ZRTP proposes the use of Short Authentication Strings (SAS), or SAS signed by PKI keys. According to our analysis, we did not have found known attacks breaking this media security.

D. Analysis of security features of SIP clients and servers

As a part of our analysis, we made a research focusing on the state of security mechanisms support. We have focused on freely available SIP solutions, i.e. those that are available under an open source license, are free of charge or provided as the freeware. Similar, but more generic oriented research was made in 2011 and was published in [16]. Table 1 provides the overview of open-source SIP clients (in some sources called the RTC communicator). Compared to the analysis published six years before, there is seen a shift in the number of supported security features for all clients.

Nowadays, the majority of mobile devices became connected to the internet. These devices often act as endpoints of IP multimedia communication, using their data connection they offer communication alternative to a primary mobile voice service. The analysis of mobile SIP clients available for the Android platform shows, that two of the most progressive SIP clients (CSipSimple and SIPDroid) offer the security of signalization through the TLS, and the media encryption by SRTP. In addition, the CSipSimple client offers ZRTP. SIPDroid has not been

TABLE 1.

SECURITY FEATURES – THE SIP CLIENTS ANALYSIS

SIP clients	Jitsi	Blink Qt	microSIP	Ring (Sfl phone)	QuteCom	Ekiga	Linphone	Empathy	Yate
www	jitsi.org	icanblink.com	microsip.org.ua	ring.cx	qutecom.org	ekiga.org	linphone.org	wiki.gnome.org/Apps/Empathy	yate.ro
Licence	Apache	GPLv3	GPL	GPLv3	GPL	GPL	GPLv2	GPL	GPL
Version	2,8	1.4.2	3.14	Beta 1.0.0	2.2.1	4.0.1	3.10.0	3.12.12	5.5.01
Latest release date	19.3.2015	11.9.2015	12.8.2016	14.3.2016	22.6.2011	21.3.2013	11.8.2016	13.5.2016	2.3.2015
Operating system	Win, Linux, Mac X,Android	Win, Linux, Mac	Win	Linux,Win, Apple, Android	Linux, Mac OS, Win,	Linux, Win, Solaris	Linux, Win, Mac, Android, WebOS	Linux, BSD	Linux, OS X, Win, Mac, BSD
Audio/video	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/Yes	Yes/No
Advanced services	SIMPLE, XCAP,	IM,XCAP	SIMPLE	IM	IM	SIMPLE	IM	IM	IM
DNS SRV/NAPTR	Yes	Yes	Yes	-	Yes	Yes	Yes	Yes	-
DNSSec	Yes	No	Yes	No	Yes	Yes	Yes	No	No
IM encryption	Yes OTR	Pro a Linux verzia - OTR	No	-	-	-	-	No	-
IPSec	No	No	No	No	No	No	No	No	No
TLS	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
DTLS	-	-	-	Yes	-	-	-	No	-
Media encryption	SDES SRTP, ZRTP	ZRTP	SRTP	SDES SRTP, ZRTP	SRTP	No	SRTP, ZRTP	No	SRTP
Key manag.	MIKEY	-	-	-	Everbbe	-	-	-	-
Identity	-	-	-	X.509	-	-	-	-	-
NAT	ICE	ICE	ICE	ICE, UPnP	-	STUN	ICE	STUN, TURN	-
Other protocols	SIP, XMPP, AIM/ICQ, MSN, Yahoo!	SIP	SIP	SIP, IAX	SIP, MSN, YIM, AIM, ICQ, XMPP	SIP, H.323	SIP	GoogleTalk, XMPP, MSN, IRC, AIMICQ	GoogleTalk, XMPP, H323, IAX
Transport protocols	TCP, TLS, UDP	TCP, TLS, UDP	TCP, TLS, UDP	UDP, TLS/SSL	UDP	UDP	UDP, TCP, TLS	UDP, TCP	UDP/TCP
IPv4/IPv6	Yes/Yes	Yes/No	Yes/-	Yes/No	Yes/No	Yes/Exper.	Yes/Yes	Yes/-	Yes/Yes

actualized, and remained almost at the same state for two years, but it at least offers SIP over TLS.

One of core SIP entities, mainly required to build own communication solutions, is the SIP proxy server. Main task of each SIP proxy is the routing of SIP messages within (from/to) the provider's network and domain. What means, that the most of SIP messages and dialogues flows through the SIP proxy. Compromising that key entity is a threat for many users and devices, therefore is very important to be familiar with their security features. The analysis of two widespread solutions - Kamailio [31] and OpenSIPS [32] shows, that both solutions support the most common forms of security. Most obvious is the HTTP Digest, and except it they support SIP over TLS. Kamailio looks a little bit more progressive solution, moreover it offers DTLS (for WebRTC), and offers DNSSEC for the securement of DNS. In addition, Kamailio compare to OpenSIPS offers a number of

modules that can be used to secure and protect the SIP proxy server from attacks.

Based on the summary assessment, we can say, that the support of security features well advanced for 2017. Whether using RTC communication with SIP clients, or building RTC platforms, security mechanism for signaling and media are available and may be implemented and used. The task and the question for the future will be their simplification, automation and improving their overall approach to the end user.

V. EVALUATION OF SIP AND PKI COOPERATION

Based on our analysis, we can conclude that RTC over SIP and its entities are capable to use a PKI infrastructure in multiple ways on providing hop-by-hop (HBH) or end-to-end (E2E) communication safety. The first way is to ensure the identity and authentication of communicating entities, i.e. SIP clients as well as SIP servers. Under the

concept of identity, we understand the username and domain of a user. Identity is usually written as SIP URI (e.g sip:alice@domain.sk). The exploitation of verified identity can be found during the authentication of registration process, or when a SIP client is establishing a session. During these processes, the SIP server usually checks and verifies the identity of a user based on user's credentials. Client could even digitally sign the message sent to the server. Based on the client identity and certificate issued to a specific domain name, server compares entries and authenticate the client. Whilst the mutual authentication is requested, the client can ask for a certificate of the server as well. Another example of use of verified identity is an inter server communication. Proxy servers serving their SIP domains can mutually verify the authenticity and validity of their identity data. To verify the identity there is the TLS protocol usually used. We can say that it is directly designed for use with a PKI infrastructure. As a part of TLS connection establishment process, communicators exchange their certificates. This directly allows the TLS protocol, which incorporates the transfer of certificates in its design. TLS supports two-way authentication ("mutual") or encryption on the HBH principle. Accepting a certificate is important to check its validity and verify its status within of PKI hierarchy [34].

The second possibility of a PKI infrastructure reuse within of SIP infrastructures is the signaling encryption. The encryption of communication can again take place between the client and the server (HBH), between two servers (HBH), or between two clients (E2E). Here once again, the TLS/DTLS protocol can be used which also ensures the transport and exchange of PKI certificates. Another option is the S/MIME extension. Clients use this technique to securely communicate with each other as it offers end-to-end security (E2E).

Encryption is not used only for the improvement of signaling security. It plays a non-negligible role in securing of media streams. For the encryption of multimedia streams security protocols such as SRTP have been developed. SRTP itself does not use PKI directly. However, it may use the ZRTP auxiliary protocol. End users are using ZRTP to exchange and agree on encryption keys. Then the ZRTP uses a PKI infrastructure for the safe transport of encryption keys. In particular, it is for the encryption of transferred key content, but also for the verification of user's identity. This prevents a "Man-in-the-Middle" attack.

If we talk on a PKI and RTC there is an important question. How SIP entities that uses certificate-based PKI techniques will gain the certificate itself? Best to our knowledge there was not for years a source describing such mechanisms closer. For years had been assumed that a parallel PKI infrastructure is built and its mechanisms of certificate distribution will be used somehow. However nowadays emerged new alternative approaches that are specifically devoted to the problem. The IETF is actually working on a DNS extension and there is identified an SIP architecture extension by the mean of CS server.

One of entities that the analysis has identified, and which has been designed as an SIP extension in order of the SIP and PKI cooperation is so called key sever (Credential server - CS). Typical CS server deployment is per a serving DNS domain, for which it performs the management of public keys of SIP domain entities. If the caller of that domain wants to contact another user in the

same (but it is the same for another domain), as a first step he/she contacts the CS server serving the target domain, and asks for the public certificate of a callee. The request is performed using the SIP "*Subscribe*" message. The CS server then replies with the SIP "*Notify*" message, which contains requested certificate [35]. Upon successful acquisition of the public key, the caller may use one of techniques described in chapter IV and contact the callee using any of these secure methods. Acquired public key of the callee can be used for securing of signalization as well as media streams. The localization of foreign CS server does not perform the caller itself. The caller sends the SIP "*Subscribe*" message directly to the callee as usual SIP messages are sent. The SIP message is delivered to that destination domain (inbound domain SIP proxy), where the remote SIP proxy server process it and redirect the "*Subscribe*" message to the domain CS server. The CS server then sends the callee's certificate to the caller via the SIP "*Notify*" message. Once the certificate has been obtained, the caller can contact the callee directly using encrypted messages/communication [35].

The CS server can also be used in situations when an existing domain user registers on a new device. This new device may ask its serving CS for a public and private key of this registered domain user. For this purpose, it creates an encrypted TLS connection to the CS server and uses the "*Subscribe*" SIP message to request both keys of the registering user. The CS server will send keys back to him using the "*Notify*" SIP message. However, there is a requirement that the user have to upload both of his/her keys (private and public) to the CS server repository at the time when he/she had registered his/her first device [35].

In the case that the CS server solution is used, a general PKI problem arises again. Namely, it is the issue of certificate's trust during the situation if the callee is not in the same tree of trust as the caller. In this case, the caller than could not verify the credibility of the certificate, because he can not reach the certificate in his own tree of trust. At present, we have not found a practical implementation of the CS server.

Another protocol that can be used to distribute digital certificates and can improve the security of SIP with PKI is DNS. DNS in SIP is used in its addressing system where it simplifies the localization of SIP entities, services and end users. As the security extension, DNS during the resolving process allows to obtain the user's certificate, respectively, the certificate of a server serving the domain. The certificate is stored in the DNS database. DNS protocol directly defines a new type of the DNS RR (Resource Record) record named the "*CERT*" RR, which refers to the PKI certificate of a SIP entity [36]. The DNS protocol provides a secure and authenticated form of data transport called the DNS Security Extension (DNSSEC) [37]. DNSSEC however, cannot encrypt the transferred data. But the DNS server through DNSSEC uses PKI certificates to verify and authenticate the identity of other DNS servers. Using these certificates, there is a possibility where SIP clients could be also authenticated against DNS servers, or signed response of a request could be obtained from a DNS server.

During the SIP URI resolving process a SIP entity can request from a DNS server "*TLSA RR*" record. This RR record maps a public key to the domain name of another SIP entity [38][39]. As an example, we can mention the resolving of a domain name of SIP proxy server through

"SRV RR" DNS records. After the fully qualified domain name (FQDN) was acquired, the SIP entity may subsequently request a "*TLSA RR*" record to the FQDN. By that means it detects the existence of proxy server certificate. According to [40][41], it should be the rule, that if the "*TLSA RR*" to domain name binding does not exist, the SIP entity immediately stops searching in the DNS database.

Based to our previous analysis, we can conclude, that the infrastructure of a public key is developed and ready, but at the same time it is still not widely deployed. Reasons are mostly in the complexity of the PKI infrastructure. PKI needs constant maintenance of entities, databases of valid and revoked certificates, what in the absence of automation is a problem in larger environments. Therefore, several auxiliary mechanisms have arisen, that simplifies the authentication and distribution of public keys, but they usually simplify the authentication process only. Some authors often refer to the fact, that today's communication is mainly on mobile devices, that may not have sufficient performance for seamless overhead communication [42][43][44][45][46].

Studying multiple resources or communicating with experts from enterprises revealed the fact, that support for PKI is rather the domain of enterprise networks as a public infrastructure. Within of closed enterprise solutions with unified security policy, the required security behavior and the support of used security mechanism spread over all entities are more enforceable than in the public domain. Preferred encryption is on the hop-by-hop basis than end-to-end. Based on the content of chapters IV and V is clear, that mechanisms exist in general, but their practical enforcement and implementation are different. Our practical experiments and findings from the chapter IV show, that HBH type of security implementation is functional, but its practical use within of public service provider's environments is limited. The reasons are mainly increased security costs, worse environment diagnosis and the fact, that in the public environment it is not always possible to force the HBH security along the entire communication path. Against the deployment of E2E security model facing a problem of message readability where multiple intermediate SIP entities require the straight access to SIP headers or message bodies for their proper processing.

VI. CONCLUSION

As the conclusion, based on all above we can say, that SIP-based multimedia communication has the prerequisites to operate securely with the use of public key infrastructure. At the present, there are mechanisms for securing the signalization as well as multimedia streams that are able to use the asymmetric encryption and infrastructure of public key. We believe that if the infrastructures of public key would be broadly deployed, the implementation shortcomings of many technologies would be resolved in a short time.

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Transborder Multi-level Digital Interactive Education – Training Platform for Innovation Oriented Co-development

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Abstract - **Based on analysis of modern tendencies in educational sphere and innovation experience; a new model of "triple integration" for Innovation eLearning is presented and a transborder multi-level digital educational-training platform for its realization is proposed. This proposal is integrated in framework of the Ukrainian-Slovak International Center for Innovations and technology transfer and may be used as a base for joint R&D and pilot project for innovative education and educational innovation.**

I.INTRODUCTION

Having completed the first decade of the 21st century by the global financial and economic crisis and entering the current decade, the world community at the UN level has identified the need to provide fundamentally new foundations for ensuring the sustainability of its evolutionary dynamics. In turn, this led to the awareness of the need for a planetary transition from a financially-driven industrial economy to a new type of economic globalization oriented towards innovation as an interdependent co-development on a new institutional basis. Thus, such a transition simultaneously involves a change in the very model of development, from the exclusive to the inclusive one. In addition, it is an appropriate replacement of its leading entity, which now serves as a globally integrated, self-sufficient economic region [1] .

Since now focusing on sustained inclusive development on an innovative basis is a priority focus, it forms an urgent request for modern knowledge not only in regard to new objects, but also, more importantly, about new participants, such as innovation - oriented regions, their institutional architecture and innovative infrastructure capable of providing an effective interactive cooperation of the regional economy with all levels of national, transnational and global one. As a result, national education systems, first and foremost, institutions of higher education face the global challenges of their ability to provide the economy and society with modern knowledge, skills, experience and competences necessary for innovative, inclusive development.

The current knowledge spectrum was formed as a consequence of system changes in public demand that took place over the past 50 years. Thus, since the 1980s, there has been a steady and deep decline in demand for routine stationery and engineering and information competencies that can easily replace by computers. Although with different historical dynamics, but since the 60s, the global recession has demonstrated demand for both traditional (routine) and non-traditional manual labor, which is increasingly carried out by machines. Instead, throughout this period (with a certain intensification after 2000), the demand for a high level of analytics, which requires deep special knowledge, abstract thinking and the ability to search for original solutions, steadily grows. However, the prevailing dynamics demonstrates a constant tendency to increase the demand for specialists capable of designing and managing long, dynamic, and interactive chains of high added value based on relevant information and communication networks [2]

In this case, it is not just said about direct communication between firms that forms the basis of trade, direct investment and inter-corporate alliances, but also include interpersonal ties, which often becomes more efficient, especially in the case of transfer of knowledge and technologies between countries with significantly different levels of development [3] Highly skilled migrants who form the entire transnational community [4] and become "new argonauts" of global network manufacturing [5] are usually the active participants of such transfer of the "brain circulation" and configurator managers of this phenomenon. Such communities generally contribute to the globalization of the movement not only of people and knowledge, but

also facilitate innovation of technologies and venture capital [6].

Of course, such complication of the processes of generation and translation of new knowledge requires serious corrections, first of all, in the system of higher education. These corrections would be responsible for increasing efficiency, improving quality and reducing inequality in gaining modern knowledge [7]. Traditionally, the higher school is responsible for the fundamental and "routine" knowledge, which is usually limited to the natural and technical and socio-humanitarian spheres and subject areas of disciplines, on the basis of which the graduate specialty is formed. For a long time such approach was in line with the economic and social needs of society. However, today, modern times require highly dynamic, innovative knowledge of interdisciplinary, as well as transdisciplinary type, and needs in new competencies that require skills of creative and critical thinking, the ability to model business behavior of economic actors and stimulate their innovation-oriented corporate motivation [8].

Such tendencies encourage the scientific and educational sphere to transform in the direction of integration with innovative business activities through formation of innovative institutions - like business incubators university scientific and academic technological parks. From other side an innovation business have to go beyond the traditional corporate forms of transfer of advanced knowledge and their diffusion through the development of information and communication, organizational and institutional networks[9]. The development of this counter-institutionalized and substantially heterogeneous movement, in turn, requires strategic coordination and appropriate coordinators. Coordinators are represented by various non-market institutions such as public and sectoral associations, non-government and government promotional agencies, independent research centers and foundations, etc. [10]. At the same time, the rapidly growing number of "players" in such potential innovation and educational market forms an urgent request on new quality, of their business activity. In turn, it needs in appropriate innovation in education and the formation of entrepreneurial competences for graduates, as well as increasing the scientific and educational provision of innovation and interactive interaction with higher education in the training of innovative entrepreneurs. However, a significant obstacle on the way to the market-based solution to this problem consist in the large number of barriers that arise in the face of such a counter-movement, primarily between the public education sector and private business [11].

In this connection, the construction of a multilevel platform-interface, which should provide not only an interactive cross-sectoral interaction of various kinds of "innovative players" in such heterogeneous polysubject

environment, but also supply integration of their activity into strategic co-ordinated inclusive development, becomes very actual. In turn, because such innovation-oriented development under the conditions of "new globalization" is possible only as a co-development, the pilot development of transborder interface, the initiative proposal of which is a practical part of this article, is of particular importance.

II. THEORETICAL-MODEL GROUNDING

The above-mentioned tendencies, of course, interactively reflect those fundamental changes that take place in the very nature of global economic dynamics. In general, these changes are illustrated in Figure 1
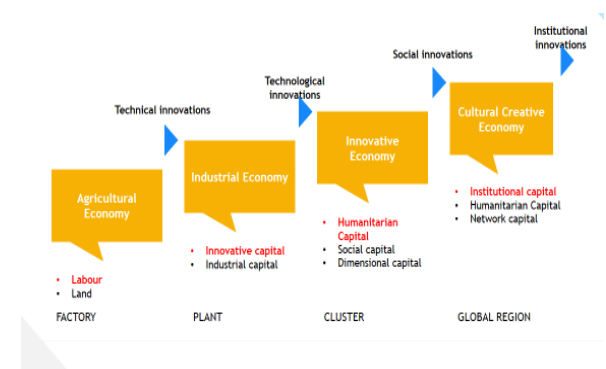

Figure 1. Economic development path

From the historical point of view, this picture shows those "evolutionary steps" that the world economy has consistently passed (of course, in its nationally diversified format), evolving from resource-oriented (agriculture and mineral extraction and industrial processing) of through structurally-organized industrialization (agrarian and industrial economics) to post-industrial types of based on, institutional-oriented economic reality (innovative and cultural-creative economy). In its entirety, this whole "economic ensemble" can only be seen in such large countries with "late industrialization" as China, but fragments of all previous stages of the formation of the global economy are integrated into national economy of any industrially developed country. From a principle point of view, it is important to note here that the role of at each evolutionary stages, main driver of economic growth ware played by different forms of capital:, the productive - in the resource types of the economy, industrial and innovative - are inherent in the early and "mature" industrialization, humanitarian becomes an accelerator for innovative economy, as well as institutional for - cultural and creative.

Each of these factors has its own institutional architecture, mode of generating, concentrating and transferring knowledge and leading innovations. Thus, innovation capital owes for its growth to the

introduction of - technological innovations, humanitarian - social, and institutional - creative institutional ones. From a theoretical point of view, such a picture basically corresponds to the 5-factor model of endogenous growth, which may be represented in factorized form as the functional [12]:

$$Y=F (L,K.A,H,I) \qquad (1)$$

Here Y is a production function, and L, K, A, H, I, is industrial, innovative, humanitarian and institutional capital, respectively, usually L and K are concentrated in classical localized form which is typical for classical trade and industrial firm, while innovative capital has multilocation, structure as in case of MNC ,humanitarian capital already has non-classical spatially distributed form of clusters and agglomerations, and an institutional – but institutional capital has complicated construction integrating its hard, soft and virtual parts. This last post non – classical virtual part opens the perspective for development of a global network with a cultural and creative hub in its epicenter. According to such changes, the post-industrial stage gives rise to, fundamentally new generators, translators and users of innovative knowledge appear - from innovative business incubators, scientific, technological and industrial parks, high-tech clusters , territories and zones of economic and technological development, global cities and regions. Based on this new institutional foundation there may being buitt a moder powerful "engines" of innovative development far new economic regions, whose principal form is presented in fig 2.
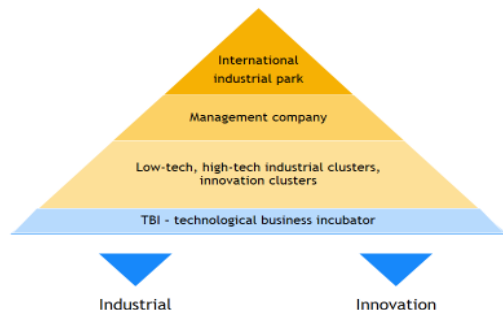

Figure 2. Institutional structure of the nucleus of the innovation ecosystem. TBI - technological business incubators; STIP - scientific, technological and industrial parks; IIP is an international industrial park

Here TBI is responsible for startup incubation based on technological innovations and for generation of new knowledge, STIP provides with design of new products and the development of industrial technologies for their further production in clustered "chains", which are obliged for industrialization and commercialization of innovations. In turn, the success of such industrialization and commercialization also requires a codified form for new knowledge – in form of innovative educational tools. The rapid increase in the number of such tools provides a reason to talk about the emergence of a new and rapidly growing industry of educational resources

(developing educational tool of industry) [11, p.134] Of course, support for such growth requires both the continuous circulation of innovative educational tools within this spatially-distributed network industry and its effective interactive communication with traditional institutes of the scientific and educational sphere.

Such circulation and communication is the only for" innovating education" and "educating" innovation. However lack of acceptable vertical integration between different levels of this activity, which reduces opportunities of small innovative firms - is a serious obstacle for the circulation of new educational tools in innovation sphere. On the other hand, there are quite a lot of serious barriers to establishing effective communication between the innovation industry and the traditional education system, as [13]
- lack of investment for innovation in traditional education;
- oligopolistic domination in the field of education of several large educational institutions ("Big Edu"), which cannot compete with small producers of innovative knowledge in a specific market of educational services;
- weak (due to the participation of a large number of participants and various intermediaries, including with state agencies and local administrations) organization of sales of innovative means in the public sector of education;
- the weakness of the technical base for testing of innovative means;
- insufficient level of advanced knowledge and business culture and weak expert function in the management of public education whichis responsible for the purchase of innovative means;
- low level of communication between the public education sector and producers of innovative educational tools;
- a limited economic scale and a long cycle of private innovative educational production in the public sector that does not generate sufficient motivation for venture capital.

Besides, it should be mentioned a lot of other fundamental defects inherent in public education, which restrain the modern innovative development of countries and regions, in particular:
- low level of integration between higher, vocational and secondary education, which limits the realm of the practical competence of a future specialist, and at the same time removes its innovative and creative potential (for example, the training of a machine operator with digital software control (DSC), except for the knowledge of operations requires yet interactive communication with programmers and technologists, and this is already a field of higher education school);
- weak link of public education with innovation industry, as well as educational theoretical programs with practice of innovation, lack of training tools for innovative entrepreneurs;
- insufficient interconnection and mutual influence of innovative, and therefore, public educational activities, with regional development programs and strategies.

Of course, the need for sustainable, institutionalized, inclusive innovation - driven development requires appropriate programs, strategies and systems with high efficiency. As a system, it should cover and harmonize interactive activities and market behavior of all its actors and participants. The first practical forward in this direction could be done by development of a multi-level interactive educational and training platform in trans-boundary version.

III. PROJECT PROPOSAL

Favorable conditions for such proposal are being formed within the framework of the project of the Ukrainian-Slovak International Center for Innovations and Technology Transfer, based on the Memorandum signed on March 20, 2017 between the National Science-Technological Association of Ukraine, Uzhhorod National University and the Technical University in Kosice, as well as their science parks. On June 30, the parties agreed on the conceptual and institutional basis for this Center, similar to the one presented in Figure 2, as well as the road map and practical steps for its implementation. The main objective of the Center is to develop the international infrastructure for designing, investing, configuring and managing to cross-border and transnational clusters and networks for industrialization of innovations in the priority directions of joint activity. Of course, the basical level of this activity is oriented on intensive and interactive exchange of innovative knowledge, ideas, technologies and competencies. However, the effectiveness of this interchange activity critically dependent on the ability of such an infrastructure to overcome successfully both the aforementioned and new cross-border barriers. In turn, it needs in new institutional mechanisms and modern innovation platforms. One of such new institutions, focused on concentration and generation of innovative educational tools, as well as formation of the necessary competences for cross-industrialization of industrialization, could be proposed in form of the International High School of Innovation Entrepreneurship.

The fundamental reason for this proposal consist in is the complex nature of modern knowledge and the multidimensionality of cognitive space. On the one hand, this space is rather universal and does not depend on the specific context codified as general knowledge (knowledge - K), special knowledge (expertise - E), as well as skills - S and experience (e). General and professional knowledge (K & E) form the educational basis, while specific (S & e) – knowledge are responsible for global competitive advantages within the framework of the post-industrial knowledge-based theory of the firm [13] . At the same time, the new knowledge generated by small innovative firms which,

contains an original, "hidden" part of the civilization-cultural context generally dependent on the "tacit knowledge" (T[14], as well as its contextual component (contextual knowledge-C) [15]. This "tacit" and contextual (T & C) knowledge serves as the source of own original and creative, innovations.

However, in order to become the emerging industry for new educational tools, innovative firms have to create a collective cognitive field as well as a favorable reflexive and active environment, which will the initiative and creativity of everyone. It means that success of this process is critically dependent on collective K & E, as well as on S & e-competencies in the areas of:
- team building [16] and development of creative potential of the firm [17];
- effective implementation of the common cognitive function [18] and the ability to distinguish and "extract" from local T & C networks, codify and broadcast new knowledge within corporate network [19];
- supporting entrepreneurial passion [20] and promoting globalization (G) for business initiatives to build new G & S & e-knowledge within the framework of such a "global-learning scenario" [21];
- accelerated growth of social and human capital based on dynamically increasing potential of G & S & e - knowledge and capabilities of corporate networks [22] .

Such a differentiation of knowledge by their nature and mode of generation, depending on the "collective subjectivity" and the cognitive potential of the management team of the firm, substantiates the need to form a separate subject field which may be called as - innovation entrepreneurship. At the same time, its needs in creation of the appropriate institute - the Higher School of Innovative Entrepreneurship (HSIE).

The idea of the HSIE reminds us the historic precedent of the creation of business schools mm on mature stage of industrialization ,that combine university education and entrepreneurial activity. Specialized master's programs created in this integration, oriented mainly within the framework of the subject field of "International Business" as well as on theories and strategies of the firm. But transition to post-industrial types of the economy (innovative and cultural-creative), as well as the replacement of exclusive model of development on inclusive one, required the introduction of the subject "International business" as the newest educational field of knowledge [23]. Unlike the "International Business", where a localized (or multi-local) firm acts as the basic entity, there is a subject-oriented transition to the study of innovation as a manifestation of entrepreneurial spirit. This spirit is the source of creative innovation, including technological, social and institutional ones.

Really, the social and institutional innovations are responsible for organization and self-organization of

spatially distributed polysubject and multicultural reflexive-active environments. Therefore, they require in-depth knowledge of the nature, design, investment and strategic management for these complex systems (scientific, technological and industrial business incubators and parks, clusters, agglomerations, special economic zones and other innovative territorial entities).

In turn , such transformation needs in for the professionalization of this kind of knowledge and competencies from the point of view of global challenges, rebelled against the evolutionary economic dynamics of the planet. First of all, there are concentrate actual request for three categories of innovative top-specialists:

- top managers for innovation-oriented territorial entities (including innovative business incubators parks and zones, clusters and agglomerations, cities and regions);

- top management of innovative teams, firms and other institutions;

- deputy heads of regional administrations and local self-government bodies responsible for strategic (innovative) development issues.

Thus, the HSIE would promote the integration of traditional education and science with innovative educational and business activities. In addition, it would create the necessary conditions for the integration of innovative ecosystems with the system of institutional planning and strategic management of sustainable inclusive development for both new regions and traditional territories.

In the format of the International School, starting with the development and launch of a common eLearning platform, this would form a single communicative space of understanding that would also take into account the diversity of T & C knowledge and top management competencies. Without such an understanding, it is difficult to rely on effective cross-border innovation-oriented interaction.

On the other hand, a common network of competencies tools with unifiedqualification requirements and standards is needed to form a common E & S & e-knowledge space. Indisputably, first and foremost it may be done in the form of appropriate cross-border eLearning platform. However, for the practice-oriented integration of such professionally oriented E & S knowledge, it is necessary to overcome three types of previously identified barriers: institutional, structural and functional fragmentation of the sphere of education, separation of this sphere from the innovation industry and the lack of effective coordination between innovation ecosystem and regional development. How to overcome these obstacles becomes clear from the model of "triple integration" is shown in fig 3.
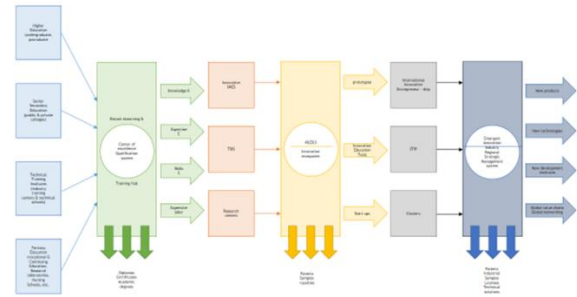

Fig. 3 The model of «triple integration» e -Learning innovation education platform

There are presented three integrated by own local IT platform parts including digital eLearning & training center, prototype center and regional innovation development system. The first part based on center of excellence and qualification system integrates advanced opportunities of higher, senior secondary and technical schools.

As a joint pilot project of transborder system for educating and training adapted to EU requirements and standards specialists this center may be located in Uzhgorod and Kyiv cities on ukrainian side. Taking into account the actual demand from V4-countries, especially from automotive cluster in Slovakia, such collaboration could be started from training for broad spectrum of mechanical engineering specialists, including operators of DSC machine-tools, programmers, designers, technologists, etc. Basic model of such eLearning training center is shown in fig. 4.
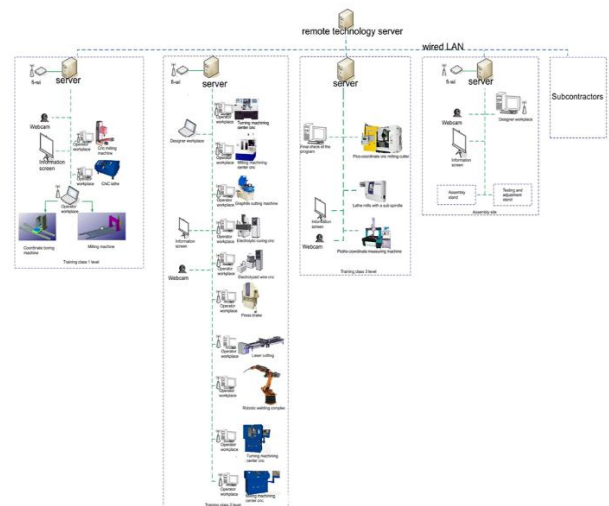

Fig. 4 Local interactive eLearning center for training mechanical engineering specialists

Presented in fig. 4 model has three educational (basics, middle and top) levels based on small machine-tools interactive modules and e-simulators. The basic level is responsible for training to operators of DSC machine-tools, while the middle one supplies not only future operators, but also designers and programmers

with more complicated training, as well as the top level is obliged for training to technologists, system integrators and administrators, chief engineers and technical directors, etc. In case of equipping such center with robots and 3D print machines it transform into full format innovation educational-training eHub.

The second part of the presented in fig. 3 platform is responsible for integration of such eLearning & training center with basics innovation activity, prototyping and startups incubation, while the third part is obliged for integration of this activity into regional innovation development system. Thus, presented there platform as an transborder innovation-oriented interface serves as the base for further multilevel integration in framework of appropriate super platform, as it is shown in fig. 5.
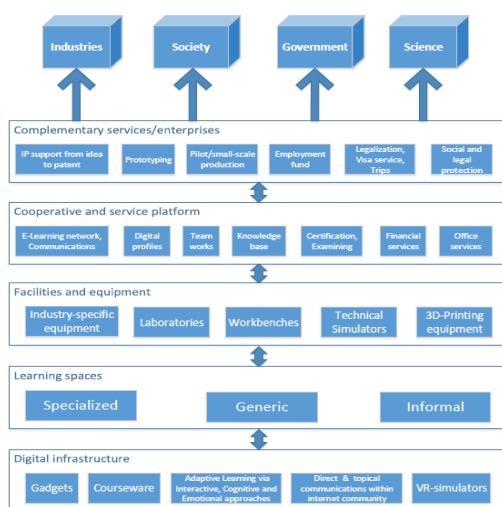

Fig. 5 Transborder multi-level digital interactive eLearning service platform

There is presented technical order on the server and software solution for the transborder multi-level digital interactive education-training platform which integrates all above mentioned sub platforms. As a joint transborder project such platform will promote to innovation-oriented co-development of each country and region-participant.

IV. CONCLUSION

Sustainable development goals and global transition from actual financially-driven exclusive model of mainly industrial development to the Innovation-based Inclusive one needs in new, non-classical types of advanced knowledge, trans-disciplinary expertise, duly, modern competencies and experience (K&E&S&C&e). Such complex K&E&S&C&e - set is dispersed among a lot of institutions and tools, both traditional and innovation ones. It gives rise to understanding of necessity in creation of joint integration IT-platform at least. This platform will be served as a bridge between

traditional education sphere and emergent industry of innovation educational tools. This way opens a realistic mechanism for innovating education and educating innovation on K&E&S&e - base.

From another side, innovation activity needs in integration into regional systems of sustainable inclusive development and in training of modern competencies and multi-level professional skills and experience as well. A sound foundation for such solution gives us the presented new model of a "tripled integration" for innovation eLearning.

In framework of this model there were proposed two new types of innovation institutions - Higher School of Innovational Entrepreneurship and local interactive educational-training centers for adequate E&S&C&e - set.

As a general result and project proposal for joint R&D activity there is presented a transborder multi-level digital interactive educational-training platform for innovation- oriented co-development. This platform may be easy integrated as an important part of the Ukraine-Slovak International Center for innovations and technology transfer.

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Some aspects in e-learning for persons with disabilities

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Abstract—**The paper deals with several aspects of e-learning accessibility while supporting students with disabilities. The crucial problem is to enable support for blind persons. There are available efficient tools as screen readers enabling access to text information. However, there are still weak points when using web, and accessing a graphical information. Authors describe our activities to improving access to Mathematics at our University for blind students, but not only to them.**

I. INTRODUCTION

E - learning is an effective tool how to create a 24 hours available access to courses materials for students. It is especially important in case of students at the higher education who have lower mobility and their special needs are induced by an impairment. Enabling a better access for students with visual impairments studying Mathematics using e-learning would empower them with important obligatory part of knowledge and skills at technically oriented Universities.

The total number of University students with visual impairments in Slovakia is relatively small. Working on the new e-learning supporting study of Mathematics, we plan to offer it also to students at the secondary schools in the same time who are potentially incoming new students to our University. The other reason to offer an e-learning course is that study materials available to blind students on both levels of education are limited. To prepare a course for students with visual impairments requires applying specific tools and methods to get accessible and usable results.

A. Multimedia and e-learning for persons with special needs

It is obvious that e-learning should be available for everybody. Inclusive education means accessibility and usability for all students, and this is required also for e-learning environments and courseware.

E-learning platform structure requires nowadays not only text form, but also audio, visuals, videos, virtual reality, and other forms. Often such systems use multi-sensorial devices to create an interactive environment. It is obvious that students with visual disabilities cannot access multimedia interactions. Assistive technology can help, but usually with lower quality of perceived information.

Therefore, teachers at all levels of education should be looking for the advanced and efficient solutions. A specific approach to obtain usability and accessibility has to be used when preparing e-learning for persons with visual impairments.

If we look on actual methods and tools used for such accessible courses for visually impaired persons, we can find wide range of the approaches:

1. Assistive technology and Information Communication Technology (ICT) aids.
2. Different accesible human computer interfaces.
3. Virtual reality and games.
4. Special teaching systems for mathematics.
5. Assisted navigation.
6. Hardware and software aids making accessible printed materials.
7. Adaptive educative web portals, and many others.

It is known that ICT offers real opportunities with access to an inclusive education and helps to overcome the obstacles they exist in classical educational systems. Some authors use concepts concentrated on assistive technology and some put stress on the universal design and/or user centred design.

B. Assistive technology and accessibility

Assistive technology nowadays offers many alternative ways for arranging access to information. It includes:

- Scren readers (JAWS, Wintalker, NVDA,…),
- Magnification devices or software (Magic, different kind of magnifying devices…..),
- Braille displays or notetakers,
- Alternative input devices (Software keyboard, Special ergonomical keyborads, …),
- Keyboard enhancements and accelerators (Shortcuts, Mnemonics, Stick keys,….),
- Alternative pointing devices (foot operated mouse, joystick, head mounted pointing device, eye tracking system,….)

However, researchers stress [1, 2, 3] that for the development of an accessible online learning environment for persons with disabilities, we need to provide users with efficient web accessibility tools.

Even when web pages comply with Web Content Accessibility Guidelines (WCAG), blind and visually impaired users still face navigational problems. Many studies conclude that for blind and visually impaired users, software solutions do not a priori guarantee digital content accessibility, hence many aspects need to be considered including the cultural ones [2]. For example, navigation on the web through a screen reader for the blind is sequential by nature. On the other hand, the web usually offers parallel and non-sequential content. Blind users prefer for navigation a keyboard instead of a mouse when using their computer because it works better with specialized screen reader softwares. So, there is a real need for adaptive web accessibility.

The references 1 and 3 describe the development of such adaptive system, where the main goal is offering web page content in formats tailored to individual users based on their personal preferences. They developed a meta-model for accessible e-learning systems, which is able to generate a specific system for specific needs. It resulted in the development of the Moodle^{Acc+} that offers several services to e-Learning designers [3]:

- Learner Assistance Tool,
- Author Assistance Tool,
- Accessible Course Generation Tool,
- Platform Accessibility Evaluation Tool.

Such approach may enable to personalize web content and format to persons with different impairments even for cognitive impairments.

Efficient tool for web page adaptation offers also tools like Easy Web page Browser developed by IBM [4]. However, its functions are limited. The main aim is to help unexperienced users, seniors, and people with limited vision or eye fatigue to gain access to information on a web site. It enables users to enlarge text and characters and change background color. This can make web pages easier for people with low vision to read. Such functions are offered by several software systems concentrated on the user interface.

C. User interfaces for visually impaired

The most common interface for blind users of a computer is a screen reader. However, students need systems that are more efficient when they want to provide active tasks. An efficient way seems to be using a spoken language dialogue system. Researchers at Masaryk University developed for blind programmers and students two systems [5]:

- Dialogue programming system DIALOG
- Speech oriented hypertext system AUDIS.

DIALOG supports blind persons during writing code to minimise errors. Communication of the user and system ran via dialogue. AUDIS performs speech communication for blind studetnts to access the studying materials in the appropriate form using voice commands, speech synthesis output, earcons and environmental sounds.

Many authors offered new supporting systems for visually impaired users of the internet and web information [6, 7] enabling faster and easier way of reading e-mails, searching some information, etc. Majority of such support is devoted to text information, but some of them offer also a tool for access to graphical information.

D. Study of Mathematics

Teaching visually impaired students at higher education oriented on technical sciences, where the knowledge is represented mostly by math formulas, charts, graphs, etc., developing e-learning platform for mathematics is a difficult task due to the lack of accessibility for the blind. There are methods based on the decomposition of the typical mathematical exercise into a sequence of elementary sub-exercises [8]. This allows interactive resolving of math exercises and assessment of the correctness of exercise solutions at every stage. Regardless of the level of complexity of the math formulae the level of math formulae understanding was higher for alternative structural description.

Some authors try to develop their own portal offering blind users an adapted environment like in reference [9].

In this study, they developed a distance education portal that makes educational materials and sources easily accessible to visually impaired. It enables an easy access to a variety of education packages with different contents and durations. The developed distance education portal was coded in PHP, MySQL was used for the database, and JAWS as the screen reading software. HTML pages were coded using HTML5 and CSS3 technologies, and were designed to be compatible with JAWS. The portal provides visually impaired with many dynamic and interactive educational opportunities.

User oriented methodology preferred in current inclusive solutions influenced several systems for applying mathematics in the praxis of engineers or natural sciences, which allows to use mathematics in a user friendly way without deep knowledge of classical procedure for solving a mathematical task, more-less automatically. We will describe our experience with LAMBDA and MATLAB.

II. SOME SOLUTIONS FOR ACCESS TO MATHEMATICS

A. Designing environment for e-learning for visually impaired students at TUKE

Recent developments in web design and user interface adaptations in generally promise a comfortable solution for the visually impaired persons to get improved access to e-learning paltforms.

Designing accessible e-learning platform for visually impaired students at TUKE, we have chosen the following tools:

- MOODLE,
- JAWS, NVDA,
- Braille display and/or printer,
- Duxbury Braille software.

MOODLE is a wide spread e-learning tool, and we have it at our University. LMS Moodle as a web-based learning management system is primarily designed to manage and produce courses. According to the description, it is fully accessible for the blind and the visually impaired, therefore supports screen readers such as JAWS, NVDA, WindowsEye, Thunder. It also depends

on the web browser used by the user, it is necessary to choose the most appropriate and most supported.

Before launching our study content into MOODLE system, we realized that it is very important to prepare all content to be accessible.

An effective support of students with severe visual impairments to be able navigate and fully understand study materials in technical courses and mathematics requires to prepare well structured information. It means that study materials have to be adapted [10].

As it was described in the first chapter, blind users need also to get a graphical information, which is not accessible through screen reader. Therefore, it is necessary to prepare additional form of information using other sensorical function complementary to a hearing one.

Such role can play Braille readers and/or tactile information printed by Braille standard printer or special printers for tactile graphics like Zyfuse Heater, VP SpotDot, TactisPlay Table. Software tools like Tiger software suite or Duxbury enable direct transformation of text into the Braille. It is important that study materials must be adapted for better navigation through a document, for example using short sentences, dividing texts into several compact parts in a sequence,…

As we already mentioned, specific solutions are necessary for accessing Mathematics.

III. LAMBDA COMPATIBILITY WITH NVDA

A. LAMBDA editor

New software, affordable prices of computers and Internet access created technical preconditions for a successful preparation of students with visual impairments. This article tackles some ways to overcome possible technical problems rising during solutions of differential equations.

Currently, we are working on improving access to information based on mathematical content to enable an efficient work in existing standard e-learning platform available at our technically oriented University. We are looking for the best forms how to make easier to apply mathematics in engineering tasks without using standard mathematical process moving up through all steps. We tested compatibility of basic mathematical softwares with LAMBDA editor and NVDA screen reader.

The LAMBDA editor is based on the functional integration of a linear mathematical code and an editor for the visualization, the writing and the manipulation of the text. The code (Lambda Mathematical Code) directly derives from MathML and it was designed to be used with Braille peripherals and the vocal synthesis. It is automatically convertible, in real time and without mistakes, into an equivalent MathML version and, through it, into the most popular editing formats for math (LaTeX, MathType, Mathematica...), both input and output [11].

The editor allows to write and to manipulate mathematical expressions in a linear way and provides a series of compensatory functions. In fact, the user is supplied with some aids to reduce the difficulties in understanding and managing the text, due to the visual handicap and to the need to use a linear code to manage

the formulas. LAMBDA was meant for secondary-school to university students; some basic skills in computer science are necessary.

The current version LAMBDA editor can correctly work with JAWS, WindowEyes a portable version of NVDA, the whole installation procedure is described in [12].

Editor LAMBDA can be installed by running the file LambdaSetup.exe whose trial versions, the two months after free registration (entering name and email address) can be downloaded from the web page. The whole installation procedure is very simple and completely managed by the installation program. It is possible to customize the installation of the selected language, working directory, etc., or you leave the default choice. After the installation, the user is asked whether he/her wishes to install and adaptation to the screen reader.. The current version of LAMBDA editor can correctly work with JAWS, Window Eyes, and NVDA.

However the LAMBDA editor only works with the portable version of NVDA, and for the proper functioning you must first download and install ScriptLambda.pyo, which can be downloaded from [13]. The portable version of NVDA is available at "Tools-> Create portable version" in the main menu of NVDA. ScriptLambda.pyo after withdrawal should be copied to the userconfig \ appModules in the main root of NVDA. If a user also wants to have the possibility to see graphical output of mathematical expressions, the plug-in MathML must be installed in a special window, which allows such views.

B. An example of work in LAMBDA with MATLAB

Many of technical problems in practice can be described by differential equations, and systems of ordinary differential equations (electrical engineering, economics, physics, mechanics, robotics, ...). Already in the first year of study at the technical universities, students meet mathematical expressions in technical courses. A proper way in using of mathematical software enables to arrange an access to mathematical tasks for students with visual impairments in a full content.

We demonstrate here an example of the solution process using the LAMBDA Editor showing views for both student and assistant.

Example

Determine the loop current in a circuit when the coil flow at the time of connecting the source with constant values of voltage $u(t) = U_0$ and current I_0; the capacitor had at that time voltage Uc. Voltage is applied at $t = 0$.

Based on the first Kirchhoff's law we can obtain the following equations:

$$\frac{di_1}{dt} = -\frac{R}{L}i_1 + \frac{R}{L}i_2 + \frac{U_0}{L}, \quad \frac{di_2}{dt} = -\frac{R}{L}i_1 + \left(\frac{R}{L} - \frac{1}{RC}\right)i_2 + \frac{U_0}{L}, \text{ where}$$
$$i_1(0) = i_0, \ i_2(0) = -\frac{U_C}{R} + i_0.$$

For constant values U_0 =10 V, i_0 = 0,5 A, U_C = 20V, R=100 Ω, L= 2 H, C = 10^{-4} F, we have system of differential equations:

$$\frac{di_1}{dt} = -50i_1 + 50i_2 + 5, \quad \frac{di_2}{dt} = -50i_1 - 50i_2 + 5.$$

a) Entries in the LAMBDA editor

Example 1.1 Determine the loop current circuit when the coil flows at the time of connecting the source of constant voltage u (t) = U0, I0 current and the capacitor was at that time voltage Uc. Voltage is applied at t = 0.
Based on Kirchhoff's law one can obtain the following equations:
$\frac{d}{dt}i_1 = -\frac{R}{L}i_1 + \frac{R}{L}i_2 + \frac{U_0}{L}$, $\frac{d}{dt}i_2 = -\frac{R}{L}i_1 - \frac{R}{L}i_2 + \frac{U_0}{L}$.
Where $i_1(0) = i_0$, $i_2(0) = -\frac{U_c}{R} + i_0$. For constant values $U_0 = 10V$, $i_0 = 0,5$ A, $U_c = 20$ V, $R = 100$ Ω, $L = 2H$, $C = 0,0001F$,
we have system of differential equations:
$\frac{d}{dt}i_1 = -50i_1 + 50i_2 + 5$, $\frac{d}{dt}i_2 = -50i_1 - 50i_2 + 5$.
For students, it is preferable write the differential equation in the simple form.
We rewrite variables and partial derivatives in following way:
$i_1 = x$, $i_2 = y$ $\frac{dx}{dt} = x'$, $\frac{dy}{dt} = y'$, $\frac{d^2x}{dt^2} = x''$.
So, we solve the system of differential equations
$x' = -50x + 50y + 5$, $y' = -50x + 50y + 5$, where x(0)=0,5, y(0)=0,3.

Solution: We use the elimination method. First equation implies that $50y = x' + 50x - 5$. It follows that $50y' = x'' + 50x'$. Substituting these expressions for y, y' in second equation we obtain $x'' + 100x' + 5000x = 500$. We begin by finding the general solution of the complementary equation $x'' + 100x' + 5000x = 0$. The auxiliary equation for this homogeneous equation is $k^2 + 100k + 5000 = 0$ which has roots $k_1 = -50 + 50i$, $k_2 = -50 - 50i$. Thus, the general solution of the complementary equation is $e^{-50t} \cdot (C_1 \cos 50t + C_2 \sin 50t)$. So, the general solution of $x'' + 100x' + 5000x = 500$ is $x(t) = e^{-50t} \cdot (C_1 \cos 50t + C_2 \sin 50t) + X(t)$, where $X(t) = 1/10$. Substituting x(t) and $x'(t)$ in the second equation we have $y(t) = e^{-50t} \cdot (-C_1 \sin 50t + C_2 \cos 50t)$. Thus, the general solution of the system of differential equations is $i_1(t) = x(t) = e^{-50t} \cdot (C_1 \cos 50t + C_2 \sin 50t) + 1/10$, $i_2(t) = y(t) = e^{-50t} \cdot (-C_1 \sin 50t + C_2 \cos 50t)$. Substituting the initial conditions C_1=0,4 and C_2=0,3, we obtain particular solution: $i_1(t) = e^{-50t} \cdot (0,4 \cos 50t + 0,3 \sin 50t) + 1/10$, $i_2(t) = e^{-50t} \cdot (-0,4 \sin 50t + 0,3 \cos 50t)$.

b) View for assistant

Grafické zobrazenie

Example 1.1 Determine the loop current circuit when the coil flows at the time of

connecting the source of constant voltage u (t) = U0, I0 current and the capacitor

was at that time voltage Uc. Voltage is applied at t = 0.

Based on Kirchhoff's law one can obtain the following equations:

$$\frac{d}{dt}i_1 = -\frac{R}{L}i_1 + \frac{R}{L}i_2 + \frac{U_0}{L} \quad , \quad \frac{d}{dt}i_2 = -\frac{R}{L}i_1 - \frac{R}{L}i_2 + \frac{U_0}{L} \quad .$$

Where $i_1(0) = i_0$, $i_2(0) = -\frac{U_c}{R} + i_0$. For constant values

$U_0 = 10V$, $i_0 = 0.5A$, $U_c = 20V$, $R = 100\Omega$, $L = 2H$, $C = 0.0001F$,

we have system of differential equations:

$$\frac{d}{dt}i_1 = -50i_1 + 50i_2 + 5 \quad , \quad \frac{d}{dt}i_2 = -50i_1 - 50i_2 + 5 \quad .$$

For students, it is preferable write the differential equation in the simple form.

We rewrite variables and partial derivatives in following way:

$$i_1 = x \quad , \quad i_2 = y \qquad \frac{dx}{dt} = x' \quad , \quad \frac{dy}{dt} = y' \quad , \quad \frac{d^2x}{dt^2} = x'' \quad .$$

So, we solve the system of differential equations

$$x' = -50x + 50y + 5 \quad , \quad y' = -50x + 50y + 5 \quad , \text{ where } x(0)=0.5, y(0)=0.3.$$

Solution: We use the elimination method. First equation implies that $50y = x' + 50x - 5$.

It follows that $50y' = x'' + 50x'$. Substituting these expressions for y , y' in second equation we obtain $x'' + 100x' + 5000x = 500$. We begin by finding the general solution of the complementary equation $x'' + 100x' + 5000x = 0$.

The auxiliary equation for this homogeneous equation is $k^2 + 100k + 5000 = 0$ which has roots $k_1 = -50 + 50i$, $k_2 = -50 - 50i$. Thus, the general solution of the complementary equation is $e^{-50t} * (C_1 \cos 50t + C_2 \sin 50t)$. So, the general solution of

$x'' + 100x' + 5000x = 500$ is $x(t) = e^{-50t} * (C_1 \cos 50t + C_2 \sin 50t) + X(t)$,where $X(t) = \frac{1}{10}$.

Substituting x(t) and $x'(t)$ in the second equation we have

$y(t) = e^{-50t} * (-C_1 \sin 50t + C_2 \cos 50t)$.

Thus, the general solution of the system of differential equations is

$i_1(t) = x(t) = e^{-50t} * (C_1 \cos 50t + C_2 \sin 50t) + \frac{1}{10}$,

$i_2(t) = y(t) = e^{-50t} * (-C_1 \sin 50t + C_2 \cos 50t)$.

Substituting the initial conditions C_1=0,4 and C_2=0,3, we obtain particular solution:

$i_1(t) = e^{-50t} * (0.4 \cos 50t + 0.3 \sin 50t) + \frac{1}{10}$,

$i_2(t) = e^{-50t} * (-0.4 \sin 50t + 0.3 \cos 50t)$.

We can show to students the same example in a more simple and acceptable form when using MATLAB and results can be read by NVDA.

The previous example written in MATLAB:

```
>> [i1,i2] = dsolve('Di1=-50*i1+50*i2+5,
Di2 =-50*i1-50*i2+5', 'i1(0) = 0.5, i2(0) = 0.3')
The  result:
i1 =
1/10+exp(-50*t)*(2/5*cos(50*t)+3/10*sin(50*t))
 i2 =
-exp(-50*t)*(2/5*sin(50*t)-3/10*cos(50*t))
```

IV. CONCLUSION

New software, affordable prices of computers and Internet access create technical preconditions for a successful preparation of students with visual impairments. Experience confirmed by reviewing blind students and their teachers that use ICT as support in their learning process is nowadays the main supporting tool in inclusive education process. The teacher's experiences show that both students and teachers need not only access to Assistive Technology and ICT tools but also a proper training how to use them effectively. Authors will continue in further work on preparing study materials for Mathematics course as e-learning suitable for secondary schools and technically oriented universities.

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Virtual-Reality Technologies and Smart Environments in the Process of Disabled People Education

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Abstract— **Information technologies impact our daily life in many significant ways. Nevertheless, there is a lack of availability of some technologies to the wide public caused by their location and price. This insufficiency seems to be even bigger for disabled people. LIRKIS laboratory of Technical university of Košice proposes solutions in education of these people and develops technologies of virtual reality which are capable to fulfill their needs. This paper is aimed at user interfaces (as VR technology) and the smart environment from human-centered perspective. The development process could become time consuming because in many cases the electrical network, sensory network and other physical elements need to be rebuilt to begin another test. Virtual reality technologies could solve this kind of issues low cost and fast. In this work a CAVE system was used in the comparison of standard approaches.**

I. INTRODUCTION

New information technologies and their user interfaces especially HCMT (Human Centered Methods and Technologies [1]) are important trends of present day, not only for health people, but also for disabled people. Some technologies are very good for application in this field. These technologies are virtual reality and smart environment.

Virtual reality and its technologies represent a relatively young but perspective area. It is also one of the fastest developing disciplines of informatics and information technologies. It provides a solid ground for a fundamental change in human-computer interaction in a way that will make the interfaces simpler and more natural for people, including those with handicaps.

Research in the field of smart environments (SmE) is connected with Human-centered Computing (HCC). In spite of the fact that computers are hiding from the user's direct view they stay in close interaction with the user through sensory networks, wearable devices and robot assistants. All these devices with appropriate application software could bring extended solutions in safety, security and privacy, health, wellness and ergonomics, resource saving, education and training and, of course, entertainment and convenience.

They are developed with highly human-centered approach (HCA). A human being is not recognized as a direct user of information technologies but rather as someone whose abilities need to be supported and improved. Suitable view on the development of SmE user interface is supposed to be paradigm of localized information including methods and approaches of human factor engineering and cognitive processing. It is important to notice that UI for SmE based on human body movements and activity recognition is strictly bound to contextual data describing conditions under which activities occur [2]. Content of contextual data defines extended information like timestamp, status of physical environment in the form of measurable data and biochemical and physiological data of the user [2].

Although handicapped persons are not the primary target group of virtual-reality technologies and systems and smart environment, we can see the rising number of implementations of these technologies for their benefit. When applied correctly, they can help people with both physical and intellectual disabilities. More detailed description of selected results can be found in [3],[4],[5], [6],[7]. Some experimental experiences of our team were obtained in cooperation with Pavol Sabadoš special boarding school in Prešov. This school is special school for handicapped children.

II. VIRTUAL REALITY AND SMART ENVIRONMENT

SmE includes components which could be divided into two categories, sensors and actuators, which offer "off screen" interaction. We can control and monitor physical environment where we live using posture, gestures, speech and hand writing. The user interface which is inspired by natural way of communication is capable to fulfil requirements of easy understanding and learning to work with the user interface.

Realization of such an interface is possible by involvement of known input of such an interface is possible by involvement of known input and output devices which are widely used in navigation in variety of virtual worlds. Virtual reality technologies (VR) are supposed to be used to simulate SmE to evaluate new ways of interaction and also to become a part of the SmE itself (e.g. virtual environment for wheelchair). There are two widely used techniques to deliver immersive and semi-immersive experience of virtual reality with satisfying predictions of desired results for SmE virtualization: CAVE and HMD. Another way is a development of special devices, such special school desk.

CAVE (Cave automatic virtual environment) is a room-sized space consisting of several projection walls. Despite the stereoscopic projection is adjusted according to one user's view, others could share the same virtual environment without additional cost on view change synchronization. The user can freely move in the space of a CAVE and experience his/her body in close interaction with virtual scene, mostly through contactless motion capture system.

HMDs (Head-mounted displays) are suitable devices to bring virtual environment to one user at a time. They are becoming highly portable and available for a price with a decreasing tendency. Most popular and available HMDs include *Microsoft Hololens* (Figure 1.), *Oculus Rift*, *HTC Vive*, and *PlayStation VR*. Sensing of user's movement could be provided by cameras and motion capture systems. Recorded outputs have to be mapped to virtual objects representing human body parts.


Figure 1.   User with Microsoft Hololens (LIRKIS DCI FEEI Košice)

For providing the experience similar to the living laboratory physical space, it is appropriate to virtualize SmE using the LIRKIS CAVE system shown in Figure 2. Requirements include the possibility of rapid prototyping and sharing a virtual scene with multiple people. Another advantage is usage of real electrical appliances and other devices inside of the physical space of CAVE.

The system includes 20 stereoscopic screens (thick black lines in Figure 2 a) in a non-cubic layout (a decagon), spatial sound system and user's movement is captured using a markerless Optitrack system. The Optitrack system consists of 8 cameras (red triangles in Figure 2 a) with seven situated in the top corners of the screens and one behind the user on a steel frame (dashed grey square in Figure 2 a). LIRKIS CAVE engine consists of three parts: Control Center, Java Console and Video Renderer. Control Center is the core of the system and it mediates the communication between other parts. Java Console is used for the remote control of the whole system and also provides opportunity to interact with currently loaded virtual environment. Video Renderer is responsible for 3D scene rendering and it is based on

OpenSG toolkit [19]. Scene package includes textures and 3D models. Additional logic and interaction with enhanced peripheral devices is implemented using Ruby script, which is included in the package. Thus the system requires only changes on the level of the scene.
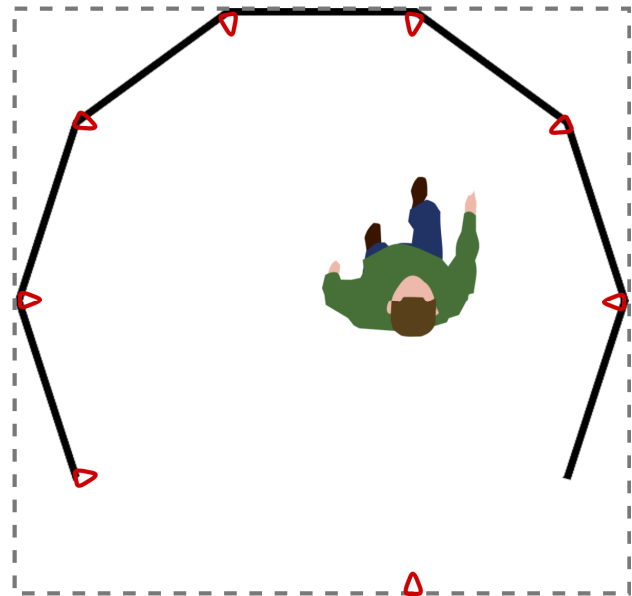
(a)

(b)

Figure 2.   LIRKIS CAVE (LIRKIS DCI FEEI Košice): A schematic showing the spatial configuration of the CAVE (a) and a photo of a user inside the CAVE. The position of the user is approximately the same in both cases.

III.   VIRTUAL REALITY AND DISABLED PEOPLE

Disabled users are not only users with physical or sensory disabilities but also cognitively impaired ones (e.g. users with learning disabilities or concentration problems). So, VR technologies will be primarily used to create a natural user interface ([8]) with improved accessibility for them.

To be able to create such a user interface it is necessary to understand how they access information and what their specific problems and needs are. They are specific with respect to individual disabilities, which can be divided into the following categories:

- Physical disabilities (gross and fine motor skill disorders, limited mobility, etc.),
- Sensory disabilities like hearing impairment, visual impairment and sensory impairments (e.g. olfactory and gustatory impairment),
- Intellectual disability (e.g. caused by the Down syndrome).

Disabled people need to use supporting technologies to work with computers [9], mainly alternative user interface tools such as readers (text to speech software) or screen magnifiers. According to [10] information and communication technologies can help impaired people primarily in the areas as making access to information easier, assistance in recovery from disabilities, assistance with daily activities, communication with intact people and preparation of specific teaching materials and tools for impaired people this important area for our team).

The most supported groups nowadays are visually and hearing impaired, less supported are cognitively and physically impaired (This is despite the fact that one of the first use of VR for the impaired was a training of disabled persons in wheelchairs in virtual environment).

Most of the special items for disabled people just emulate the function of classical input devices – the mouse and keyboard. From the VR point of view, it is also possible to use the devices mentioned in the previous sections, especially the contactless sensors, muscle tension sensors and EEG machines.

For rehabilitation and training of disabled persons a utilization of augmented reality technologies seems to be very promising. The augmented reality (AR) is similar to VR, but differs in using real-world objects and not only virtual ones. AR technologies are used to insert virtual (i.e. computer-generated) objects into a live view of a real-world environment and manipulate these objects. The utilization of AR for the rehabilitation can be in a form of a "virtual training table" device. The device will consist of a real table, a video projector, a motion tracking sensor and a computer. The projector will project some image on the table (e.g. some keyboard) and the task for the person will be to hit particular part of the image. The sensor will track movement of the person's hand and the computer will evaluate the movement. The device can be used for training gross and fine motor skills of the physically disabled. An example of using such technologies for rehabilitation purposes is a special shoe, described in [11]. Considering other VR technologies, we can also utilize 3D printers, which can be used to print various aids, such as prostheses [12].

Cognitively impaired persons have problems with solving one or multiple types of mental tasks [13]. This impairment usually manifests in decreased ability to process information and to recognize connections between pieces of information. It is not easy to create a user interface for cognitively impaired as it has to provide an easy and clear navigation. Words used should be simple and unambiguous. It has to be clear what is label, caption or a navigation element. The structure of the interface should be expressed visually (i.e. using various font types and sizes) and semantically [14]. It is recommended to illustrate meaning of words with pictures (icons, photos) or animations. The ordinary text should be bigger than usually. The same is true for an unused space around interface elements as it should be clear where their borders are. Using 3D displays can be also useful, but they should be autostereoscopic, i.e. without a need to wear additional equipment (glasses). The most suitable input devices for cognitively impaired are touch screen displays, because they are natural and intuitive. However, the screens should be medium to big size as a significant number of these people have problems with motor skills, too. An interactive school desk (Figure 3.) has been developed at LIRKIS, which uses a 24-inch touch screen LCD. The desk was used in education of children using special symbolic-text method [14][15] with multiple handicaps, including cognitive, and the size of the display has been found sufficient.

Hearing disability limits use of computers far less than the visual one. The only significant limitation is inability or decreased ability to perceive audio information. To avoid this limitation, the information should be also provided in a visual form, i.e. as pictures or text (subtitles). Contemporary technologies also allow real-time speech recognition (speech to text translation). While not entirely reliable, it can significantly increase understanding when the visual form of information is not available.

Muscle tension sensors are contact sensors (i.e. there is a need to wear them) but are more comfortable than data gloves and can communicate with other devices wirelessly. EEG scans brain activity, so it allows us to capture an intention to make a gesture (or say a word) instead of the gesture (word) itself. This can be very useful for persons with multiple handicaps. A serious disadvantage here is a relatively high price of more precise (multichannel) EEG. Both these technologies will be a subject of future research and development activities at LIRKIS lab. However, in most cases, size and price of these sensors/actuators limits their usability.

Figure 3.   Interactive school desk for disabled children (LIRKIS DCI FEEI Košice)

IV. DISABLED PEOPLE IN SMART ENVIRONMENT

Virtual reality in combination with smart environment or smart environment in combination with virtual reality technologies as user interface can represent a new way in the use of information technologies in the lives of disabled people. From the user's perspective we identified two most common ways of interaction with a SmE:

- Natural user interface (NUI) in the meaning of hands-free interaction based on human body movements, speech and other activities captured using sensory network.
- Monitoring and control through personal smart and wearable devices.
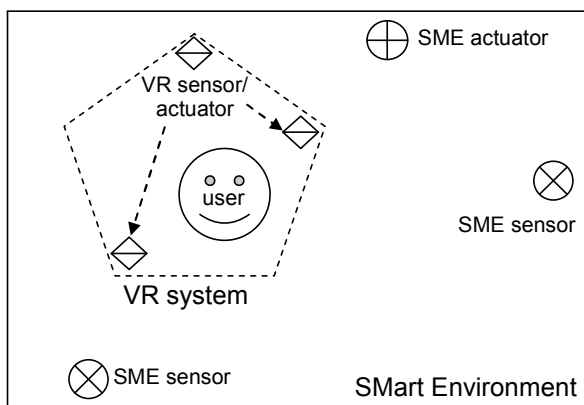
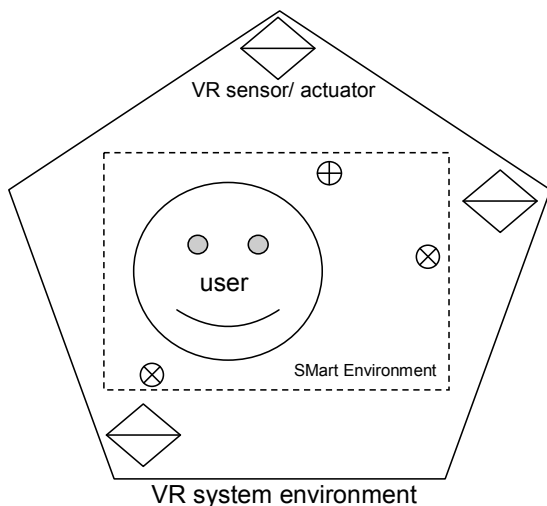Figure 4. Conceptual model: SmE master – VR slave

Figure 5. Conceptual model: VR master – virtualized SmE

The user is able to monitor and control SmE using an Android application; installed on his/her smartphone device (it represents mainly model VR master – virtualized SmE). Supplementary user interface development was aimed at two parts: Unified user interaction resolver (*Unusir*) and Android application. Android application is used to notify the user about his/her activities performed in the space of LIRKIS CAVE. *Unusir* is responsible for data acquisition in the

form of captured users' movements, their storage and analysis. User's movement data is captured and transferred by tracking system placed in the space of Therefore supplementary user interface for LIRKIS CAVE system was developed. The main part of the whole system - *Unified user interaction resolver* - was designed to provide opportunity to experiment with both types of interaction in cooperation. This component is designed to mediate interaction with the LIRKIS CAVE engine and also to the potential non-virtualized SmE and other clients through API. Conceptual model can use combination of VR system and SmE from two points of view:

- SmE is master system and VR system is its part (Figure 4.)
- VR system is master and SmE is virtualized in it (Figure 5.).

LIRKIS CAVE. In this early stage of development it supports movements based on stereoscopic glasses spatial position change. If a movement is recognized for the first time, the user is notified of its occurrence per Android application. If this movement is recognized again and its purpose is set, the particular action is mediated to LIRKIS CAVE and the change of scene is performed. Module is also capable of providing status of virtual SmE and communicates with additional sensors/actuators. This data will be used for collection of contextual information to evaluate the circumstances under which user's activity occurs. API communication extends scalability of the system as it provides opportunity for other application software.

V. MODEL VR MASTER - VIRTUALIZED SMART ENVIRONMENT

A particular effort was dedicated to the modeling of a SmE scene. The user can freely navigate through virtual space by his/her moves. LIRKIS CAVE also disposes with advantage of the use of particular peripheral devices like joysticks and gamepads.

Several experiments were aimed at dynamic lighting to bring more realistic experience. Best results were achieved with baked textures because other approaches become highly demanding on computational power which causes low frame-per-second rate. Vividness of the environment was improved by skyboxes with photographs and photorealistic rendering.

During this phase were built two scenes of smart environments - a living room and a kid's room (there is a assumption for disabled people usage). Each of them includes two types of devices. There are devices with two states (on/off) and devices with configurable properties e.g. color, volume and others. Disabled people can train their future activities in this environment.

VI. DISABLED PEOPLE IN LIRKIS LABORATORY

To provide handicapped people with an opportunity to try all technologies available at LIRKIS we arranged a visit for the pupils from the partner school for children

with multiple disabilities, the Pavol Sabadoš special boarding school in Prešov. During the visit the LIRKIS CAVE attracted the most attention. The immersion of the children to its virtual scenes evoked several strong emotions and sensations, such as fear of heights, imbalance and surprise.

Given the various types of disabilities, not all of our devices were suitable for each child. For example, with the fine motor skill disorder it was difficult to control 3D scene using the mouse. However, it showed the potential for possible improvements in the user interface with a focus on the problem. In cooperation with Pavol Sabadoš special boarding school in Prešov, the laboratory developed some special devices and applications for handicapped schoolchildren. Thanks to the reduction of prices and increased quality of touch screens touch interfaces became more and more common in mobile applications. The main advantages of this type of control are: absence of input peripheral devices, compactness and intuitiveness, low implementation cost and reducing of mental burden of the user [16].

The design of user interface focusing on visual part of the computing process output is based on thirteen principles of perception and processing this information from user. The principles can be divided to specific categories: perceptual principles, principles of mental model, principles based on attention and memory principles [17].

During the development of user interface including touch interface, the method has been applied of repeating processes of designing, testing and result evaluation (in the environment of previously mentioned school desk). This method can be applied after the user identification, identification of tasks (they will be transferred through the interface) and also the way to implement the empirical evaluation [18]. The desk supports also augmented reality technology. At the time of writing this article, it is placed and tested in the educational process at Pavol Sabadoš special boarding school in Prešov.

This environment and the tools presented in the paper create an ideal chance to truly understand the needs of disabled people, children in particular, and adjust the tools to their needs. The field-testing started in 2012 and includes also other solutions, such as software adjusted for deaf and mute children (sign language).

VII. CONCLUSION

Virtual-reality technologies and similar technologies have the greatest progress in present. These technologies allow the creation of previously impossible procedures. These procedures especially their visual aspect and interactivity may change streamline and shorten the process of interaction between human and computers.

This work deals with new approaches to the development of smart environments from a human-centered perspective with orientation to disabled people. Its goal is to present some of our achievements in this area. We proposed a solution with the use of VR technologies. LIRKIS CAVE system is the space where the near-life experience could be tested and additional changes in the virtual scene are performed without significant effort. Early stages of supplementary user interface development were finished. The whole system is in usability testing phase. The future work will be

dedicated to implementation of communication with additional sensors (EEG, a galvanic skin resistance sensors etc.), acquisition of rich contextual data and better user's activity recognition.

Working with disabled children in our laboratory proved to be two-beneficial. The first benefit has a popular character. The LIRKIS laboratory provides real-life VR technology experience for these children. The second benefit is the potential of research. Modifying user interface or creating a new 3D scenes in combination with SmE technology, shows new possibilities for using such technology to work with disabled people. Our future work will be oriented towards mixed reality use in rehabilitation.

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Digital Methods of Calibration for Analog Integrated Circuits in Nanotechnologies

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Abstract—This work deals with the influence of increasing rate of integration (i.e. technology downscale) on the main parameters of integrated circuits. Our concerns are focused on calibration methods of analog integrated circuits that can compensate undesired side effects of technology downscale. The paper describes both the general principle of calibration system as well as design requirements for main blocks of the calibration subcircuit. Then, the approach for calibration employment in operational amplifiers is described, where the voltage offset cancellation is of the main concern. Consequently, a specific application of previously described calibration fundamentals is presented. For this purpose, statistical results on the input offset voltage of the operational amplifier are used, where the operational amplifier is realized in 130 nm CMOS technology.

Index Terms—calibration system, technology fluctuation, input offset voltage, low-power design, bulk-driven approach

I. Introduction

Nowadays, a steep trend in shrinkage of integrated circuits (IC) die is allowed by enormous advance of semiconductor process technology. The minimum circuit element dimension reaches $7\ nm$ [1]. The main benefits of IC technology downscale include smaller chip size and lower energy consumption. On the other hand, the technology development brings also certain drawbacks. For example, smaller dimensions of circuit elements and interconnections are followed by random fluctuation of process parameters (e.g. semiconductor doping profile or thickness of dielectric layers). Such deviations already appear within a single die.

II. Motivation

One of the particular electric parameters of an IC, affected significantly by the technology process variations, is the transistor threshold voltage (V_{TH}). V_{TH} standard deviation of MOS transistors fabricated in $45\ nm$ CMOS technology node reaches 16% of V_{TH} mean value [2]. While the operation of a precise ICs strongly depends on the element layout and differential paths matching, any random fluctuation actually causes mismatch, and thus, production yield and IC reliability is decreased.

Other electrical parameter of ICs, which is corrupted by process variations also include parasitics of chip interconnects, namely parasitic impedance and parasitic capacitance [1]. Since characteristics of structures alter with time, thus IC electrical parameters are influenced by ageing as well. This is further described by the phenomenon called negative-bias temperature instability (NBTI).

Eventually all described variations deteriorate the most of IC electrical parameters, whether they are AC or DC. However, the input offset voltage V_{in_OFF} of the operational amplifier (OA) is of significant concern. Its presence consequently affects the characteristics of more complex systems based on OAs.

Another trend in the IC design is decrease of the supply voltage. Since this results in lower power consumption, mobile devices are allowed to remain charged longer. Nevertheless, low value of the supply voltage limits energetic conditions that might cause some IC characteristics to impair. Among other affected parameters, especially dynamic range, power supply rejection ratio ($PSRR$) and signal-to-noise ratio (SNR) are the most important [3]. To keep these IC parameters at the level, which is required by specification of a target complex system, it is essential to implement sophisticated topologies and design techniques. Here design approaches such as controlling the transistor through the bulk electrode appear to be promising. If a MOS transistor is controlled by bulk instead of the gate electrode, the need to overcome V_{TH} in the signal path is avoided [4].

Presented undesirable consequences of process, voltage and temperature variations (PVT) result in demand for compensation of affected IC characteristic parameters and parasitic parameters. This can be provided using appropriate technique of the circuit calibration. Therefore, this paper deals with characteristics of a selected calibration technique and described expected effect. Section III describes the calibration process fundamentals, while Section IV provides the insight into issues of compensation for the input voltage offset of a fully differential operational amplifier.

III. Calibration fundamentals

Calibration subcircuit consists of additional circuit blocks and elements, which are connected to the calibrated circuit during the calibration process. The frequency of calibration

depends on continual change of factors influencing the variation of IC characteristics. If the change of parameters due to ageing is considered, single calibration iteration at the device initiation would be sufficient. If the IC parameters vary with temperature, the calibration could be performed with low frequency (in order of Hz). In case the change of parameters has a rapid rate (for example due to flicker noise), calibration process needs to be performed with higher frequency [5].

A. Calibration cycle

Fig. 1 depicts the block diagram of a simple IC system with a calibration subcircuit that consists of several important blocks.
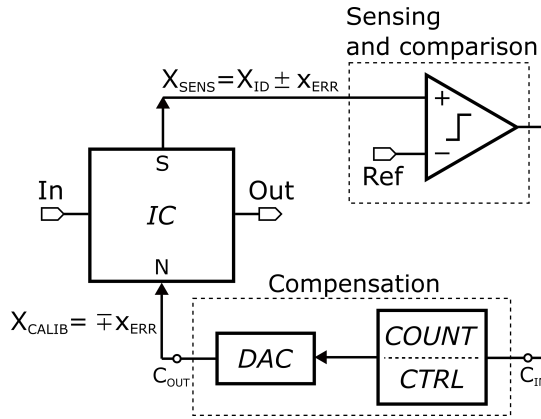
Fig. 1. Block diagram of IC with a calibration subcircuit.

At first, it is essential to choose an electric parameter of the calibrated circuit which reflects the influence of PVT variations significantly. Such a parameter is then sensed and compared to the reference value through the comparator. The sensed parameter can be generally expressed by the following formula:

$$X_{SENS} = X_{ID} \pm x_{ERR}, \qquad (1)$$

where X_{ID} is the ideal value of the sensed parameter X_{SENS} according to specifications and x_{ERR} is the actual deviation of X_{SENS} from the ideal value caused by PVT variations. Depending on the comparator output, the control block together with the counter (CTRL/COUNT) generates corresponding code for a digital-to-analog converter (DAC). Then, the DAC connects the negative actual value of the compensating parameter deviation to null port (N) of the calibrated IC.

The IC nodes, represented by ports S and N, need to be chosen in accordance to nature of the sensed parameter and also specific IC topology. General requirements for this selection will be explained in more details in Section IV. The control block main role is to control the intervals in which the calibration is performed. Its design needs to meet calibration frequency requirements described above. Significant concern should be directed to the time required for single calibration

cycle, in which the compensated parameter deviation is sufficiently cancelled.

Fully calibrated value of a selected circuit parameter can be defined as follows:

$$X_{CALIB} = X_{ID} \pm x_{MIN}, \qquad (2)$$

where x_{MIN} is the minimal deviation that can be achieved with respect to the accuracy of the whole calibration subcircuit. This accuracy depends especially on precision of comparing process and DAC imperfections. The duration of particular calibration cycle depends on the magnitude of x_{ERR} and also on the DAC switching frequency. The counter sequentially generates increasing digital codes during the cycle and DAC feeds corresponding analog compensating signal $\mp x_{ERR}$ to nulling port of the IC. When the equivalence $x_{ERR} = x_{MIN}$ is achieved, control block terminates the calibration cycle. This is further described in the following section.

B. Control logic

Fig. 2 shows the block diagram of the control and counter circuit. While the absolute value of X_{SENS} (from eq. 1) is higher than X_{ID} (which means that $\pm x_{ERR}$ surpass x_{MIN} from eq. 2), the comparator holds the output voltage high. The comparator output is fed to the NAND gate. While one of the NAND inputs is in high state, the gate is transparent for the other input, which is the clock signal. According to principle mentioned above, the counter generates consecutively rising binary codes. The DAC respectively increases the value of analog compensation signal $\mp x_{ERR}$, which is fed to the IC null port. If the X_{SENS} value falls below the X_{ID} value, the comparator output signal immediately swings to the low value. Consequently, NAND provides high voltage at its output. While the counter receives the constant signal at its clock input, it sustains the lastest set output digital code. Finally, the DAC feeds corresponding constant compensation signal to the IC null port. In this way, the single calibration cycle is terminated. The calibration subcircuit remain in the same state, until the value of $\pm x_{ERR}$ again exceeds x_{MIN} due to temperature change. The comparator then swings its output to opposite rail and the mentioned compensation loop starts again. Apparently, it is crucial to keep the propagation delay of logic circuits as low as possible in order to reach sufficient accuracy and time of compensation.
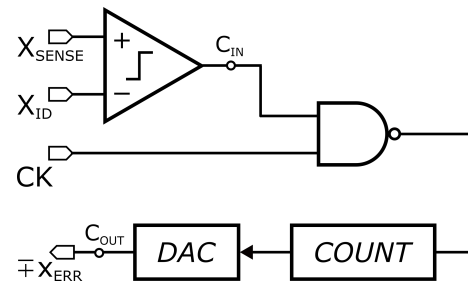

Fig. 2. Block diagram of the control subcircuit.

C. DAC operation

From the accuracy point of view, it is important to consider the influence of PVT variations also on the calibration subcircuit itself. Here, characteristics of DAC require special attention. Optimum function of this block can be provided using so called M/2M or M/2$^+$M digital-to-analog converter [6], [7]. This can be further compensated with the algorithm for radix conversion at the same time [5].

As described in the previous sections, the main goal of the calibration algorithm is to find the most suitable digital control value for the DAC, which results in minimum residual deviation of the compensated parameter X_{CALIB} from the ideal value. Fig. 3 represents the ideal transfer characteristics of the DAC. This displays the relationship between the output analog compensation value and digital input code. X_0 represents the ideal compensation value (which corresponds to X_{CALIB} from eq. 2), so that the adverse deviation is canceled as much as the accuracy allows [5].

If the DAC generates a compensation value higher than X_0, it results in overcompensation of the compensated parameter. Similarly, on the other hand, the undercompensation occurs in the case if the DAC generates a compensation value lower than X_0. In order to find the DAC digital input code that results in the output value closest to X_0, the successive approximation algorithm can be used. This is further explained in work [5].
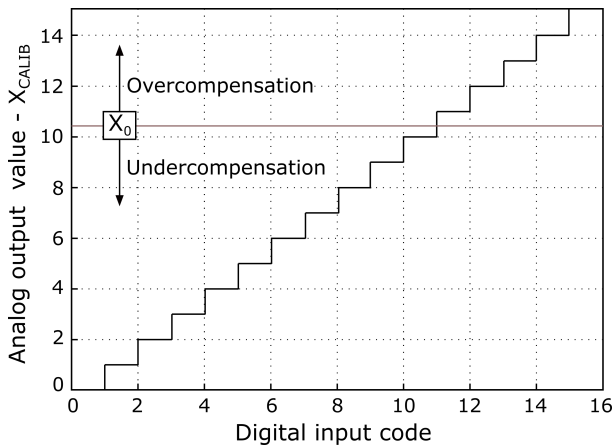

Fig. 3. DAC ideal transfer characteristics.

The R/2R ladders represent a well-known realization of binary-radix DACs. There are two variants of this circuit. It can operate in voltage-mode, when it adds up fractions of the reference voltage to produce a desired voltage output. This topology is further described in [8]. The other arrangement of the R/2R ladders based DAC is the current-mode ladder, which collects split components of the reference current to produce a current output [5].

However, more practical solution is to use MOS transistors instead of resistors in the DAC divider network. In general, each resistor of R/2R network is substituted with a MOS transistor that acts as a pseudo-resistor having an equivalent resistance. In this way, one can get M/2M ladders. The fundamentals of this matter are disclosed in [9], [10].

Fig. 4 depicts the schematic diagram of 4-bit M/2M current-mode digital-to-analog converter, presented in [7]. As already described, the M/2M transistor network corresponds to the R/2R resistor ladder. Transistors M_1 - M_9 perform the role of pseudo-resistors with appropriate resistance according to the bit weights. The transmission gates, controlled by clock signals $D_0 - D_3$ (inverted clock signals $nD_0 - nD_3$), acts as switches allowing to set the desired output current in the particular branch ($Branch1$ or $Branch2$ in Fig.4). Transistor M_{10} - M_{13} implement two current mirrors providing compensation currents I_{COMP+} and I_{COMP-} at their outputs.
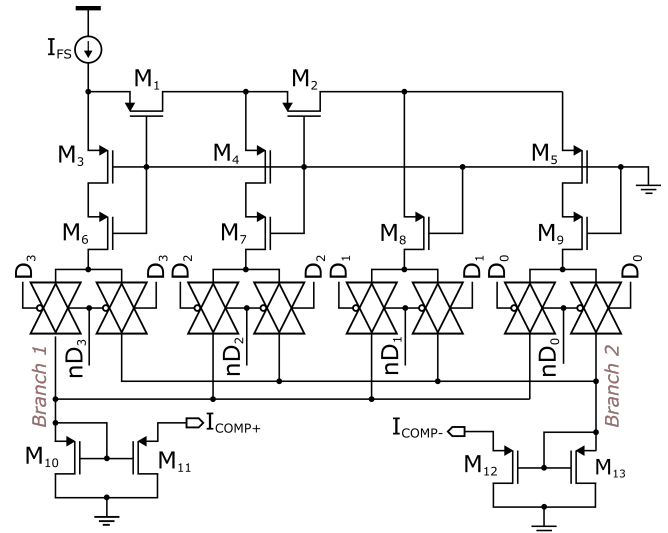

Fig. 4. The 4-bit M/2M ladder DAC [7].

IV. CALIBRATION OF DIFFERENTIAL OPERATIONAL AMPLIFIER

As mentioned above, the calibration of any circuit parameter can be targeted. The selection of a proper parameter depends on the IC type since different circuits differs in critical parameters considerably influencing the circuit function. In the case of the differential OA, such critical parameter might include $PSRR$ (power supply rejection ratio) or $CMRR$ (common mode rejection ratio). Nevertheless, the input offset voltage V_{in_OFF} receive special attention in the OA design, as this parameter crucially influence both the amplifier performance and its application in more complex systems. By definition, the V_{in_OFF} represents the voltage difference between the input terminals of an operational amplifier, at which the output voltage difference is $0\ V$ (between output terminals in the case of symmetric output OA or relative to ground in the case of asymmetric output OA). The V_{in_OFF} voltage can be effectively modelled by constant voltage source that is connected to one of the OA inputs, as depicted in Fig. 5.

As it was previously suggested, in order to implement the selected calibration technique properly, it is required to identify two nodes in the calibrated IC – the detection node
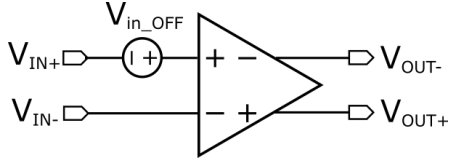
Fig. 5. The model of input voltage offset in differential OA.

and the compensation node [5]. Criteria for this choice are the following:

a) The sensed signal is a function of the calibrated parameter and it is independent of the other IC parameters,

b) The sensed signal level is significantly higher than the noise level and adverse signals level originating particularly from calibration subcircuit defects [5].

The nodes chosen in this way corresponds to the partial steps of the calibration cycle (as described in Fig. 1). Then, it is needed to determine the overall configurations for detection and compensation of the impaired parameter.

A. Detection configuration

Detection configuration of the whole system is the one, in which the degraded parameter can be directly or indirectly observed in the selected detection node. Dependently on the degree of IC output function continuity, it is possible to run the detection in parallel with the IC operation with no interruption. Respectively, if the IC operation allows that, its topology can be periodically modified, so that the detection can take place. In this way, the IC is switched between function and detection modes.

Fig. 6 presents the V_{in_OFF} detection of a fully differential OA in closed loop configuration. This detection configuration does not demand for modification of the IC topology, and therefore, it is appropriate for systems with continuous function required.
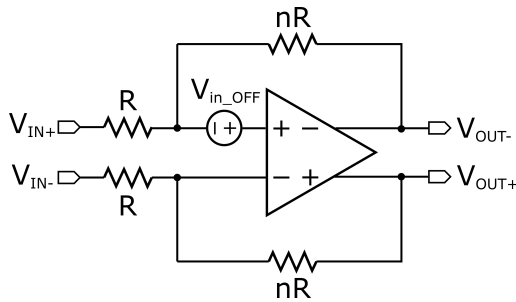

Fig. 6. The detection configuration of the OA for offset compensation.

The constant voltage source, connected to the positive input terminal of the OA, models the input offset voltage. From the following expression, the voltage V_{in_OFF} can be provided:

$$V_{in\_OFF} = \frac{V_{OUT} - A_{CL}.V_{IN}}{A_{CL}}, \qquad (3)$$

where V_{IN} and V_{OUT} represent the differential input voltage and the differential output voltage of the operational amplifier,

respectively. A_{CL} is gain of the overall closed loop amplifier configuration.

B. Compensation configuration

Compensation/correction of a deviated parameter is possibly realized through the injection of appropriate compensation current via IC compensation node. This node of the compensated OA needs to be selected in such a way so that the maximum correlation between the injected current and the corrected V_{in_OFF} can be achieved. On the other hand, it is important to maintain the correlation between the injected current and other parameters as low as possible [5]. The presented compensation approach is convenient for circuits, which are based on MOS transistor operation. In these circuits, their input voltage is transferred into the current flowing through the circuit.

The information signal processed by the OA is primarily carried by the current and consequently converted to the voltage by means of the OA output impedance. Therefore, the V_{in_OFF} is effectively corrected at the OA output [5]. Fig. 7 depicts the optimum compensation configuration on a general example of differential OA. The V_{in_OFF} voltage proportionally determines the difference between currents of particular OA branches. By correcting these currents, the V_{in_OFF} can be effectively eliminated. The current mirrors formed by PMOS transistors are connected to the both outputs of the OA. The current mirrors appropriately distribute the compensation current I_{COMP+} or I_{COMP-} to the corresponding branch of the OA. The choice and magnitude of required compensating current are specified by control block (in fig. 1). The ideal currents sources in Fig. 7 represents the outputs of DAC, which is in this case differential.

The design of the whole calibration subcircuit needs to follow particular rules, so that its backward influence on the IC under calibration is negligible. The range of possible channel lengths for transistors M_{P3} and M_{P5} is determined by the channel conductivity g_{DS}. This needs to remain sufficiently low so that the compensation node small-signal impedance would remain untouched. On the other hand, the channel length of mentioned transistors needs to be long enough, so that the voltage fluctuation in the compensation node would not influence the injected compensation current. This voltage instability is caused by channel length modulation (CLM) of a MOS transistor in saturation regime. The CLM is characterized by the coefficient of channel length modulation [11]:

$$\lambda = \frac{\Delta L}{L.V_{DS}}, \qquad (4)$$

where L is the total channel length of a MOS transistor, ΔL is the decrease of effective channel length due to modulation and V_{DS} is the transistor drain-source voltage.

C. Calibration objectives

Fig. 8 shows the example of Monte Carlo simulation results obtained for the input offset voltage of the fully differential
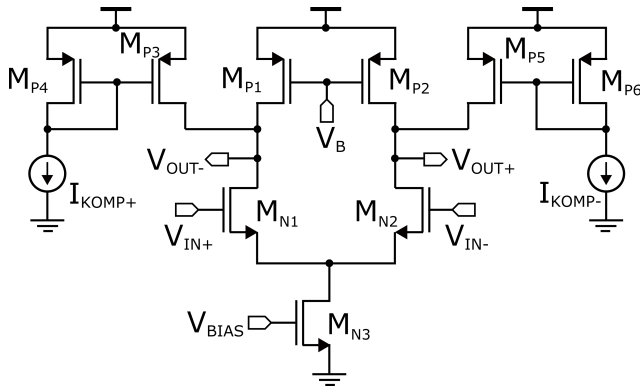
Fig. 7. Compensation configuration of the fully differential OA.

amplifier. The amplifier was realized in 130 nm CMOS technology with the supply voltage $0.6\ V$. The analysis use 60 samples, and the V_{in_OFF} standard deviation and mean value reach of $6.85\ mV$ and $2.98\ mV$, respectively.
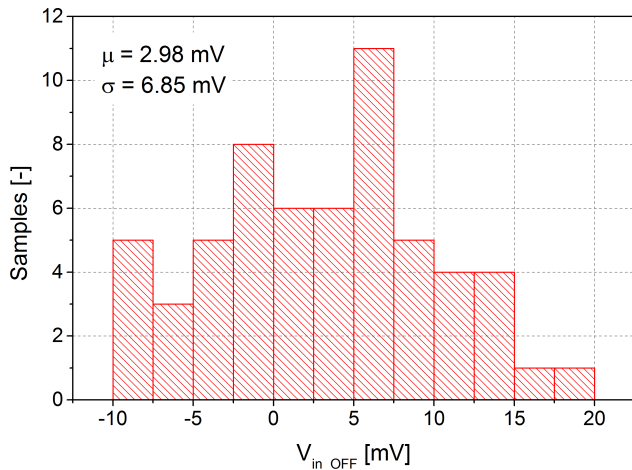

Fig. 8. Monte Carlo analysis results of the OA input offset voltage.

Fig. 9 depicts the comparison of V_{in_OFF} statistical distribution for the number of samples before calibration (as for example in Fig. 8) and target shift after the use of calibration. The values in this plot represent the trend line of histogram. The aim of calibration technique is the reduction in mean value of V_{in_OFF}. However, it will be more important to decrease the standard deviation to the value of σ_c, as can be observed in Fig. 9. IC samples exceeding the specification limits need to be retested or discarded. It is important to note that in this way, the increasing integration (projected in increased IC parameters fluctuation) cause the increase of overall production costs. The test expenses in some integrated systems reach 40-50% of the total costs [2]. Therefore, the decrease of V_{in_OFF} standard deviation achieved by the calibration would bring the higher amount of samples satisfying the specifications. Consequently, the production yield might be enhanced.

The limit of V_{in_OFF} interval $\mu + 3\sigma$ in Fig. 8 reaches the

value of 23.53 mV. This value of the input voltage difference is consequently amplified by the overall loop, as it is actually the differential voltage. The presented amplifier reaches the voltage gain of approximately 33 dB. The output voltage difference increases to 1.05 V, which is above the value of supply voltage. Thus, the output dynamic range will be reduced significantly [12].
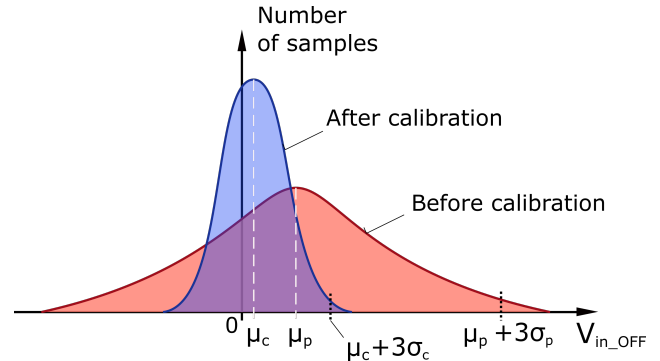

Fig. 9. The input offset voltage of the OA before and after calibration.

V. Conclusion

In this paper, general fundamentals of calibration techniques for low-voltage analog ICs fabricated in nanoscale technologies are addressed. The main goal of the calibration is to compensate the undesired influence of ageing, fluctuation of technology process parameters and temperature variations on the IC performance.

The first and most important step in the design of a calibration subcircuit is the analysis and comparison of particular calibration techniques. The comparison criterion is generally the effectiveness of reducing the impact of PVT and ageing variations on IC operation. It is also important to consider the minimum backward interaction of the calibration subcircuit with the circuit under calibration. Here, we have to find the trade-off between the technique effectiveness and drawbacks. Then, particular blocks of the calibration subcircuit needs to be designed and implemented in the overall system with the compensated circuit (e.g. operational amplifier). To meet low power requirements it is promising to use MOS transistors controlled through the bulk electrode while designing particular blocks of the system. We have presented an example of statistical results of Monte Carlo analysis for the input offset voltage of the differential operational amplifier. As it was shown, the OA output dynamic range would be significantly constrained due to shift in the operating point across large amount of samples.

Considering the actual state of the art, it appears worthwhile to utilize the compensation technique also for noise cancellation. Since the noise behaviour quite differs from the V_{in_OFF}, it might be effective to utilize another technique for noise compensating and combine both together. This paper presents the fundamentals in specific utilization of particular calibration technique to a certain degree. There were discussed

the design essentials of a calibration subcircuit from the overall system functionality point of view and also at the level of individual blocks.

Our next steps will lead to implementation of specific technique for calibration of OA input offset voltage. Particularly, the calibrated device will be the low-voltage variable-gain amplifier, which was realized in 130 nm CMOS technology. According to the recent results, V_{in_OFF} will most probably vary in the range of $\pm$ 20 mV. We will try to develop individual blocks of calibration subcircuit and overall integration, with adjustment to the mentioned V_{in_OFF} range.

ACKNOWLEDGEMENTS

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Testing cognitive loads in solving algorithmic tasks

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Abstract—**In their work, educators are increasingly relying on the knowledge of information processing mechanisms such as perception, attention or memory to explain the processes involved in learning and teaching. This article discusses the results of eye tracking experiments on external cognitive load (related to perception or attention control) when solving algorithmic tasks. The analysis of eye tracking indicators has determined which factors reduce the cognitive effort. However, there were no significant differences in the parameters analyzed, which led to the assertion that the distracters presented in the task did not increase the cognitive load, which may indicate that in the case of difficult tasks, the internal cognitive load plays a dominant role. It was noted that the low efficiency of solving algorithmic tasks constitutes a major impediment to statistical inference.**

I. INTRODUCTION

The curriculae in IT specializations mostly focus on mastering competencies in the development, reading and interpretation of algorithms and programming skills. Numerous studies indicate that the learning of these skills appears difficult to students, and failures in this field, largely due to the excessive cognitive load [1] experienced by students during the learning process, discourage them from learning programming [2, 3, 4]. Hence, not only have a number of studies been undertaken to diagnose the causes of these difficulties, but also attempts have been made to develop teaching strategies [5] and systems that support the effectiveness of instructional programming, frequently based on program visualization techniques [6, 7]. Education concepts have also been developed to reduce cognitive load while learning programming [8, 9]. They focus mainly on designing the appropriate instructional materials for this domain, but also offer software tools such as CORT (Code Restructuring Tool) which has been created to utilize this part-completion method [9].

The purpose of the research described in this article is to verify by means of objective eye tracking indicators the relationship between factors that increase or decrease cognitive load and the effectiveness of solving algorithmic tasks (understood as the effectiveness of indicating the correct solution). To this end, two versions of the same task were developed, and one of them was accompanied by factors that increase the external cognitive load which relate to the way in which the information is presented. In the first step, an attempt was made to answer the question whether the task version differentiates the correctness of answering questions. The next step was poised to see to what extent the external load affects the values of the oculographic parameters. Researchers' focus was on answering questions about the management capacity (in particular its reduction) of internal and external cognitive load. It has been asserted that simple text-organizing activities can effectively reduce cognitive load. It seems that a greater degree of control over external cognitive load can be achieved by simple manipulations than was the case with internal loads, yet it has not been shown that its reduction positively affects the efficiency of solving algorithmic tasks.

II. LITERATURE REVIEW

A. Cognitive load when solving algorithmic tasks

Research on the human mind has shown that it has limitations in terms of observation, storage and processing of sensory input [10] and has contributed to formulating a concept called Cognitive Load Theory (CLT) [11]. It is closely related to the working memory (WM) concept of short-term memory (STM), which stores information from sensory stores, the effects of current information processing, as well as information recalled from persistent memory. CLT assumes that working memory is limited and that processing and maintaining information uses a certain proportion of these resources. In the theory of cognitive load, there are mainly two types discerned, i.e. intrinsic and extraneous. The former is related to the degree of difficulty of the task (its structure or complexity) and is referred to as the individual's effort to understand the information presented. External cognitive load is related to the way information is presented [12]. In literature, researchers also use the concept of germane cognitive load, referring to the remaining cognitive resources needed to solve the task, devoted to acquiring and automating schemata in long-term memory [13]. The cognitive load of the individual can also be influenced by other factors such as emotional state, time pressure, sleep deprivation, noise, and other factors.

In practice, it is not possible to completely remove the effect of cognitive load – no matter whether it is internal or external. Also, both types do not appear separately,

even though their contribution to total cognitive load may vary and oscillate depending on the specificity of the task. If there is a high level of both types of load, the task may not be feasible.

While a high level of internal cognitive load is obvious in the course of solving algorithmic tasks, yet its excessive increase may be due to, for example, the need to compute in memory and store the results of the calculations (the more figures, the more complex calculations, the greater the cognitive load) . As mentioned earlier, the internal cognitive load depends to a great extent on individual characteristics (human intellectual potential, experience, and other factors); therefore, it is necessary to take measures to reduce the external load, for example by using techniques such as the study of programming examples. Other factors influencing the level of external cognitive load are, for example, the form of the presented algorithm, information redundancy, the necessity of structuring information or making decisions about the selection of content as a guide in the task. Manipulating these factors can increase or slow down the pace of problem solving, and reduce or increase the cognitive effort of students to understand the material presented, and consequently reduce or increase the efficiency of solving tasks.

B. Oculographic factors of cognitive load

In recent years, much attention has been devoted to investigating cognitive load. To this end non-physiological measures based on the rating scale have been applied (eg, the NASA Task Load Index, (NASA-TLX) which have become the subjective assessment tools [1] or the dual-task paradigm, in which the researchers evaluate the performance in a secondary task performed in parallel to assess the cognitive load devoted to the main task [13] Objective methods of measuring cognitive load are those based on physiological factors such as heart rate variability, skin conductance and respiration rate. Oculographic parameters constitute a separate group of tools, discerned owing to the relative ease of their recording. [13] It is considered that the time of fixation (relatively stable focus of eyes on the element of the presented object) and saccades – fast angular changes of eyeballs which lead to such setting that the axes of both eyeballs connect a new fixation point with macula lutea of retina, may become the basis for objective cognitive load measurements.

Currently, for the measurement of ocular movements modern video-occulography is used where a camera or a special apparatus records the location of special reference points which are a part of the visual apparatus. Infrared light directed at the eyeball bounces differently from its individual elements. The reflected cornea rays are visible as reflections, and it is on their basis that coordinates are determined - the x and y coordinates of the eye.

The most commonly used eye trackers eyeglasses are of two types: mobile (headset, also called eyepiece) and stationary (in the form of a device integrated with a computer monitor or a free-standing monitor, operated by a researcher or a system which is not portable and which allows full stabilization of the person relative the measurement apparatus). Eye trackers also vary in the measurement frequency (number of measurements per second) ranging from 30 Hz to 2000 Hz. The frequency with which the device works should be matched to the

type of study being conducted, and the quality of the results and the precision of the measurements involved depend on it. During eye tracking tests there are several to a few dozen eye movement parameters recorded [14].

The most commonly used indicator of cognitive load is the change in the pupil size, which increases in diameter under constant lighting conditions, as the difficulty of the tasks of the person increases [15]. The pupil width remains under the control of the autonomic nervous system and cannot be controlled by the individual. However, due to the fact that this parameter is sensitive to changing lighting conditions, it is prerequisite to provide a specific test environment. A much debated measure of cognitive load is the frequency of blinks and their time. The ambiguity of the results obtained and the multiple determinants of the values of the blink parameters - inter alia their high dependence on the specifics of the task, advocates prudent use of the results and directs the researcher's attention towards other oculometric indicators [13].

Increased cognitive performance can be attributed to longer fixations and shortened saccades. It has also been shown that the number of fixations is a negative correlation with the efficiency of the visual search. This means that a good organization of the information transfer should allow the number of fixations to be reduced. It is also assumed that the longer the fixation time, the greater the difficulty of the visual task. Extension of fixation time signals a problem with information acquisition.

The number of saccades is also related to the spatial organization of information. Frequent changes in the position of the eyes may be due to improper organization of the environment of functionally related elements [16], which also increases the cognitive load.

In summary, many studies have confirmed that longer fixation times and shorter saccades are associated with higher cognitive load [17], hence the two indicators were analyzed in detail in the experiment.

III. METHODS

A. Eye tracking apparatus

The Eye Tracker from SensoMotoric Instruments iViewX ™ Hi-Speed500 / 1250 was used to capture data streams at 500 Hz. Measurements of visual position, pupil width, fixation parameters and saccades were made. The eye tracking system allowed the head to remain stable without limiting the field of vision of the subject. During the test, the task was presented on a 23 "diagonal LCD monitor with Full HD resolution of 1920 x 1080. Prior to each test, a 9-point calibration was performed with validation. The calibration fault was set to no more than 0.5 degree. The SMI Experiment Suite ™ 360 Software Suite, Design - SMI Experiment Center ™ 3.4 was used to design the experiment, and the SMI iView X ™ module allowed recording the data, whilst data analysis was performed using the BeGaze ™ application. In the course of the experiment, all participants were assured identical temperature, lighting and sound insulation.

B. Participants

The experiment was attended by 55 pupils aged 16 (25 girls and 27 boys). Measurements of 10 students were rejected for technical reasons (incorrect calibration) and

45 cases were further analyzed. The sight of all subjects was normal or corrected to normal (the eye tracking system is highly tolerant of contact lenses and spectacles). A diagnostic survey was conducted before the study, which confirmed the assumption that all pupils had a problem solving task incorporated in their school education.

C. Procedure

The algorithm presented in the article and solved by the investigators was presented as a flow chart. Two versions of the task have been developed. The first of them (see Figure 1), labeled as Tv1, contained two elements that were supposed to increase the cognitive load; some of the sections of the content were colored, and a legend was added that, although it appeared to be a helpful addition, did not contribute any relevant information. This task was solved by 22 students.
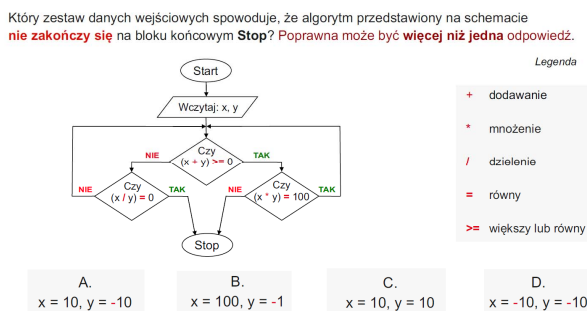

Figure 1. Task – version 1 (Tv1)

The second version of the task, marked with the symbol Tv2, (see Figure 2) was stripped of any additional elements that could be the source of the external load. This task was presented to 23 participants.
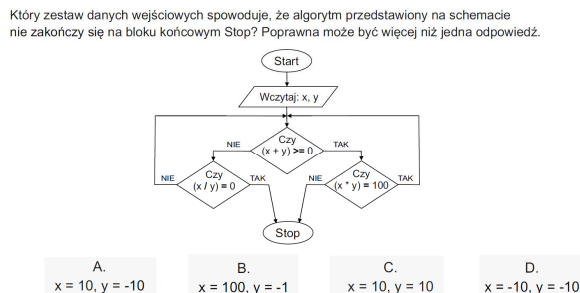

Figure 2. Task – version 2 (Tv2)

The task required feeding in the input data as a pair of figures and performing basic math operations on them (addition, multiplication, or division). It was necessary to indicate such a set of input data, for which the algorithm did not end in a stop block. The two pairs of figures from the four proposed represent the correct answer (in the illustrations, this is the answer marked with C and D).

Student visual activity was recorded during task solving. Having given the oral answer, the students solved subsequent tasks, and after completing the registration of the eye tracking data, they took part in a survey in which they assessed the difficulty level of the tasks presented and their emotional state in the course of solving the tasks (including the level of their anxiety).

IV. RESULTS

Statistical calculations were conducted with the application of Statistica version 13 program and Excel MS Office spreadsheet. The correctness ratio of solutions to both versions of the same task amounted to 29.1%, and the correct answer was provided merely by 16 pupils. Seven pupils provided a correct answer to Tv1 task (25.0%) out of 28 pupils included in the experiment, whilst 9 pupils (29.1%) out of 27 strong group participated in the second version. A special correlation table was constructed (see Table I) to answer the research question whether there was some correlation between the number of correct answers and the version of the task . The statistical analysis included the answers provided by all the pupils (55 pupils) which were subject to the test.

TABLE I. CORRELATION TABLE OF THE CORRECTNESS OF ANSWERS AND APPLIED VERSION

Type of task/answer	Correct	Incorrect	Total
Tv1	7	21	28
Tv2	9	18	27
Total	16	39	55

The calculated chi square statistics amounts to 0.463 at the assumed level of significance p=0.05 (df=1) and the theoretical value χ^2=3.841, hence, it may be inferred that the differences between the analysed variables are not significant. That means it was not feasible to show a relation between the version of a task and efficiency of its solution.

The analyzed task was evaluated by the students as rather difficult (on a scale from 0 to 10, where 0 meant that the task was very easy, 10 - very difficult, the calculated average was 5.33). The 11-point rating scale was also proposed to assess the stress experienced during its resolution, and here a similar result was obtained (mean = 5.47).

TABLE II. DESCRIPTIVE STATISTICS OF THE DEGREE OF DIFFICULTY AND THE STRESS EXPERIENCED DURING TASK SOLUTION

Statistics	Difficulty	Stress
Average	5.327	5.473
Standard error	0.374	0.387
Median	5	5
Standard deviation	2.776	2.873
Kurtosis	-1.206	-0.942
Skewness	-0.245	-0.165

The high value of the kurtosis index indicates that a relatively high number of extreme ratings can be observed (see Table II). Declared levels of difficulty assessment and perceived stress indicate a relatively high internal cognitive load that significantly influences the effectiveness of the solution.

In the next step, an attempt was made to seek the external factors bearing on the cognitive load, and the selected oculographic indexes were analysed (in the subsequent part of the study, only the measurements for 45 pupils were posted).

As it has been already mentioned, the tasks were slightly different from each another; in the first version there was an additional field with some text. All respondents spent some time on becoming familiar with it, yet the results showing total time devoted to solving both tasks proved surprising (see Table III).

TABLE III. DESCRIPTIVE STATISTICS OF TIME SPENT ON SOLVING THE TASKS

Statistics	Time of solving the tasks [ms]	
	Tv1	Tv2
Average	108 056.5	103 408.0
Standard eror	12 562.9	15 948.4
Median	86 785.4	83 660.5
Standard deviation	58 925.3	76 486.0
Variance	3 472 195 700.2	5 850 107 981.9
Kurtosis	2.8	7.3
Skewness	1.8	2.5

The Mann-Whitney U test for independent groups has shown that there are no significant differences in median time for task solving in both versions (the value of the test statistics was $Z = 0.783$ and $p = 0.44$). The values of skewness coefficients indicate a large asymmetry in the distribution of values (which also justifies the choice of the test used).

For data analysis, an additional area of interest (AOI) was defined for the Tv1 task area, including the proposed factor load in the form of a legend in the right part of the slide, named Commentary (Figure 3). By using areas of interest, it is possible to ascertain with great precision how much time the respondents spent on viewing (reading) particular elements of a task (Dwell time coefficient shows that).
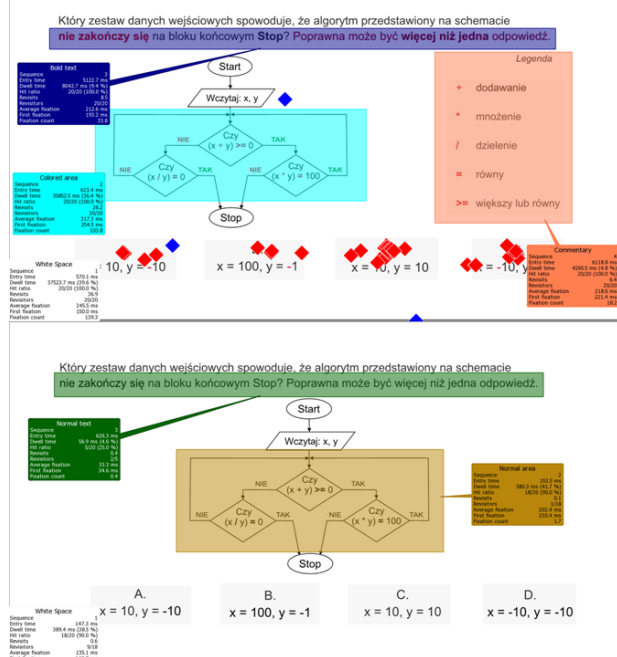

Figure 3. Two versions of the task with the highlighted areas of interest

In the next step, the researchers sought to answer the question whether objective measures in the form of oculographic data will allow indicating the importance of additional elements included in the task in the context of increasing or decreasing the cognitive load.

A. Fixation parameters for two versions of the task

Literature analysis has allowed us to assume that longer duration of fixations and their smaller number will indicate that the task is difficult, but characterized by a good spatial organization of the content. In the case of long fixations and their large quantity, it can be assumed that the task is difficult and there is an external load factor, which is the way of presentation of the task

TABLE IV. FIXATIONS IN SPECIFIC AREAS OF INTEREST FOR BOTH VERSIONS OF THE TASK

Task version	AOI	Fixation Count		Average Fixation Duration [ms]	
		Mean	SD	Mean	SD
Tv1	BT	35.9	10.5	248.6	34.3
	C	94.7	87.3	221.5	28.8
	CA	122.0	84.1	263.8	47.6
	WS1	157.4	89.0	250.6	27.1
Tv2	NT	45.9	30.0	254.4	58.6
	NA	120.2	84.7	307.5	58.1
	WS2	141.7	85.7	245.6	37.0

Table IV presents mean times of fixations in particular AOI for two versions of the task. The following denotations were used:

BT (*Bold text*) - AOI referring to fragments of the text which were highlighted with color or bolded (in version Tv2 the same fragments were plain and denoted NT = Normal text),

C (*Commentary*) – AOI, which includes explanation of the symbols of arithmetic operations applied in the algorithm (this element is absent in version Tv2),

CA (*Colored area*) – AOI which includes a fragment of the algorithm with color highlights (in version Tv2 the same fragment is plain and denoted with NA symbol – *Normal area*),

WS (*White space*) – the rest of space, WSI for Tv1and WS2 for Tv2 , respectively,

The structure of the task allowing comparing mean values of a number of fixations and mean duration time of a single fixation within: BT and NT, CA and NA (see Table IV), WES1 and WS2 as well as Dwell Time for WS1(mean=42 451.9, SD= 23 201.1) and WS2 (mean=39 655.7, SD=28 765.9).

Verification of a null hypothesis of statistically insignificant differences in fixation and fixation times was performed with the application of the Mann-Whitney U test, for which the median trend measure is the measure of the central tendency. In each of the above cases, the median of the analyzed parameters did not show significant differences between the groups studied (BT and NT: for Fixation Count p=0.291, for Average Fixation Duration [ms] p=0.716 and CA i NA: for Fixation Count p=0.768, for Average Fixation Duration [ms] p=0.420).

B. Saccade parameters fr both versions of the task

In the analysis verifying the variation of the saccade values for the two versions of the task, the amplitude of the saccades and their average number were taken into account. The saccade amplitude is the distance between subsequent visual fixation points, and its mean value is considered a measure of the scanpath strategy [18]. The results are shown in Table V.

TABLE V. VALUES OF SACCADE PARAMETERS FOR BOTH VERSIONS OF THE TASK

Task version	Parameter	Mean	Median	S^2	SD
Tv1	Saccade Count	309.2	240.5	27407.2	165.5
	Saccade Amplitude Average [°]	4.6	4.3	2.4	1.5
Tv2	Saccade Count	278.7	215.0	27928.9	167.1
	Saccade Amplitude Average [°]	4.0	4.0	0.4	0.6

The Man-Whitney U test was used to assess the significance of the differences between the saccade parameters for the two task versions (as in the previous cases the significance level $p < 0.05$) was used. For Saccade Count $p = 0.256$, Saccade Amplitude Average $p = 0.183$, which means that there is no difference between the values of these parameters.

V. DISCUSSION

The research did not show any difference in the values of the oculographic parameters for the different versions of the task.

Fewer fixations in case of the text including highlighting and bolding (BT mean=35.9 vs. NT mean = 45.9) may indicate that this form of content is easier to understand and/or memorize. The results confirm the research conducted to date [16]. No difference in mean time and fixation values in the block diagram area may be due to the fact that coloring of text fragments was not a sufficiently significant factor to increase cognitive load or facilitate the organization of the presented information.

A bigger number of fixations due to the inclusion of commentary in one version of the task natural, but the total mean fixation time in this area is significantly less than that for the rest of the areas and it seems that the legend was not a factor significantly increasing the external cognitive load. Placing an explanation at a slight distance from the message of the task resulted in an increase in the average length of the saccades, yet the difference in the values of the analyzed parameters for both versions of the task, both amplitude and number of saccades, proved to be statistically insignificant. It appeared that in this case, making decisions about the selection and use of the message as a guide in the task did not contribute to an increase in external cognitive load.

A. Conclusion

Similarly to other research [2, 3] it has appeared that pupils found solving algorithmic tasks difficult. This aspect seems to have a significant impact on the results obtained – a statistical comparative analysis for research groups which varied by giving the correct answer was not feasible.

The study did not show that the distractors attached to the task constituted elements that significantly increased the cognitive load - neither the respondents nor the oculographic indicators confirmed this. It turned out that the applied bold and font coloring, directing pupils' attention to important parts of the text of the command is not a hampering factor, and the effect properly applied - even supports the organization of information content. The research material was prepared, however, with a view to real-life formulated tasks. The avoidance of exaggeration has, however, led to difficulties in seeing significant differences in the mean values of the parameters tested. It may be advisable to include more distinctive distracters in the next study. Another study should also be conducted on two groups - experts and novices. Both groups must also be significantly more numerous, as the risk of incorrect responses is high, and this factor is a significant obstacle in the analysis of results.

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Encouraging scientific thinking and fostering scientific careers in the environment of the Slovak University of Technology in Bratislava

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Abstract—**The Advanced Technologies Research Institute (ATRI) as a scientific institute has a unique position in the environment of Slovak universities. One of ATRI ambitions is to spread knowledge and foster science in the environment of the faculty and university with the expected outcome to wake and encourage interest in science among students and the public, promoting education and training in materials science, chemistry, information technologies and create a well-educated workforce for the future. The measures and tools implemented and planned to execute at ATRI, personal as well as institutional, to reach that goal are, among others presented here, the *Minerva Group* platform for undergraduate, graduate and PhD students, *Young Trainees* programs, Seminars with invited scientists, *Science With a Glass of Wine* meetings or pilot for faculty interdisciplinary R&D project. First success stories are the *Think and go* project developed by students in the *Minerva Group* resulted in a prototype of a brain-controlled electric wheelchair; individuals and teams of students with topics from Minerva Group won two independent sections in the faculty contest in student's scientific activities; the faculty dean's award for the best master thesis; two members of the *Minerva Group* are continuing in their studies as PhD students, first two trainees are finishing their scientific work at the ATRI.**

I. INTRODUCTION

Research and education are the cornerstones of the world's best academic institutions, where publishing innovative ideas and producing successful, well-informed students are key objectives [1]. Research institutes within the universities have a unique position which predetermines them to spread knowledge and foster science in the environment of the faculty and university.

The Advanced Technologies Research Institute (ATRI), belongs to the Faculty of Materials Science and Technology in Trnava (MTF), Slovak University of Technology in Bratislava (STU), and is the core institute at the University Science Park CAMBO (UVP) having an interdisciplinary team of researchers, engineers, PhD candidates and junior researchers. Historical brand used till present is SlovakION UVP.

While the teacher's task is to foster learning, one of the scientist's tasks is to encourage young promising students to an R&D and scientific career. ATRI, as a modern Slovak proactive and scientific institute with the ambition to become a leading and unique transdisciplinary research

institution in Central Europe, is also dedicated to this mission: spread knowledge and foster science in the environment of the faculty and university with the expected outcomes e.g. to wake interest and encourage scientific thinking among the students and the wider public, promoting education and training in materials science, chemistry, information technologies(IT) and produce well-educated graduates for the society.

That is the reason we have undertaken an analysis of the situation in Slovakia to find answers to questions such as what ATRI can offer to students, how to approach them and get their interest, what will make difference in the competitive environment of the Slovak universities and the current miserable situation with student outflow abroad. And, in the end, to make positive PR to the public and future students spreading information about ATRI research areas, results, projects and future opportunities. Outcome is the concept fostering science, included in ATRI innovative scientific management strategy, with personal as well as institutional platforms, programs and tools.

A. University Science Park CAMBO (UVP)

STU committed considerable investments into the research infrastructure of UVP with €42M European Structural Investment Funds (ESIF) funding, which was invested in building and acquiring all necessary supporting infrastructure to host ion-beam and plasma technologies including a purpose-built building within the STU MTF campus in Trnava (Fig. 1).

Figure 1. SlovakION - University Science Park CAMBO

SlovakION UVP infrastructure is dedicated to ion-beam modification, ion-beam analysis and plasma based surface processing and deposition technologies as well as state-of-the-art analysis tools. The labs within the SlovakION

building are equipped with a 6MV Tandetron accelerator with end stations for ion implantation and ion beam analysis, 500kV implanter, magnetron sputtering deposition and plasma immersion ion implantation technologies. One of the laboratories is dedicated to modelling and simulation, equipped with two state-of-the-art computational nodes and UVP has access to the SAV Computing Centre, which is known as the Slovak National High-Performance Computing Centre, supercomputer AUREL.

B. ATRI – SlovakION

ATRI personnel, including personnel allocated to operate the Ion Beam Centre (IBC), is comprised of mostly young scientists, technicians, PhD candidates and junior research trainees. The interdisciplinary team is composed of physicists, chemists, IT and automation experts, materials scientists and accelerator scientists. About 2M€ (co-funded by ESIF) was spent in training 14 of them at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR), a world-leader in the field of ion-beam related science and technologies. They acquired the necessary knowledge and competence in relevant fields required to operate the new scientific facility including scientific support for users and researchers in need of these technologies. The general objective is to build up ATRI as a modern technology research centre with both an excellent reputation in the scientific community as well as an effective link to the regional and European industry. Historically, Europe's ion beam facilities have suffered from a lack of reach-through with industry, and an unevenness of accessibility across different regions and application fields, thus an IBC that bridges the gap between research and industry in fields such as automotive and smart electronics is sorely sought for.

Figure 2.   ATRI addressing societal challenges

Research at ATRI is directed at advanced, tailored materials and functional surfaces based on material synthesis and modification from the millimeter down to the nanoscale in order to obtain desired properties and give new insights in understanding physical mechanisms accompanying these. Novel materials are increasingly based on nano-composites, nanoparticles or functional films on patterned surface nanostructures.
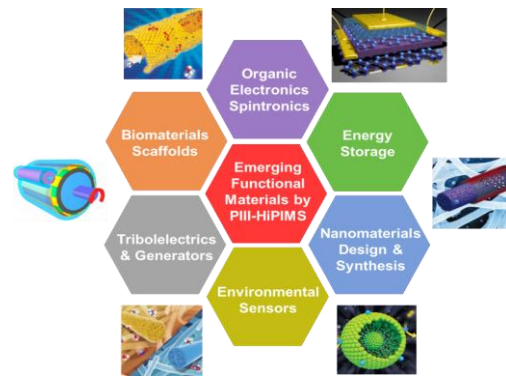

Figure 3.   Topics and novel materials research

Manipulation of matter on the atomic scale is one of the main goals of worldwide materials research. Tailoring material properties at these scales to the application is a must, ranging from large bulk processing systems to several nanometer-sized transistors, MEMS and NEMS. Yet some of the basic effects and processes are not fully understood. Motivation for this is the industrial development in recent years, emerging topic surrounding that of Industry 4.0 and the immense competition in this sector which, hand in hand with increasing awareness of related environmental and social consequences, is the source of continuous and ever increasing pressure to higher efficiency of materials utilization, clean energy and its efficient usage (Fig. 2).

Promoting an attractive, balanced and diversity friendly multidisciplinary environment is a highly prioritized goal for ATRI to fulfil, as only open and friendly working conditions (unfortunately often not the case) can attract broad spectrum of talented researchers contributing with innovative topics and ideas within the research field of interest (Fig. 3).

C. Students and Status Quo

STU is Slovakia's strongest university in the fields of engineering and materials sciences. This background raised many good researchers now helping to reinforce ATRI and continues to deliver many promising students and junior scientists.

Nevertheless, ongoing brain drain in Slovakia is alarming and affecting all Slovak universities as well as their faculties, STU and MTF being no exception. This situation is very well shown in the analysis performed by the Organisation for Economic Co-operation and Development (OECD).

Brain circulation or foreign students studying in the country versus national students studying abroad is shown in Fig. 4. Share of the Slovak student outflow is close to 15% vs. 5% inflow. Only Luxembourg has a worse number. On the other hand, Luxembourg has more than 3 times higher inflow as Slovakia.
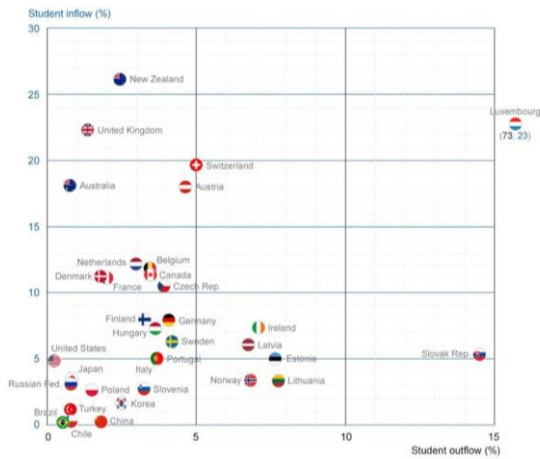
Figure 4. Student Outflow vs. Inflow. OECD Indicators [2]

The answers, why does Slovakia have such a bad position in this regard, is most likely connected with low governmental expenditures on education and science on the long-term, which are at 3.9% share of the Gross Domestic Product (GDP), Fig. 5, which his moreover diluted to a large number of universities and education was not considered a priority by any of the post-communist governments in Slovakia.
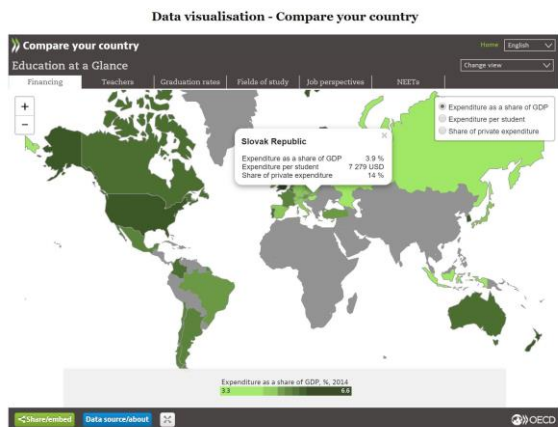

Figure 5. Expenditures on Science and Education in % GDP

The attractivity of a scientific career in Slovakia is very low not only due to mediocre remuneration not competitive to other branches of the economy, but also due to the administrative burden placed on scientists, often the result of inefficient administrative apparatus, lacking culture of excellence, closed-mindedness and reluctance of senior aging colleagues handing over leadership and management positions to their younger fellows. This resulted in a "lost generation" of academics, i.e. the personnel is mostly composed of old, just before retirement professors and young, not-yet professors and researchers.

II. ENCOURAGING SCIENTIFIC THINKING

The general concept of the scientific management at ATRI combines best-practice learned from successful research institutes and universities (HZDR, Technische Universität Dresden), where STU has a long-decade long cooperation.

A. Objectives

Overarching goal and motion is to promote the most valuable resource of scientists – knowledge. ATRI management pushes the implementation of the following concepts:

1. to instill best practice research principles in the next generation of scientists,
2. prepare students for real-world careers, scientific as well as industrial,
3. involvement of PhD students, postdocs and other researchers in ATRI activities,
4. promoting ATRI research topics to students and the public,
5. Strengthening the scientific competence of technical staff by developing and disseminating good practice.

B. Concept

The main pillars of scientific management are

- An innovative, flat rather than hierarchical, management structure
- Individual personal career development plans
- Transparent decision-making procedures
- Friendly working environment,
- Open discussions

factors, that are currently missing at most academic institutions in Slovakia or STU. Not all of the pillars and related frameworks are already fully established at ATRI due to missing finances, faculty or university procedures, persisting resistance to change and other obstacles.

The concept to encourage scientific thinking is tailored to Slovak conditions including knowledge spreading, supporting education, encouraging science in the environment of the faculty and is demand-driven to the present and future students, PhD. students as well as the wider public. Main parts of the concept and activities within are shown in Fig. 6.
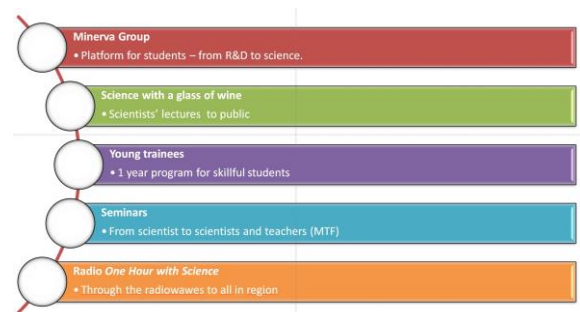

Figure 6. ATRI concept for encouraging scientific thinking

Based on outreach, external activities (directed at people outside the institute) are:

- The *Minerva Group* is a platform for students and young researchers to exchange ideas, experiment with creative science tools, investigate interesting problems or work on R&D projects with many supporting or common activities.

- *Science with a glass of wine* is a *Café Scientifique*-like chain of informal sessions with invited scientists from different fields discussing with a wide audience about their research.
- *One Hour with Science* is a radio program, where interesting scientific topics and research, domestic as well as worldwide, are discussed in an informal manner

Activities directed at the institute itself

- *Seminars* – lecture and discussion with an invited expert in a field related to ATRI research.
- *Young trainees* – students have a possibility to work during their studies at the institute.

C. Expected impacts

1. Providing a platform for students and young researchers to undergo a well-rounded PhD education.
2. Strengthening individual capacity development at graduate/postgraduate/young researcher level, promoting education and training in related fields of research.
3. Strengthening the institutional capacity, creating better synergies among internal resources and other faculty or university institutes.
4. Raising general public interest in science as well as attract the best students to enter a scientific career.
5. Contributing to the transformation of academic culture at the STU and Slovakia.

III. MINERVA GROUP

Minerva Group is a concept dedicated to students and PhD students aimed at education and scientific basics, common activities with students and project development as an essential learning model, especially in the field of applied informatics and automation. This is supported by establishing the Minerva Group as a non-profit organization in 2015 ensure wide fundraising and the eligibility for grant applications as well as for participation in various kinds of youth scientific contests. It is also the precondition for a sustainable future. While initial investments to the hardware, software licenses or devices were granted by the founder and leader, further financial needs are to be covered by efforts of the group and members themselves via grants, contests etc..

Members of the group are master students and PhD students lead by the founder and ATRI deputy director in one person and supervised by the vice-rector of STU. Minerva Group is fulfilling the mission - to raise interest of students in knowledge and science. Along with the mentioned, there is a strong link and cooperation with the Qintec a.s., IT and automation company, which brings knowledge and expertise from industrial point of view as well as the transfer of knowledge to industrial innovation. Attracting young and highly motivated students, willing to learn additional practical skills and something new besides the basics at the University and to work in the Minerva Group is of highest interest.

A. Interest

We let the members of this group to select what they want to do and what they wish to learn in combination with unavoidable mandatory topics essential for a good

start to their further work. Common activities together with the leader are important as well. Typical examples are regular sports (running) trainings, or participation in various contests as well as studying distance courses online provided by coursera.org. Every member including the leader had to select one and finish it. Already after a short time, the students themselves found the topic of interest they wish to explore and work on: Using brain activity via electroencephalography (EEG) signals monitoring to control various devices, e.g. car, RC model of a tricopter etc. We decided to invest in a brain-control interface and the EPOC was the system of choice. EPOC+ is a headset device which works as an interface between the brain and the computer. The device processes EEG signals, which are normally used for the investigation of the actual electrical activity of the brain. [6]

Later, the idea developed further, and inspired by our participation in the *Wings for Life* running contest, which is a beneficiary event for raising funds for disabled people, we decided to build a wheelchair control system which would help people bound to wheelchairs to move more easily. At the same time, the software development itself is an irresistible challenge.

1) Think and Go

The aim of the project is to design an integrated electric wheelchair control system for HealthCare systems, hospitals or individuals, with independent control being implemented without contact, using the patient's thoughts only. The mental commands are put in by the user using an EPOC device, then amplified and transformed into useful data.

We have modified a donated wheelchair to our needs. The control hardware is based on an Arduino processor and related converters, which have been added in order to control two motors - one for each wheel. Along with the hardware, the software had to be developed in order to read signals from the EPOC and transfer them into the VisMove software which actually controls the motors via Arduino (Fig. 7) .
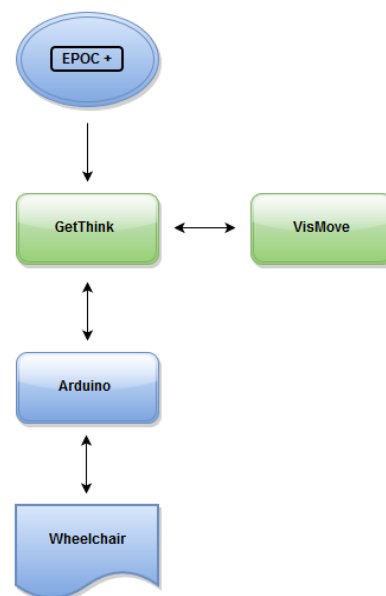

Figure 7.   Originally designed architecture [3]

We have received a grant from Tatra Banka to modify our wheelchair and to buy the new hardware including the EPOC.

After two years we have moved from virtually nothing to a wheelchair controlled by solely by the brain activity. This summer we have presented our progress to the media and television with incredible response and success. Fig. 8 shows one of our students during Think and Go project presentation for media.

Figure 8.   Presentation of the *Think and Go* project [4]

2) Science

Another field of interest lies in science as the involved we are all from university environment. Students from the Minerva Group have participated in various events and contests over the years.

Figure 9.   Filip Škoda, Miroslava Karasová, Marcel Nikmon and Patrik Bystrický (from left to right), winners of their respective section at the Student Research Conference [5]

Two were winning in the English section of the Student Research Conference at MTF STU, another two have won in the section dedicated to Applied Informatics and Automation (Fig. 9). They were also present at the Doctoral Seminar held by the Faculty of Organization and Informatics in Varaždin and also participated at the 24th International Engineering Fair and the contest therein.

B.   Future

Since the Minerva Group is operated by students there is a highly evolving and circulating structure. Students generally remain for two years, which is the time of their mater study. Currently, a core of students which have been responsible for the Think and Go project graduated and left the university and most of them got good positions in industry thanks to the experience and knowledge gained during their activities in the Minerva Group. Three students are currently working on their PhD theses, one of which will end next year.

The next step is to find further motivated students to continue working on the project and bring in new ideas.

IV.   YOUNG TRAINEES

One of the instruments to attract promising young people was opening trainee positions for students interested in ATRI research topics. Each trainee is assigned a guiding tutor. The contract is for one year and in case the tutor is satisfied with the results, a PhD or permanent position can be offered.

V.   SCIENCE WITH A GLASS OF WINE

This activity is inspired by the *Café Scientifique* concept, where events taking place in cafes, bars, restaurants and even theatres, i.e. always outside the traditional academic context, targeted at a wide non-academic audience to explore and discuss the latest ideas and achievements in science and technology [6]. The event is organized in cooperation with the popular *Leháro café* in Trnava and scientists are invited from various interesting fields of research.

Figure 10. Dr. Andrej Dobrotka with Binaries in space

Goal of these sessions is to promote science to students and the public and to attract students to ATRI. Invited speakers present their research and topics mainly from physics, chemistry, astrophysics, depending on contacts and active collaborations, and the fields are getting wider. The speakers invited were, well-established experts in their field, from the UVP itself, other universities as well as the Slovak Academy of Sciences (Fig. 10).

A wide audience is reached, from within the faculty as well as outside and as a first success the contracting of two trainees can be regarded as their interest was awaken by these events (Fig. 11).

Figure 11. Science with a Glass of Wine

VI. SUMMARY

ATRI scientific management strategy and parts that were implemented (depending on possibilities and degrees of freedom) is successful and effective. The *Minerva Group* succeeded in several ways: prototype for a wheelchair mind control within the Think and Go project, award for best master thesis, winners of student scientific activities contests and acquiring a grant from the Tatra Banka fund contest called „Know more".

Outreach of all mentioned activities is beyond expectation. They resulted in the interest of journalists and newspapers as well as the television. Also the friendly and open atmosphere at ATRI contributed massively to this success, where ideas are shared and individual efforts valued. This improves the attractiveness of our institute and in combination with exceptional career opportunities for scientists could have decisive impact on further successful development of ATRI. These are the foundations to attract international or national excellent scientists to spend some time at ATRI, but also to educate and foster the profile of our own people at the Alma Mater.

Finally, yet the most valuable outcome is knowledge itself.

"The whole of science is nothing more than a refinement of everyday thinking"

Albert Einstein

ACKNOWLEDGMENT

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The Role of Games in Popularization of Science and Technology

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Abstract—**This paper is concerned with authors' experience in design and utilization of web based games in popularization of science and technology. This versatile tool has a strong perspective in the task of reducing the lack of students' educational motivation in the field of electrical engineering. It is already desirable for primary and secondary school children to get some basic information about this topic. The authors discuss the main challenges and opportunities in context with the usage of digital games as effective tools to create interest in Science and Technology. As a practical outcome of this discussion, the authors are presenting an original educational game for children Mystery of Electrical Engineering. The game offers a nice and playful environment and ensures quite an easy way how to familiarize young pupils with the world of electricity.**

I. INTRODUCTION

In a global view, electrical engineering has a key industrial position and an extraordinary strategic importance. This sector of industrial evolution, with its many subdisciplines e.g. power engineering or electronics, is considered as a driving force of today's modern civilization. It has not only a direct impact on the quality of life but also on the symbiosis of technology and nature. It is a continuous effort to improve environmental friendly solutions and to reduce the impact of technical production on nature and wildlife. Utilization of alternative energy sources, ecological elements, development of intelligent "smart" materials, devices, networks and even cities [1] is more and more significant.

The electrotechnical industry is particularly interested in highly qualified graduates who will be able to integrate as quickly as possible after graduation into the manufacturing and development processes of leading companies. Despite this trend, there is an decreasing interest of students in electrical engineering education at universities, which is the reason, why we need to find new motivational possibilities and promote these at secondary and primary schools. All these institutions are sources of young scientist who can contribute to our brighter future. Popularization of science with focus on the young generation is a possible solution of the present situation.

The absence of new, qualified experts who are capable to use new progressive technologies will be an important issue in the future.

Our young generation, described as digital natives [2], are growing up in a world of information and communication technologies (ICT), who at a young age are already familiar with the personal computer, web 2.0, the social network, mobile phones, tablets, video games and various gadgets. They have interest in interactivity rather than a passive way of entertainment, hence the differences in old fashioned education and gaming [3]. A good example on this is the Internet compared to television. Children nowadays are practically in a non - stop online contact, they have access to an immense amount of information from high quality to lowest possible even entirely inappropriate.

Modern information technology solutions and devices, that formed digital natives have also opened many possibilities in the field of education and the popularization of science and technology. Highly anticipated from these are educational games. It is a well-known fact that 75% of a "learning by doing" activity is basically knowledge earning. Interactivity in learning and teaching is the follower of a natural human feature, gamesomeness. It is both effective as well as popular. Interactive educational games are entertaining software solutions that involve several technologies, devices and approaches, interpreted as different gaming genres [4].

However, to ensure a that these games are used in a proper way, that fulfill an educational goal, it is necessary to develop and dedicate these to proper target groups and different age categories. In this practical example creators of educational games tried to connect the importance of future engineering education and the power if interactive games, the two important aspects that are crucial in the popularization of science and technology. Developers were focusing on the target group of primary and secondary school students and young pupils.

Why especially children? The answer is quite simple. This generation is more attached to computer games as others, motivated to play rather to learn the actual curriculum [5]. Young people in this age group are in a life stage, when they choose their future interest, the field in which they would like to study. Moreover, today's youth spends a lot of time on social networks, they are exchanging everyday experiences, information and knowledge. In fact, all these experiences are developing

youngsters' cognitive abilities, transforming their expectations from the virtual world, to the educational process itself. Old fashioned learning is not effectively motivating anymore. The standard and academic curriculum becomes a never-ending senseless and uninteresting knowledge base [6], creating a mismatch between formal education and the digital non-formal learning environment experienced outside of school [7]. The difference creates a really challenging task to create balanced educational games, both playable and knowledge oriented.

The aim of this paper is to discuss main challenges, roles and opportunities, related to the utilization of educational digital games anticipated as effective tools for the learning motivation of students in the field of science and technology. As a practical outcome of this article, we describe an original educational game developed for children.

II. GAMES OF ELECTRICAL ENGINEERING

Why is an educational game an excellent tool to ensure awareness about some of the basics of electrical engineering? To answer this question, we need to examine the following facts and aspects.

- Over the last years computer games are becoming more and more popular, not only in the entertainment but also in education. It is a perfect way of how to beat the students´ lack of interest. Kids simply love computer games.

- Nowadays children and young people prefer Internet as the dominant source of information, much more than the other ones.

- Games have a strong motivation power [8].

- Games can offer a nice and playful environment for children and an easy, interactive way how to familiarize them with new information, and the world of electrical engineering.

- Developers have an enormous palette of technologies and they can use and optimize these for various problematic and scenarios.

A. The Concept of Interactivity - Learning by Doing

To fulfill all the above described points, it can be really challenging. Among others the goal of an educational game must ensure an interactive solution and provide information to the target group in a playful way so, that the included knowledge is transferred with a high percentage. The player needs to be engaged, ready to take action whenever needed and being part of the story thereby increasing his/her interest. Although high amount of educational games is available, there is no standardized concept how to create them [9].

From a psychological point of view, it is a good idea to make the game as simple as possible so that the player is immediately able to understand what to do and react in a short period of time. It is not recommended to use too many text fields and input possibilities, long explanatory texts and too many options, which can give rise to uninterested as well as decrease in the length of time spent playing the game, and in the end a completely unfinished goal [10]. The problem is often associated with ambiguity and difficulty as well. It is important, that the game leads

the user to the end, fulfilling his expectations and the educational purpose.

The concept of educational games in our specific field requires clear and specific actions that the player must take to accomplish certain levels. Main idea is to familiarize the student with elementary facts they encounter in everyday life. Interactivity is therefore essential. This is achieved with various visual effects that keep the user in a constant focus helping him/her to handle the whole game, by various functional elements such as: suitable range of colours, highlighting visible objects that need to be handled, switched, moved, connected, dragged, animated [11], and dynamically changed during manipulation.

B. The Technology

Technology can have a crucial impact as well. The vast majority of educational games are distributed in the form of websites and can be categorized as browser games. This is a good option since it can be alternatively used in various gadgets browsers and different media. The advantage of this interface relies in a wide availability. The player just needs to own a personal computer and have an Internet connection, or in special cases a recommended updated of the internet browser installed. Browser-enabled games do not require any additional installation or purchase of installation media.

A front-end one-page web application is a proper technology base that is compatible with technologies such as HTML5, CSS, and JavaScript platforms. The composition of individual game elements can be developed and designed using the JavaScript framework AngluarJS 1.X. Interactive characters and elements are controllable with keyboard or mouse peripherals. The game can be realised as a two-dimensional platform where the animation works on the principle of rendering a given image from left to right, depending on the x-axis performed each time the image is downloaded and refreshed again.

C. Reusability and Requirements

Individual games were developed and implemented with collaboration of many bachelor students. Their different knowledge with various technologies ensured a wide variety of potential software solutions to use. The work was organized as individual or team projects. In an overall view, the games were developed with a highest degree of standardization as were possible, so further bachelor students can keep up and extend existing solutions.

Our interactive educational games were developed to meet the following requirements:

- Games are programmed using the paradigm of object-oriented programming.

- Games are freeware available as part of the popularization of science and technology.

- To ensure an interesting and interactive gameplay to educate the player in the field of electrotechnics.

- Storyline – every game has a story upon which it is based, and a story line that it follows.

- Games provide at least three levels, the difficulty of which increases linearly.

- Individual levels require some investigations leading to an eased understanding of the problematic

- Puzzles and games featured in "drag-and-drop" principles.

- Challenge/competition – might be against the game, against one's self, or against other players.

- Immersive graphical environment – the sensory representation of the experience layer of the game, including 2D/3D graphics, sound, and animation.

These projects were created with the focus on electrotechnical principles, however part of the solution can be reused in other fields as well. Reusability was also a driving factor in the realization. Four games have been created in accordance of the above described. The following titles were chosen: Mystery of Electrical Engineering, Secrets of electronics and photonics, From light bulb to the Internet and Secrets of electronics in the car. As an example of the final game the Mystery of Electrical Engineering will be described in more detail.

D. Collaboration and Background

The Institute of Electronics and Photonics in Slovak University of Technology in Bratislava has been developing e-learning projects with integration of interactive animations from the year 2001.

From 2008 it is in a close cooperation with the Institute of Power and Applied Electrical Engineering in Slovak University of Technology in Bratislava and with Department of Technical Education and Information Science, Faculty of Education of the Masaryk University.

This cooperation made possible to develop interesting and interactive projects in a wide technological range supported not only by technicians and developers but also by didactics of various fields.

Within the Grant No. 020STU-4/2015 of Cultural and Educational Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic "Interactive forms of support of the technical education in primary and secondary schools" we have created the education popularization e-learning materials. The access to these projects is free. The proposed grant is focused on increasing motivation and interest of students in their further studies mainly at secondary technical schools and universities. Furthermore, on development and implementation of progressive approaches such as e-learning, blended learning and hands on activities in teaching, education and extra-curriculum teaching at elementary and secondary schools.

The project also includes preparation, design and creation of a set education games about electrical engineering. These are made for primary and secondary school children. These games are free available on portal eLearn central URL http://uef.fei.stuba.sk/moodle/.

III. THE INTERACTIVE EDUCATIONAL GAME MYSTERY OF ELECTRICAL ENGINEERING

The game Mystery of Electrical Engineering (Fig. 1) is implemented as a two-dimensional platform game in which the main character jumps to various stages, collects objects, uses these from the inventory, and performs individual actions necessary to solve defined tasks [12].

Interactivity was designed in such a way that the player (Fig. 2) must perform tasks, solve puzzles perform movements, drag and drop actions in order to proceed to next levels.

The main story is placed in a city, hit by a storm causing a black out (Fig. 3). To accomplish the game the player must do its best to climb a high-power pillar, pick up insulators, fix the damage and light up the city again.

Figure 1. User´s view: The Interactive Educational Game "Mystery of Electrical Engineering" - Intro menu, in-game menu, ending menu

Figure 2. Sprite-sheet player

Figure 3. City blackout animation process

After starting the game, the opening animation shows the player's problem to solve - City blackout (Fig. 4). The aim of this animation is to introduce the player into the game and to describe the main problem and explain how to control the game. The player must investigate the problem and proceed to each section after performing tasks collecting artefacts that help him/her to understand principles of electricity.

The main character is prepared to repair the pillar by mini stages:

School - gaining certificate in First Aid, Work Safety, and Electrical Knowledge in the form of quizzes (Fig. 5). This certificate will allow the player to access the mini-level of Equipment: Clothes, Tools, Head Protection, Gloves, and Shoes (Fig. 6). The player must select all the appropriate items for the high-voltage pillar repairing.

In level 1 (Fig. 7), the player will see a list of tasks to perform. At this level, there are three obstacles to handle
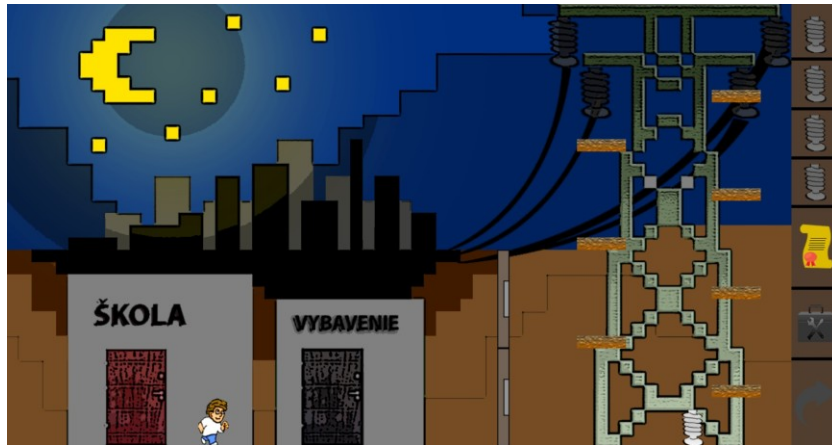
Figure 4.   Starting the game "Mystery of Electrical Engineering"
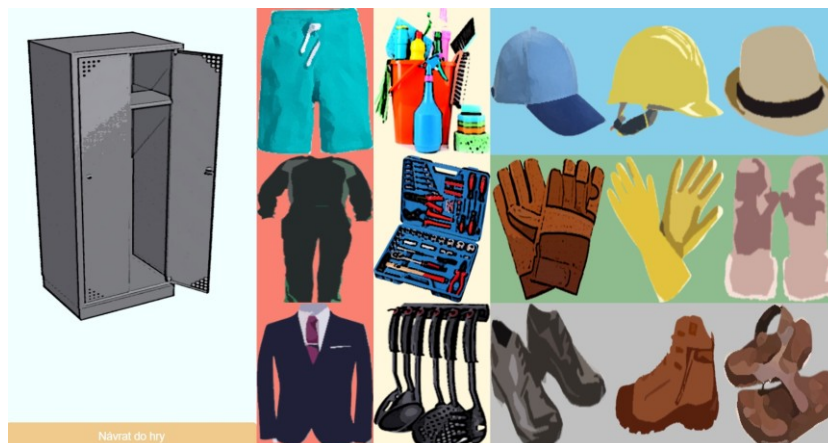

Figure 5.   School level - Quizzes

Figure 6.   Equipment level - "drag-and-drop"

water, electricity and a pit that prevent the player from getting an isolator. The player must first stop the rising water that must not touch the live part of a stripped driver. If the player succeeds the water will be drained in time, however a pit will remain. The player must figure out how to get to the insulator that is high on the lamp. He must use the ladder, which he takes and then places so that he can jump on to it and pick it up. The last obstacle, is the live wire without isolation which can be handled by

switching off the power supply through the circuit breaker.

The main goal of the second level (Fig. 8) is to repair a socket outlet, which is used for a switch opening the barrier behind which the insulator is located. The player has to avoid some water once again. The socket repairing is a mini level where a drag and drop motion is needed to properly connect the phase, neutral and protective wires in place.
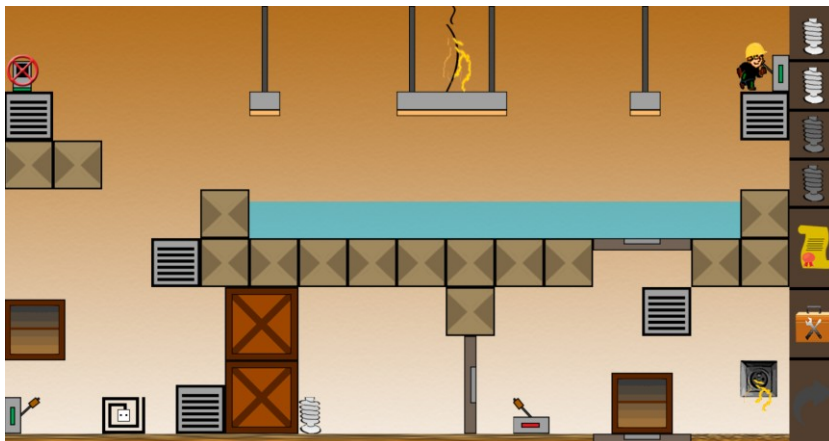

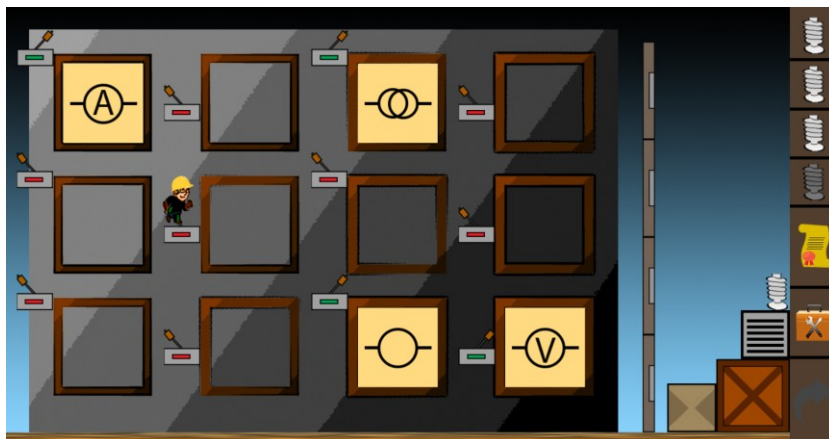Figure 7.   First level

Figure 8.   Second level

Figure 9.   Third level - logical puzzle game

The goal of the final level (Fig. 9) is to get the last insulator and illuminate the panel. This level is realized in the form of a logical puzzle game of electrical signs. The player must find a suitable pair of these to illuminate windows of a building. When the all pairs are found, the barrier is removed from the building and the player can take the last missing insulator. After all levels are finished the 3 insulators can be place on the pillar and the city is rescued. Closing animations appear (Fig. 1).

The interactive form of this game was tested by children of elementary schools. The project received a positive feedback and a good reaction, which encouraged us to continue in the development of more and complex and extended game

IV. CONCLUSION

Nowadays the term "digital game" is automatically connected to addiction, bad habits, obesity which can have a negative light to other potential utilisations of this promising media. If we are able to capture children´s attention and draw them into the story, we can use these sources as highly effective, modern and interactive ways of education and knowledge transfer. Children will get the required knowledge given by the syllabus in playful and natural form. This way the standard, of the uninteresting learning methods, can turn into an entertaining and interesting way of education.

This article focuses on some challenges and possible roles of digital games as effective educational tools to create interest of children in Science and Technology. A practical example was described that was designed and developed for young students of elementary schools in the light of the discussed aspects of educational games. This educational game "Mystery of Electrical Engineering" for children offers children a nice and playful environment and quite an easy way how to familiarize some basics of electrical engineering. The educational character and the importance of the game were achieved by an interactive content, both textual and visuals guides and story. The created game is fully functional, with the option of a global transition and extension, applicable to a similar type of interactive educational software, and is freely available to popularize science and technology on the eLearn Central Open Learning Portal, URL: http://uef.fei.stuba.sk/moodleopen/.

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Virtual Reality vs. Reality
in Engineering Education

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Abstract—**Virtual reality has become significantly popular in recent years. It is also widely used and more frequently implemented in education, training, and research. This article discusses the potential and the current state of virtual reality, and its tools in engineering education. The focus is put on some opportunities, challenges and dead ends of implementation faced by the authors. In this point of view, virtual reality is the future of creative learning, however it has its limits in terms of practical experiments, learning by doing, which is still more effective as virtual ones.**

I. INTRODUCTION

Merriam webster dictionary defines virtual reality (VR) as an artificial environment, that is experienced through sensory stimuli (such as visual and audio input) provided by a computer and in which the person's actions partially determines what happens in the environment [1]. Burdea and Coiffet [2] encompass the basic characteristics of virtual reality as the three 'I's of virtual reality, specifically immersion, interaction, and imagination. This is a VR triangle presented in Fig. 1. Immersion is achieved by removing as many real sensations as possible and replacing them with sensorial feedbacks provided by the virtual environment (VE). Interaction enables the end-user to change the state of the VE in real time. Imagination is needed to design a VE in order to make it credible and adapted to the target use case.

The phrase "virtual reality" was first formed in the mind of Jaron Lanier, during an intensive research period in 1987 [3]. Before this action in 1984, Jaron Lanier has set up the VPL Research (Visual Programming Language). This company was the pathfinder of virtual reality and 3D research, and sold the first VR gears, such as: data gloves, VR glasses, and later a complete data suit. A major cultural impact which brought the topic of virtual reality into mainstream had been evoked in 1999 by the cult film The Matrix [4].

Around this time the VR technology became very common, although this anticipation soon dropped by a yawning gap between technological limitations and public expectations. VR technology has been around with no significant achievement and acceptation in mainstream applications or commerce adaption [5].

Nowadays, virtual reality technology is dynamically evolving with the help of low-cost devices and the interest by large companies (Microsoft, Facebook, Sony, Google, NVidia, and HTC [6]) to invest in entertainment, communication and visualization. Generation of
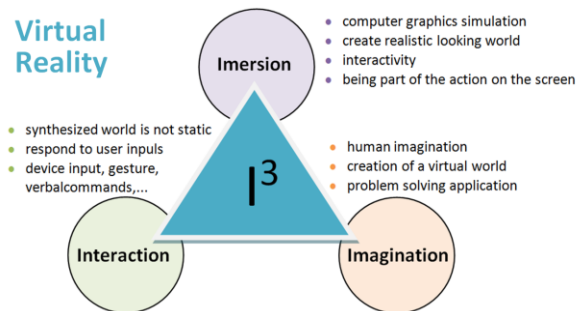
Figure 1. The three I's of Virtual Reality [2]: immersion, interaction and imagination

lightweight technologies are also considerable, hence the rise of smartphones having high-density displays and 3D graphic capabilities have practically enabled us to have personal VR devices. Sensors like depth cameras, different interfaces and motion controllers are already part of daily human computing tasks.

Current personal VR technologies tend to fall into one of three trends: computer peripherals, smartphone-based and self-contained headsets. These personal solutions were introduced since 2014, when Goolge released interim VR products such as the Google Cardboard, a DIY headset that is driven by a smartphone. This affordable, fun and simple system brought an immersive experience to everyone. 2014 was also the year when Facebook acquired Oculus Rift (a VR headset company) for $2 billion. This acquisition was a signal to other companies of the industry that virtual reality is promising to invest in the future [7].

Samsung had extended this concept further with Galaxy Gear, which is being mass produced and contains features such as gesture control. In 2015 YooTube introduced the possibility to upload 360° videos, while Facebook a year after builds its VR empire a 22,000 square-foot hardware lab. The following years Facebook will prototype its solar drones, Internet-beaming lasers, VR headsets, augmented reality devices and next-gen servers. In terms of 3D sound engineering Google released Omnitone, an open source 3D audio for web-based VR and launched the Daydream platform for high-quality mobile VR technologies. Daydream View powered and used by any Daydream-ready mobile phone is an easy-to-use and comfortable, headset designed to be adaptive as a choice in mind [8].

Year 2016 was a breakthrough of virtual reality technologies. Big names hit the marketplace in commercial production, hardware like the Oculus Rift, HTC Vive [9] and PlayStation VR all hit the marketplace,

which started a flood of content, clever implementations that had made early adopters to promote this exciting new technology. In the near term, all of the company focused on trying to bring in more developers, attract a larger audience and get more content for their systems.

It is also key reason that there has been an increasing interest in the utilization of virtual reality in education [10]. VR education solutions are able to empower students by primarily engaging with their subject through immersive interactive experiences. The virtual reality method gives opportunity to hinder memorization from the learning process. By transiting from the traditional approach, students are given the possibility to apply, analyze and evaluate their knowledge. This approach, improves the user's creativity, critical thinking, problem solving, decision-making, communication and teamwork.

In this paper, the authors discuss the current use of virtual reality tools and their potential in engineering education. The focus is put on some opportunities, challenges and dead ends of implementation.

II. BEST VIRTUAL REALITY HEADSETS

As we have discussed above, we have encountered virtual reality "explosion" over the last half year. In this year, 2017 there is a wide multiformity of VR headsets available.

Which is the most interesting VR headset out there?

For user money it's the best HTC Vive [11], for its use of room-scale tracking to offer gamers and users the freedom to walk around and interact in the virtual world like never before.

The Oculus Rift and HTC Vive headsets pack have dual OLED displays with a resolution of $1,080 \times 1,200$ per eye, both have a 90 Hz refresh rate and 110-degree field of view, and both need very similar PC requirements to run. In addition to the 37 sensors in the Vive headset, which provide a fluid and seamless motion, there is also a front-facing camera included. All these can make a VR environment of difference. HTC's cameras allow to make use of the Chaperone safety system. This technology is able cast a blue safety outline on walls and even objects when you move in a close distance. It can be even set as a Matrix-like look on all environmental obstacles at once [9]. The key to the HTC Vive's popularity is the Lighthouse room tracking solution, which enables the user to move around when the headset is on. Meanwhile, the Vive's Tracker tech is able to bring any real world object into the virtual image. The current generation of hardware has connected the user to a powerful PC via annoying cables. The Vive can also function in a wireless mode, thanks to the it's TPCast module, and even eye tracking is on its way. The VIVEPORT subscription service is also beneficial, which gets the user whole bunch of VR content for a monthly fee of $6.99.

VR has its bright future. The potential in this technology is anticipated by many-many start ups that were able to raise a huge amount of money, more than $100 million in funding and $1.46 billion in venture capital. According to Kota Ezawa, it is expected, that the VR market will grow to a $15.9 billion business 2019 [5]. This will have an impact on the network, hardware market, software and generated content will increase up to a $200 billion value by the year 2020 [5]. The user base explodes and numbers will grow rapidly. 2017 will witness a massive jump in user counts. From 2014 with around 200,000 to a projected 90 million in 2017. These numbers represent a 450% increase, from which around 10% of the 90 million will be probably gamers, while the rest around 23 million early adopters [12]. This indicates that the next few months will present the ideal opportunity to put new VR application into the hands of an engaged and motivated audience. One of the forecasts expects, that 500 million people will own a VR headset by the year 2025 [13].

There are various challenges to face along the path to a global mass adaption. BC analyst Mark Mahaney expects VR mass adaption will take place from 3 to 5 years from now [6]. Today the VR headset technologies require a vast of computing power, not to mention health and the factor of the outer environment Moreover a commercial setup remains expensive. Most of today's users remain largely gamers

Google hopes, that mass acceptance will come sooner as expected. The first-generation of Google Daydream View was announced on October 4, 2016, and has become more or less available to hundreds of millions of smartphone users [6].

III. THE BENEFITS OF VIRTUAL REALITY IN EDUCATION

VR solutions, starting from simple graphic applications made for entertainment and studies are now used more frequently in many professional fields [14, 15]. An important area of application has always been as a training possibility for real-life activities such as: job training, introducing audience to a new concept, gaining experience and practice. Simulations can provide trainings equal or nearly equal to real life practice, with reduced costs, greater safety, non devastating or demoralizing mistakes, not being damaging to our environment, and not capable to cause unintended capital damage and wasting materials [10]. These aspects show that, to use VR in education is cost sawing and a new effective way of learning. They include fact that it provides motivation; can more precisely illustrate processes, features and physical phenomena than other means, moreover it allows extreme close-up and distance object examination , showing the subject in a whole rather than a part, allows disabled persons to participate in different environments, experiments or when they are not able to do so otherwise. This possibility also gives the opportunity to view the presented subject in a new perspective, allows the learner to proceed and improve his/ her abilities through a new experience [16].

VR has it many benefits in government and military solutions as well. In 2014, the British government made an announcement, that it would incorporate the Oculus Rift technology into its trainings used by medical emergencies on the battlefield. Other military uses include e.g. simulations to treat improvised explosive devices [14]. VR gear simulations are used also by Astronauts and jet pilots. These are usually implemented in head-mounted displays that make possible to navigate and react to unexpected situations, before they actually fly a space shuttle or jet aircraft in real action [10].

VR training and assessment is more frequently used for 5 key fields: health care, industry, commercial training, gaming, rehabilitation and remote education such as

Massive Open Online Courses. Adaptation can be realized on five core VR technologies including haptic devices, adaptive content, stereo graphics, assessment and autonomous agents. Automation of virtual reality trainings can contribute to various procedures including remote and robotic assisted surgery, which can reduce injuries and improve accuracy of any procedure. Automated haptic interaction enables presence from a distance, virtually controlled interaction from either remote or simulated environments. Such automation and machine learning play a considerable role in providing a trainee-specific, adaptive and individual training content.

Rapid technical advances that would nowadays support more complex VR applications open new challenges. The interactions are associated with improved learning outcomes related to nontechnical skills in particular, communication, teamwork, and decision-making. The findings suggest that the VR method is applicable to various disciplines and may play a significant role in preparing students for practice and development of individual schema enabling transfer of learning of nontechnical skills to new situations.

VR in the classroom could mean virtual field trips, immersive games, and even utilization for children with special needs. The main focus is put on science centered subject that are hard to memorize and understand. These include anatomy, geography, astronomy etc. All these curricular subjects are considerably extended through interaction with 3D objects, living beings and environments [5]. VR modeling and architecture technologies are used to construct and examine architectural, engineering schema, models, recreations of historic or natural sites and other special renderings.

IV. Virtual Reality in Engineering Education

Engineering is a practicing profession. This profession devoted to harnessing and modifying the three fundamental resources that humankind has available for the creation of all technology: energy, materials, and information [17]. The overall goal of engineering education is to prepare students for the practice of engineering and, in particular, for the solution of forces and materials of nature.

Thus, from the earliest days of engineering education, instructional laboratories have been an essential part of undergraduate and graduate programs. Indeed, prior to the emphasis on engineering science, it could be said that most engineering instruction took place in the laboratory [18].

According to practicing engineers go to the development laboratory for two reasons [17]. First, they often need experimental data to guide them in designing and developing a product. The development laboratory is used to answer specific questions about nature that must be answered before a design and development process can continue. The second reason is to determine if a design performs as contemplated. Measurements of performance are compared to specifications, and these comparisons either demonstrate compliance or indicate where, if not how, changes need to be made.

What is the role of VR in the education of these engineers?

One of an interesting possibility is useful for architects e.g. Field Trips. These technologies enable students to virtually visit locations that they aren't able to examine physically. See technical solutions and realizations. While our community has long conducted virtual field trips using video technology virtual reality promises to enhance student engagement and outcomes through increased immersion [19].

Another really useful option is Training. It's well known that learning by doing (75%) is for many learners more sufficient as compared to just visual inputs (20%) or audio materials (10%). Virtual reality offers the users the chance to experience the action and process they are faced, whether it is a flying an airplane, or conducting technical measurements.

One of many challenges of particular applications is faced in the field of Design. One of the early uses is dated in the field of architecture. Being able to visit, examine and explore a building in a close up before any construction is an extraordinary useful approach. Nowadays the VR technology is anticipated in all technical fields.

VR has its potential also in Distance Learning. For example the Stanford School of business offerings a VR certificate program. In addition students and faculty at Penn State has illustrated how the implementation of virtual reality can improve study outcomes [19].

Probably the most important way how the VR technology is being used is collaboration. It has implications not only in the field of research, but practically in any other fields. Virtual reality is going to change the way how we cooperate over distance.

Interesting possibility is to utilize VR in Recruitment of future engineers. When choosing which university to attend, new joiners like to visit the campus to get a better feel and understanding of the institution itself. Some schools are already making this possible for students by offering virtual campus visits [14].

Most of the discussed possibilities can be implemented as a Virtual Lab. Benefits and Challenges Associated with Virtual Laboratories Solutions can be assessed as follows [17].

The benefits of virtual labs are discussed by both teachers and researchers in terms of convenience, flexibility and hands-on learning. The challenges to be faced by administrators include educator's preparation, changes in technology, software solutions and teacher's resistance. Other challenges faced by educators included the student's competency, failure to handle the equipment, lack of communication, adequate knowledge and training. Solutions offered by administrators included the following: to provide funding for training and technical resources. Teacher's solutions listed the collaboration with other educators and seminar leaders, training and knowledge transfers, arranging alternative plans, and the competencies of students. The considerations of development, planning and implementation of virtual labs, according to both administrators and seminar leaders included infrastructure, audience, student characteristics, qualifications, and mode of instruction [20].

Even the initial steps of development of a virtual laboratory may be expensive, there are cost saving benefits in the long term run. New cheaper equipment will be commercially available. This means that the developers are able to recoup their expenses after some time and should not be discouraged by initial costs.

Among many other options e.g. in the case of the utilization of dangerous and expensive materials and chemical solutions, using virtual labs prove to be safe, cost-saving options. Not to mention, that students are not exposed to real dangerous environments. In cases when too many participants are involved, virtual labs can be used to reduce overcrowding since students will be doing the labs at a location of their convenience.

A. The Model of Blending Virtual Labs with Physical Labs

Similarly as in e-learning, the model of connecting virtual labs with real ones should be considered in relation with the best model of enhanced education Blending Virtual and Physical Labs can, indeed, become beneficial for learners. The most effective way to assist students to learn the curriculum as effective as possible is to blend these two environments together. The research participants encouraged to use virtual labs prior to physical labs, which should ensure students to be at a higher level of understanding at the point once they enter the real lab environment. They have also considered the case when resources are limited, when expensive equipment are unavailable and materials for physical labs are not common, using virtual labs would reduce resources needed to establish physical labs. In other words, with the increasing number of publicly available electronic devices and those that will be introduced in the future, mixing virtual instruments with real labs may be beneficial and easier than currently thought.

In order to achieve success, a virtual lab needs to be interactive so that each concept is presented in form of exercises and laboratory tasks that are challenging and can enhance problem solving abilities of students. This satisfies the aspects of constructivism, since when students encounter difficulties, they will have to decide how to take action and find solutions.

It is very important, that if students want to achieve success in a virtual lab education, they have to accomplish certain prerequisites in advance to real life participating. These prerequisites should include technological background and competence, and academic skills in safety questions and measurements. If students are not proficient in all of these topics, their chance to be successful will be low [20].

Virtual Lab is a unique support, a practice for the real experiment. One it is not able to provide is the real experience. Example on this is sample preparation and contacting (Fig. 2) which is not possible to reproduce virtually, due to the need of fine movements and motoric functions that are important to handle in reality. It is therefore needed to consider the applications where VR

Figure 2. Real contact field in Physical Labs

can have effective solutions for engineering education.

Hypothetic virtual laboratory in clean rooms (Fig. 3) for the OLED growth is a great example of benefits and limitations of virtual reality in engineering education. In a real clean rooms laboratory, costs of devices, energy, materials and people is very high, skilled personnel is needed, view through the eye-slit does not provide any educational information, the entire process is very time consuming and only a certain number of people can be present in clean rooms before the ventilation is overloaded. Virtual reality can show the physical process, students and teacher do not have to worry about damaging the devices and destroying samples and many more experiments can be accomplished in shorter time. Creating the VR laboratory allows all the students to experience the clean rooms and if they are interested they can later choose an individual project that deals with device processing in the real clean rooms.

It is necessary to consider the utilization of the VR laboratory, because hardware and software requirements are still very high.

B. Summary of Virtual Reality in Engineering Education

Nowadays gap between public expectations and technological limitations of VR decreases. 3D visualization is used extensively in research and industry. VR and virtual world are gradually becoming an essential part of modern academic education and/or an achievable alternative in comparison to traditional learning, thanks to the rapid development of information technology and the VR hardware/gear. We can easily introduce VR in higher education, because our target groups will already be prepared. Future trends will bring VR applications to support every engineering education program. In our opinion visualization is essential in the learning process. In case of electronics and photonics VR can help students to understand physical principles of semiconductor materials and devices, functionality of circuits that are not visible. It can be used in places and situations where the actual reality is not able to provide further information about the object, when it is not accessible for students due to costs or dangerous environments.

VR has a major role to play in engineering education in the future. VR will change the way of education and training. Engineering education will benefit from it. Very important in our technological society is implementation of VR as one of several forms of technology enable us to educate tomorrow's technological elite.

V. VIRTUAL REALITY PROBLEMS

2016 was stated to be 'the year of VR', and that with a good reason. While 2015 experienced only a potential in two VR headsets entering the market, Samsung Gear and Google Cardboard, , last year welcomed the leading new joiners like HTC Vive and Oculus Rift and, as well as Google entering the race with Daydream View [21].

It is important not to forget that with above mentioned great VR opportunities there always come some disadvantages, dangers and risks. There had emerged stress or anxiety between people after use of in many occasions [22]. There are more of these as eyestrain, nausea or motion sickness. Last but not least we cannot forget maybe the biggest danger - loss of contact with real
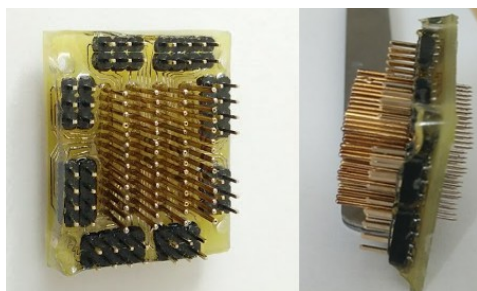
Figure 3. Clean rooms as Physical Labs

world. We have to learn from current situation - even though our technology is still limiting us, this problem appeared with social media or with normal video games.

Gaming and entertainment are only few reasons to use VR. Quality VR content is the gap in new utilizations. Publishers are already ready, creators not [23]. Possible heath issues are also subjects of many debates. VR sickness or cyber-sickness, is one of the side-effect experienced by some users. Symptoms are comparable to motion sickness, disorientation, nausea, pallor, sweating and headaches leading to vomiting [21]. It's widely discussed that this is related to a conflict within the biology of the brain. Our auditory and visual sensor inputs tell us that we are moving through a real space, while our inner ear is not able to detect the corresponding motion. Many these short-term side effects and problems have been reduced by adequate technological solutions and developments, which were introduced over the last few years and will continue refined as time rolls by. Among others, improved resolution and screen refreshing rates have had a positive impact together with proper game designs, when developers gained a deeper understanding of the conditions that make a stable VR experience [21].

Experiments of team Professor Mayank Mehta made possible to conclude, that VR activates less neurons as true reality. However other researchers think, that is too early to draw any final conclusions. Development, research is ongoing, and many studies are contributed on the topic, to define what impact this technology may have on the brain. At least this intimates the industry and researchers to take this issue serious enough to examine physical and mental health more cautiously [21].

A huge problem of VR can be social immobility with isolation and reclusive behavior of everyday users, that can even cause depression, suicide attempts and even virtual-world conflicts that are transformed into real-world violence.

VI.   Conclusion

Development of low-cost devices (Oculus Rift DK1), as well as the expanding interest of large electronic entertainment companies (Samsung, Microsoft, Sony) leads to commercialization of the VR technology. This has a primary affect on the virtual world and the utilization on VR in various disciplines, like higher education where it has a great potential.

The rising acceptance of virtual reality in the e-learning field brings new challenges of implementation, training and producing student-centered courses, which are automatically customized for individual student's needs. Thanks to all the sensors and hardware of VR, learners of kinesthetic, visual, and auditory modalities can benefit from virtual reality based education, and as a primary result of this to achieve higher levels of cognitive abilities.

VR education solutions directly engage with the subject matter through immersive interactive experiences, and empower students to learn by-doing. This transition from traditional memorization makes possible for students to be able to analyze, use evaluate and judge their acquired knowledge by problem solving, and communication. VR training based self-adaptive technologies help students to learn faster, decide better and remember longer.

Authors see virtual reality as the future of creative learning but also consider the other side, where virtual

reality is not able to substitute real experiments. Real learning by doing in many cases are still more suitable than virtual reality ones.

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Search using a swarm of unmanned aerial vehicles

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Abstract – **Unmanned aerial vehicles are becoming an effective platform to perform all kinds of civil missions nowadays. This paper focuses on path planning for multiple unmanned aerial vehicles devices performing search missions. This planning consists of several logical steps - first, an area must be split into smaller logical areas, then the search algorithm is selected, ground path is generated and transformed into aerial path. All these steps are described and the most common approaches are detailed. We also mention approaches to create network using drones to further optimize search procedure.**

Keywords-drone; robots; search; manet; fanet;

I. INTRODUCTION

Unmanned aerial vehicle (UAV), commonly known as "drone" is reusable, aerodynamic flying system without human pilot on board. It is also referred as Remotely Piloted Vehicle or Unmanned Aircraft [1].

Until 2010s UAVs were primarily used for military usage. First military use case was the invention of aerial torpedo - simple aircraft controlled by radio filled with explosives [2]. In the same time, UAVs started to be used for the reckoning of enemy infantry positions to gain tactical advantage. Modern reconnaissance UAVs are used for the same purpose but with much advanced technology able to gather much more information [3]. Another popular use case in the military is the usage of UAVs as practice targets [2]. The least popular but probably the most known usage of UAVs is using them as lethal weapons [4].

There are three classes of UAVs from the military point of view: pilotless target aircraft that are used for training purposes, nonlethal aircraft designed to gather intelligence, surveillance, and reconnaissance (ISR) data, and unmanned combat air vehicles that are designed to provide lethal ISR services [3].

Target aircrafts are often made from old aircrafts or they can be designed for this purpose. Since target UAVs have short lives, they should be more cost effective to use than using standard aircrafts.

Intelligence gathering UAVs are generally required to have a long range and long flight time. They can be used to flight over enemy territories so high flight altitude is necessary. They have to be controlled from safe distance and should be as manoeuvrable as possible. They can operate from different distances and have different shapes.

In the last years, UAVs found their way into the non-military sectors. The number of non-military UAVs is growing quickly. Usages include remote and inaccessible settings that would be challenging for pilots and aircrew or put them into risk [1]. On-board cameras are predisposition for usage in photography, TV and movies. Movies benefit greatly from this and UAV technology enabled the usage of aerial shots in the way that was not possible before and decrease expenses comparing to usage of helicopters [1].

Public safety is one of the main areas where UAVs can greatly help. They can be used to spot and follow criminals or detect potential dangers in the crowd. They can also be used for crime scene investigations, to evaluate training, or for border patrol missions [5], [6].

The advantage of flight height and relatively low maintenance costs can be used in mapping. UAVs provide here a level of insight that is invaluable to industries like agriculture, construction, mining, and land and resource management, or for gathering data for any area that needs to be looked at closely and often. UAVs can also be used to track building construction process, ease the process of inspection of bridges, infrastructure inspection for oil and gas pipes, electricity and telecommunication poles [5].

Increasingly popular usage is in the agriculture to monitor status of crops and use gathered information to increase the precision of treatments. This can be effectively combined with the information gathered from satellite maps [1], [7]. It is also possible to tell the status of crops more accurately and even use gathered data to place fertilizers more effectively [8].

UAVs can also be of use in emergency services and disaster recovery. They can be sent to hazardous area providing no risk for human personnel, used in search and rescue operations, used to deliver medications, or used to gain better overview of situation [5], [9].

Use cases mentioned above do not contain all usages of UAVs. They just help to describe the versatility of UAV technology and outline its usage.

The paper is organized into eight sections. "Area coverage" section introduces problems related to decomposition of area into smaller pieces. "Search algorithms" section lists algorithms used by ground robots to create path to effectively cover specified area, "Generating of ground path" section describes physical movement of robots over the path and "Aerial waypoints transformation" section describes physical ground path transformation into aerial path. Section networks using outline possibilities to create wireless network using UAV devices.

II.   AREA COVERAGE

Unmanned aerial vehicle missions often require covering certain area and performing specific action. When there are enough devices to cover the whole area at one time, devices are needed to take positions and hover. When there are not enough devices, area coverage algorithms need to be used. These algorithms can be divided into two groups - real-time algorithms that continuously cover the area and algorithms that need to circle the area at least once.

These algorithms are based on boustrophedon decomposition of target area into smaller areas. The reach of sensory equipment on a device determines the size of such smaller area called "cell". Therefore, when covering UAV device moves from the centre of one cell to the centre of another means both cells are covered. Cells are often represented as squares to simplify a process of area decomposition. Complete coverage is gained by finding a path in a graph that covers each node at least once. This problem is similar to "travelling salesman" problem [10], [11], [12].

In [11] Arkin and Hasin describe the usage of "covering salesman" problem that is a variation of travelling salesman problem where every node visited must be within specified covering distance of main graph nodes. It also demonstrates that this problem requires non-deterministic polynomial time to solve [14], [15].

The main goal of area coverage algorithms is to make the movement calculated by them as effective as possible. The effectivity can be achieved in completion time and the percentage of area covered. For UAV missions time is closely related to distance travelled and energy consumed. Huang et al. describe energy consumed in [16]. Total energy consumed is

$$E = E_L + E_T$$

where E is an energy consumed by device, E_L is an energy consumed during the linear movement and E_T is an energy consumed during turning. Energy spent on linear movement can be decomposed into

$$E_L = F_L \frac{A}{W}$$

where F_L is a force needed to move device along the straight line, A is a size of an area device have to search and W is a width of a cell device can cover from one position. $\frac{A}{W}$ equals to linear distance a device must travel.

$$E_T = D \frac{E_{oT}}{W}$$

represents energy consumed by all turns combined where D is a span of a region in direction and E_{oT} is an energy consumed at each turn. Combining these equations provides us with

$$E = F_L \frac{A}{W} + D \frac{E_{oT}}{W}$$

where A, W, F_L and E_{oT} are variables we are unable to change and therefore an algorithm must minimize a span direction to minimize an energy consumed. This can be achieved by minimizing of a count turns performed [16].

Three path-planning algorithms based on spanning tree coverage (STC) algorithm are presented in [17]. On-line spanning STC does not know environment before search agents are launched and therefore a spanning tree is created "on-the-fly". Off-line STC must have an a priori knowledge of an environment and therefore spanning tree can be constructed before search agents are launched [17]. Ant-like STC marks visited cells, often on physical or chemical basis. This is hardly usable on UAV devices. All these algorithms based on basic STC algorithm tend to form a Hamiltonian cycle – a path along the graph where every cell is visited exactly once. Therefore, a coverage is complete and non-repetitive [14].

Apart from time and energy effectiveness of area coverage, coverage completeness is also one of the most important parameters. Area coverage algorithms mainly focus either on time effectiveness or on robustness when using multiple search agents. STC algorithm based approaches are highly focused on non-redundant coverage. When any search agent malfunctions, part of target area remains uncovered. This can be eliminated for example by shared memory, redundant path coverage or error reporting/detection. Shared memory requires constant communication that can be quite problematic if UAVs are used. They can fly too far from each other to communicate directly. Redundant path coverage reduces time effectiveness of area coverage process but guarantees completeness if a single search agent malfunctions. Error reporting maintains completeness but may require communication that presents possible problem. Error detection can be performed either by devices if communication is present, by central control point if present or by personnel on the ground. If the malfunction is detected and no redundancy is available, coverage mission must be replanned for every search agent.

A.   Area decomposition

Coverage path planning is the process of determining the path that a search agent, in our case UAV, must take to pass every point in an environment. Probably the most popular way in a robotics is boustrophedon cellular decomposition. Exact cellular decomposition breaks area into smaller cells. Each cell is covered in simple back and forth motions. When all cells are covered, whole area is covered. This assumption simplifies the area coverage process into the process of finding the shortest exhaustive path in the graph with represented adjacency relationships [10].

Some algorithms also need to create a Hamiltonian circuit, also called Hamilton cycle, which is a graph cycle through a graph that visits each node exactly once.

Figure 1.   Cellular decomposition approaches [14]

There are coverage algorithm approaches with cellular decompositions divided into three categories - approximate, semi-approximate and exact. Approximate area decomposition shown on the left part of the Figure 1 shows us that all cells are of the same shape and size. Cells containing obstacles or areas outside target area are not processed. Semi-approximate area decomposition shown in the centre of the figure slices target area into strips of constant width. This increases completeness of area coverage since partially unsuitable cells are not ignored. Both these approaches have low memory requirements on search agents. Exact cellular decomposition splits target area into several smaller non-intersecting areas with no space ignored. This can be seen on right part of Figure 1 [14], [18].

III. SEARCH ALGORITHMS

There are a lot of search algorithms to be used for ground robots but only few of them are suitable for cooperative search or aerial search.

A. Real-time algorithms

This type of algorithms is used to provide continuous movement over pre-defined pattern. After the movement is completed, it continues and makes another cycle. An area to be covered is represented by oriented graph and there is need to use shared memory when using multiple devices in the most cases [19].

1) Random Walk

This is the simplest algorithm without any real decision logic. It uses random direction decision after each step it takes. Statistically it covers every cell evenly when infinity cell movements are taken.

2) Edge Counting

This kind of algorithm counts how many times was each edge in oriented graph used. Every decision and usage of edge increments counter. Decision is based on the lowest counter number on edges from current node. This algorithm is good to be used with multiple robots since decisions are based on history.

3) Node Count

More effective evolution of Edge counting algorithm with similar logic with the difference that node traversals are counted instead of edge traversals. When there are multiple next-hop node options with equal counter count, decision is made by random choice out of them.

4) Learning Real-Time A* (LRTA*)

This algorithm is based on Node Count, but looks one step ahead into the future when considering next step. It is one of the most popular algorithms to be used with single-robot area coverage.

5) PatrolGRAPH*

Algorithm similar to Edge counting algorithm that is effectively usable with multiple robots. Total count of traversals from one node to another is counted and the next step is taken based on the probability parameter on next node visit. All probabilities make together transition probability matrix that is counted before the main area coverage process is started. This matrix serves as a path optimization. When the transition probability matrix is not calculated, but filled with even values, time needed to complete the area coverage is increased.

B. Spanning tree algorithms

This type of algorithms is initially more computationally difficult than previous approach but the oriented graph with multiple smaller trees needs to be computed only once. Advantage when compared to real-time algorithms is its lack of need for shared memory. This makes every operating device autonomous but they need to be synchronized from time to time to let know others or central station of their current search status. If the system was not synchronized, device failure would mean its previous results would be lost or at least the area would need to be covered again [20].

Zheng et al. evaluate the usage of STC algorithms for multiple search agents and introduce multi-robots forest coverage algorithm in [21]. They also compare this approach to the usage of a single search agent using STC algorithm.

1) Spanning Tree Coverage (STC)

The principle of the algorithm is to break the whole usable area into large square cells containing four smaller cells and create a minimal spanning tree of the graph whose nodes are the large cells and whose edges connect adjacent unblocked large cells. Robot moves in Hamiltonian cycle to cover the whole tree. This algorithm provides the most efficient way for a single robot to cover a specified area - it solves the single-robot coverage problem in polynomial time. When using multiple robots, each robot has its associated zone or several zones that it must cover and does not cooperate with others.

2) Multi-Robot Spanning Tree Coverage (MSTC)

A single spanning tree is created out of whole oriented graph representing the area to be covered. Multiple robots are evenly distributed in a way that they can together move in a Hamiltonian cycle in graph. Every robot has its part that it must cover.

3) Multi-Robot Forest Coverage (MFC)

This is a heuristic method significantly enhancing MSTC algorithm. It is based on an algorithm for finding tree cover with trees of balanced weight, one for each robot. Results of this algorithm are significantly better in most cases when compared to MSTC and are the same in worst-case scenario. The additional upside of using this algorithm is that robots tend to return close to their starting position. This is a great benefit when using UAVs.

C. Conclusion

Depending on a requested mission type, different algorithms are optimal to be used with several UAV devices. When the mission is continuous and the area needs to be covered several times, PatrolGRAPH* is a good choice. If the mission requires covering the area exactly one time, Multi-Robot Forest Coverage algorithm is a good choice. They both perform well when used with several cooperating devices.

IV. GENERATING OF GROUND PATH

Ground path consists of a set of waypoints a search agent must pass in specified order to complete its mission.
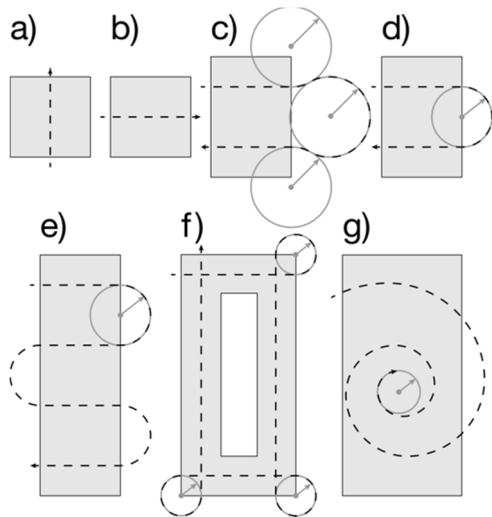
Figure 2.   Ground path movement patterns

It is based on graph algorithms like the ones from previous chapter. The difference between a path in graph and ground path is the transformation from graph nodes to real-life path.

Several movement patterns can be used to transform graph path into real one. They reflect movement possibilities of a ground robot. These patterns can be seen on Figure 2.

Basic ones as described in [14] are one-pass movement pattern that can be seen in a Figure 2 a) and b). They represent horizontal and vertical movement in a graph respectively. UAV traverses a cell in a single direction, covers it completely and moves to another cell. Two-pass movement pattern shown on figure parts c) and d) is used when a cell is wider than a range of sensory equipment range but not more than two times wider. Figure part c) shows a UAV complete turn when a turning diameter is greater than a sensory range diameter. Part d) shows complete turn with minimal turning diameter smaller or equal to sensory range diameter. The lawnmower movement pattern shown on part e) is a back and forth movement to cover an area by the simplest way possible. It is closely related to two-pass pattern but suitable for a larger area. The perimeter movement pattern shown on part f) follows the inner circumference of a target area. The spiral movement pattern shown on part g), as indicated by the name, uses a search agent in a way that they start from an initial starting point and circles in a spiral, continuously reducing diameter, and finishes when a mission is finished or when a movement radius is too tight to perform.

V.   AERIAL WAYPOINTS TRANSFORMATION

This process transforms a ground path generated from a graph into a real path UAV will take. It must consider UAV device and sensory equipment constraints like a roll of a device and related change of equipment angle relative to ground when changing direction and non-linear coverage pattern. Therefore, a UAV will go over slightly different ground-relative path when compared to calculated ground path. Centre point of its sensory equipment coverage should point along the ground path [14].
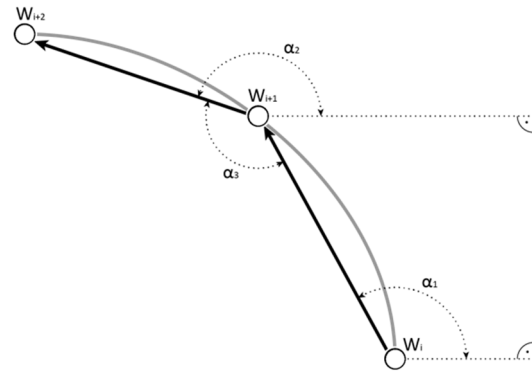

Figure 3.   Three waypoints turning movement

Calculation of a single aerial waypoint according to [12] is performed by calculating the yaw, pitch and roll rotation matrices for sensory equipment and yaw, pitch and roll rotation matrices for UAV device.

To find an aerial waypoint, sensory equipment must be rotated and translated so that sensory imaging centre falls on a desired ground path.

To calculate an aerial path instead of single aerial waypoint, multiple waypoint calculations are needed. To calculate a single path, starting and ending waypoints are needed. However, to calculate a turn, at least three waypoints are needs, four or more to optimize a path.

Turning calculation is performed using three waypoints as seen on Figure 3. If four waypoints are used for a single turning operation, they are split into two overlapping sets of three.

Turning equations according to Gabriely and Rimon in [14] find angles α_1, α_2 and α_3 that signalize a direction and sharpness of a turn and we assume that all these angles are valued between 0 and 2π, including both limiting values. If the resulting angle α_3 is $0 < \alpha_3 < \pi$, UAV device is performing left turn. If it is $\pi < \alpha_3 < 2\pi$, UAV device is performing a right turn. If the angle is equal to π, all three waypoints are on a single line and UAV device is heading forwards without changing directions.

If the direction between two following waypoints is greater than UAV device turning radius, it is considered a simple turn that can be performed by three waypoints, otherwise wider turn in opposite direction and resulting additional waypoints are needed.

VI.   NETWORKS USING UAVS

If UAVs need to share search results among themselves or to synchronize their search algorithms, wireless network consisting of UAVs is necessary. In the following section, we describe the types of wireless networks to be used with UAV devices as network nodes.

A. Infrastructured wireless network

Wireless network infrastructure consists of base stations connected by cables or wirelessly and form the backbone of local area network. This is the most widely used type of wireless networks in buildings and public places. Base stations are usually connected to the Internet and serve as access points to the network. Endpoint users are connected to one base station at a time and need to

reassociate to another one when the signal is low. Network using one base station is called Base Service Set (BSS) and network using several base stations is called Extended Base Service Set (EBSS). Reassociation in EBSS is done using handoffs. Infrastructure wireless network use one node connected to the Internet as gateway. It is connected using the cable in most cases [22].

This type of network is not usable by UAVs in the most use cases. The only set of use cases where infrastructure wireless network is usable as a backbone for a flock of UAVs is when they are to be operated in the same area repeatedly. It limits the possibilities of UAV devices able to fly greater distances than standard Wi-Fi range.

B. Infrastructureless network (Ad Hoc)

Infrastructureless wireless networks, commonly known as Ad Hoc networks, are made of nodes that are not configured in fixed formation but can be dynamic and can function as endpoints and routers at the same time. Ad Hoc networks use different routing protocols that react to events happening in the network and are able to reconfigure the network automatically at any time [22]. This kind of network can be connected to larger network like the Internet but can consist of two endpoints communicating with each other as well.

Ad Hoc networks can be also called self-healing networks [23]. Every node in a network must be able to continuously search for neighbouring nodes, determine the optimal path to the other parts of a network and automatically try to "heal" communication gaps after one or several of nodes disconnected from the network or repositioned themselves. Self-healing techniques try to balance the reliability, assurance and performance [24]. Traditional techniques try to identify and eliminate the root cause of the fault. Self-healing networks change their data paths so they can resume their functioning [24]. This is very important for UAV devices that have very limited uptime and therefore the network needs to be reconfigured quite often.

Typical problems of ad hoc wireless networks are high power consumption of communicating nodes, relatively low bandwidth between nodes and high error rates in communication [22].

C. Mobile Ad Hoc Network (MANET)

MANETs are the special use case of Ad Hoc networks. They consist of multiple wireless mobile hosts without any centralized infrastructure or centralized administration. MANETs are self-organizing and self-configuring multi-hop networks, structure of which changes dynamically over time [25].

A routing procedure is always needed to find a path from the source to the destination since the network changes continually. To help mitigate this challenge, network-wide broadcasting is used. It provides route establishment and control functionality for both broadcast and unicast routing [25].

The specialty of MANET is that the nodes are moving or at least are able to move. This makes usage of traditional routing or switching concepts impossible. The principle of MANET routing is the usage of hosts as communication

nodes. Different number of hosts based on quality and actual topology of network forwards traffic from other nodes to another part of network. When the nodes move enough to be of immediate range of communication, the link is lost and it is necessary to determine new route [26]. This causes the process of network convergence and new route(s) are created in the network.

D. Vehicular Ad Hoc Network (VANET)

Vehicular Ad Hoc Network (VANET) has evolved from MANET network when the growing number of wireless devices became able to be used in vehicles. These include remote keyless car opening, smartphones, tablets, notebooks and many more. This situation evolved into the need for vehicle-to-vehicle communication to improve road safety, traffic efficiency and comfort for the driver and passengers. Another increasingly important part of VANET communication is Vehicle-to-Roadside and Vehicle-to-Infrastructure communication. This can lead to revolution in Intelligent Transportation Systems [27].

VANET can be used for many safety and non-safety applications like traffic jam warning, automatic toll paying, enhanced navigation, and collision prediction [27], [28]. To enable some of these functions, vehicle must be equipped with GPS or DGPS receiver [27].

There are three communication types in VANETs – inter-vehicle, vehicle-to-roadside and routing-based communications. All the types require being able to push information both directions quickly and effectively in unreliable environment [27].

E. Flying ad hoc network (FANET)

Flying ad hoc network is a special type of VANET network but it does not fully match its characteristics [29].

FANET is a network of UAV devices that is highly mobile with extended operational range. Comparing to usage of single UAV, we gain the improved speed in the missions like reconnaissance, surveillance or search and rescue. It is also more cost effective to acquire and maintain multiple relatively cheap devices than extremely expensive one. Usage of multiple UAVs also increases fault tolerance of a network in the means of device failure [29].

Routing in FANET network is a challenge because of its quickly changing node positions and limited information about network. Two possible communication types can happen in FANET – UAV-to-UAV communication is in-air communication that happens between single devices and UAV-to-Infrastructure between airborne device and ground infrastructure. UAV-to-UAV can be used to synchronize information with neighbouring nodes or to cooperate on mission fulfilment. It can be direct or multi-hop communication. UAV-to-Infrastructure communication can happen between UAV and infrastructure like ground station, satellite, ship, etc. This can also be a challenge [29].

VII. CONCLUSION AND FUTURE WORK

Depending on a requested mission type, different algorithms are optimal to be used with several UAV devices. When the mission is continuous and the area needs to be covered several times, PatrolGRAPH* is a good

choice. If the mission requires covering the area exactly one time, Multi-Robot Forest Coverage algorithm is a good choice. They both perform well when used with several cooperating devices. Other search algorithms we mentioned are either more suitable for single UAV search or are not well suited for aerial search.

Our future work will include real tests of suitability of algorithms mentioned. Simulator to perform this is currently being developed under our supervision.

We will also focus on interconnecting multiple UAVs using FANET network to obtain fully functional swarm of drones that autonomously search specified area and share information about searched area.

VIII. ACKNOWLEDGEMENT

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Sage Math for education and research

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Abstract—**Sage Math is a complex system that can be applied to perform complicated calculations but can be also used in education. This contribution describes how and in what areas the system can be used in general. In addition, we describe our experiences with this system in the following areas:**

- **Subject teaching – in local network**
- **Elaboration of diploma thesis – in local computer**
- **Research and publishing – in Cloud**
- **Simple calculations in Sage Math Cell server**

Keywords: **Sage Math, Python, CoCalc, online computation environment, interactive web page.**

I. INTRODUCTION

Sage Math is a free open-source mathematics software system licensed under the GPL, see [7]. This system can be applied in different areas of research. The book [1] provides examples of applications for the following areas: Microeconomics, Biology, Chemistry, Physics, Industrial optimization, Cryptology, Pure Mathematics and Electrical Engineering.

Sage Math can be used in a variety of ways. It can be applied on a local computer, in a local network and also in the Cloud. In the Cloud, Sage Math called CoCalc [6] can already function as a complex eLearning system. CoCalc has a collaborative environment for teaching and for research collaboration. Moreover, the system has an online computing environment. Note, the vast majority of complex eLearning systems do not have such online computing environment.

The main purpose of this contribution is to describe our experience with Sage Math in education and research.

II. SAGE MATH IN LOCAL COMPUTER - A MONTE CARLO METHOD

The first way to use Sage Math is to use the system on a local computer. In this case, it is necessary to install the system. The binaries can be found on the official Sage Math website [7]. The Windows machines need to install a Virtual Machine - Oracle VM VirtualBox. Detailed installation steps can be found on the web page: http://wiki.sagemath.org/SageAppliance.

We used this method to create a diploma thesis [5]. The work deals with a parallel programming. Note, Sage Math 7.0 and higher versions support parallel programming. For parallel programming techniques, we were trying to do a simple example of the method of Monte Carlo. The
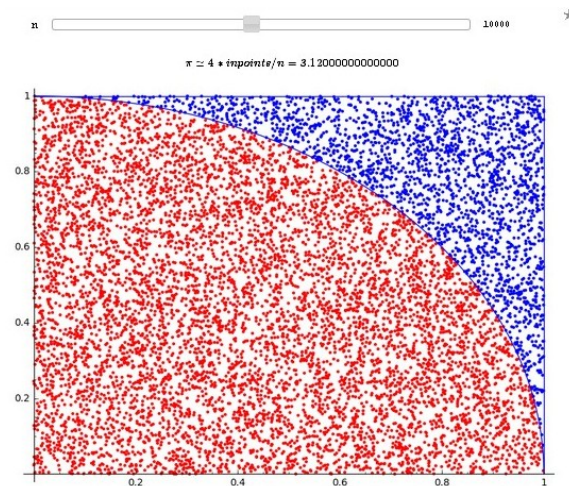

Figure 1.   A Monte Carlo method

principle of the method is to generate a big number of random points in a unit circle. These points are used to estimate the π number, see Fig 1.

The Sage Math source code of this method is located on the interactive web page:

http://people.tuke.sk/peter.szabo/SageMath_Monte_Carlo.html.

Sage Math codes written in Python can be run on the SageCell server, see. https://sagecell.sagemath.org/.

SageCell server windows can be embedded in the web page and we can be created an interactive webpage that enables Sage Math code execution [1].

III. WORKING ON THE LOCAL NETWORK – NUMERICAL MATHEMATICS

On the local computer, there is not allowed effective collaboration between teachers and students. In the subject Numerical mathematics, we used the system on the local network. In this case, the teacher, administrator Sage Math, and students logged on to the Windows server where the Sage Math was running.

It was possible to log on to local server using an Internet interface (http://localhost:8000 /, where 8000 - is an adjustable communication port). It was necessary to create accounts for students and define the conditions for the file sharing. The main advantage of such a system is that the teacher can
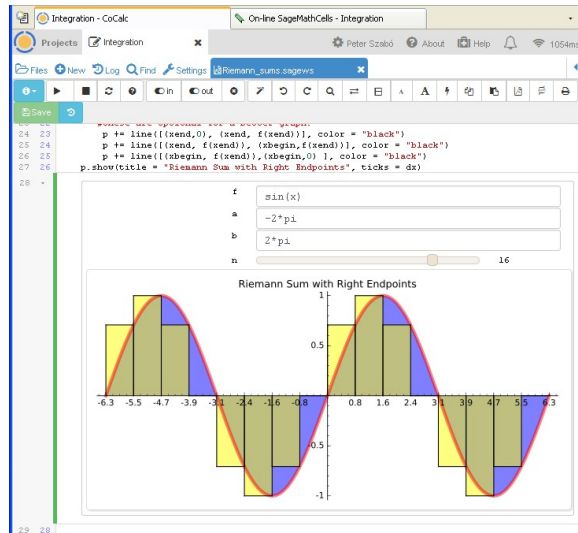
Figure 2.   Riemann Sums in Sage Math

monitor exactly every work of the students. The disadvantage is having an administrative part eLearning. This part contains basic information about course, such as syllabus, references, applied technologies, readings and exercises, homework, tasks, and assessment of students.

For the administrative part of the course we used an open-source learning platform Moodle, see https://moodle.org/.

The Sage Math part was the computation environment of course. Some examples of course, such as *Riemann Sums* (see. Fig. 2.) and *Trapezoidal Rule for Numerical Integration* can be found on the interactive web page: http://people.tuke.sk/peter.szabo/SageMathCell_MatII.html

These examples were created on the basis of the book [2].

IV.   COCALC, WORKING IN THE CLOUD – RESEARCH COLLABORATION

Sage Math is also a part of the cloud CoCalc [6]. This cloud has an online computing and a collaboration environment. There is no need to install and run the software when applying this technology. Just have an account and after logging in, it's already possible to solve projects. Collaboration environment provides tools for teaching, for project solving and project collaboration.

We tried cooperation in this system during the creation of an article [4]. This work contains executable source codes, a mathematical software, for the article "Goldbach's conjecture in max-algebra" published in the journal Computational Management Science [3]. Source codes can be applied in the system Sage Math. These codes, written in Python, allow us to study max-algebraic version of Goldbach's conjecture and work numerically with individual objects and algorithms of the article. To solve such problem in CoCalc, we needed to create a project. Our project included two programs:

The *Random Triangular Toeplitz Matrix Generator* (RTMG) program is designed to generate special input vectors, matrices.

Figure 3.   An iterative algorithm

The program *Data Structures, Computations and Algorithms* (DSCA) which loads input vectors and input matrices created by the RTMG. The program computes graphs, paths, partitions and other mathematical objects and executes algorithm from the Fig. 3.

In addition, the project includes two solvers, collaborators and many inputs, output files. Collaborators must have an account in the system. Each account holder can invite another CoCalc user to collaborate. This is the basic principle of cooperation in the system.

The development environment of CoCalc and a part of source code of program RTMG are shown in Fig 4.

In cooperation environment, CoCalc also provides creating a course, assign students to the course, create assignments and distribute them to all students, collect and grade assignments. Unfortunately, this is already a paid part of the system.
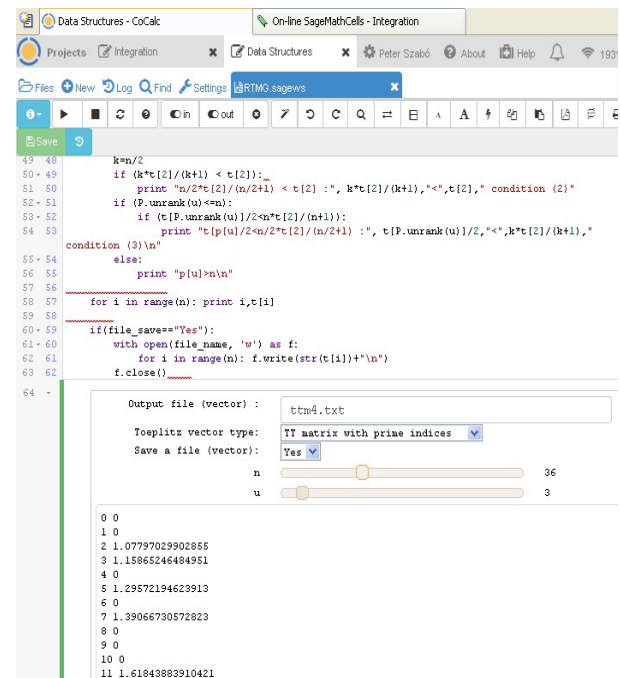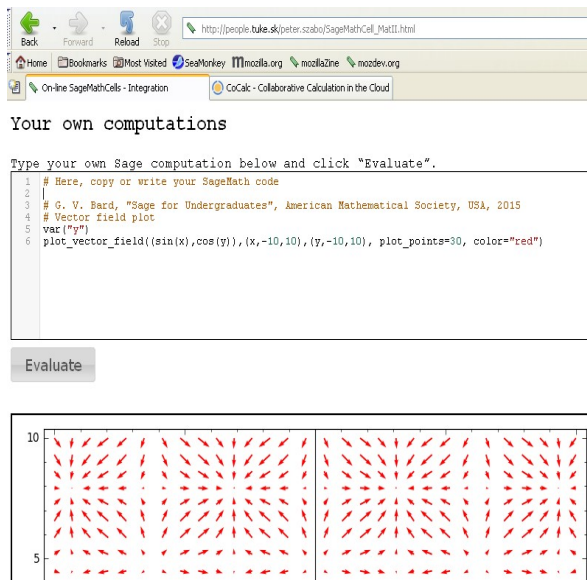

Figure 4.   A source code in CoCalc

Figure 5.   A Sage Math Cell example

V.   SAGE MATH CELL SERVER − ELECTRICAL FIELD VECTOR − A MINI PROJECT

Sometimes, we only need to make a simple calculation. When the Internet connection is available, we can do this by using the Sage Math Cell server. An example of such a calculation is the Electric Field Vector plot from the book [1].

When we want to draw an electrical vector field given by a function

$$f(x,y)=(\sin(x),\cos(y))^T$$

just write the following code into the Sage Math Cell server:

```
var("y")
plot_vector_field((sin(x),cos(y)),(x,-
10,10),(y,-10,10), plot_points=30)
```

and then run the code (button Evaluate). We can see execution code and its output in the Fig. 5.

For eLearning projects with simple calculations, it is possible to apply Sage Math Cell server or interactive web pages for online computing and e.g. Moodle for course administration. Such application will show in the next chapter.

VI.   SEMINAR IN THE CLOUD

In this example, Sage Math is used as an assistive technology in mathematics teaching. We will use the Sage Math Cell server to draw basic mathematical

objects, to solve a system of equations, to count limits, derivations, and integrates.

The outputs of this system are used to control computations and to visualize individual objects. These outputs do not replace the analytical solutions of the individual tasks only help to better understand individual mathematical objects, processes, and algorithms.

We will also apply another information technology - OneDrive. This is a Microsoft's Cloud Computing solution. Every user of Windows 8 - 10 and above can use this technology. It is a data extension of a system into which data can be stored. Such data extension only works when an Internet connection is available.The size of such a data extension is 5 gigabytes - which is free. Each user of the operating system Windows has such a Cloud, OneDrive. For a fee, it can be extended to several terabytes. That is Cloud OneDrive for Business. For our project, we only use a personal teacher's Cloud OneDrive. Here are stored files related to the subject. OneDrive has many interesting features, it is possible to apply the MS Office online or make online notes or implement the system on mobile devices.

A.   Mathematical Seminar in the Cloud with Sage Math

Our lectures, exercises, and seminars are available for our basic course in Mathematics. This course is also supported by the Moodle - eLearning system, where study materials such as topics, lectures, a database of exercises, study literature and other static content are placed. The Seminar is also supported by Sage Math, so students have access to the Cloud. Here are placed source codes, which are used to create interactive content.

OneDrive Cloud link:

https://1drv.ms/f/s!AvpDyUNjSUjBhodHE_o9m-dn_gl8cw

Once this link is opened, students can choose a topic that they need in their helpful, interactive materials, see Fig. [6]. After opening the directory of the topic, it is possible to open a specific help file. Let's give an example of *drawing elementary functions at intervals [a, b]*. The Sage Math source code for drawing elementary functions:

```
# Drawing elementary functions at [a,b] -
Sage Math 8.0
#
# Elementary functions:
# f(x)=ux+v - line (polynomial of first
degree)
# f(x)=px^2 + qx + r - quadratic function
(second order polynomial)
# f(x)=abs(x) - absolute value function
# f(x)= sqrt(x) - the square root
# f(x)= 2^x - exponential function
# f(x)= log(x) - logarithmic function
# f(x)= sin(x), cos(x) - trigonometric
functions
```

```
##########################################
# September 26, 2017 P.Szabó

@interact
def funkcie(
    f = input_box(default = x^3-3*x^2+2*x) ,
    a = input_box(default =  0) ,
    b = input_box(default = 2),
      auto_update=false):

    f(x)=f

    #plot the function f(x) on [a,b]
    p = plot(f, x, a,b, color = "blue",
    thickness = 2, alpha = 0.9, fillcolor =
    "red", fill = false)

    p.show()
```

Now, it is necessary to run the Sage Math Cell server as in the previous chapter. Then, copy the source code into the Sage Math Cell box and run the program after clicking on Evaluation button. The system will draw a given elementary function at a given interval. Using outputs, it is possible to show and explain some basic concepts of this topic as the domain of the function, zero points, asymptotes, periodic function, even or odd function, function continuity or discontinuity points.

Elementary functions and intervals can be modified and their graph draws interactively. The source code of the program can also be modified.
It is also possible to learn some basic, general programming techniques. In the source code, the *auto_update = false* command means that after updating inputs (elementary functions, intervals), it is possible to run the interactive page update.
The main added value of this method is the practical work with mathematical objects.
This topic and chapter is just one simple example of a Sage Math Cell server application.

This approach can also be applied to projects that need simple and more complex computations. At the same time, it is an example of Sage Math Cell server collaboration with external Cloud Computing.
This chapter was developed as a study for the possible application of the project in acknowledgement.

VII CONCLUSION

For the purpose of complex eLearning, Sage Math is a suitable system for technological subjects that apply mathematics, algorithms and computations (mathematics, physics, programming, electro-engineering, etc.).
In the Cloud, the advantage of the system is that it also provides an online computing environment and collaboration environment that allows a course
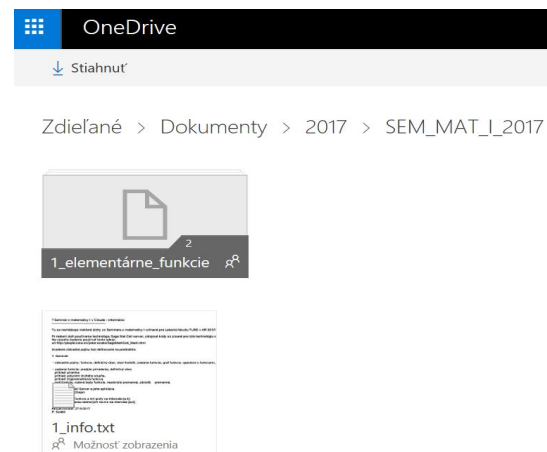

Figure 6. Cloud OneDrive with Sage Math

management, the assignments, control, and evaluation of all the tasks and students. Another advantage is that nothing is required to install on this system, just use it. The disadvantage is that the teaching part is for a fee.

Scientific cooperation part of the system can be used free of charge but with limitations, see [6].

If you want to use Sage Math for teaching, as an online computing management, on a local network as mentioned in Chapter III, so for course management, another eLearning system is needed. In this case, the administration of the courses is more demanding.

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Computer-aided education and evaluation of student exam tasks from MS Excel

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Abstract— The MS Office suite is currently one of the most used software. Perfect mastery of the work with its components, especially with the MS Word text editor and the MS Excel spreadsheet has become a virtually indispensable requirement in every profession where personal computers are used. Operating numerous, more complex functions, for example MS Excel, is necessary for efficient and fast work with spreadsheets, and yet for many users these features are literally "scary". Even though MS Excel has already been taught at secondary schools, its level of mastery by students is inadequate for practice, and therefore it becomes a part of the curriculum in many higher education programs. In the article, we describe the software that we created for the automated evaluation of students' tasks from the program MS Excel. The software is capable of evaluating multiple tests of different types all at once. For defining the tests, the software uses an XML file in which the respective questions with multiple parameters are described. For example, in tasks where students have to copy Excel terms, the original term, the address of the original term, the direction and length of the copy are given in the XML file. Naturally, the software has some limitations; nevertheless, it is a useful tool for a teacher.

I. INTRODUCTION

Unfortunately, even at universities and colleges we still encounter the problem that students cannot handle the proper use of the components of office suites (MS Office, OpenOffice, LibreOffice, etc.), which are virtually indispensable requirements in every profession where personal computers are used. In the case of text editors, we encounter documents that show that they were inappropriately formatted, do not use the basic features and benefits of the editor, and resemble those documents written with ordinary typewriters (without alignment, tabs, automatic indents, numbering, etc.). In the case of spreadsheets, we see the problem of using various functions. Students either do not know the functions at all therefore not using them, or if they know them, they cannot properly apply them to the given problem. And we are talking only about the knowledge and skills that students should have at the end of the secondary school. However, a teacher who enters the practice after completing their studies should have this knowledge and skills, so it is necessary to remove this gap in students' attainments during their study.

II. HOW TO TEACH TO WORK IN A COMPUTER PROGRAM

Teaching any software product is especially interesting because the content of the curriculum and the learning aid is the very same program. Without proper software, it is virtually impossible to teach someone to write text documents and to use spreadsheets correctly. It is true that the principles of correct text preparation, its format, layout, spelling are the same and it does not matter in which program package we will create it, but document creation skills can only be obtained while working and using some appropriate software which also allows us to adhere to the principles of correct creation and contains the necessary functions for making such a document. The design of the program, the layout of its functions on the screen, the appearance of respective icons is not substantial if we know what we want to do with the document; it is only necessary to determine whether the given program allows it and find the appropriate function in its offer. If such a function is not part of the program, it may be possible to bypass by the use of other commands that it contains. Either way, in education we do not get along without working with specific software.

The role of the teacher can also be built oppositely. In the case of having the specific program in which they have to teach students to work, their task is much simpler because they can focus only on explaining those functions and options that the software provides. However, they must not forget that in practice their students can also meet other similar programs and should therefore deal with explaining the suitability of the use of various functions, when, where and why to use them, how to use them correctly, so that students could universalize the respective work procedures with the given program and if necessary, apply it to other software of the same scope.

In pedagogical practice at universities, we also encounter the problem that students come with wrong habits (for example alignment with the help of spaces), which should be removed. To do this, they need to understand why the thing they are doing is wrong, what kind of errors can result from bad habits, and at the same time to learn how to do things right.

III. TEACHING HOW TO WORK IN MS EXCEL

Knowing how to work with a spreadsheet is a necessity for a modern teacher. In practice, the requirements of the higher-ranking institutions for different statistical reports

are almost on a daily basis. Electronic communication allows sending different spreadsheets, the filling of which electronically takes much less time than filling and calculating manually. Often there is no time for that, since the results are required to be sent by return.

Graduates of the faculties of education, particularly the approbations of Informatics with combination, most often with the English language or Mathematics, are often employed outside of education. It is obvious that the knowledge of mastering any software program is an advantage for them, which only increases the price of their work on the labour market.

Working with MS Excel program is included within the subjects of the general basis for the preparation of future teachers. The names of the subjects vary according to universities, it may be Informatics, Information-Communication Technologies, Introduction to Informatics, et cetera. The contents, however, are almost identical, including the work with the MS Office suite.

Students' knowledge of the MS Office suite is very diverse. There are students with an ECDL certificate, others have experience with this program package from primary or secondary schools, and some of them have only basic or no knowledge and skills to work with the program. Our task is to get everyone to the same level of knowledge, possibly higher than the best students' level of knowledge was.

If it was possible to classify students according to their level of mastery of work with MS Excel into different study groups, the teacher's approach to them could be differentiated. However, such an option is very rare, and therefore demandingness of teacher's work is increasing, since education must take its course so that none of the students was bored during the class, but at the same time, none of them fell behind.

According to our opinion, which results from our many years' experience in teaching this issue, students should have the following skills after the completion of the subject that also included MS Excel:

- *Formatting tables and their content, i.e.* font size and type setting, border, cell colouring, alignment, cell merge, image, shapes and filter insertion ...
- *Using basic functions*, such as sum, calibre, minimum, maximum...
- *Inserting more complex functions,* such as mathematical, statistical ones and mastering the work with database functions is very advantageous, as it provides a good basis for working with MS Access...
- *Charting*, nevertheless it is necessary to know when, where and what type of chart to use depending on the character of the displayed data (discrete or continuous values)...

Many students already have the basics of the aforementioned skills, it is only necessary to repeat them and add more. A very good widening of knowledge is when students additionally learn:

- *creating pivot tables,*
- *making macros*,
- *the basics of programming in* VBA (Visual Basic for Application).

From the outcomes of our practice, we can see, however, that some students already manage these extensions with difficulties or not at all.

Some problems of learning how to work in MS Excel already show up when working with the functions. It does not concern the acquisition of skills as how to insert functions, rather it is about what function to insert and where. We also notice that students with approbations of science subjects such as mathematics, computer science, and physics have little or no problem understanding the more complex functions of MS Excel, compared to students of humanities or preschool and elementary pedagogy.

Thus, it is evident that sufficient mathematical knowledge acquired beforehand is needed to master the work with the spreadsheet without which problems may arise in solving some types of assignments.

Differentiation of students to science and humanities disciplines is even more striking if we want them to write a simple macro using Visual Basic for Application that can be aptly used in MS Excel. Here, sometimes all attempts and efforts fail, and therefore it is up to the teacher whether to include these elements in the curriculum.

Another problem we encounter in teaching not only working with computer programs but also in other subjects is insufficient reading literacy of the students, i.e. reading comprehension. It is a very dangerous phenomenon, which is also reflected in international tests of students (e.g. PISA). Not comprehending tasks, assignments, ordinary texts may lead to fatal errors in later practice of a person's life. It is therefore a matter to think about where the failure is in education if such problems have to be dealt with at universities.

The above-mentioned implies that despite the efforts of teachers, not all students can handle the issue of spreadsheets equally well.

IV. COMPUTER-AIDED EXAMINATION OF KNOWLEDGE AND SKILLS

At present, using personal computers in educational process is a matter of course. They enable and facilitate the achievement of basic didactic goals of education such as providing educational information, practicing curriculum, knowledge verification etc.

When examining students' knowledge by means of computers, it should not just be about a replacement of a pen and paper with a keyboard and a screen. Current multimedia computer assemblies enable us to integrate images as well as audio-visual elements into the test questions. Another advantage is that the computer can evaluate the results immediately, making the work of the teachers simpler, and often increasing objectivity of the evaluation.

Adaptive testing can also be done with the help of a computer when the computer continually evaluates the responses of the test person and depending on them selects additional test tasks from the appropriate database. [1]

According to Rafajlovičová, the aim of testing is to ascertain the level of competence of individuals and groups objectively and as precisely as it is possible. With the help of tests evaluation, we can verify the effectiveness of education, and to determine the overall

level of aim achievements; to identify the learning process and the development of respective students; to collect the materials for classifying students; to obtain information for decisions on further education of students; to develop self-reflection and constructive self-criticism of students. [2]

Examination of knowledge through tests, whether filled in on paper or using a computer, also has its shortcomings. Filling in a test as well as its evaluation is faster, but its preparation is more demanding compared to, for example, oral examination using spontaneous questions. When creating a test, it is important to plan the content and scope well, to decide what type of test tasks to choose (closed, open with a choice of answers, yes-no questions, tasks of completion, arrangement, assignment...), to find out their difficulty for a given group of students. A good test requires development, during which it gradually improves.

Testing is usually understood as follows: the teacher prepares the test questions from any subject, puts them in a suitable program that can be freely accessible (e.g. Google Forms) or creates it themselves, using a commercial or also a freely available program (e.g. Hot Potatoes) and students can complete the test on-line or off-line. We also meet educators who design and program the appropriate test environment into which they build their questions and tasks.

However, none of these methods is entirely appropriate for verifying the level of knowledge and skills of working with any optional software product, including MS Excel.

If we want to find out how students have learnt to work with this program, it is not enough to ask them a question like: "Write a function to calculate the sum in MS Excel" and the answer will be "SUM", because with this type of question we cannot ascertain whether the student can use this function even in practice and whether they can properly apply it to a given example.

Examination of the level of knowledge and skills of working with an optional computer program must be done directly on the computer and the student must demonstrate their knowledge in the given program. Assignments and tasks must be formulated so that the student had to take the appropriate steps and procedures in the program to get the right answer and the result had to be visible on the screen.

Nor is this assignment well formulated: "Use SUM to calculate how many pieces of books have been sold", because the student does not have to think about what function to use, the task have already answered it for them. Similarly, task types such as "Calculate the sum of the cells and write into cell F3...", that is, where there are specific information given to the respondent, are less effective in terms of the end result of teaching process. Tasks should be of a nature that requires students to apply acquired knowledge and skills, ability to solve theoretical and practical problems, and also creative and evaluative thinking.

We think that a correct assignment to examine the knowledge of working in MS Excel should consist of a task table in which the individual columns and rows are clearly defined and the initial data to be used by the student are stated. The table should set out the tasks, either directly in the worksheet together with a spreadsheet, or in printed form on a sheet of paper into which, once the tasks

Tovar	Predané množstvo	Obchod	Jednotková cena bez DPH	Jednotková cena s 19% DPH	Príjem
Biely chlieb	500	Kaufland	24		
Biely chlieb	1000	Tesco	23		
Biely chlieb	700	Metro	21		
Biely chlieb	250	Billa	24		
Biely chlieb	200	Ister	25		
Tmavý chlieb	500	Kaufland	23		
Tmavý chlieb	1500	Tesco	22		
Tmavý chlieb	500	Metro	20		
Tmavý chlieb	500	Billa	23		
Tmavý chlieb	100	Ister	24		
Žemľa	1500	Kaufland	2		
Žemľa	1500	Tesco	1,5		
Žemľa	800	Metro	1,2		
Žemľa	500	Billa	2		
Žemľa	450	Ister	2		
Makový koláč	1000	Kaufland	7		
Makový koláč	2500	Tesco	6		
Makový koláč	500	Metro	5		
Makový koláč	230	Billa	6		
Tvarohovník	500	Tesco	6		
Tvarohovník	400	Metro	5		
Tvarohovník	120	Billa	5		

Figure 1. Example of the task table

have been solved in the program, the student writes the calculated results to the marked places.

Formulation of tasks or questions should be in a form so the student is forced to think, that is, they must understand the text, interpret the data listed in the table (exercise book, worksheet) correctly, deduct, i.e. determine the correct function or combination of functions accordingly, use them and get the right result, which they should also be able to verify if needed.

Figure 1 is an example of a spreadsheet that contains fictitious sales figures for bakery products in various department stores. Based on the data presented in the table, students must calculate assigned tasks of the type (Fig. 2.): "How much does the most expensive bakery product cost?", "What is the average price with VAT of buns?" "How many pieces have been sold from white bread, dark bread and poppy seed cake together?" etc. using the options and functions of MS Excel.

Such assignments approximate most closely students' problems from the praxis and practical life.

Otázka	Použitý vzorec - výsledok	
1. Vyplňte chýbajúce stĺpce tabuľky!		
2. Koľko druhov pekárenských výrobkov predáva Billa?		
3. Koľko kusov výrobkov sa predalo v Metre?		
4. Koľko je priemerná cena s DPH bieleho chleba?		
5. Koľko stojí najlacnejší pekárenský výrobok?		
6. Vypočítajte priemernú cenu s DPH produktov vo Ft-och, ak je kurz 0,12!		
7. Do koľkých obchodov môžem ísť nakupovať, ak chcem kúpiť tmavý chlieb a tvarohovník?		
8. Koľko má sumárny príjem Tesco?		
9. Koľko kusov predali obchody spolu z bieleho chleba, tvarohovníka a makového koláča?		
10. Na základe výsledku výpočtu úlohy 4, vypíšte k jednotlivým obchodom, či daný produkt je drahší alebo lacnejší ako priemer!		
11. Navrhnite taký graf, ktorý názorne ukazuje percentuálne rozdelenie predaja tmavého chleba medzi jednotlivými obchodmi!	Ukážte na obrazovke skúšajúcemu!	
12. Vytvorte graf, ktorý názorne porovná celkový predaj jednotlivých tovarov!	Ukážte na obrazovke skúšajúcemu!	

Figure 2. Example of a paper version of the answer sheet

The answer sheet can be in both paper and electronic form, the student completes the designated places with Excel formulas and results, respectively these are displayed on the computer screen.

The ability to solve assignments of this type in the MS Excel spreadsheet supports students' analytical as well as critical thinking.

V.   MS EXCEL TEST EVALUATION SOFTWARE

The assignments of the described character acquitted very well in our pedagogical practice. They will definitely test how students can work with a spreadsheet and show gaps in their knowledge and skills. Students "test" themselves whether they are able to work independently with MS Excel and solve practical problems and they also find out where they have shortcomings.
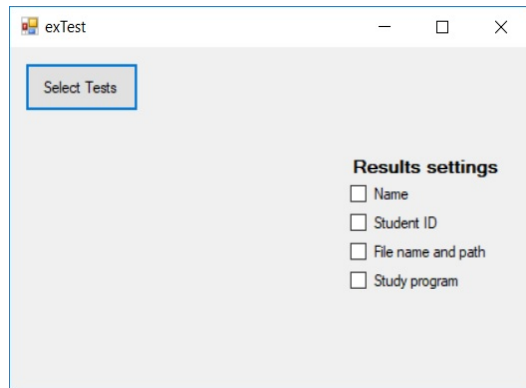

Figure 3.   exTest – initial window of the program

These types of tasks allow objective and fast evaluation for the teacher as well.

The problem, however, is that if the results of student work are displayed on the screen of the computer being used by the student, the teacher has to check each assignment separately on every computer, which increases the time intensity of the evaluation.

To facilitate the teacher's work and to reduce the time needed to control students' workloads, we have created simple software that we called *exTest*. The program serves to simplify and accelerate the evaluation of assignments from MS Excel solved off-line by students.

A.   exTest

The software was developed in the C# programming language for the .NET Framework 4.5.2 platform, using the Microsoft Office Library 15.0. Analysis and elaboration of the Excel formulas was the most difficult part of the development. During the so-called text processing tasks, we used regular formulas [3, 4].

MS Excel files open in the background, causing a slowdown in activity. The evaluation of 10 tests takes 38,4 seconds (configuration PC: Windows 10 x64, Intel Core i5-3310M, RAM 6GB DDR3). Although processing time seems to be relatively long, it is certainly shorter than manual evaluation.

The generated software aims at evaluating the functions used in the tasks.

Figure 3 shows the content of the initial screen of the exTest program. In the "Results Settings" menu, there are selection options, which, in addition to the points obtained, should be displayed in the evaluation:

- *Name* – displays/hides the name of the student,
- *Student ID* – displays/hides identification number of the student (e.g. the student's card number),
- *File name and path* – displays/hides file name and the path to it,
- *Study program* – displays/hides the student's study program.

If we want to have anonymous results, we need to hide everything.

Figure 5.   The first task type

B.   Structure of tasks

The structure of individual tasks can be two-fold:

- In the first task type (Figure 4) the task must be resolved and the result stored in the cell of the given address.
- The second task type (Figure 5) requires the task to be solved, the result to be stored in the cell of the given address, and apply the same to further cell domains.

Figure 4.   The second task type

An example of a task of the first type can be: "Calculate how many pieces of the most expensive item were sold in the 3rd month of the year. Write the result in the cell D22!" (Figure 4)

The second task type is: "For all the rows in the given table, calculate how many pieces were sold altogether from the given goods and enter the result in column Q." (Figure 5)

Numeric values in respective tasks are not constant, but they change after each operation. In this way, the originality of each assignment is secured and the option of deprecation is minimized.

```
<q>
    <test_id>A</test_id>
    <q_n>1</q_n>
    <val>=AVERAGE(D5:D16)</val>
    <row>19</row>
    <col>D</col>
    <rep>1</rep>
    <direction></direction>
    <points>3</points>
</q>
```

Figure 6.   Preview 1 of the contents of tests.xml file

C.   Required definition of assignments

An important part of the exTest program is the *tests.xml* file. In this file, it is necessary to define the constant addresses of the cells and domains that store the Excel formulas used for calculating the solutions in the students' tasks. This ensures that the exTest program always finds the necessary data; therefore, *tests.xml* file must be in perfect agreement with the created Excel assignments.

In a file with an Excel assignment, there is a reserved domain with a three-cell range, which is constantly made up by B1:B3. At these addresses, exTest looks for the data serving to identify individual students. In particular, these cells contain the following data: B1 = study program, B2 = student's name, B3 = student's identification number.

The following is valid for the evaluation for each type of questions:

- If the task does not require the use of copying the formula, the student gets the full score for the correct formula and zero point for the incorrect formula, (Figure 6)
- If there is a possibility of the use of copying the formula in the task, the points are evenly divided according to the number of possible copies, and it holds even if the student did not use this option and entered each formula separately. (Figure 7)

```
<q>
    <test_id>A</test_id>
    <q_n>2</q_n>
    <val>=SUM(E5:P5)</val>
    <row>5</row>
    <col>Q</col>
    <rep>12</rep>
    <direction>down</direction>
    <points>5</points>
</q>
```

Figure 7.   Preview 2 of the contents of tests.xml file

The meaning of each element of the *tests.xml* file:

test_id – type of the test,
rep – amount of copying,
q_n – question number,
points – points for the given question,
val – expected formula (in the case of copying, only the value of the first formula),
row a *col* – cell address where a formula is to be,

direction – direction of copying (down, right).

The assignment file must be in *.xlsx format. The type of the assignment is distinct in the name of the file, where the first letter indicates the task version, for example: **A**test.xlsx, **B**assignment.xlsx, etc..

Creating new tasks and assignments can be quite simple based on the stated structure, of course some aforementioned limitations have to be observed.
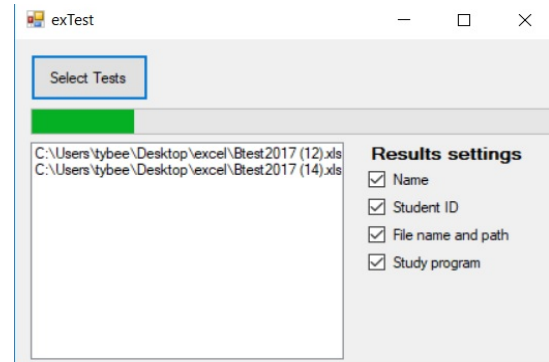

Figure 8.   Progress of the evaluation in exTest program

The assignment is not fully secured against possible changes, such as inserting or removing rows or columns that could affect the evaluating process. As a result of such changes, the address of the monitored cells could be altered by exTest and the evaluation would be partially or completely incorrect.

D.   Evaluating process using exTest program

Working with the program is very simple. After the installation and launch, the aforementioned initial screen appears (Figure 3). First of all, we tick off the appropriate options in the "Results Settings" menu as needed, that is, which data should be displayed in the evaluation.

Subsequently, using the "Select Tests" button, we select those Excel files that contain the resolved assignments of the students we want to evaluate.

After selecting the tests, the software launches the evaluation process in the background. On the preview of the exTest software window (Figure 8), we can see the procedure of evaluation on the progress bar during the previously mentioned process. In addition, the message box calls attention to the end of the evaluation process (Figure 9).

As a result of the evaluation, we will get another Excel file called *results.xlsx* (Figure 10), which contains the results of the evaluated tests (type of test, obtained points for respective questions, sum of achieved points, perhaps even the name, study program and identification number of the student). This file is located in the directory where the software itself is stored [5].

The program does not evaluate tasks for formatting, charts, and macros, yet.

The exTest program is designed for newer version of MS Excel and the evaluated files must be of *.xlsx type.

VI.   CONCLUSION

The exTest program has been tried in practice, approximately on 70 tests and it worked without errors.
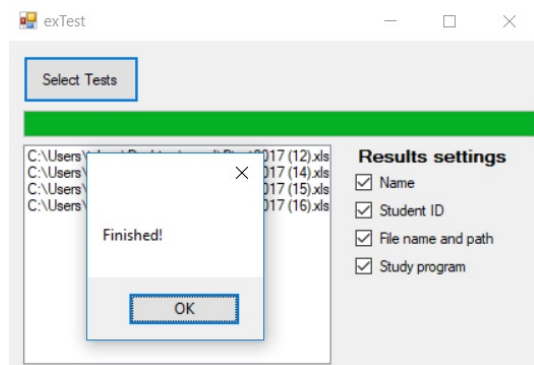
Figure 9.   Evaluation in the exTest program has been completed

Although it still has certain limitations, we think that it can be a useful tool for educators nevertheless.

Figure 10. Preview of the contents of the results.xlsx file

During its development, we would like to add new options to the software hereinafter. In the next version, we planned the possibility of examining additional functions and equivalent solutions (e.g. use the commutative and associative property), and sending the results automatically to each student.

Provided the opportunity, it would be ideal if the student could only upload a file to a server and the evaluation would be done there with a rather quick feedback, therefore we want to create the system also in the form of a web application. In that case, the student could log on to the website with their account (based on the LDAP server data), upload their assignment, and practically get the information about the result of the evaluation by return.

We hope that the tool we have created can help others' work in their effort to teach the aforementioned issue. Finally, we believe that by improving the preparation of students we will contribute to increasing their digital literacy.

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Utilization of specialized ICT infrastructure in the processes of science management in Slovakia

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Abstract—**Contribution is focused on presenting existing and intended tools, information systems and software applications, as a support infrastructure for managing electronic information resources in the field of research and development. At the same time, the infrastructure is used in the process of science management and evaluation in Slovakia. This infrastructure is being developed mainly within so called "national projects" implemented by the SCSTI within the Operational Program (OP) Research and Development in programming period 2007-2013 and OP Research and Innovation in actual programming period. Within the currently implemented projects, an emphasis has been put on mutual interconnection and interoperability of individual systems, including automated exchange of data and information among them. Besides that, the new functionalities of existing systems, together with completely new tools and applications, are under development. The aim is to provide scientific community, experts, the Ministry of Education, Science, Research and Sport of the SR and other relevant institutions with effective instruments for supporting processes connected to management and implementation of R&D activities.**

I. INTRODUCTION

Slovak Centre for Scientific and Technical information (SCSTI) was established by The Ministry of Education, Science, Research and Sport of the Slovak Republic (MESRS SR) with the effect of July 1, 1999. SCSTI is a government subsidized organization with a legal entity related to the government funding through the section of The Ministry of Education, Science, Research and Sport of the Slovak Republic (MESRS SR). The SCSTI's mission is to contribute to the development of science, technology and education, and to ensure data creation and information processing to support management and development of the areas belonging to the core competence of The Ministry of Education, Science, Research and Sport of the Slovak Republic. In this connection SCSTI supports the development of science, technology and education by building and operating information and communication systems for research and development, providing information services,

methodological and analytical activities for the support of management and evaluation in the field of research, development and universities, popularization of science and technology in the society and preparation and implementation of projects supporting research, development and education. Financial sources are gained from government budget contributions, the European Union Structural Funds, the European Regional Development Fund, grant agencies. Selected national information registers are operated according the Ministry's regulations.

In SCSTI the development of information and communication technologies (ICT) and providing information resources for science and education is based on two main authorities – regulations and requirements of the statutory authority (MESRS SR) and the needs of science and research community in Slovakia. The regulations and requirements of MESRS SR emerge mainly from the responsibility of the Ministry for elaborating and updating a methodology on determination of subsidies from the government budget from Ministry section to universities, accreditation of educational programs, providing information and communication systems for the needs of research and development, evaluation of individual qualifications to conduct research and development and implementation of activities related to definition of priorities and utilization of funds for the area of science and technology [1]. The examples are the Central Registry of Art Works and Performance, the System of science and research or the Central register of graduation and qualification works operated by SCSTI. MESRS SR as a sponsor of these systems determines functionality requirements and it is responsible for the allocation of funds from government budget.

The requirements of science and research community on information and communication support are monitored by SCSTI through the surveys of community's interest in researchinformation sources, through tasks defined in the action plans for development of the civil and knowledge society and according to its own professional conclusions

in relation to the global trends. These are, in particular, information sources and ICT, the provision of which can be legislatively supported, for example by the government approved action plans, while achieving of necessary funds is a responsibility of administrator. In this case SCSTI seeks to obtain funding mainly from the EU structural funds and grant agencies.

I. Development and Usage of Specialized ICT Infrastructure for Science Management

The development of independent systems for the support of science and research has begun in SCSTI already in the period of organization establishment but the systems for the specialized ICT infrastructure for science management started to be built especially after 2007. In this year SCSTI participated at the Operational Program Research and Innovation based on calls by MESRS SR and had a mandate to develop information support for science and research through national projects. Thereafter SCSTI prepared two complementary national projects:
1. The National Information System for Research and Development support in Slovakia – Access to Electronic Information Sources (NISPEZ) is focusing on:
- Coordination of selection and optimization of electronic information sources (EIS) portfolio for research and development,
- Building the efficient system for using electronic information sources for research and development based on extended tools and technologies,
- Building the Central database of the Slovak information resources for research and development and a portal solution to access other, partially processed Slovak electronic resources (SCIDAP),
- Developing new functionalities (SK CRIS) for the Central Information Portal for Research, Development and Innovation (CIP VVI) while respecting the EU standards and focusing on effective project work and including interoperability with other systems [2].
2. Infrastructure for Research and Development – Data Centre for Research and Development (DC R&D) is focusing on:
- Technical modification and realization of the main Data Centre with a storage workstation and a connection to SANET network, provision and implementation of hardware and software elements which are necessary for launching DC R&D services,
- Procurement and implementation of data content and application software in the Data Centre for Research and Development,
- Building a professional workstation for digitization and electronic archiving of the content of books, prints and documents at the premises of SCSTI [3].

The national projects have been successfully implemented and SCSTI has established a basic ICT infrastructure for research and development community in Slovakia. The infrastructure consists of the Data Centre operation, specialized information systems and access to electronic information sources (EIS). Nowadays, the specialized ICT infrastructure for science management is built by the following systems operated in DC R&D:

The Central Information Portal for Research, Development and Innovation (CIP VVI) which has a mandate from the Department of Science and Technology

MESRS SR has been run by SCSTI since 2002 under the name Research and Development Potential Information System (RDPIS). It was a local database application that collected research projects data and reports on statistical findings of research and development potential. Thereafter, since 2005 SCSTI operated the website focused on government research policy [4]. CIP VVI was operated since 2008 following the Act No. 233/2008 on the organization of government support for research and development [5] and also the Action Plan for Science, Research and Innovation, approved by the Government of the Slovak Republic by the Resolution No. 557/2005 of 13 July 2005 [6]. The Action Plan task No. 10 related to the establishment of Central Information Portal for science, research and innovation. The important part of the portal was a database application containing the migrated RDPIS data and data collection forms. According to the decision of MESRS SR and Act No. 233/2008 SCSTI became the portal operator. According to later analytical studies, the technologies used for the Central Information Portal and the database module did not allow to implement the EU standards for research information, particularly recommended CERIF format. The modification of the module was not recommended as an appropriate solution [7]. Therefore, a new information system on research, development and innovation called SK CRIS was built and has been in operation since 2013.

The system SK CRIS was built within the national project NISPEZ in the program period 2007-2013, legally is a part of the project CIP VVI. SK CRIS registers and makes available data on projects financed from public funds, the register of research and development organizations as well as research results, including related publications and the database of researchers. The system is designed to evaluate the qualification to conduct research and development, to provide incentives to increase a level of research and development and to evaluate their use within Act No. 185/2009 on stimuli for research and development [8]. Currently the system includes 25 549 records of researchers, 17 097 projects, 1 613 organizations, 309 668 research publications.

The Central Registry of Publication Activity (CREPČ) was built as a response to emerging needs of MESRS SR in 2007. CREPČ was established as a development project coordinated by the University of Constantine the Philosopher in Nitra and was supported by the consortium of selected universities. The first administrator was MESRS SR and subsequently, based on the protocol on uploading and downloading program modules and a mandate for the operation of information system, it was transferred under SCSTI on December, 11 2009. The system CREPČ is according to Act No. 131/2002 on universities according to § 108 a,c [9] and according to the decree of MESRS SR no. 456/2012 on CREPČ [10] a part of the government information systems. Based on the above mentioned legislation, a new contract was concluded between MESRS SR and SCSTI in 2013 which assigns to SCSTI the responsibility for CREPČ management and the operation and the implementation of related activities. SCSTI is the only organization operating such a system in the Slovak republic and provides unique records of publishing activities especially for educational, scientific and specialized institutions. Currently the Registry includes more than 517 000 records.

The Central Registry of Art Works and Performance (CREUČ) was built in 2008 as a development project of MESRS SR. The responsibility for this system is assigned to SCSTI within the tasks resulting from Act No. 455/2012 on universities [11] and MESRS SR decree No. 456/2012, including the responsibility for its operation and a verification of contained data. CREUČ is the database of records of university artistic activities. CREUČ statistical outputs, as well as CREPČ ones, present a basis for the annual calculation of MESRS SR government subsidy for universities. Each record of artistic activity registered in the register undergoes a control and the content verification. From the formal point of view records are inspected by SCSTI. In terms of the content, records of artistic outputs are a subject of expert assessment by the members of Professional Evaluation Body under SCSTI General Director. Currently the Registry includes more than 26 000 records.

The Central register of graduation and qualification works (CRZP) is a repository of electronic versions of graduation and qualification papers from universities in Slovakia. Together with antiplagiarism system Antiplag for detecting plagiarism was built in 2008, when MESRS SR declared its intention to develop a comprehensive system solution for detecting plagiarism at the national level. Thereafter, the project Collection of graduation (qualification) papers was carried out and a new legislation the Amendment to the Act on universities [12] and the Methodological guidelines on graduation papers, their bibliographical registration, originality check, preservation and accessibility [13] were developed. The Amendment to the Act on universities established SCSTI as an administrator - based on the contract on the operation of the Central register of graduation, rigorous and habilitation papers concluded with MESRS SR. Simultaneously SCSTI was established to be the operator of Antiplag launched in 2010. The objective of the registry is to preserve documents and related metadata from all Slovak universities for 70 years. The Antiplag's task is to compare and verify graduation papers and online resources, detect plagiarism and collect originality check protocols. Currently the Registry includes 538 031 qualification papers.

The Central database of the Slovak information resources for research and development (SCIDAP) was developed within NISPEZ project in the period 2007 – 2013 to provide missing central information on Slovak research and specialized journals to research and science community in Slovakia. In the period 2009 – 2012 the technical development was conducted as well as the research determining criteria for indexing Slovak e-resources in the database. The database was launched in 2013. It provides a central access to the bibliographic records on Slovak research and specialized journals and papers. Currently the database includes 65 500 article records, more than 25 000 institution records and more than 100 000 author records.

The elementary part of specialized ICT infrastructure is information support through the access to the licensed electronic information sources (EIS). The ministry MESRS SR provided subscriptions and a remote access to EIS through development projects in cooperation with academic libraries until 2008. At the end of 2008 the situation changed and MESRS SR delegated the responsibility for subscribing the licensed EIS to SCSTI. Subsequently upon the ministry MESRS SR project call, SCSTI included the EIS subscriptions in the national NISPEZ project (within the Operational Program Research and Innovation).

To increase efficiency and also to simplify usage of various information sources and to provide their safe preservation, SCSTI acquired licenses for the operation of the integrated search engine PRIMO and for the digital archive Rosetta within the complementary national project DC R&D in the program period 2007-2013. PRIMO is a tool for searching and providing digital documents through one integrated and user-friendly interface and it enables simultaneous search in a number of heterogeneous resources. In SCSTI PRIMO search engine integrates all EIS subscriptions, SCIDAP database, library catalogue DaWinci, PRIMO central index and also free e-resources. The digital archive Rosetta is a preservation solution for long-term archiving of digital-born or digitalized documents from academic and government institutions. SCSTI acquired this repository especially for the safe preservation of papers from the Central register of graduation and qualification papers (CRZP) to fulfill the ministry MESRS SR methodical regulation on a long-term digital archiving of graduation and qualification papers from Slovak universities.

II. THE DEVELOPMENT OF SPECIALIZED ICT INFRASTRUCTURE FOR RESEARCH MANAGEMENT

A. The Operational Program Research and Innovation

After completing the Operational Program Research and Development SCSTI, upon the call from MESRS SR, joined the following Operational Program Research and Innovation for the program period 2014 – 2020. The call was opened to applications for irrecoverable financial contributions on the continuity of national projects, NISPEZ and DC R&D included, providing convenient conditions for further quality development of the specialized ICT infrastructure. SCSTI prepared the project plan *The Information System for Research and Development – Access to databases for the research institutions* (continued NISPEZ project) focused on:
- co-ordinated access to the electronic information sources for research and innovations in Slovakia, including support activities for their effective usage,
- providing discovery system for effective search in the research content and for the management of electronic content,
- updated system of acquiring and long-term preservation of digital research content with an increased emphasis on the support of Open Access publishing.

Within the project SCSTI will provide to research and science institutions in Slovakia the continuity in the access to global research content, which is a fundamental element for further development and quality improvement of science Simultaneously SCSTI updates the current PRIMO search engine and upgrades it with the system of the electronic resources management - ERMs. This will significantly improve and simplify using the EIS for researchers and other users. The key project activity is modernization and improvement of the specialized ICT

infrastructure through the development of the current systems or acquiring new ones. We build the Comprehensive Information System for acquiring, processing, preservation and provision research and bibliometric information and publications (The Comprehensive Information System). The Comprehensive Information System will reflect the EU initiatives and recommendations for working with research data and publications, the area of support to Open Science and Education and the area of ICT interoperability [14].

The project plan for continuing DC R&D was prepared under the title The Horizontal ICT Support and Central Infrastructure for Research and Development and is focused on:
- development and modernization of the application software equipment
- ICT development and modernization for research and science community
- development and modernization of the digital department.

Within the project SCSTI will analyze the ICT needs of research and science community and the current trends. Subsequently this analysis will result into the plan for the modernization and development of existing systems, their operation and their integration with other systems. SCSTI will arrange the modernization of Data Centre technologies and the mutual ICT integration, both regional and international. We will also focus on building research cloud and the infrastructure for Big Data and research data. Simultaneously The SCSTI digitalization department supporting the digitalization of research information resources in analogue format will be also modernized, The project also includes an international cooperation with the providers of similar services as well as educating the research and science community in using individual ICT services provided by the Data Centre [15].

NISPEZ project is focused especially on the development of the current and new software systems and databases determined for working with information and data. The project DC R&D is focused on the development and modernization of hardware equipment and related software systems. Both projects are mutually coordinated and they will result in the Comprehensive Information System which is to be operated by the modernized Data Centre DC R&D for research and science institutions.[1]

B. Action Plan

The government of the Slovak republic approved the Action Plan for the Open Government Initiative in the Slovak republic for the period 2017 – 2019 [16]. The Action Plan sets duties related to the outcomes from research and development and MESRS SR is obliged to fulfill the tasks on Open Access.

Through the projects NISPEZ and DC R&D in the program period 2014 – 2020 the ministry MESRS SR is to fulfill specifically the following Action Plan tasks: opening the Open Access national contact office, examining research data in Slovak institutions, establishing and operating the repository for the storage and preservation of science and specialized publications, research data and grey literature and the active raising of

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[1] The projects NISPEZ and DC R&D were approved by MESRS SR in the first half of 2017.

public awareness of Creative Commons licenses and the advantages of open publishing.

C. Research and Science Community Needs

As mentioned above, the solutions for ICT development and for providing information resources for research and education SCSTI co-ordinates with two main authorities – the statutory authority MESRS SR and its instructions and regulations and with Slovak research and science community and its needs. In developing a specialized ICT infrastructure in line with the needs of the research and science community SCSTI comes out of a general research process and of the standard research stages – following up a research data life cycle. The objective of NISPEZ project for the program period 2014 – 2020 is a continuous saturation of individual research stages with a required supportive ICT system for researchers or research outcomes evaluation authority.

Figure 1 shows basic research stages and a related research data life cycle. It presents the specific system of specialized ICT infrastructure supporting a researcher in the relevant research stage, an upgrade/development of which is included in the NISPEZ Comprehensive Information System:
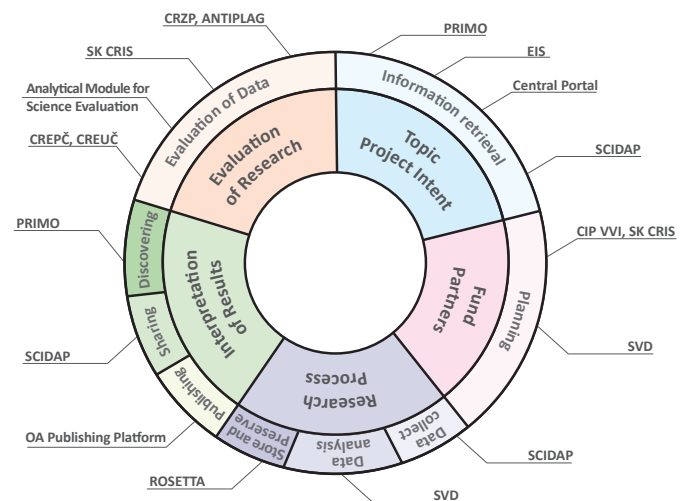

Figure 1 The systems of SCSTI specialized ICT infrastructure by research stages and research data life cycle [17]

To obtain the overview on current and global level of knowledge in a given topic and to create a project plan, scientists need to perform an information survey in quality information resources. In the specialized ICT infrastructure, these resources are licensed international electronic information sources (EIS) from renowned producers and suppliers. These include research journals, research monographs, patent information and citation and abstract databases. Information survey in such a number of EIS is centralized, available through remote access. For scientists there will be a new source of information - the SCIDAP repository assigned to save and provide access to research and scholarly publications published by universities and research institutions in Slovakia. The SCIDAP repository, formerly a bibliographic database, will be transformed to the system for saving and providing access to full texts as well as for processing descriptive metadata. SCIDAP will support the philosophy of open access to information and, in compliance with the Action

Plan, will enable authors to use Creative Commons licenses designed for documents and publications saved in the repository. All systems in the specialized ICT infrastructure will be integrated and managed by the central portal with integrated search. The portal will be another source of information and an entrance gateway to the Comprehensive Information System. A central search in all integrated systems or direct access to a single system from a central point will significantly simplify the phase of information survey and creation of a research project plan.

Surveys on possible sources of funding and potential partners suitable for building a research team in the planning stage are to be found in the Central Information Portal for Research, Development and Innovation CIP VVI and in the information system on science and research SK CRIS. CIP VVI provides access to information related to the government support of science and its funding, it includes public calls on projects, recent news on the European Union regulations and international research cooperation. The system SK CRIS contains the lists of researchers, organizations, projects and results of science and research in Slovakia. After the upgrade, the CIP VVI will run on a modernized software solution. SK CRIS will be updated on the latest version of CERIF format and new logical linking between the data presented at the portal and those saved in SK CRIS will be activated. A new supporting ICT system for enhancing effectiveness of planning processes will be introduced: Research Data Management (RDM). It will consist of the application on creating plans for research data management and of a repository for harvesting, saving and providing access to research data. RDM will help researchers to fulfill requirements of legislation, grant agencies and the programs financing research projects and requiring plans for research data management. The RDM system will enable to record complete data management from its entry to the research cycle through to the saving, archiving and ways of sharing and simultaneously it will enable to save produced data in the RDM repository.

Data harvesting, their analyses, storage and protection in the research cycle require specific supporting ICT systems. The research cycle as a key phase of research will be supported by the RDM repository for harvesting, saving and protection of research data. This system will be able to differentiate between open and closed data, it will be interoperable with SCIDAP repository for scientific and scholarly publications and will enable to link data on the basis of definable relations. The repository will be interlinked with long-lasting digital archive Rosetta which, as a closed digital archive, will support long-term protection of valuable research data.

After the research cycle is finished, the interpretation of results is performed through publishing, sharing in various information-communication systems, through their searching and using by other researchers. For this, the specialized ICT infrastructure provides the new system – Open Access publication platform. It will be used by publishers of scientific journals and monographs who are about to publish through open access. It will be interlinked with the SCIDAP repository to save new publications and to archive them in the digital archive Rosetta. Searching and sharing will be enabled through its own presentation layer or the central portal.

In the phase of evaluating research and data, the Analytical module for research evaluation will help to analyze, compare and evaluate the quality and quantity of research. This module will be used by the ministry MESRS SR, by government institutions and grant agencies to evaluate research results and to allocate financial resources to scientific institutions, researchers and universities. As the main sources of data it will use the content of the SCIDAP and RDM repositories, SK CRIS data content as well as the electronic information sources (EIS). The Analytical module will use unique metric indicators to evaluate activities of research and science institutions, their cooperation with non-scientific institutions, to evaluate countries, to analyze unstructured data and provide competency development indicators. The systems CREPČ, CREUČ, SK CRIS, CRZP and Antiplag, mutually interoperable and integrated into the Comprehensive Information System, will be also significant for research evaluation and evaluators.

D. Interoperability and integration

Interoperability stands for the ability of heterogeneous systems based on different hardware- and software platforms, data structures and interfaces to exchange data with a minimum loss of content and functionality [18]. The concept model of the European Interoperability Framework (EIF) defines four basic levels in this respect: the legal, organizational, semantic and technical interoperability level, emphasizing the context of cooperation policy between partners with joint and mutually compatible visions and priorities [19]. The major obstacle to interoperability according to the EIF pose obsolete systems, since historically, those applications and information systems have been developed in the public sector with a "top-down" approach, striving to solve problems in a particular field, as well as local issues. This resulted in "ICT islands" which were difficult to interconnect [19]. A similar situation is evident also in the public sector institutions in Slovakia, including SCSTI. Initially, the current systems of the specialized ICT infrastructure were developed as stand-alone systems which are also the reason, why each of them has its own presentation layer of various design, different data recording formats, as well as different user management. Within the individual NISPEZ and DC R&D projects and the solution of Comprehensive Information System, SCSTI will primarily focus on achieving technical and semantic interoperability. The objective will be the exchange of data between systems via compatible formats, their transmission and presentation through secure protocols and standardized presentation interfaces - even in the context of the corporation policy of specified partners providing similar services internationally, which is one of the objectives of the DC R&D project. The systems will be integrated into the Comprehensive Information System, which will be subsequently integrated with the ICT infrastructure into the R&D Data Centre, in the environment of which all systems are supposed to be operated. Within the solution of semantic interoperability, we will focus on preventing metadata duplication for one and the same object in multiple infrastructure systems, saving time and money in

processing. Also the implementation of the Single Sign-On (SSO) mechanism is significantly important as it will provide a unified authentication and authorization of users. The central portal will consider also the solutions of the integration platform with respect to the comprehensive and flexible user interface for accessing various kinds of text-based and structured data and for the provision of a mechanism managing the communication with users.

III. CONCLUSION

The national modernization projects of specialized ICT infrastructure - NISPEZ and DC R&D - will become sustainable after being implemented, when there will be the infrastructure and wearable for providing comprehensive services in the acquisition, processing storage and providing scientific and bibliometric data and publications. During the sustainability period SCSTI will intensively co-operate with individual science and research institutions in order to acquire relevant content for repositories and databases and tackle the issue of providing the acquired content on the background of copyright issues and the Open Access philosophy. SCSTI also assumes the possibility of generating profits from the use of supplementary services, as e.g. providing a supercapacity storage for extensive research data beyond the set standard capacity in repositories or in a long term storage system. Apart from the tasks defined in the international projects, SCSTI will deal also with other missing links for making the science management in Slovakia through ICT more efficient. It will be particularly looking for solutions eliminating the ambiguous identification of persons to avoid mistakes in the systems registering authors of research publications and project administrators. In this respect it will become necessary to tackle also the integration of the research publication database of the Slovak Academy of Sciences (EPCA) into the CREPČ register. Significantly also the decision of the technical solution for eliminating the risk of Slovakia's disconnection from the prepaid content of licensed EIS, i.e. by archiving this content and securing it permanent accessibility.

If and when the implementation of the national projects NISPEZ and DC R&D will succeed, Slovakia gets a Comprehensive Information System for the acquisition, processing, storage and provision of scientific and bibliometric data and publications, along with a modern Data Centre. The infrastructure will be beneficial for all subjects involved, providing a huge potential in utilizing processed and published data, not just in the public sector - but in the private sector as well.

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Packet Capture Infrastructure Based on Moloch

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Abstract—**To identify all the hidden details that are left after or during a network incident, the computer forensics is used. The purpose of computer forensic techniques is to search, preserve and analyze information on computer systems to find potential evidence for a trial. Computers are getting more powerful day by day, so the field of computer forensics must rapidly evolve. There exist many computer forensic tools that are used to apply forensic techniques to the computer. We present our investigation with Moloch tool, that is promising for today's computers. We describe components and architecture of Moloch, its application feasibilities and hardware requirements. We present our implementation and experiments with Moloch, our performance tests and statistics and application of useful scripts for Moloch and its components. We focus on integration with other alerting tools, such as IDS, to help speed up analysis.**

Keywords: Network Forensics, DDoS, Moloch, Monitoring, Archiving, PCAP, IDS, Snort, Suricata, SIEM.

I. INTRODUCTION

The solutions of security problems and crisis situations are accompanied by many specific traits. One common trait of crisis situations is shortage of time and information which places high demands on managers and decision-makers. Definition of traits, qualities and skills, which are necessary for effective solution of problems in different fields of security, as well as results of surveys between graduates and employers evaluating their expertise and competencies, as well as contemporary requirements of practice is highly required [1].

Archiving of data network flows was not solved at our department nor the faculty in any way. There was a big lack for highly scalable and open source full packet capture system with ability to parse and index billions of network sessions to provide an extremely fast and easy to use web application for navigating large collections of PCAP based on IP, GeoIP, ASN, hostname, URL or filetype. We required capture from the wire live for use as a network forensics tool to investigate compromises. We needed effective way for searching and interacting with large PCAP repositories for research (malware traffic, exploit, scanning traffic). We needed tool able to integrate with existing Security Event and Incident Management systems (SEIM) or other alerting tools (Snort) and consoles to help speed up analysis. Our intention was to solve partial problems in the research project "Security of Information and Communication Networks" at the Department of Information Networks at the Faculty of Management Sciences and Informatics at University of Zilina. The project focuses on four plains of security, with our research team addressing tasks from plane 2:

Plane 1. Security architecture – involves solution of security architecture relationship to relevant partial architectures, paradigms of security architecture.

Plane 2. Infrastructure and data acquisition technology – involves creation of CC infrastructure (CC services and their security), collection of real network streams (monitoring [2], attack detection and archiving), generate packet flows with available hardware and software generators.

Plane 3. Detection of attacks by analysis of network traffic flow – involves methods of modeling flows in the communications network, methods of detecting attacks on the communications network [3], analysis of signatures contained in packet headers, complexity of attack detection algorithms, new methods of attack detection, adaptation of methods to real-time detection algorithms, editing attack recognition methods

Plane 4. Implementing network traffic collection and new methods for real-time detection of attacks in FPGAs [4] and memristors [5], [6]. According [7], packet capture for measurement of several network parameters on high-speed networks requires high clock resolution and the capability of analyzing different protocol functions for behavioral functionality.

Our project team provides technological and infrastructural support for group 3 and 4 and gather required data and information about attacks and protocol weaknesses for group 1.

Forensics involves procedures, steps, phases, or processes in order for the investigation to be successful. According to [8] and [9], the forensics phases include preparation and planning, accessing crime scene, collection, preservation, transportation, analysis, documentation, and presentation. These phases apply also to mobile forensics. New digital forensic tools in cloud computing environment are being developed [10], [11], [12] and also mobile device forensic tools [13].

II. EXISTING NETWORK FORENSIC TOOLS

There are several systems that have the required features for monitoring and archiving network flows. After the initial analysis of the commercial tools that we excluded for the price, and open-source tools that did not have full functionality as commercial tools, we were attracted by the Moloch tool that we decided to deploy and test for our needs. First, we briefly introduce some interesting tools that provide capture, archiving, and packet analysis.

A. NetworkMiner

NetworkMiner [14] is a Network Forensic Analysis Tool (NFAT) for Windows, but also works in Linux, Mac OS X, FreeBSD. NetworkMiner can be used as a passive network sniffer/packet capturing tool to detect operating systems,

sessions, hostnames, open ports etc. without putting any traffic on the network. NetworkMiner can also parse PCAP files for off-line analysis and to regenerate (reassemble) transmitted files and certificates from PCAP files.

NetworkMiner makes it easy to perform advanced Network Traffic Analysis (NTA) by providing extracted artifacts in an intuitive user interface. The way data is presented not only makes the analysis simpler, it also saves valuable time for the analyst or forensic investigator.

NetworkMiner has, since the first release in 2007, become a popular tool among incident response teams as well as law enforcement. Free edition of this tool provides live sniffing, parse PCAP files, IPv6 support, decapsulation of GRE, 802.1Q, PPPoE, VXLAN, OpenFlow, SOCKS, MPLS and EoMPLS, receive Pcap-over-IP, OS Fingerprinting, parse PcapNGfiles. Paid version provides Port Independent Protocol Identification (PIPI), export to CSV, Excel, XML, CASE, JSON-LD, configurable file output directory, configurable time zone (including UTC), geo IP localization, DNS whitelisting, advanced OS fingerprinting, web browser tracing, online ad and tracker detection, host coloring support and command line scripting support.

B. Xplico

The goal of Xplico [15] is extract from an internet traffic capture the applications data contained. For example, from a pcap file Xplico extracts each email (POP, IMAP, and SMTP protocols), all HTTP contents, each VoIP call (SIP), FTP, TFTP, and so on. Xplico isn't a network protocol analyzer. Xplico is an open source Network Forensic Analysis Tool (NFAT).

Xplico is released under the General Public License (GNU) and with some scripts under Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported (CC BY-NC-SA 3.0) License.

C. Wireshark

Wireshark is a freely available tool for network traffic monitoring and packet analysis. It is often referred to as a network analyzer, network protocols analyzer, or sniffer.

Captured packets can provide the network administrator with information about individual packets such as transmission time, source, destination, protocol type, and header content. This information can be useful for assessing security actions and addressing network security issues. Wireshark is among the best freely available packet analyzers. It is available for Linux and Windows. It allows importing, exporting, but also storing captured data, and displaying different streaming statistics for different filters to display specific outputs. Wireshark is very widespread and is therefore used by many network administrators, protocol developers, but also by students for better understanding of protocols [16].

Quick access to very large pcap files are provided by paid solutions by Riverbed products which integrate with Wireshark [17].

D. Sguil

Sguil [18] is the analyst console for network security monitoring built by network security analysts. Sguil's main component is an intuitive GUI that provides access to real-time events, session data, and raw packet captures. Sguil facilitates the practice of Network Security Monitoring and event driven analysis. The Sguil client is written in tcl/tk and can be run on any operating system that supports tcl/tk (including Linux, BSD, Solaris, MacOS, and Win32).

E. Moloch

Moloch [19] is an open source, large scale, full packet capturing, indexing, and database system. Moloch augments our current security infrastructure to store and index network traffic in standard PCAP format, providing fast, indexed access. An intuitive and simple web interface is provided for PCAP browsing, searching, and exporting. Moloch exposes APIs which allow for PCAP data and JSON formatted session data to be downloaded and consumed directly. Moloch stores and exports all packets in standard PCAP format allow us to also use other PCAP ingesting tools, such as Wireshark, during our analysis workflow.

Access to Moloch is protected by using HTTPS with digest passwords or by using an authentication providing web server proxy. All PCAPs are stored on the sensors and are only accessed using the Moloch interface or API. Moloch is not meant to replace an IDS but instead work alongside them to store and index all the network traffic in standard PCAP format, providing fast access. Moloch is built to be deployed across many systems and can scale to handle tens of Gbps of traffic. PCAP retention is based on available sensor disk space. Meta data retention is based on the Elasticsearch cluster scale. Both can be increased at any time and are under our complete control.

III. MOLOCH

Authors of the tool Andy Wick and Eoin Miller are members of AOL's Computer Emergency Response Team (CERT). Andy Wick has more than 15 years of development experience at AOL. He has come into the CERT group and has begun developing tools for defense and forensics. Eoin Miller specializes in using IDS and full packet capture systems to identify drive by exploit kits and traffic that feeds them (malvertising in particular). He regularly contributes the developed signatures to Emerging Threats - Open Information Security Foundation (OISF). OISF is a non-profit foundation organized to build community and to support open-source security technologies like Suricata, the world-class IDS/IPS engine [20].

A. Components and architecture of Moloch

The Moloch system is comprised of 3 components

1. Capture - A threaded C application that monitors network traffic, writes PCAP formatted files to disk, parses the captured packets and sends meta data (SPI data) to Elasticsearch. Alternatively, it can be called from the command line for manual import of PCAP files for analysis and archiving. It analyzes the various 3rd to 7th layer protocols, creating SPI data that it sends to the Elasticsearch cluster for indexing purposes.

2. Viewer - A node.js application that runs per capture machine and handles the web interface and transfer of PCAP files [21]. It is an event-driven Javascript platform on the server, based on Google Chrome Javascript, with its own HTTP and JSON communication. It runs on every device with a Capture module and provides a web interface for browsing, viewing, and exporting PCAP files. GUI/API calls are performed using URI, so
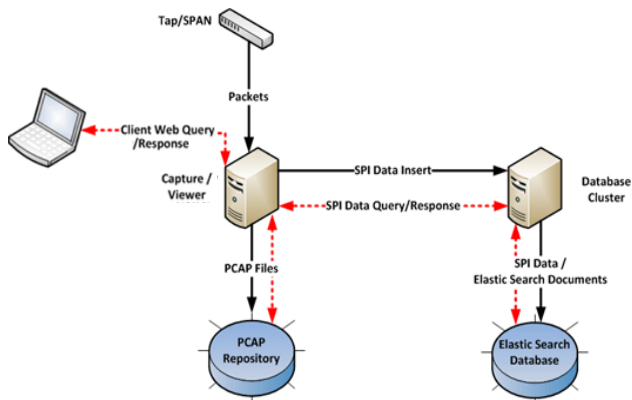
Figure 1.   Single node architecture of Moloch

Figure 2.   Multi node architecture of Moloch

integration with SIEMs, consoles, or command line for PCAP or optional connection is possible.

3. Elasticsearch - The search database technology powering Moloch based on Apache. Requests are received via HTTP, and the results return to JSON. It has automatic data sharing across multiple. It's fast and scalable.

All components can be located and work on the same node (Fig. 1), but it is not recommended for larger data flows. Whether it's a larger data flow can be detected if the query takes too long, then it's good to use Multi-node architecture (Fig. 2). The individual components have different requirements. Capture requires a large amount of disk space for received PCAP files. Elasticsearch, on the contrary, needs a large amount of RAM for indexing and fast searching. Viewer is the smallest of them and does not have high demands, so it can be anywhere.

Moloch can be easily scaled to multiple nodes for Capture and Elasticsearch components. One or more Capture instances can run on one or more nodes while sending data to the Elasticsearch database. Also, one or more Elasticsearch databases can run on one or more nodes to increase the RAM capacity available for indexing. This kind of architecture is therefore most recommended for capturing and indexing data flow in real-time.

B. Application feasibilities

We present some interesting examples of using the Moloch tool, but the set may also be wider for individual users if they find other applications for Moloch:

- DOS Attacks - Analyzing connections that are suspected as attacks to refuse a service.
- Geolocation - Landscape identification when connected.
- Access Intelligence - Helps analyze legitimate or unauthorized access to system resources, applications, servers, system operation, and features. We can also perform in-depth analysis by tagging a specific system, application, or service running on the network.
- Use ports on connections - the number of connections that were associated with a specific port
- Usage of URLs for connections - the amount of connections that were associated with a specific URL using queries.
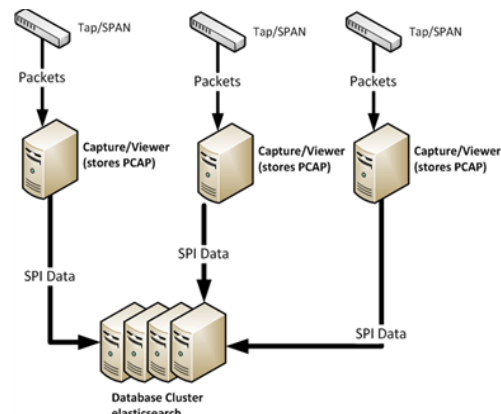- Data volumes

C. Requirements

Moloch is built so that it can be spread over multiple machines for larger packet flows. For small networks, demonstrations, or deployments, it's possible to have everything on one machine. However, when capturing large data volumes at high transfer rates, it is not recommended to have Capture and Elasticsearch running on the same machine. Moloch allows us to test the demo version of the software directly on a web page. It also allows replication to be turned on, resulting in twice the amount of disk space consumed, so this step needs to be thoroughly thought out.

The number of Elasticsearch nodes we should use depends mainly on:

- How much memory each node has?
- For how many days do we want to store meta data (SPI data)?
- How fast are the drives?
- What amount of traffic is HTTP?
- What is the average bitrate of all interfaces?
- Whether connections are short or long term.
- How fast a response should be in the query?
- How many people we estimate will be simultaneously searching at the same time?

We should also consider that at 1 Gbps of network traffic, an estimated 200 GB of disk space per day is required to store metadata (SPI data) from the Elasticsearch module. For example, for 14-day archiving at 2.5 Gbps average network traffic, we need approximately 7TB disk space.

The approximate formula for calculating the number of nodes needed for Elastisearch is ¼ * average network traffic in Gbps * the number of days we want to archive. As an example, we can say that at 1 Gbps and 20-day archiving, we would need 5 nodes. If we want to deploy Moloch on more powerful machines, it is possible to have multiple Elasticsearch nodes on one machine. Also, introducing a new node is not a complex process, so it's better to start with fewer nodes and then add them gradually until we get the requested query speed.

For Capture, it is important to note that with an average 1 Gbps network traffic, approximately 11 TB of disk space per day is needed to archive PCAP files. So, for 7 days with an average speed of 2.5 Gbps, we need 192.5 TB of disk space. The total bandwidth size must include both directions of the traffic. 10Gbps line can approximately

TABLE I.
PARAMETERS OF USED HARDWARE FOR OUR MOLOCH DEPLOYMENT

Server	Operating server	RAM	CPU	HDD
Cloud server	Ubuntu 16.04	2 GB	2 cores	40 GB
Lab server	Ubuntu 16.04	32 GB	2*4 cores	2,8 TB
Official min. requirements	Cent OS 6/7, Ubuntu 14.04/16.04	64-96 GB	2*6 cores	4-6 TB

generate 20 Gbps data for capture, 10 Gbps in each direction. In view of this, it is recommended to have multiple lines connected to Moloch. As an example, we can say that for 10 Gbps lines where the average bit rate is 4 Gbps in each direction, it is better to use two 10 Gbps lines to capture, otherwise packets may be lost.

To capture more data (~ Gbps), we can list the recommended hardware components:

- Memory: 64 GB to 96 GB
- OS drives: RAID5 is recommended, SSD disks are not necessary.
- CAPTURE discs: 20 + x 4TB discs or 6 TB SATA.
- RAID: A hardware RAID card with at least 1G cache.
- NIC: New Intel network cards are recommended, but also others should work.
- CPU: At least 2*6 cores, the larger the average line speed, the higher the speed per number of cores. Moloch allows to divide the load between more Moloch-Capture devices using mirroring.

When considering purchasing additional SSDs or more expensive network cards, we should rather consider adding another monitoring device to the group.

IV. IMPLEMENTATION AND EXPERIMENTS WITH MOLOCH

Our main goal is to have a deployed and functional data archiving system. It should be possible to export relevant data from the archive when detecting an attack as well as any other data that suits the requirements. We have therefore explored the possibilities of interconnection the Moloch system to IDS system. Firstly, we present our deployment of Moloch in our conditions.

A. Used hardware equipment

From the beginning, we planned to deploy the Moloch in our Cloud server, but the hardware requirements of the virtual machines in the cloud were deeply below the requirements according official Moloch site. However, the Moloch in our Cloud was deployed for test purposes, where we tested the individual settings and scripts that were

subsequently applied on a more powerful server located in the laboratory after testing and debugging.

Table 1 shows the hardware of the used servers along the recommended parameters for comparison.

Because the switch used for connecting all three laboratories did not have enough free ports, we used another additional switch to take advantage of port mirroring to our Moloch server. Fig. 3 illustrates the integration of Moloch to monitor the network traffic from and to the laboratories, and the integration of Moloch in our cloud.

Capture, Viewer and Elasticsearch database are applied on one server. Moloch cannot run all of its components automatically, so after restarting the server on which Moloch runs, it is highly desirable to have a script ready to turn on all three components (Capture, Elasticsearch, Viewer) [22]. We added a buffer extension to the script and disconnected some of the network card features.
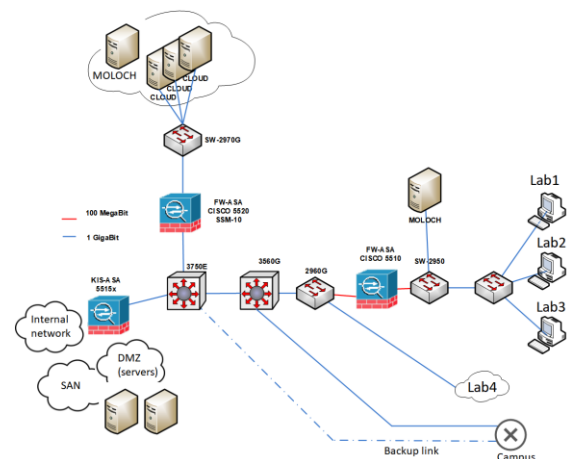

Figure 3. Integration of Moloch servers in our infrastructure

B. Performance tests and statistics

In current topology, our server is behind firewall, which filters out some unwanted traffic. However, as we are interested in this kind of traffic, we decided to move Moloch to a more strategic location, in front of the firewall, and to monitor the busy interface at the faculty level. Before this change itself, we performed several performance tests, which we now introduce.

The formula for calculating the number of nodes of the Elasticsearch that we already presented shows that for 2Mbps data flow, 1 node is sufficient and the archived traffic will take 22GB daily. We are then able to archive about 113 days of raw captured data. Only 7GB (22%) of the RAM is used. Disk space utilization was 340 GB (17%) in the first week, 220GB (11%) in the second week and 140GB (7%) in the third week. When we started to archive

TABLE II.
OPTIONS FOR STATISTICS IN MOLOCH

Packets/Sec	Sessions/Sec	Active TCP Sessions	Total Dropped/Sec	Free Space (MB)
Bytes/Sec	Input Dropped/Sec	Active UDP Sessions	Fragments Queue	Free Space (%)
Bits/Sec	Active Sessions	Active ICMP Sessions	Active Fragments	Memory
Memory (%)	CPU	Disk Queue	Overload Dropped/Sec	ES Queue
ES Dropped/Sec	Packet Queue	Closing Queue	Fragments Dropped/Sec	Waiting Queue

Figure 4.   CPU and Elasticsearch utilization in test 1 (one source)
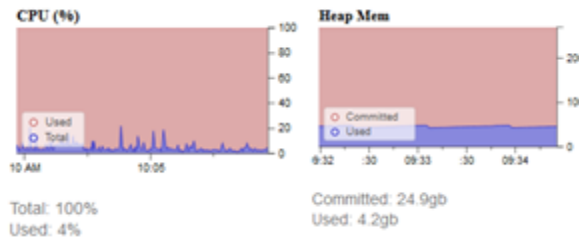

Figure 5.   CPU and Elasticsearch utilization in test 2 (many sources)

just packet headers, we could archive 4 months of traffic. 52% of the disk space was consumed, which is 1.3 TB. Moloch uses only about 5% of CPU, and uses 1.0-1.3 GB (3-3.5%) of RAM. We used also Bigdesk plugin to track Elasticsearch statistics. We will discuss it later.

One option to gain some interesting statistics is directly in Moloch with Stats tab in main menu. It provides both a visual representation and a table representation of the metrics listed in the Table 2 for each node.

Statistics provide the current node time, number of connections, free space, CPU utilization, RAM usage, how many packets are in a row, number of packets per second, number of bytes per second, number of dropped packets per second, number of overload dropped packets, number of packets dropped by Elasticsearch per second. Clicking on the plus (+) icon will show charts that provide a visual view of these statistics. Elasticsearch statistics provide the number of documents stored under the unique ID, HDD size, heap size, OS usage, CPU usage, number of bytes read per second, number of bytes write per second and number of searches per second.

Furthermore, we used two other tools, Nload and Iftop, to determine the average speed of the current flow from the laboratories. Nload is a console application that monitors network traffic and real-time flow rates. The statistics we received were displayed in two charts (1 for uplink and 1 for downlink). It provides more detailed information about the total amount of data transferred and the average, current, minimum, and maximum speeds. We used this extension in the simplest nload_interface mode, but there are many display extensions and add-on configurations using various switches.

Iftop is an application that monitors network traffic on the named interface or the first interface that is not specified, and displays a table with current flow information in pairs, thus source vs. target communication. Again, various expanding options and filters for desired networks can be used.

We have made two simple tests to determine how the increase in monitored packet flow to the performance of the device implies.

In the first test, we generated only 93Mbps flow from one source to one destination IP address. The volume of incoming data and the effect on performance were observed by the above-mentioned interface monitoring tools. We can see on Fig. X, that at the moment of the increase of the flow, the processor utilization has fluctuated, but it did not exceed the limit of 20%. In the graph on the right we can see the use of RAM memory by Elasticsearch itself, which was allocated at startup of 25GB of which only 4.2 GB is used. Because we've found, that Elasticsearch is unnecessarily blocking a lot of memory, we've lowered the size of the allocated memory to 18GB after the test.

Sessions in test 1 had many common features, so we've made second version of generating packets from a randomly generated IP source addresses using Kali Linux. The flow rate in this test 2 remained unchanged at 93 Mbps. As a result, CPU performance has risen and ranged from 20 to max 30% (see Fig. 4). The Heap Mem graph shows that 6.3GB of 18 GB RAM allocated for Elasticsearch is used. After the test, we have further reduced the amount of allocated RAM memory for Elasticsearch.

C. Application of Useful Scripts for Moloch and Its Components

Moloch cannot run by default all its components automatically, so after restarting the server on which Moloch runs, it is highly desirable to have a script ready to turn on all three components (Capture, Elasticsearch, Viewer). We added a buffer extension to the script and switched off some of the network card features.

Since packet capturing has high disk space requirements, it should be investigated how to save disk space so that we can capture the data for as long as possible. There exist different techniques for IP flow information data reduction [23]. We have decided to archive only packet headers, more precisely the first 96B. Payload is insignificant from the point of view of collaborative plane 3 in our project. Their detection methods need to be compared, tested, and trained just on header flags. The Moloch tool alone can only truncate the whole stream of connection to the initial "n" packets, which is not our goal. We needed the whole packet flow, from which just payload need to be truncated. As a solution, we have exploited the functionality of Moloch that, in addition to capturing and analyzing captured data streams, it also allows the import of external files in the PCAP format. Therefore, the first possible solution was for us to truncate the data using tcpdump. We then import the truncated data into the Moloch system, aiming to automate the entire process. We created a script for data trimming, which then stores them at hourly intervals into a file. The script cuts data on the first 96 bytes, which also covers all the necessary information. The script saves the packets into files in the year_month_day_hour format.

Subsequently, we created and used a script for importing truncated packets into the Moloch tool. Moloch implicitly does not allow importing files with truncated packets, it is necessary to change the readTruncatedPackets parameter in Moloch configuration file. It is also important to set the folder permissions from which Moloch imports truncated packets. The import itself did not cause a significant increase in load. By testing, however, we encountered a problem in the subsequent attempt to export data for a longer period from Moloch. It is not possible to precisely define the time interval that the Viewer manages to export, and vice versa, which is not. We did not find any information in the created logs that would point to the cause

of the problem. We have explored the possibility of data export failure when searching for data captured directly by the Capture instance. We also consulted with the developer of the Moloch through the tool support forum [24]. Developers have warned that Moloch is not recommended to work with truncated packets. Part of their recommended solution was to change the Elasticsearch configuration to be able to export many different sessions. We added the following line to the Elasticsearch configuration file:

index.query.bool.max_clause_count = 10240.

However, this offered solution didn't solved our problem and the export stopped immediately after the download started and failed.

Since Elasticsearch was designated as the point of the problem, we tried to get an overview of Elasticsearch behavior. There are different extensions of Elasticsearch that allow us to track its status in different graphs and statistics, e.g. Kibana. Initially, we focused on making it easier to monitor with the available plugins (Bigdesk and Head). Bigdesk [25] is the easiest plug-in available, which makes it easy to keep track of what Elasticsearch is doing. Head [26] is a front end of the Web API that allows us to browse, search, and interact with the Elasticsearch cluster. It allows both a look at the Elasticsearch state as well as working with individual daily batches of indexes. In the default configuration after Moloch's installation, the Elasticsearch cluster is launched at localhost. Since we are accessing the server using Secure Shell (SSH) only to the terminal, installing plugins solved our problem only partially, because we did not have access to the plugin's graphics environment using the console. The goal was to make Elasticsearch available for remote access using a browser.

Moloch has the property that when it fills the disk space above a certain boundary, it starts erasing the oldest data. However, this property does not apply to imported data, Moloch will not automatically delete them. That's why we've created scripts that resolved this. This would prevent the disk space from getting full. We've added these scripts to the crontab to run each day. We do not recommend that scripts for importing and truncating packets run from two files, as the import script can be triggered before the hourly clipping interval of the truncated data expires. As a result, Moloch could import a file, for example, with only 20 minutes of network traffic and the other 40 minutes would be saved just after import. With the next import, only the data from the next set of new hours will be imported again. Moloch would create large empty time windows. Therefore, we have edited the run_tcpdump.sh file so that both truncating and importing is done from this file. We set a pause of 5 minutes between the truncating and importing. This prevents the import of files into which the data is still stored.

We have also to consider that tcpdump has only a limited buffer size, and it starts to drop packets when buffer is full. However, the buffer size can be configured, and we recommend increasing it. Packet drops were tested by running packet truncating with the output displayed on the console for several hours during which we generated flows at a rate of 93Mbps using a 100Mbps line. Then we stopped the truncating and the console showed an output with the number of received, captured, and dropped packets.

D. Cooperation of Moloch with the IDS system

Our aim is to link Moloch with an IDS system that would detect attacks, and according to this detection, the archived data in Moloch would be labeled with the appropriate tag. Subsequently, it would be possible to request data from the archive with a certain tag and export it for further analyzes, respectively to create a custom dataset of attacks. Since we are using Snort as IDS system, the initial plan was to explore Moloch's cooperation with this tool. The Moloch system does not allow direct connection to IDS/IPS systems [27], but there are specific plugins that allow Moloch to connect to IDS systems.

In our first approach, we used a solution using the Pigsty plugin [28]. Pigsty is very efficient and customizable spooler for the unified2 file format. IDS Snort logs are stored in this U2 format. Pigsty is based on adding plug-ins for specific needs for specific system. Our effort was to install the developed pigsty-moloch plugin after installing the Pigsty itself. This plugin looks up the logs in the U2 format, pulls out information about the attacks, and marks the relevant flows in Moloch. According to this tag, we could filter the streams in Moloch. At this stage of the solution we had to return node.js to version 0.10.48, which was supported by Pigsty. Finally, we failed with Pigsty-Moloch plugin. The original solution was developed for IDS Suricata, but it also allowed IDS Snort to work together with minimal variation. However, Suricata has stopped supporting the U2 format. JSON format became the new format for these logs. At the time, this original solution ceased to be developed and a new one was created [29], which is available only for Suricata. While there might be a possibility to convert the old U2 format to JSON, the other scripts that are part of the solution are created for the configuration files and components of the Suricata itself.

V. CONCLUSION

Moloch is a useful tool for network forensic analysis and its usefulness would be enhanced by its interconnection with IDS systems and SIEM systems. The installation and adaptation of components for infrastructure is not very complicated, according to our experience. Moloch does a full packet capture by default and since we wanted to save the disk space, we've solved packet truncating and then importing these data to Moloch. The solution is promising, but there is a problem with exporting those data in some cases. In the case of full packet capture, the export takes longer, because the data represent a bigger volume of network traffic, and the export fails only exceptionally in case of an invalid index, when the viewer instance that needs to restart falls. Moloch in the new version of 0.19.2, however, also claims to eliminate data export issues, so this option remains interesting for us and we will continue our future research.

There exists solution with Pigsty-Moloch plugin for connection of Moloch with IDS Snort. Unfortunately, it is not further developed and it is not working with the current version of Snort. It is our intention, however, to remove this critical point and allow Moloch to interconnect with IDS Snort so that we can also use this tool to detect attacks. In parallel, we will be dealing with the Moloch tool interface with IDS Suricata in our upcoming research. Suricata is a high-performance, open source Network IDS, IPS and Network Security Monitoring engine, and is owned by the OISF. Since Eoin Miller is a contributor to OISF, we assume that connection of Moloch and Suricata will

continue to be developed. In the future, we will also concern about connection of Moloch with SIEM systems, and deploy the Moloch tool as multi-node system.

VI. ACKNOWLEDGEMENT

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Development of the Support Tool for Education process in Informatics

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Abstract—**The subject "Informatics" is part of many specialties, including non-technical specialties. Thus there are some complications in learning of this subject for students with different levels of knowledge in computer science. The development of support tool for education process is necessary to improve the level of understanding of principal paradigms in informatics and programing for students of non-technical specialties. In this paper the development of supported tool named FRIMAN is considered. The tool allows introducing and teaching of students the basics of programming taking into account minimal skills in computer science. The tool architecture is considered in the details. The functions of all modules are presented too. The possibility of the supported tool development in future are discussed too.**

Keywords—learning tool; structural programming; flow diagram; Unified Modelling Language; informatics education

I. INTRODUCTION

The teaching of computer science programming at universities is a complicated process. Programming brings different programming paradigms that are quite different. The best known of them are procedural programming, object – oriented programming, declarative programming, functional programming and the other paradigms. It is advisable and necessary for students to prepare themselves to complete several programming paradigms at the end of their education.

At our faculty we teach the first informational subjects related to programming, already in the first semester of the first year of bachelor study. Informatics is taught in three distinct fields of study, such as Management, Computer Engineering and Informatics. Students in these fields come to study with a different level of knowledge and experience in programming.

Most of our students have no knowledge of programming and designing information systems before the courses and, therefore, many students have usually problems to understand them [2].

In Management and Computer Engineering, this knowledge is almost zero. In Informatics, about half of the students have already met with programming in high school. They have mostly met a structured programming in different programming languages, such as Pascal, C language, Delphi.

On our faculty we begin to teach programming using object - oriented paradigm. This method is very well accepted by the beginners because it is possible to describe the real world and its systems with a certain degree of abstraction. A practical tool for teaching was decided Java.

On the other hand, students need to create simpler algorithms [5] in the methods and constructors bodies. At our faculty, a structured programming and process of creating algorithms are not taught independently. As the knowledge of computer science students is not homogeneous but diverse, there is a need to create a software tool that allows them to learn about structured programming [1].

During the teaching Informatics, we found that one of the biggest obstacles for passing the courses successfully by beginning students is to understand the principles of syntax and compliance with the Java language. For these reasons, we have tried to find a solution that would simplify initial lessons of the courses and, at the same time, allow grasp and understand the basic concepts of structural programming and software development.

Main aim of described tool is to familiarize students with the basic principles of structure oriented programming and object-oriented paradigm without using the Java syntax. This part of teaching results in a common understanding of the basic principles necessary for the courses.

For this purpose, we have designed a learning support tool for teaching students in the bachelor study program. This tool was named FRIMAN, and it has been developed in the frame of Project course, which is taught in the master study program "Informatics" at our faculty.

In this way, students will learn about teamwork and work on a larger project in the engineering field.

In additional we plan to teach students considering constructions of the Java language. In this step, a tool suitable for development more complex Java applications will be used. For the purpose we use development environments at our faculty like: BlueJ and Netbeans. Using this approach, we want to achieve a gradual consolidation of the most important knowledge.

II. TOOL REQUIREMENTS

In the following, we will focus on the description of the FRIMAN tool in terms of requirements. In developing this tool, we need students to present the basic features of structured programming and process of creating algorithms.

It is necessary that the FRIMAN tool to be:

- suitable for beginners,
- user friendly,
- be able to work with code fragments in structured programming,
- be able to work with object – oriented paradigm in Java programming language,
- prepared for possible extension to work in other programming languages.

We plan to implement these requirements using also with the following FRIMAN features:

- syntax validator of the code in created classes,
- model which allows users to create instances of implemented and compiled classes with a help of the graphical user interface (using flowchart diagrams),
- debugging module for compiled classes,
- color distinction between individual sections of the code,
- created instances have an ability to receive messages in a graphical way,
- view the internal state of the instance by inspecting values of the attributes,
- automatic setting correct positioning brackets especially in blocks or nested blocks of the code.

One of many problems of starting students in Java programing is using the output terminal window. The current design of application graphical interface is good, but use of more complicated constructs, such as "System.out.println(parameter)" or formatted output, seems to be very confusing for beginners.

Entering input data using class Scanner is also difficult to understand for beginners. The inputs and outputs handled by more advanced way, e.g. by class JOptionPane from package javax.swing, means even much more challenging task.

It follows from the text that the FRIMAN tool should also solve the problem of inputs and outputs.

III. Tool Proposal

The analysis of problem state show that we looked for a new environment that would satisfy determined requirements. Similar application which we found was Greenfoot [6] and BlueJ [7].

In Greenfoot, students acquire knowledge by creating simple computer games. This approach can be very interesting and attractive for students. The latest versions of Greenfoot contain a pseudo language called Stride, which allows creating simple game applications in more professional way.

A big benefit of this tool is a possibility to select individual statements and language elements from the menu placed in the right column. After the selection, the user fills the fields of the statement, e.g. the condition and

executed code in case of if-statement. The code created using Stride is then automatically converted into Java.

Furthermore, this tool also allows developing applications by direct use of the Java programming language.

However, the main drawback of the solution based on Greenfoot is a necessity to learn another programming language, i.e. Stride. Students would have to learn two languages and that could complicate the situation for beginners and bring confusion into acquired knowledge. Another ground for refusal of Greenfoot was the fact, that Greenfoot environment uses a construct of inheritance, which can be very difficult to understand by beginners. For these reasons, we had to look for other solutions.

Within the scope of the Project-based courses at our faculty, the graduate students in the field of informatics participate in development of various information systems. In this way, students acquire not only the latest industry knowledge but also many important skills, such as teamwork. We also lead several students in these courses and, therefore, we decided to develop the learning tool that would meet all the requirements described in the previous sections in cooperation with them.

Within the basic programing courses we also use graphical representation for classes and the associations between them. For formulate algorithms in a graphical way is usually used UML. For this purpose, we use software tool developed at our faculty. This tool is named UML FRI [4], and it has support for several kinds of UML diagrams. In these courses the most often used type of UML diagrams is class diagram. Work with this diagram brings students an overview of the design phases of software applications.

In the basic programing courses, every student has to create a semester project. The project is a simple application in Java, and it should present the knowledge gained during the semester. The semester project includes a documentation that contains class diagrams of the created application. Our experiences show that work with UML diagrams and tools for its creation is an important for students to gain knowledge. Usually, students do not have a problem with drawing the diagrams.

Later lessons in other courses will be able to familiarize students with Java and will be focused on re-development of algorithms proposed using diagrams in Java.

The issue of implementation, which depends on a specific programming language, will be considered in other courses created for students that are interested.

The tool is designed with respect to the previously mentioned requirements and could be extended by other functionality that allows transformed the created project into other object-oriented programming language. This way, students can obtain valuable awareness on significance of the analytical phase of software development [7].

At the same time, they will be able to realize the fact that the model of the tool is independent of the implementation language, which is important from a pedagogical point of
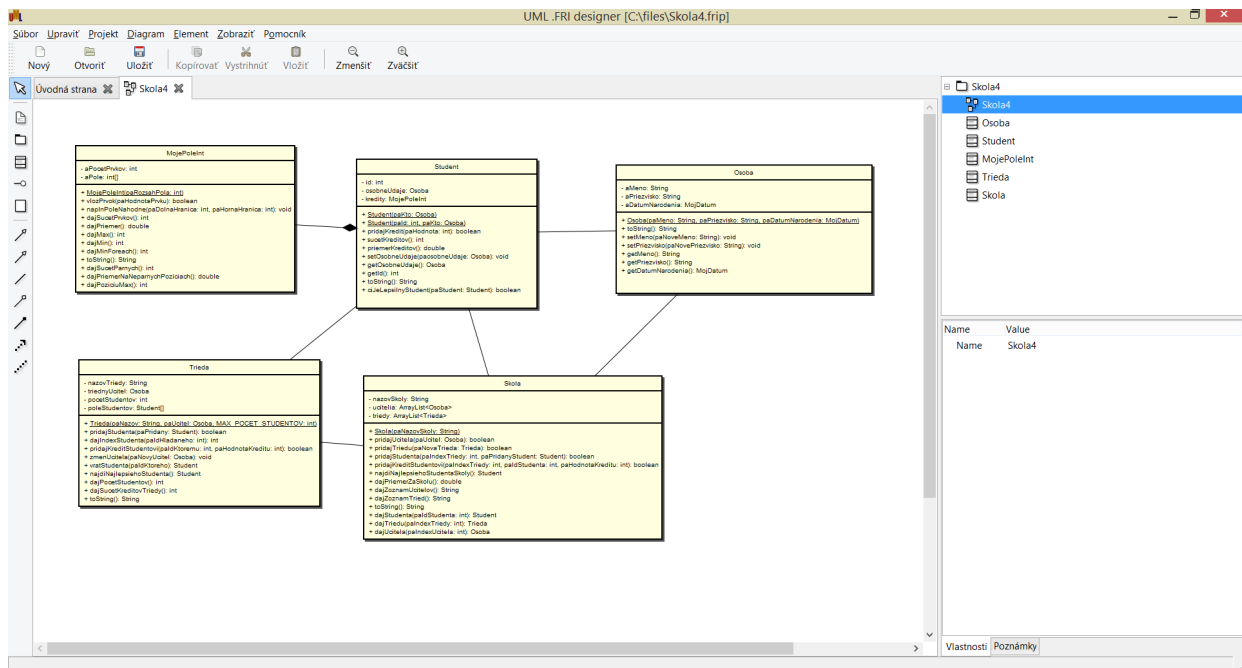
Figure 1.   Example of Class diagram in UML FRI tool

view. By applying this extension, the tool could also be simply adopted in future change of the programming language used in both courses.

This language is currently Java, but it can be exchanged for any other programming language without changing the basic curriculum of the courses. The development of programming languages is a permanent process and more appropriate programming language may appear in the future [8].

Since we have found no suitable system to meet our requirements, we have decided to design a new software tool to support FRIMAN Computer Science.

The proposed tool was named FRIMAN as the connection of the abbreviation of the name of our faculty (FRI) and word "management" [4]. The basic idea of the tool is to teach programing using intuitive graphical interface without need to use syntax of a specific programming language.

The FRIMAN tool will connect with the UML FRI application. The diagrams used in the FRIMAN will in fact

based on XML documents generated by UML FRI. Graphical interface of the FRIMAN will be user friendly to be easy to use and attractive for students. An example of class diagram in UML FRI is in Figure 1.

IV.   DESIGN OF ARCHITECTURE FRIMAN TOOL

We created the basic architecture of this tool that is presented in Figure 2.

The tool we divided to these basic modules:

- Editor
- Debugger
- Build system
- Core with parser and Lexer
- Loader of App
- Interpreter of graphical compotents
- Classviewer
- User interface

The Editor module will allow you to create flowcharts of individual methods and constructors bodies via graphical components. Generally, understanding and creating flowchart diagrams is much easier for beginners than programming itself.

Editing individual programming constructs will be performed through graphical components. Individual graphical components must provide help for their operation. Every component that can work with variables (attributes, parameters and local variables) has to offer access to them. In the case of reference variables, the component has to be able to show interface of the referenced object.
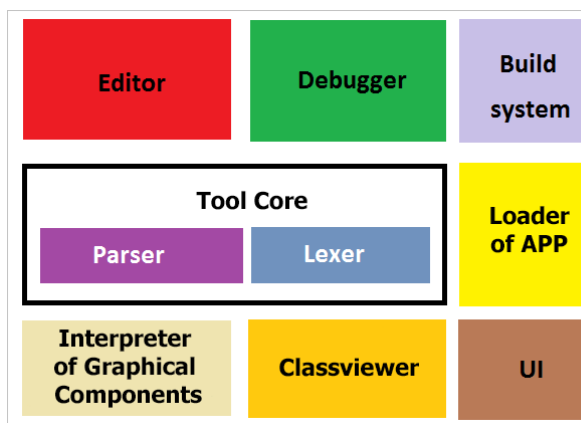
Figure 2.   Base architecture of tool
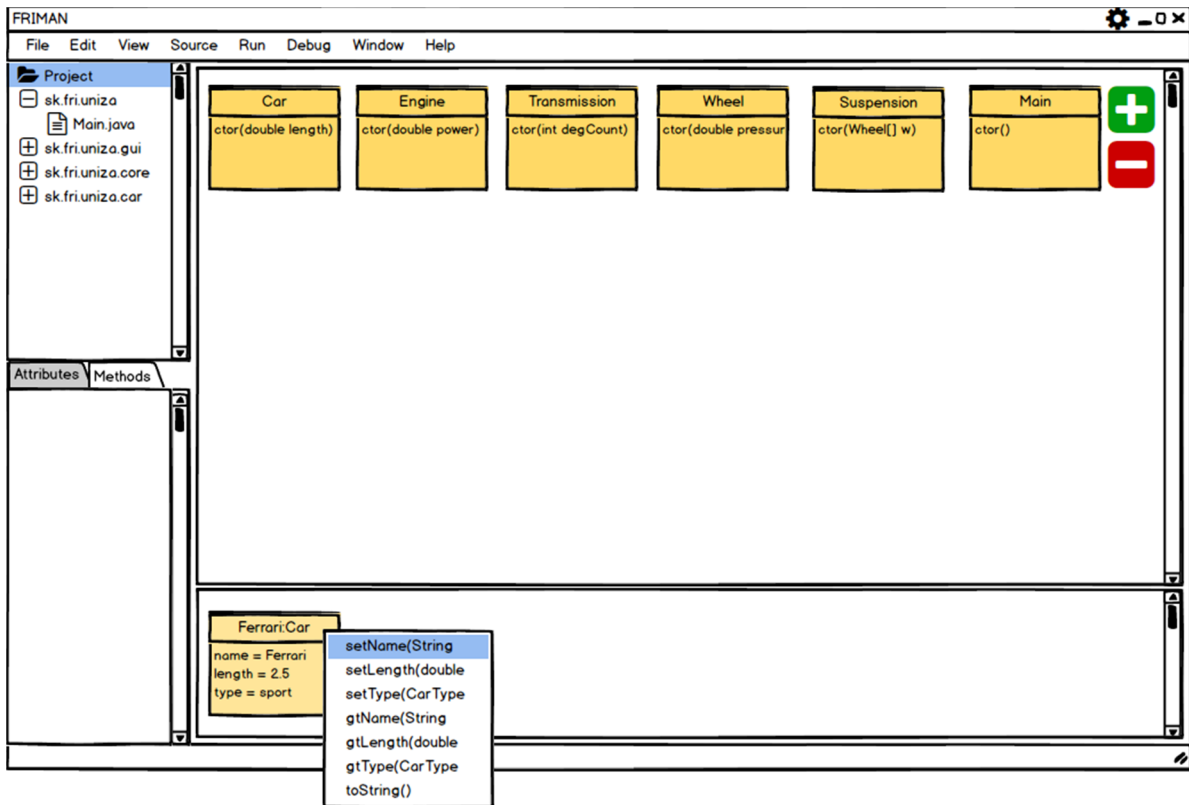
Figure 3.   Example of class viewer gui in real project in FRIMAN tool

The editing module is connected to the module Interpreter of graphical components, whose function is transformation of graphical components into Java and vice versa.

Debbuger module will allow you to search for logical errors in the proposed algorithms. As algorithms are designed as flowchart diagrams, in a user-friendly way, modul Debbuger will step through flowchart diagrams [9]. However, in fact, it will perform a code transition transformed into one of the programming languages. In our case, it's Java. This process will run in the background and will not be visible to the user of the tool.

Furthermore, the FRIMAN will be capable to debug the generated code, and the debugger will be connected with the graphical components. This allows students to see their logical errors directly in the diagrams.

Graphical components can correspond not only to one command in Java but also to several. In this case, it is necessary to ensure that the debugging module will correctly interpret line numbers of the various graphical components. Further, if it is necessary, the module has to allow identifying the fault line. This problem is not trivial, and its solution requires finding correct transformation.

The Build System module will allow you to create projects and edit existing projects. One project will be able to include several classes and describe relationships between them through composition and association relationships.

The core of the tool is designed as several co-operating modules. One of the modules - Parser - will be to compile the source code in the given programming language (XX.java) into the executable code (XX.class). In this Java programming language module, it is planned to use an original Java compiler.

Modul Lexer will be responsible for attaching additional classes from API libraries.

Class Viewer will allow the user to view, add, and manage individual classes in a given project. It will also be able to create instances from each class. Instances created will be able to send messages and display return values from the appropriate methods. This functionality is shown in Figure 3.

At the top of the GUI Class Viewer, the individual classes of the project are displayed. Among them is the Car class. At the bottom of the GUI class viewer, the instance of the Ferrari Car class is displayed, with the individual attributes of the instance and their values. In addition, the interface of the given instance is displayed (a list of individual messages that can be sent to Ferrari Car instance).

Graphic interpreter will be transformed from graphic components (represented by flowchart diagram) into source code in the given programming language (Java).

The Loader Module will ensure the ability to run an application and execute individual commands in the FRIMAN environment.

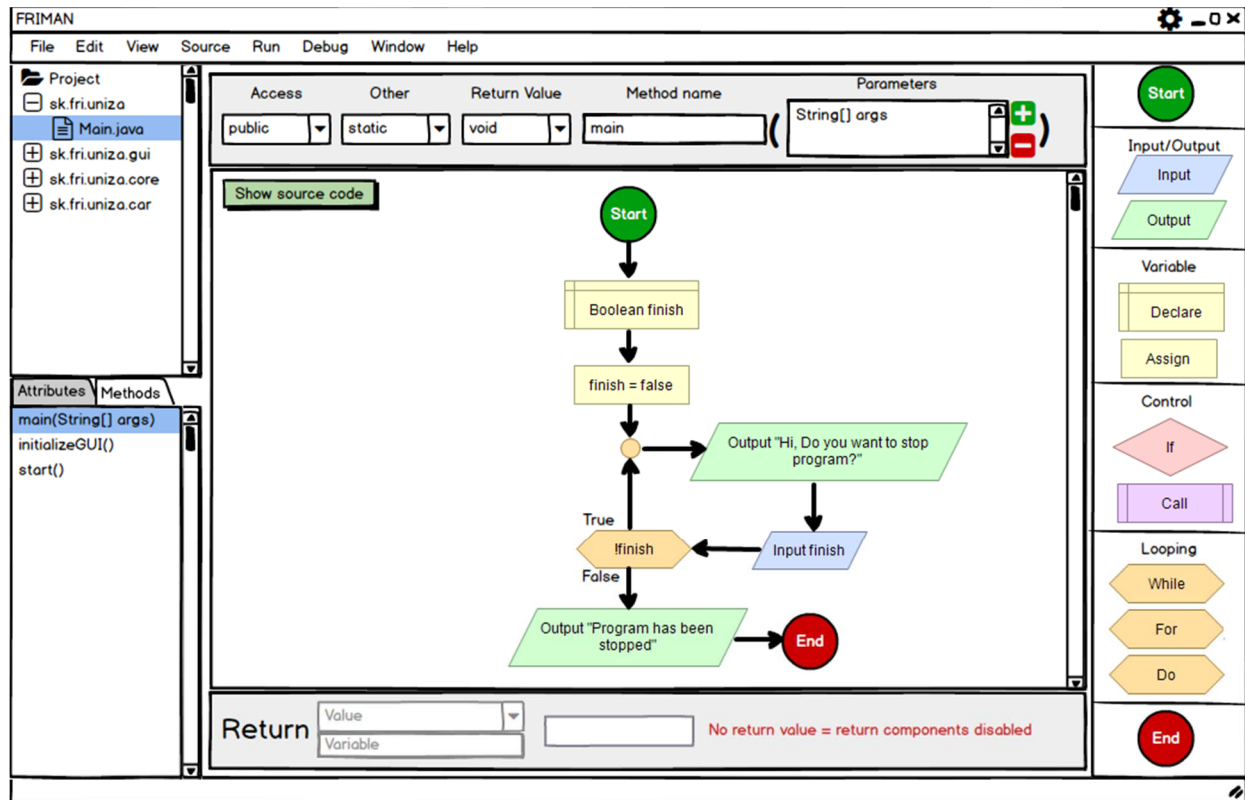The user interface module covers the display of user functionality of each FRIMAN module.

Figure 4.   Example of code flowchart in FRIMAN tool

V.   IMPLEMENTATION OF TOOL

Learning tool FRIMAN and its architecture brings a number of issues that needs to be resolved. Therefore, we plan to implement it utilizing the latest technology of object-oriented programming and using the JAVA language. One of the technologies that will be used is reflection.

Using the FRIMAN, students can develop applications based on the following steps:

(a) designing classes including relationships between them using class diagrams provided by UML FRI tool;

(b) the FRIMAN creates basic representation of the classes, their attributes and headers of the methods and constructors by parsing the appropriate XML files obtained from the UML FRI;

(c) students will implement algorithms as the bodies of the generated constructors and methods with the help of graphical components provided by the FRIMAN;

(d) the FRIMAN transforms diagrams into Java language;

(e) debugging the final application using graphical representation of instances created from implemented classes.

We have started the realization work with several modules, which will be described in the following text.

First, we will deal with the FRIMAN graphic editor, which allows you to create flowchart diagrams.

Figure 4 shows the design of the Friman GUI interface. This is a part that represents the display of user functionality in terms of the FRIMAN graphics editor.

In the top left of the window there is a list of projects between which the current project is selected and marked. Within the project is selected and marked a specific class. This functionality does not differ from the free user environment of programming tools.

In the lower left, you can switch between the following:

- fields,
- methods.

A list of methods is displayed on the image, and the main method is selected. In the middle of the window, you can use the graphical editor to create a flow chart of the selected method. On the top bar there are combo boxes, which allow characterization of the head of the given method:

- access – public, private ...
- types of class – static, abstract ....
- return value – void, int, boolean, object value...
- identificators of method
- parameters – in brackets (there is possibility to add and remove them)

Under the header, a portion of the window is reserved for creating and drawing a flowchart diagram.

In the bar in the right part of the window, individual components are displayed, from which a flowchart diagram representing the algorithm in a structured programming can be scanned.
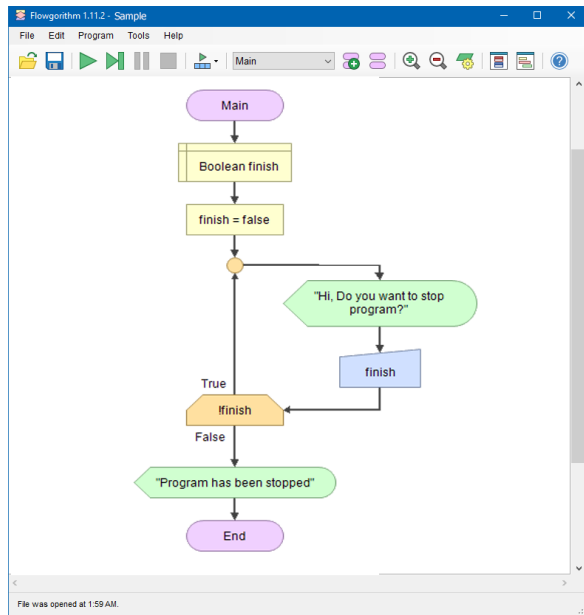
Figure 5. Example of code flowchart in Flowgorithm tool

A return value is displayed at the bottom of the window, where the user can select the return value type and the specific variable.

In base window, you can switch between the different modes of the tool, namely:

1. complete class diagram of a selected class;
2. flowchart diagram of a selected method (it is on figure 4);
3. source code of a chosen method of a selected class in Java language.

Another implemented module is the class viewer module shown in Figure 3 and its functionality is described in the previous chapter.

When developing the system, we are looking at the latest trends in the field of application that can be implemented in the proposed instrument. One of these new applications is a Flowgorithm tool [3]. The tool allows creating flowcharts and triggering them. However, the other functionality requirements of the developed tool do not meet. For example, it does not allow working with projects and linking multiple classes or methods, and so on.

For this reason, we do not consider this tool as sufficient and we continue to implement our tool with idea of flow diagram. Figure 5 shows the same algorithm in the Flowgorithm tool [3] as in Figure 4 in the FRIMAN tool environment.

VI. CONCLUSION

Today's time is closely related to information science. The training of IT specialists and programmers is an important area of education. The most important part of education in any area is the foundation. The basis of programming is to understand the process of creation

algorithm of the problem solved. The algorithm can be described using a flowchart diagram.

For this reason, we have decided to create a support tool for teaching the basics of programming workers using flowchart diagrams.

We have worked out the specified requirements, and based on them, we have created the basic FRIMAN architecture. Gradually, we develop the individual modules of this tool. Some modules were exposed to various hidden issues during implementation, which were not apparent at first. For this reason, the implementation of the tool will require many inventions and routine work to complete.

We plan to test the final tool in the process of Project teaching at our faculty where possible malfunctions are identified. In short time the tool will be tested in practices laboratory classes of students in first year of a Bachelor's degree program in courses as Informatics for Managers 1 and Informatics for Managers 2.

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Object tracking in multicamera systems

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Abstract — **This paper deals with object tracking in multicamera environment. It this paper system is designed for object detection, tracking and evaluation in multicamera environment. Primary use of this system is for tracking humans and their figures. For different types of scenes, system allows adjusting of key parameters for detection process, tracking process and object evaluation. System output consists of object evaluation based on calculated metrics. For object evaluation, camera is selected with the best view of given object. Metrics calculation is based on object position, object size and object rotation towards the camera.**

I. INTRODUCTION

Object tracking and object detection in multicamera environment belongs to the computer vision field. This field deals with graphical information analysis and processing, that is included in images or videos. It is trying to simulate human vision. However, this task is very difficult due to complexity of human vision. There were created many methods in computer vision that solve partial problems of this field.

This field went through fast development in last years. Main reason for this fast development is raising computational speed of new devices that have no problem with processing of graphical information by methods of computer vision. Nowadays, majority of new devices are equipped with cameras which contribute to development of this field. Methods of computer vision are becoming part of applications for everyday use.

System for tracking humans in multicamera environment should consist of four major parts. Detection part that detects objects and decides whether is it object of interest. Part for object identification between cameras. Tracking part in which object is traced through frames. Evaluation part where object information are extracted and evaluated.

II. OBJECT DETECTION

First step in object tracking is to find object that will be tracked. For that object of interest has to be detected and evaluated whether is it good fit for later tracking. There are four types of object detection methods based on different object properties [1]:

1. **Shape of the object**. These methods are based on automatic analysis of geometric shapes of objects and theirs comparison with shapes stored in database. The most commonly used parts for comparison are object boundaries. Also representations of whole object volume or particular object points are used. Commonly simplified representation of object shape is used which is called shape descriptor.

2. **Object movement**. Detection based on object movement is probably the most commonly used method. There are three types of methods used: optical flow, background subtraction and frame differencing.

3. **Color of the object**. These detection methods are based on image color properties. Two main color properties usually used for object detection are: distribution of lighting intensity and object surface reflection. RGB is the most commonly used color model for object color representation. However, this model is not defined in uniform color space. Because of that other color models are used, such as Lab and Luv which are uniform or HSV which is relatively uniform.

4. **Object texture**. Methods for detection based on texture use information about structural layout of object surface and relationship of object surface to its neighborhood. For human it is easy to describe object texture, however, for computer it is difficult task and it requires exact definition and analysis. Usually texture is represented by texture descriptors. These descriptors track homogeneity of each object area and histograms of bounding areas.

For human figure detection Gaussian mixture model is used. This method uses continuously updating background model for detection moving object in video frames. It is recursive method for background subtraction. This method is used mainly for effective modeling of multimodal backgrounds such as moving tree branches, waves in ocean, light reflections, etc. It has ability to adapt to continuously changing illumination of scene. For lower computational complexity is this method suitable for use in systems of real-time [2]. This method is based on the modeling of specific pixel values as a mixture of Gaussian distributions. Based on the stability and change of each mixture of Gaussian distributions, it is decided which Gaussian distribution can match the colors of the background. Pixels with values that do not correspond to the background distributions are also marked. The foreground label for the pixel persists until the Gaussian distribution is found that it is likely to contain value of this pixel [3].

For every video sequence one instance of mixture Gaussian model is used. This method provides detection of new objects that could appear in the scene. Output of this method is binary mask which represents areas of the frame with detected movement. Morphological operations are then used on this mask for smoothing. Detection of new object consists of several steps. At first, it is determined if there is failure of detector. If such event occurs, large areas of background are labeled as foreground. Detector is marked as failed when there is

bigger ratio of positive pixels to all pixels of the frame that defined threshold. In this case, detection of new object is terminated for current frame.

In the next step, edges from the frame are extracted and then subtracted from binary mask, for division of objects and neglecting the effect of boundary pixels. Canny edge detector is used for edge detection. Next step is evaluation of detected objects whether they are good fit for tracking. At first, areas which are considered to be small are deleted from binary mask. In the next step, the biggest object is found that meets these conditions:

- Ratio of the object width to frame width is bigger than defined threshold.

- Ratio of the object height to frame height is bigger than defined threshold.

- Deviation of the object height to width ratio from ideal ratio is smaller than defined threshold.

- Distance of the object from frame boundaries is bigger than defined threshold.

Smaller areas that were rejected before and could belong to the object are connected to this object. In Figure 1there is shown detection of new object that meets all conditions.
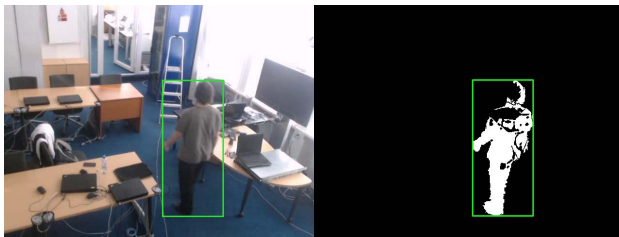
Figure 1 Detection of new object

III. OBJECT TRACKING

Tracking is based on combination of three methods. First used method is movement detection in the frame by the same method as in new object detection process. Second is detection based on object color. This method uses color histogram of the object in HSV color model. This model is better suited for object detection and tracking due to separate representation of color from brightness. This model consists of three components [4]:

1. **Hue**. Represents tone of color. This component is defined on color wheel where colors are defined by angular dimension. On this wheel colors are changing from red at 0° to green at 120° and from green to blue at 240° and back to red at 360°.

2. **Saturation**. Represents color purity. At maximum saturation color does not contain any other colors. As the value of saturation decreases, the proportion of other colors increases.

3. **Value**. Represents the level of color brightness. At a minimum brightness value, the color is black. With rising value, depending on saturation, the colors are brighter or whiter.

For object detection based on color, algorithm of histogram back projection is used. On the basis of the color histogram which describes the color representation of an object, it is possible to determine the position of the object in the image. This algorithm was introduced in [5]. There is an object model M in the form of a multidimensional color histogram. The color histogram I is created for the image in which the object is searched

for. Subsequently, the third histogram R is created based on the ratio of the histograms M and I. For each pixel in image, the probability that this pixel belongs to the object is calculated. The result of this algorithm is a gray scale image that indicates the probability of an object occurring in the image regions.

Last method used for tracking is Kalman filter. This filter consist of a set of mathematical equations that provide means for estimating process state in several aspects. It supports an estimation of past, current and future system states. This estimate can be made, even if the exact nature of the system is unknown. Filter estimates the state of the process at a certain time and receives feedback in the form of noise measurements. The Kalman filter equations are divided into two groups. The first group consist of time-updating equations that provide forward-scheduling of the current state and the error covariance equation for estimation in the next time step. The second group consist of the measurement update equations that provide feedback. It includes equations for: Kalman gain, updating the filter status estimation and updating error covariance [6].

A. Tracking initialization

After suitable object for tracking is found tracking process is initialized upon this object. Based on binary mask of new object from detector and the current frame color histogram is created. Two-dimensional histogram is used for color representation based on H and S component of HSV color model. This histogram is thereafter normalized. Then the color histogram of background is created based on inversion of object binary mask. This histogram is also normalized. For object there is instance of the Kalman filter created to track the position of an object in the image. The Kalman filter is initialized by the initial position of the object.

In the initialization phase of the tracking, object is tracked and its model is gradually upgraded. This phase successfully ends if the number of iterations exceeds the defined minimal number of iterations of initialization phase and the conditions for terminating the initialization phase are met. These conditions are:

- The object width deviation from the average of object width history is not greater than the defined value.

- The object height deviation from the average of object height history is not greater than the defined value.

- The deviation of the number of pixels of an object from the average of the number of pixels of the object history is not greater than the defined value

If all these conditions are met, normal object tracking begins. If the object is lost from the scene during the initialization phase, it is deleted and the tracking ends. Tracking ends and the object is deleted even after a certain number of failures in the initialization phase.

B. Object classification

After successful tracking initialization, the object is compared based on the color histogram with other camera objects to find identical objects between the cameras. Output from this comparison is numerical value, which states how much two histograms similar are. The Gale-Shapley algorithm is used to find optimal pairs between objects. This algorithm solves problem called stable marriage problem. It is problem how to find stable

matching. A matching is defined as mapping from one set of elements to another. It is called stable whenever there is no element of first set that prefers an element of second set that is not paired with and vice versa. There are *n* men and *n* women. All men and all women are ranked by all members of the opposite sex in order of preference. The problem to be solved is to marry all men and women so that there are no two people of the opposite sex who are not matched together but prefer each other more than their current partners. Gale-Shapley algorithm consists of steps [7]:

1. **Step 1**. Every man proposes to the woman who is the highest in his list of preferences. Each woman accepts proposal from the man who she favors the most from list of those who proposed to her. Others are refused.

2. **Step n**. Every man who is not engaged asks for a woman who is the highest in his preference list and who has not yet rejected him. Each woman will consider the new men who have proposed to her in this step and the men she was engaged with. Preliminary accepts the proposal from the man she prefers the most. Others are refused.

3. **Final step**. This process ends when all men and women are engaged.

The result of this algorithm is creation of n pairs and all of these pairs are stable. With unequal number of objects in cameras, lists of camera objects are extended with dummy objects for the proper functionality of the algorithm. When using more than two cameras one camera is marked as reference camera. Objects of other cameras are compared with objects of reference camera and pairs are found. Object preference list consist of values from histogram comparison between objects.

C. Tracking process

For object tracking process algorithm of histogram back projection is used. Based on the histogram and the object and the current frame, a probability mask is created which for each pixel indicates the probability of the pixel belonging to the object. A probability mask is also created for the background histogram. Subsequently, the object mask is divided by the background mask. From the resulting mask and from the motion mask obtained by the detector, the final binary mask is created by bitwise OR operation. By applying the CamShift method, a boundary rectangle is obtained which marks the object in the frame. The input for this method is the final binary mask and boundary rectangle from the previous frame. When a detector fails, the object is tracked only based on the Kalman filter's prediction. Size of the bounding rectangle does not change in this situation.

D. Object loss and occlusion

In the object tracking process there is determined whether a sufficient number of motion pixels has been detected for the object. If this number drops below the threshold, tracking is stopped. Thereafter, it is decided whether the subject has stopped or disappeared from the scene. Loss can occur, for example, when object enters a door. Decision is made by comparing the object histogram and the calculated color histogram in the last known position of the object. If the object is not found at this location, its tracking is disabled and is considered lost.

Tracking of stopped object will continue when a sufficient number of motion pixels are detected.

When object loss is detected, object tracking is stopped and object is labeled as inactive or deleted. If tracking inactivation is set, for each new detected object, it is determined based on the comparison of color histograms whether it is an object that was previously tracked. If the same object is found, the tracking of the inactive object is resumed. Object is labeled as lost when it reaches frame boundary.

Object occlusion detection, for each object in the frame evaluates whether it is possible for the object to be in the next frame occluded with another object. Based on the Kalman filter prediction, it is determined whether the boundary rectangles will overlap in the next frame. When this situation occurs, these objects are labeled. Based of the objects labeled in this way it is determined for the following frame whether the objects are actually occluded. If occlusion occurs than objects are labeled as occluded and begins tracking using the Kalman filter. For each subsequent frame, it is then checked whether occlusion of the objects ended. If the objects are no longer occluded normal tracking of the object continues.

IV. OBJECT EVALUATION

Output from the system is the information, which camera has the best view of each object. Metrics is computed for each occurance of the object through cameras. This metrics evaluates the object properties in the current frame. Metrics computed for the same object are compared to find camera with the best view of this object. The object properties used for the evaluation are extracted from the current frame and from the object tracking process. There are four properties used for object evaluation:

1. **Object location**. Location is basic property for object tracking. It states in which part of frame object is located. Object closer to the frame center is considered to be in better position than object closer to the frame boundary.

2. **Object dimensions**. Object height and width determines which camera sees object as the biggest. Bigger objects are considered to be closer to the camera and they should have a better look at them than smaller objects.

3. **Ratio of object dimensions**. Ratio between object height and width shows whether tracking process detected whole or at least majority of human figure. Tracking bounding rectangle should cover whole figure and should be higher than wider.

4. **Object orientation**. For human figures tracking the most interesting view is from the front where the face is visible. For moving object this property can be easily determined by object movement. If the object moves to the camera, the front of the object should be visible because people rarely walk backwards.

For each object that is tracked across cameras metrics is computed and camera that captures object with the highest metrics is selected to be camera with the best view on this object. For object O metrics M^o is computed as:

$$M^o = c_x x^o_m + c_y y^o_m + c_w w^o_m + c_h h^o_m + c_r r^o_m + c_d d^o_m,$$

where c_x; c_y; c_w; c_h; c_r; cd are weights for each parameter. Parameters for metric calculation are:

- Evaluation of object location x_o m in the image on the x-axis. The best position is in the center of the frame where $x^o_m = 1$. The worst position is on the frame border where $x^o_m = 0$. This value is calculated based on the location of the object x^o and the width of the frame w^f as:

$$x^o_m = \sin(\pi x^o / w^f).$$

- Evaluation of object location y^o_m in the image on the y-axis. The best position is in the center of the frame where $y^o_m = 1$. The worst position is on the frame border where $y^o_m = 0$. This value is calculated based on the location of the object y^o and the height of the frame h^f as:

$$y^o_m = \sin(\pi y^o / h^f).$$

- Evaluation of object width w^o_m in the frame. With the increasing width of the object, the value of w^o_m rises. This value is calculated based on the width of the object w^o and the width of the frame w^f as:

$$w^o_m = \sin(\pi w^o / 2w^f).$$

- Evaluation of object height h^o_m in the frame. With the increasing height of the object, the value of h^o_m rises. This value is calculated based on the height of the object h^o and the height of the frame h^f as:

$$h^o_m = \sin(\pi h^o / 2w^f).$$

- Evaluation of the deviation from the ideal height to width ratio of the object r^o_m in the frame. The best height to width ratio is defined as 3.4 when $r^o_m = 1$. With increasing deviation the value decreases. This value is calculated based on the height to width ratio of the object and the ideal ratio r_I as:

$$r^o_m = \sin(\pi r^o / 2r_I).$$

- Evaluation of the motion direction d^o_m of the object. The highest value will have the object moving towards the camera. This value is calculated based on the location change of the object Δy^o on the y-axis and the distance d^o, which reflects change of the object position. If $\Delta y^o < 0$ then $d^o_m = 0$ otherwise, this value is calculated as:

$$d^o_m = \Delta y / d^o.$$

V. RESULTS

For testing purposes set of three video sequences were used which are showing scene from three different views. This scene with corresponding layout of cameras is illustrated in Figure 2. Four different people appears in the scene. These video sequences were recorded with resolution of 640x480 pixels and with frame rate of 30 frames per second.

The processing speed of individual camera frames in the system is dependent on the number of video sequences being processed, the number of objects in scene, and the resolution of video sequences. For three video sequences with one to four objects appearing in the scene, the average was 11.3 frames per second. When the resolution changed to 480x360, the value went up to 12.6 frames per second. After changing the resolution to half the original resolution, i.e. 320x240, the value increased to 27.8 frames per second. Despite such a reduction in resolution, the system was functioning much like with the original resolution. The greatest impact on processing speed has functions that perform pixel level operations. Most of the processing time, almost one half, is required for updating tracking objects. At tracking process, the detection of the

objects based on the color histogram back projection is most time consuming operation. Detecting a new object and assessing its suitability for tracking takes about 10% of the total frame processing time.
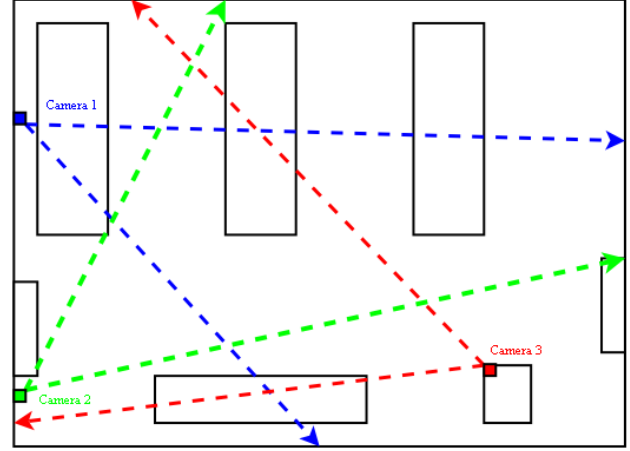

Figure 2 Test scene with layout of cameras

When using detection based on background modeling methods, there may occur situation when parts of background are marked as foreground. This situation can be caused mainly by camera movement in process of video capturing. System captures this event without any difficulty, and cope with it by tracking it with Kalman filter. The detector detects the people in the image quite well. The conditions for detection are specific enough to detect moving human figures. Object classification based on the Galea-Shapley algorithm is relatively good. Problematic are only objects that are color very similar. In this case, the object in one camera may be paired with an incorrect object in another camera. Object occlusion occurs using Kalman filtering. In some situations, tracking of the occluded object by Kalman filter fails. Particularly in the case when the object suddenly changes the direction or speed of movement or the object stops. When an object moves away from the camera view, the detection of object loss works correctly and the object is not tracked anymore. There may also be situations in the scene when the tracked object leaves camera view, such as entering the door. This situation is similar to the situation in which the object in the frame stops, since no movement is detected at the position where the object should be located. Deciding whether or not an object is lost from frame or has stopped is in most cases correct. Problematic is only very similar color representation of the object and the part of the background where the object should be located.

VI. CONCLUSION

Detection based on the motion detection using the background subtraction method worked with sufficient precision and correct objects were detected. System copes well with the loss of objects from the scene as well as with the stopped movement of the object. Classification based on Gale-Shapley algorithm was relatively reliable. The only problem with classification occurs when there were objects with a very similar color representation. For object occlusion Kalman filter was used to track the object during the occlusion. Such tracking works properly while object maintains the direction and speed, but it can fail at a sudden and sufficiently large change in speed or direction

of movement. Tracked objects are evaluated in the system for the need to select the best viewing camera of the object (Figure 3). This evaluation is based on object metric calculation. The calculation of this metric depends on the values of the coefficients used for the individual metric parameters. According to the evaluation requirements, these coefficients can determine which parameters should have the greatest weight for the final evaluation.
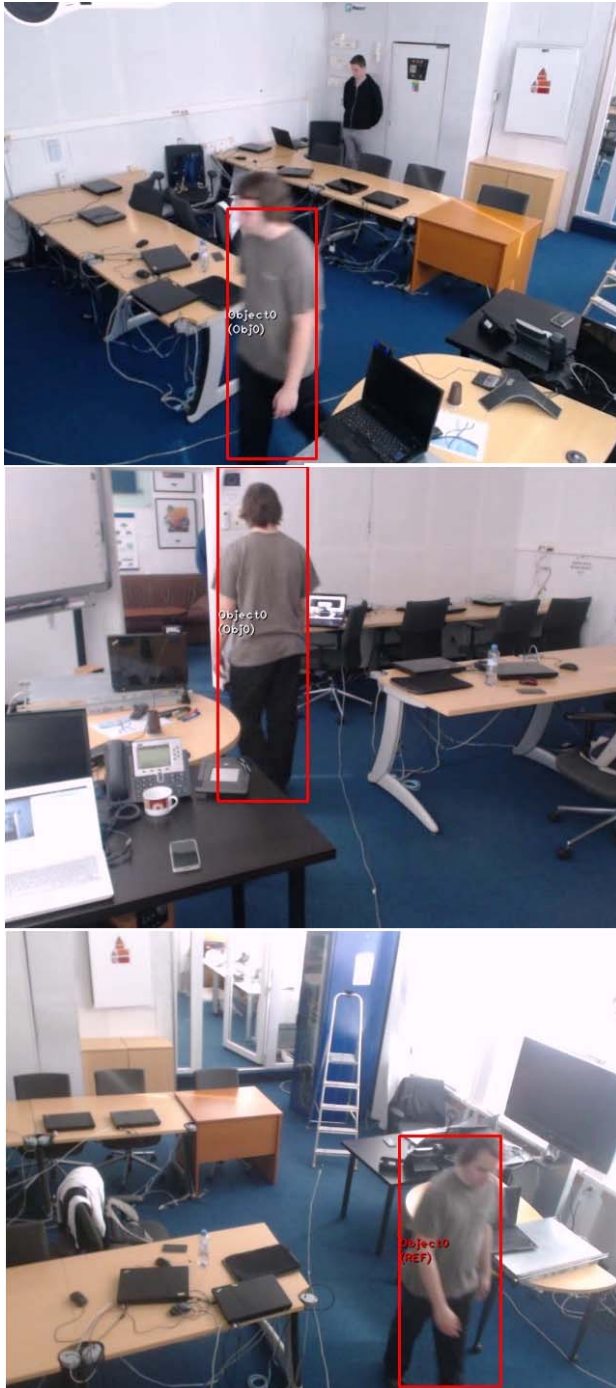

Figure 3 Tracking object in different cameras

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Graphical Environment for Enhancement of Learning Data Structures

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Abstract—**Data structures represent efficient way to organize data in a computer. They are integral part of most software. They are crucial for performance of database systems, run of vital parts of a computer, such as operating system, and they stand in the background of modern technologies supporting rapid application development. Apparently, their understanding is crucial for comprehension how to design robust programs and how their usage influence programs' performance, therefore any professional in information technology should be familiar with them. We proposed an environment to support efficient learning of data structures problematic among students of Faculty of Management Science and Informatics of University of Zilina. Students of the data structures course are provided this environment at the beginning of the course, and during the semester, they use it to implement and test relevant structures and algorithms. This approach let students focus on the data structures design so they are not forced to create user interface to test implemented functionality. Moreover, proposed environment provides library of interfaces and abstract ancestors of selected data structures effectively designed using the benefits of Object-Oriented Programming (OOP). Also, the environment itself is implemented using advanced principles of OOP such as design patterns. This allows students not only to learn data structures but also to realize how principles of OOP can be practically applied in development of big software solutions.**

Keywords–data structures; object-oriented programming; design patterns

I. INTRODUCTION

Graduates of a university should be well educated in a field they studied. They should have good practical skills as well as theoretical knowledge. The skills facilitate entry into employment while theoretical knowledge makes it easier to develop new unique solutions to problems that can arise in practice. Graduates of *Information Technology* (IT) are not an exception. They should have very good programming skills, be familiar with software engineering, and know modern technologies such as Java platform or Microsoft .Net framework. However, they should also be familiar with deeper principles of computers, understand how programs are executed and know how modern software technologies are realized and which approaches and techniques are in the backend.

The principal task of a computer is processing data. The processing should be efficient in order to obtain the results in a reasonable time. For this purpose, the processed data should be stored in structures that do not waste computer resources, such as processor time or computer memory [1, 2]. Efficient manipulation with data is a basis of any computer program or any modern computer technology.

Perfect knowledge of data structures is necessary for understanding main principles of computers, such as operating system and program execution [1, 3], design of efficient algorithms [1], compilation [4], or acquiring knowledge of realization of modern technologies [5, 6]. Because of that, each student of IT should be familiar with data structures and know them from theoretical and practical points of view, i.e., they should be able to choose an appropriate structure to solve a specific problem efficiently, but also they should know how the structure is implemented.

According to these expectations, courses on data structures should be among the most important ones on institutions educating IT professionals. Faculty of Management Science and Informatics (FMSI) of University of Zilina, has two obligatory courses on data structures. The first one is for undergraduate students (in the second year of three years bachelor study program) and the second one for master students (in the first year of two years master study program). The course for undergraduates deals with memory management, several implementations of basic abstract data types, such as array, list, stack, queue, priority queue, tree structures, associative arrays, and graphs, and sorting algorithms. The second course focuses on advanced implementations of search trees, priority queues, structures supporting multi-dimensional search, and structures for organizing data on external memories.

Data structures can be taught in different ways. On FMSI, we want students to have a proper background in implementation of data structures and to be able to use them in solving real problems. Because of that, in frame of the first course, students have to implement all data structures they are taught, and they have to make two semester projects, which are aimed to use data structures in solving practical problems, e.g., design and development of various types of information systems.

One of the principal properties of most data structures is their universality, i.e., their implementation is independent of type of data that are stored in them. This requirement can be satisfied using several techniques, probably the most suitable would be generic programming [7–9] and object-oriented paradigm [10–12]. For undergraduate students in the second year, it can be quite complicated and very time consuming to design all data structures in such a way that they will be universal, efficient, and with minimum duplicities in the code. To solve these and similar issues, we have created a specialized environment (project) for students. The project contains interfaces of all data structures that are taught during the course and provides comfort graphical interface for the testing. Thanks to it, students do not waste time by finding ways how to make data structures universal and, rather, they can

focus on implementation of algorithms that give data structures their power. Furthermore, the project is designed with respect to principles of *Object-Oriented Programming* (OOP), and design patterns [13] form its core part. Thanks to this, students can see the power of proper object design and realize why object-oriented paradigm currently plays a key role in development of complex software solutions [14].

Finally, it is important to note that data structures can also be taught using other programming paradigms, such as procedural [15] or functional [16]. Functional paradigm represents an interesting approach for programming data structures that allows develop thread-safe data structures [17]. Unlike imperative paradigms, such as procedural and object-oriented, it hides some implementation details, such as memory management, crucial for understanding of realization of data structures from low-level point of view. However, these details form one of the main goals of the first course on data structures, the understanding of memory management. Similarly, one can realize that procedural programming has some disadvantages in learning data structures comparing to OOP. The most important are non-existence of encapsulation and weak support of generic programming in case of procedural programming. The importance of encapsulation results from the fact that a data structure represents a way how data are organized together with operations that manipulate with them. Similarly, generic programming plays a key role in making data structures universal. Because of these and similar facts, we think that OOP is very suitable for learning data structures.

II. C++ AS A PROGRAMMING LANGUAGE FOR LEARNING DATA STRUCTURES

As mentioned above, understanding principles of data structures requires knowledge of an imperative general-purpose programming language that support current programming paradigms, such as OOP and generic programming, on one side, and provide facilities for low-level programing and manipulation with memory on the other. Furthermore, the language should be popular among professionals, so its knowledge allows students not only to understand efficient implementation of data structures but also it will be useful in their employment after graduation.

Multi-paradigm object-oriented languages as Java, C#, or Python, which are currently most popular languages [18–21] for implementation of projects of any sizes from small mobile applications to big enterprise solutions, are not very suitable for teaching principles and implementation of software technologies because they provide only limited facilities for low-level programming (for example, these languages automatically manage memory, so the programmer can fully focus on given task), therefore it can be quite complicated to teach how low-level structures, such as array, are realized. Other very popular languages [18–21] such as JavaScript, PHP, or R are absolutely unsuitable because they are not general-purpose languages since they are used primarily for development of web applications [22, 23] or for statistical computing [24]. Another popular language C provides perfect facilities for low-level memory access, but it is not the best choice since it lacks of syntactic sugar and, therefore, OOP using this language [25] is not as convenient as in the case of Java or C#. However, this language brings us to its descendant, C++ programing

language, which belongs to the most popular programming languages [18–21].

C++ is a multi-paradigm general-purpose imperative language, whose syntax supports most features of OOP [26–28]. At the same time, it supports generic programming using templates and allows programmers to manipulate with the memory at low-level [26–28]. Furthermore, its syntax is very similar to many other popular languages, such as Java, C#, or PHP and, therefore, familiarity with C++ can be very useful for programing in these and other languages. Because of that, we decided to use it as a primary programming language in teaching data structures. Another reason for choosing this language was a fact that our students have an obligatory course on programming in C++, which takes place one semester before the course on data structures and, therefore, they should be familiar with its key concepts, such as pointers and templates, which are necessary for efficient implementation of data structures.

One may consider Object Pascal as suitable programming language meeting all requirements. Lately the development of projects using this language has risen, since it supports several platforms (Mac OS, Linux, Windows, etc.) [29]. However, we did not use this language for two reasons. First, no course aimed on the Object Pascal is taught on FMSI, so the students are not familiar with the syntax. Second, there exists no standard of the language and some low level constructs are not performed transparently [30].

III. DATA STRUCTURES ORGANIZATION

Recall that the environment is used in the first data structures course, which introduces students into the data structures issue. Therefore the course is aimed on memory management, simple data structures and sorting algorithms. Beside mentioned topics, the focus of the course is placed on the students' ability to implement universal structures as well.

The basic premise of the course is the concept of the two levels of structures abstraction:

1. *Abstract Data Type* (ADT) is a structure composed of one or more domains (objects, items) and one or more operations on the elements of that domain. The operations are accurately specified and completely independent on the specific implementation. ADT can be considered as a black box – it is hiding its inner architecture, only the inputs, outputs and operations are known.

2. *Abstract Data Structure* (ADS) is a specific realization of an ADT. Single ADT can be realized via several ADSs. Even though widely accepted terminology refers only to the term *data structure* [1, 2, 31], we keep the word *abstract* to emphasize the generality of such a structure.

The difference between ADT and ADS on the example of the *queue* is shown in Table I.

A. ADT Specification

ADT can be specified in several forms: using axioms (Fig. 1), table (Table II), graphical specification, some symbolic language, etc. However, to successfully implement the specific ADS, ADT's specification should

be in the technical form close to the implementation of ADS. The widely accepted language to model and visualize computer systems is UML [32]. The specification of ADT in the form of UML class diagram comes out naturally (Fig. 2).

ADT Queue	ADS Explicit implementation of queue
Domain	
No further specified items.	Mutually linked dynamically allocated items of the same size.
Operations	
Insert the item into the queue.	Add the item at the end of the link of items.
Remove the item which was inserted as first.	Remove the first item from the link of items.
Is the queue empty?	Does the link of items contain any item?

$Q - queue$
$p, q - elements$
1) $Create = new\ queue$
2) $Peek\big(Push(p, Create)\big) \equiv p$
3) $Pop\big(Push(p, Create)\big) \equiv Create$
4) $Peek\Big(Push\big(p, Push(q, Q)\big)\Big) \equiv Peek(Push(q, Q))$
5) $Pop\Big(Push\big(p, Push(q, Q)\big)\Big) \equiv Push(p, Pop(q, Q))$

Figure 1.   Axiom semantics of ADT Queue

TABLE II.   OPERATIONS OF ADT QUEUE

Operation	Parameters	Return value
Create	()	↑ queue
Delete	()	
Is empty	()	↑ boolean
Push	(↓ element)	void
Pop	()	↑ element
Peek	()	↑ element

When modeling ADT, one must keep in mind the preservation of high level abstraction of domain elements and operations. Therefore the ADT is modelled as *generic interface*, what meets both requirements from the definition. Interface defines the set of methods completely independent on their implementation and the generic parameter(s) define domain and enables the designer to set the conditions on the elements of domain if needed.

Using of generics to define domain is not the only possibility, although it is very convenient to work with. Another way to specify domain of elements is using abstract class or interface. Methods of interface defining ADT will then work exclusively with the domain's abstract class or interface. However, there are two disadvantages using this approach. First, to use the real element of domain from the return values of some method of ADT will always need typecasting (since the ancestor will be returned). Second, this approach may expose implementation details and corrupt the inner state of structure if misused (e.g., the priority queue works with elements and priority, so the abstract ancestor of domain's elements defines the priority and also provides getter and

setter for it. After the element is pushed into ADS *sorted priority front*, one may change the element's priority, what may corrupt the order of precedence in the ADS).

Proposed environment's programming language is C++. This language does not support the concept of interfaces in its latest standard [27] (not taking into account C++/CLI [33]). However, using abstract class and multiple inheritance, this can be easily overcome. Also, instead generics, the templates are used in C++.

B. ADS Memory Organization

ADS implements ADT. It defines the operation, but the domain of the elements should still be treated on general level. Still, ADS may rely on the features of domain elements specified by condition in ADT.

The elements in ADS can be stored in single coherent or in several smaller linked blocks of memory. This leads towards the categorization of ADSs as implicit and explicit (Table III). Let us explain the differences on the example of list and its two widely used implementations implicit (ArrayList in Java, std::vector in C++) and explicit (LinkedList in Java, std::list in C++). Implicit implementation stores the elements in the array, which can typically contain more elements than currently present in the list in order to prevent often memory reallocation. These unused elements makes implicit implementation more memory consuming than the explicit one, which contains exactly the same number of mutually linked items as there are elements. The relations (predecessor, successor) between elements in implicit implementation can be only computed, if the index of current element is known (index −1, index +1); explicit implementation uses the pointers defined in the linked item. Since the implicit structure uses array, it is simple to access the element on given index (simply by using the mapping function of array), on the other hand, using explicit implementation one must traverse the link from the beginning to find the element on the desired index. Lastly, modification of implicit structure often needs memory reallocation, what makes it more time consuming than changing the pointers in the explicit implementation's link nodes.

TABLE III.   ADS IMPLEMENTATION FORMS

Implicit	Explicit
Implemented using array.	Implemented using linked memory blocks.
Relationships among elements are not directly accessible, must be computed.	Relationships among elements are explicitly defined using pointers.
Typically more memory consuming.	Typically less memory consuming.
Typically fast access to elements	Typically slow access to elements.
It is harder to modify existing structure.	It is easier to modify existing structure.

In order to preserve encapsulation, ADS may never expose attributes representing the data storage on its interface. Moreover, explicit implementation may never expose the link items in any form (input or output parameter of any method) either. If this rule is violated, it may lead in some cases to the corruption of the integrity of ADS – recall the second disadvantage of using inheritance instead of generic parameter in previous section.

C. Predefined Data Structures Library

As discussed in previous two sections, one must take into account several issues to proper design ADT and ADS to be reusable and not violating any object paradigms. It may be over the skill of the students of the course to both design and implement ADSs. Therefore, proposed environment comes with the library of both relevant ADTs and ADSs. Since ADT is in the form of abstract class, there is no need to do any further modifications by students. However, the ADS attributes are omitted and method bodies are kept empty (or throws later caught exception) except several simple methods with pre-coded bodies. The aim of the practical part of the course is to implement bodies of these methods according to the specific ADS. Naturally, all prepared classes are fully documented. Example of ADT class diagram with two implementing ADS is depicted in Fig. 2.

The library also defines all classes used for the explicit implementations (*LinkedListNode*, *TreeNode*, *TableNode*, etc.). Despite these are very simple and no student would have problem with their implementation, the time needed to write such a code can be more effectively used for example to implement complicated and more interesting methods of ADSs.

Summarization and categorization of all relevant data structures in the library provides Table IV. Recall that every ADT is defined to preserve the highest level of abstraction. Students program pre-defined ADS files. For explicit implementation, there is ready full set of classes. Here proposed set of classes is fully autonomous and can be reused in any project. However, the benefits of proposed environment lie not only in the prepared library of ADTs and ADSs, but in the graphical user interface as well. This will be further described in the following part.

IV. APPLICATION DESIGN

Application environment provides palette of functions that focus on the testing of ADS's implemented functionality. To create usable tool, we had to focus on its key properties:

1. For simple orientation, application must be logically separated into parts that follow the schedule of course.

2. It must be able to test all methods of ADS – constructors, destructors, various operations and present stored data (make iteration over the structure's elements, if the structure supports iteration). Input parameters and method results should be presented in uniform way.

3. Application must record and present all operations executed over the ADS. If an operation fails, list of operations executed over the ADS before can be used as test case.

4. To illustrate a time complexity of operations, application should provide a chart with processed times needed to execute them.

5. Simple version of logging should be also used. One must enable to log messages from ADS's methods if necessary, however no coupling with *Graphical User Interface* (GUI) class is acceptable.

6. Simple test framework should be included as well.

7. Design of the application's GUI must be straightforward and clean, so the students do not have to learn how to control it.

To create a robust application covering all presented properties one can use design patterns [13]. Their using makes easy to overcome well-known issues. It can also rapidly improve the communication between the project developers, since they may communicate in the terms of the patterns instead of explaining their programming intentions.

To bring in the application details, we will focus on two concepts and emphasize the design patterns applicability. First the management of the data structures and then the graphical user interface will be discussed. We would like to remark, that only the key features are presented, even though the application supports all features listed above.

Last thing to keep in mind is the used environment. Application is created in Microsoft Visual Studio 2015 [34] that uses C++/CLI for GUI applications. Application is designed in a way that data structures library created in C++14 [27] is completely independent on C++/CLI.
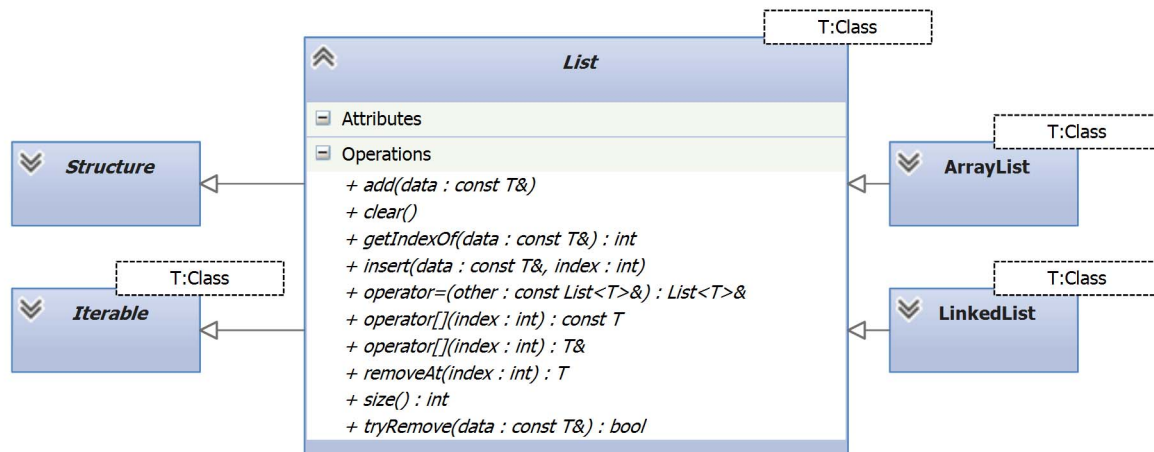

Figure 2. UML class diagram of ADT List

TABLE IV.   SUPPORTED ADTs AND ADSs

ADT	ADS
Vector	
Array	
List	ArrayList
	LinkedList
Queue	QueueByArrayList
	QueueByLinkedList
Stack	StackByArrayList
	StackByLinkedList
Priority queue	PQBySortedArrayList
	PQByUnsortedArrayList
	PQByLinkedList
	PQByTwoLists
	Heap
Graph	ForwardStar
Tree	MultiwayTree
	KWayTree
	BinaryTree
Table	NonsortedSequenceTable
	SortedSequenceTable
	LinkedTable
	DiamondTable
	BinarySearchTree
	Treap
	HashTable

A. Data Structures Management

Before designing the user interface, the proper class design of data layer must be done. The most important part is to resolve the problem of structures' lifecycle management. Selected solution has to be easily expandable (if there will be a need to add new ADS or ADT), and no additional rubbish code (code not needed by the structure, but added because of the GUI) should be added to the ADT ancestors. Also, it must be easy to specify what ADS instances are available in the application (at the start of the course there is no need to provide the instances of tables since corresponding ADSs are not implemented). We have to keep in mind the practical use from the GUI as well, so the function call to create an instances of ADS must be easily performed (we want to avoid multiple switch statements).

The design respecting mentioned properties can be built on the creational patterns *Prototype*, *Abstract factory* and *Singleton* [13]. The class diagram of all presented classes in the following text is depicted in Fig. 3.

The *Structure* ancestor of all ADTs is designed according to *Prototype* pattern, which requires a *clone* method. We wanted to keep the structures library without rubbish code and this perfectly meets the requirement. Cloning of the structures is simply the call of copy constructor of the structure itself and returning the result. Moreover, this actually calls the copy constructor, what verifies its code and meets the property on testing wide range of ADS methods as defined above.

Structure prototype is used by class *ADSFactory* to produce prototype's clone instances which lifecycle is managed solely by the factory instance (to create or remove instance of *Structure*, only the respective methods of *ADSFactory* should be used).
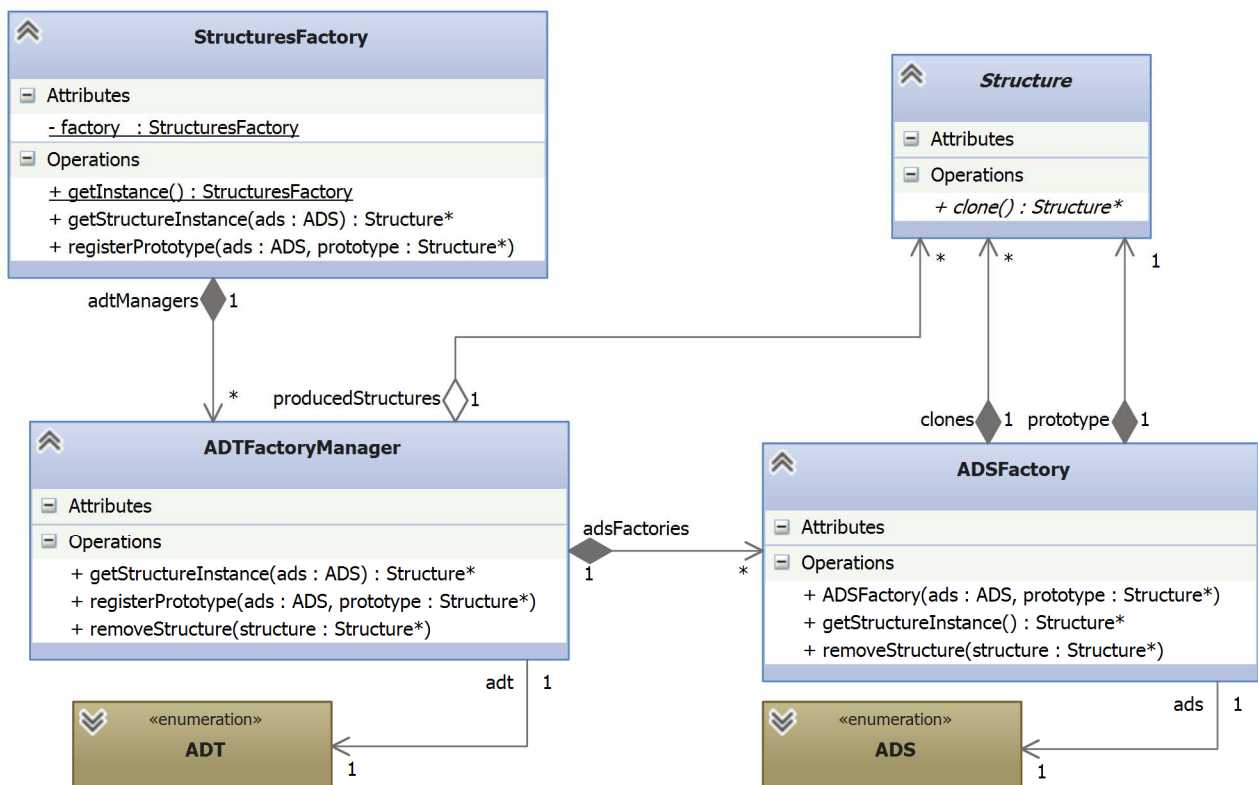
Figure 3.   UML class diagram of classes responsible for structures' lifecycle management

Instances of class *ADSFactory* are managed by instance of *ADTFactoryManager*. This object aggregates all suitable instances of *ADSFactory* (their ADSs match *ADTFactoryManager*'s ADT) in the table, which key is ADS and data *ADSFactory*. *ADTFactoryManager* is responsible for creating and removing structures by forwarding the request to the correct *ADSFactory*. Instances of *ADSFactory* are created only for the registered *Structure* prototypes. The reason for introducing another layer of factory is simple. It will be easy to present all structures of the same ADT, create new ADS instances and remove those existing from the GUI.

Similarly to the composition of classes *ADSFactory* and *ADTFactoryManager*, the instances of class *ADTFactoryManager* are stored in the singleton *StructuresFactory* in the table, which key is ADT and data *ADTFactoryManager*. *StructuresFactory* is used for prototype registration. Prototypes are registered using only the ADS, so the *StructuresFactory* decides which ADT corresponds to which ADS. Respective instances of class *ADTFactoryManager* are created only if necessary – there must be registered at least one prototype, which ADS matches ADT. If such a prototype is not registered, it will not be available in the application at all.

This approach enables us to prepare a part of the code that registers all the prototypes. Recall that structures library provides the codes with empty bodies, so the names of classes and methods are known. However, the entire prototype registration block is commented out. When an ADS is implemented, students first come to the registration block of code and uncomment desired line with prototype registration. No further action is required.

Proposed design is easily expandable. The only place that classifies ADS under the ADT is in the method *registerPrototype* in the class *StructuresFactory*. Therefore, if there will be a need for new ADS or ADT, only this method needs to be augmented to reflect desired classification.

B. Graphical User Controls

The main window of application has two parts:

1. Top part is filled with the page control containing several tabs. We choose this approach since the tab order reflects the course structure. There are three types of tabs each containing either controls for

   a. ADT,

   b. Running sorting algorithms or,

   c. Testing.

2. The bottom part is *Logger* that is used to log messages.

We will focus on the classes to create controls for ADT tabs. Inner layout of the ADT tab panel is predefined and contains three different controls as depicted in Fig. 4:

1. On the top, there is *ADS toolbar* containing controls used for respective ADS management. Only those ADSs that belong to tab's ADT are available. To create new structure, or delete or clone existing one, panel communicates only with *StructuresFactory* singleton.

2. *Structures list* is docked to the left side of the tab and provides all created and not yet deleted

structures. The structures are aggregated in the respective instance of *ADTFactoryManager*.

3. *Structure panel* is empty and is used as a place, where components used to control the ADT's operation and presenting ADS's inner state (if available) are placed.
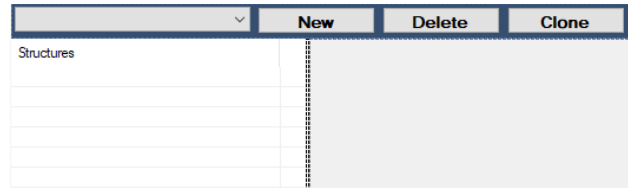
Figure 4. Layout of ADT tab

Apparently, different ADTs need different set of controls, but different ADS (belonging to the same ADT) can be controlled via the same user controls set. Therefore, it was necessary to create user controls only for different ADTs. To ensure the same look, the layout of the controls is predefined. The standard layout is presented in Fig. 5 and consists of the following parts:

1. Top *Action* panel provides space for buttons (or other user controls) to invoke a specific operation. The buttons should be created dynamically according to the operations available for the specific ADT.

2. Right *Action history* panel presents history of operations. To do so, operation must provide information about its duration. Its caption can be used to make history well readable. It is convenient to be able to revert the effect of the operation (undo) or trigger the same operation again (redo).

3. Bottom *Performance* panel plots charts for the ADS's operations time complexity. Here the times needed to execute the operation are aggregated for a specific operation (e.g., Insert) and also for a specific number of elements in the structure at the time when the operation was executed (how fast was the Insert operation when the structure was empty, contained 1, 10, 50 elements, etc.). Unique identification for the operation is therefore necessary.

4. Panel for structure *Data presentation*. This panel varies from ADT to ADT since every ADT needs different form of presentation of its data.

We defined the basic requirements on the presentation system. Again, proper using of design patterns can make the system robust and easy to expand or modify. The class diagram of all presented classes in the following text is depicted in Fig. 6.

First we have to create a mechanism to create user controls for different ADTs. We can use mechanism similar to the one presented in section IV.A. A singleton class *ControlsDirector* manages the instances of class *ControlsHolders*. *ControlsHolder* manages the panel with the ADT layout (as presented in Fig. 5) and fills it with custom controls and panels used for the specific structure's methods invocation and data presentation. The process of creation of *ControlsHolder* instance is more complicated (the panels must be created and aligned in the

form in specific order to achieve demanded result), so the *Builder* pattern [13] takes place (*ControlsDirector* represents the managing class, *ControlsHolder* the executive class of the pattern).
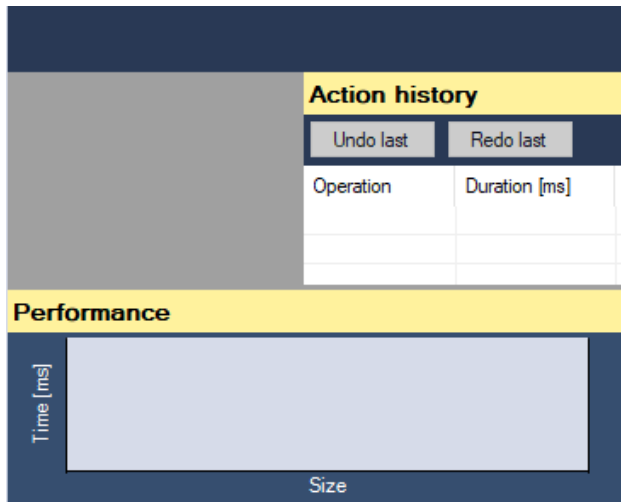

Figure 5.   Layout of ADT controls

To treat ADT operations as objects a *Command* pattern [13] can be used. Class *Action* is designed in such a way. It is defined by its ID and caption. Moreover, it contains three *Template methods* – execute, undo and redo - used by respective controls (see buttons on *Action history* panel

for example). These methods invoke protected virtual (abstract) methods, catches the exceptions, measure and log time needed for their execution, etc. The only method that is needed to be overridden by the descendant of the class *Action* is *doExecute*, if the undo support should be supported, then *doUndo* method should be overridden as well. To be able to perform an undo operation, a *Memento* encapsulating the parameters should be used.

Actions are used by *ControlsHolder*. Descendant of the class fills the action list in the method *createActions*. Then the buttons are created on the *Action* panel, and a relevant event is bounded with the *execute* method of the action.

Proposed class design is very easy to expand and use. To create controls for specific ADT, one has to do the following steps:

1. Create descendant of class *ControlsHolder* and modify proper method in *ControlsDirector* responsible for *ControlsHolder* creation.

2. Create descendants of class *Action* for every desired operation of ADT. Override the *doExecute* method of every *Action*. Return the instances of the actions in the *createActions* method of *ControlsHolder*.

3. Prepare panel for the visualization of the structure's data and return the instance of the panel in *createPresentPanel* method of *ControlsHolder*. Visualize the structure's data when *visualizeStructure* is called.
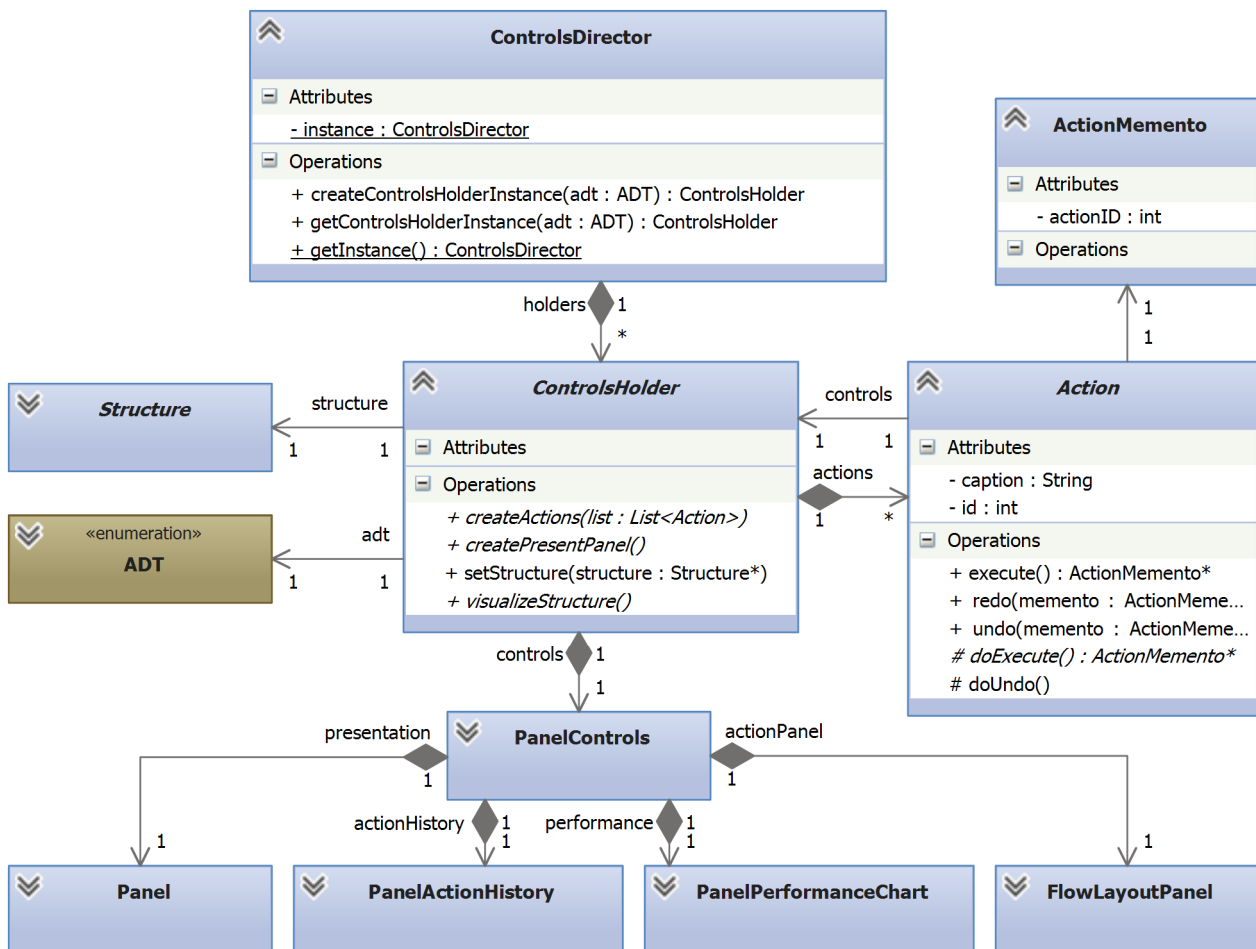
Figure 6.   UML class diagram of classes responsible for graphical user intarface

C. Final Application

Previous text proposed the design of two key parts of the application. Recall that application supports several features proposed, but not discussed in more detail in this paper (logging, plotting charts of operation duration times, presenting history list, etc.). These are completely separated frames that are convenient to include in the application, however they are not necessary for the primary functionality of the application – to provide easily extensible environment for testing of library of data structures.

The screenshot of application after some work with ADT Table is presented in Fig. 7. Application is built with all proposed features.

V. CONCLUSION

Data structures play key role in many fields of IT. They are crucial for design of efficient algorithms, performance of operating or database systems, or for acquiring knowledge how modern technologies are realized on a computer. Their importance implies all IT professionals should understand them, know the theory behind them and be familiar with their realization. At FMSI, we have developed the environment for enhancement of their learning. It allows simple implementing and testing of all relevant data structures taught during the first out of two courses on data structures. Thanks to it, students obtain knowledge of practical aspects of data structures.

The environment for learning data structures has been created in C++ programming language. This language was chosen because it allows applying most benefits of OOP and generic programming as well as low-level access to hardware of a computer. OOP and generic programming allow implementing data structures with a minimum of duplicities in the code and in such a way that they are independent of data that are stored in them. Possibility of low-level approach represented by pointers and low level functions such as *calloc* or *free* makes it possible to grasp knowledge how object-oriented code is executed, i.e., what and how is done when a constructor, the destructor, or other methods of an object are called. This allows students to understand processes that are executed in a computer (specifically in its memory) when a program runs on the computer.

It is important to note that the environment has been implemented in accordance with the principles of OOP. Specifically, a lot of design patterns have been used during its design. This fact allows students to see how principles of OOP can be used to develop robust applications that can be expanded simply by other functionalities. This allows the environment to be used in a course on design patterns (that is taught at FMSI in the first year of two years master study program). By exploring design and implementation details of this software, students of the design pattern course learn the practical application of wide palette of design patterns in real software.

One may notice that although the C++11 supports the *move semantics* [26], it is not included within the current design of ADTs (designed for C++14). This semantics denotes deeper understanding of the memory organization which is not covered in preceding courses. Despite this, in the next data structure courses we plan to augment the ADTs by the *move constructors* and *move assign operators* and adapt proposed environment to these changes. We believe, that well theoretical knowledge supported with practical applications using proposed environment help students to understand this topic and abet its usage in their next work.

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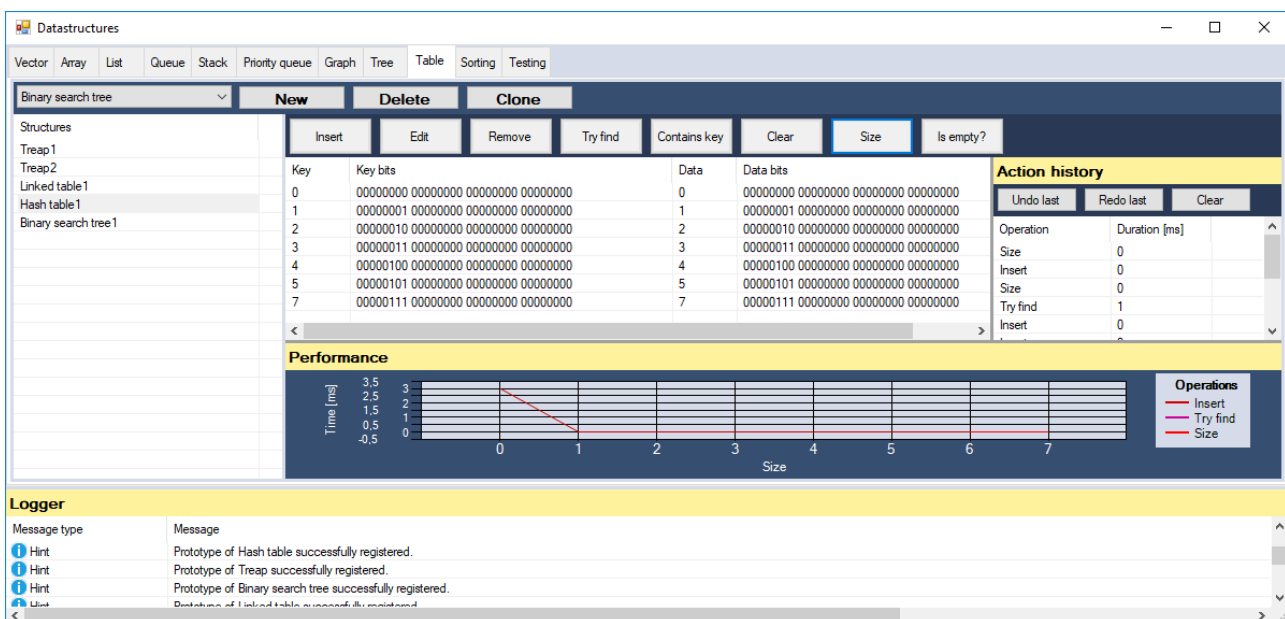[2] N. Wirth, *Algorithms and Data Structures*. Upper Saddle River, NJ, USA: Prentice-Hall, Inc., 1986.

Figure 7. Screenshot of application GUI

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Dual Education and its Importance in the Field of Age Management in Industrial Enterprises

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Abstract − **The issue of education is one of the most current topics in enterprises. The search for a valid equation to solve problems that have arisen, respectively dissatisfaction often results in the inflection declension of the dual education concept. The authors of the paper see it as a way to ensure enough qualified and trained graduates of educational facilities for practice. The importance of addressing the question of education of the future workforce is also enhanced by the demographic developments in society. The lack of young labour force to replace older workers, provides the opportunities for experts in the field of Age management. They emphasize the importance of age diversity of employees in enterprises, thus ensuring a natural exchange of experiences, skills, but also responsibilities. The aim of the article is to highlight the importance and interdependence of these two concepts. On one hand it is necessary to focus on the young generation which is the future labour supply. It is important that the amount and structure of the currently educated population is based on future labour market needs. On the other hand, businesses now have a multitude of highly qualified and professionally trained older employees with a large number of practical experiences and knowledge of corporate culture. A way of connection is the dual education in which students come into contact with long-time practitioners, who will prepare them to exercise their future profession and provide their abilities, skills, knowledge and know-how itself to younger colleagues. The aim of the article is to point out on the relationship between the dual education and age management in industrial enterprises on the example of Železiarne Podbrezová, a.s. (ZP).**

Key words – **Dual Education, Age Management, Employment, Employees**

I. INTRODUCTION

Nowadays community pays a lot of attention to vocational training. As a reason could be mentioned persistent high rate of unemployment in majority of countries. The biggest advantage of the dual education concept is that educational synopses and a theory come from an actual and assumed state of economy and, moreover, part of education takes part in the enterprise directly. Common projects of educational institutions and enterprises themselves, also in a form of graduate thesis, could represent a great benefit for research and development projects as well as for working practice. Dual training which is oriented to the practice is the way of job security. It supports the mobility of employees, increases the opportunities for career development or promotion and offers the chance to return to the workforce. A prerequisite for successful dual vocational training is to create a system that supports collaboration between the educational institution and the business world. The resulting effect is a professional qualification and immediate preparedness of graduates to engage in a business process as qualified employees. In the private school of metallurgical Podbrezová Ironworks (SSOŠH ZP) is a dual education since its inception. Theoretical knowledge in practice, students verify the right in ZP. The production of cold-drawn precision seamless tubes has an old tradition in Železiarne Podbrezová a.s (ZP). The production itself consists as a final operation of two previous operations, namely: steel plant – production of continued casting billet and hot-rolling plant – production of hot-rolled tubes [1]. The production process in ZP is oriented to the introduction of progressive methods of technology such as is the production of multi-rifled tubes [2]. Therefore, dual education in the production process is important.

II. DUAL EDUCATION AS AN IMPORTANT ELEMENT OF A CONCEPT OF AGE MANAGEMENT

The future competitiveness of enterprises and whole economies will be to a large extent based on the performance and productivity of older workers, as well as on an effective use of their skills. Thus an ageing society causes drastic changes in human resources strategies and requires a new approach to Age Management in enterprises. A growing awareness of this issue is also changing the objectives of labour market policy. In many countries its main aim is to increase the labour participation among the older population, with Age Management considered as an important factor in achieving this goal [3].

One of the most important aims of the concept of Age Management is solving the demographic situation and demographic changes in the workplace. The main factors that affect the decision of employees to work longer access their immediate superior, the superior to aging and their willingness to find solutions to problems associated with aging and the improvement of working life. These measures may include small, everyday measures in the field of ergonomics, health care, optimisation of work management, editing time work, access to training activities etc. Total comprehensive systems approach to age management is to be incorporated into the strategy of industrial enterprise and must be supported by separate personnel actions [4].

In the article the authors of the paper are dealing with a dual education as an important element of the concept of Age Management. In these terms, it is understand by the authors of the paper as a tool to foster cooperation between the different generational groups within corporations. Dual education also supports reducing the average age in the enterprise. This issue is current, because it is now a major problem in an aging society. Therefore, one possible solution is dual training when the enterprise "educate" young workers and the important role in this process played older employees, allowing them to transmit their experience and valuable advice into the practice.

A. Employment and unemployment of graduates from secondary professional school and secondary vocational school in Slovakia

A brief overview of employment and unemployment of graduates from secondary professional school and secondary vocational school shows Table 1.

Table 1 shows the number of graduates divided into secondary professional school (ended with graduation) and secondary vocational school (graduate get vocational certificate and certificate of final examination). Grammar schools are not listed in these statistics.

Graduate unemployment is counted each time as of September after leaving school year (School year 2014/2015, graduate was registered as unemployed on 01.09.2015).

TABLE I.
GRADUATES IN SLOVAKIA (OWN ELABORATION, 2016)

School year	secondary vocational school		secondary professional school	
	employed	unemployed	employed	unemployed
2014/2015	3983	4017	18555	11445
2013/2014	3095	4505	19905	14795
2012/2013	4366	4634	19637	17263
2011/2012	5015	4785	21937	15663

For a clearer view is from Table 1 created Figure 1. It shows the calculated percentages of employment and unemployment of graduates.
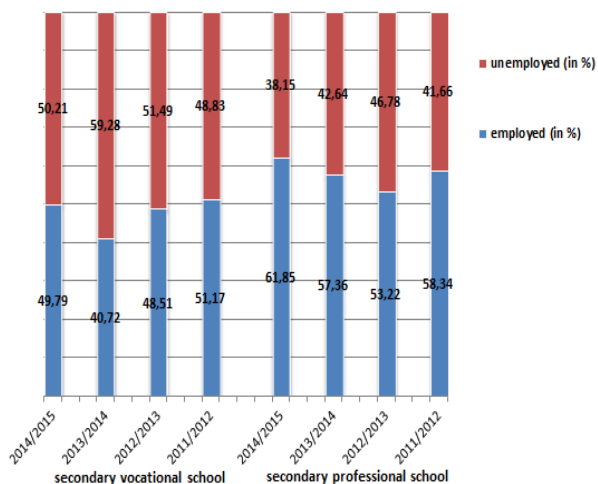
Figure 1.   Proportion of employment and unemployment of graduates in Slovakia (own elaboration, 2016)

The numerical values are from the publications by the author – Herich available at http://www.cvtisr.sk/skolstvo/regionalne-skolstvo/uplatnenie-absolventov-strednych-skol.html?page_id=10649. [5], [6], [7], [8]

Figure 1 shows, that unemployment of graduates in secondary vocational schools is about 52 % and unemployment of graduates in secondary professional schools is about 42 %.

From the authors of the paper view, the percentage of unemployment is high. This is also one of the reasons, why is dual education important to implement in Slovak industrial enterprises. With the vision of secure employment after graduating from school the students need to be motivated

B. Opportunities and strengths of the dual education

The opportunities and strengths of dual education in line with the concept of the Age Management can be characterized as:

- decreasing the average age of employees in the enterprise,
- coordination between the different generation groups in enterprises,
- reducing fluctuation,
- improving the competitiveness and image of the enterprise,
- the students are obtaining their work habits from the experienced staff,
- the older workers are being replacing, and then can are transferred to other, less difficult position.

Part of the pressure for legislation to outlaw age discrimination in employment came from enlightened employers and human resources (HR) professionals, who recognise the advantages of age diversity in organisations. A work force with a balance of youth and maturity (and diversity in other characteristics such as gender and ethnicity) is regarded as being best able to respond to the rapidly changing circumstances associated with globalisation. By restricting recruitment to so called 'prime age' workers, many organisations have prevented themselves from maximising their human resources potential [9].

III. ANALYSIS OF DUAL EDUCATION IN AN INDUSTRIAL UNDERTAKING AS AN IMPORTANT ELEMENT OF THE CONCEPT OF AGE MANAGEMENT

Dual vocational education, very much valued in the European countries and more and more being a subject of nationwide discussion is understood as combining knowledge acquisition at school and practical learning of the specific profession in the enterprises [10].

In an article has been used number of examination methods of theoretical knowledge. A fundamental step was an extensive collection of information, which has been used by a variety of publications from various sources. The important role plays a method called synthesis, whereas a large amount of information has been pooled into larger units. An important role is played also by the method of analysis and descriptive methods. Descriptive method has been described by using different

tasks and procedures for the implementation and application of the principles of dual training in Age Management. The data processing and presentation of data through graphs and tables is of great importance. In the article, the authors of the paper have focused on educational and age structure of the employees. The authors of the paper monitored the evolution of the number of employed in the enterprise ZP a.s. The average number of employees between 2003 and 2015 is about 3533 employees.

TABLE II.
NUMBER OF EMPLOYEES IN THE ZP, A.S. IN 2003 TO 2015
(OWN ELABORATION, 2016)

Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Number of employees	4122	4092	3966	3788	3807	3749	3023	3237	3417	3342	3198	3229	2964
Average	3533 employees												

On the basis of the collected data, the authors of the paper can conclude that during the period 2003 to 2015, gradually there was the loss of employees. In 2003, the enterprise employs 4122 employees, representing the highest number during the reporting period. The loss of the staff came back in the following year, 2004, when the enterprise lost 30 employees. By examining the collected data we can conclude that in 2007 there was an increase in staff since 2006. The biggest change came in 2009 compared to 2008, when the enterprise employs approximately 720 employees less. The most recent numbers also point to the drop in staff in 2015.The number of employees decreased by more than 260 employees. When comparing the first year (2003) and the last of the reference year (2015), there is a decrease of approximately 28%. The above-mentioned development of the enterprise's employment is one of the key issues that need to be dealt with in the development of strategies, plans for subsequent periods, but also in the daily management of the enterprise. The trend of employment development in relation to education and age will be examined also in the following sections. This trend is illustrated in Figure 2.
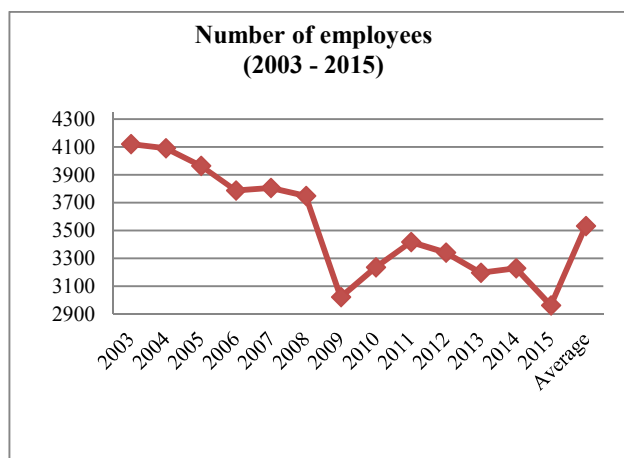
Figure 2. Evolution of the number of employees in 2003 to 2015 (own elaboration, 2016)

The research results shows a positive trend in the field of the educational levels of employees in the enterprise ZP, a. s. The gradual increase in employee education is ensured by a system of dual education and a system of lifelong learning, which also takes place through cooperation between the enterprise and the school. The following table shows the educational structure of employees distributed into four categories (secondary, secondary vocational, higher education and basic full). Statistics show that most employees (49%) achieved a complete secondary education. The enterprise also employs persons with only primary education. Their representation is only 5% of all employees. The number of employees with secondary vocational education is not negligible. Those employees compose 36%, which represents around 1270 persons. Enterprise ZP a.s. puts great emphasis on the education of its employees, and therefore regularly monitors the development of the educational structure and thus enables employees a wide range of opportunities for further education. ZP, a.s., provides several dozens of courses and trainings that empower employees and many of them also work assessments. Different forms of education are an important element of the Age Management concept. [11]

TABLE III.
THE EDUCATIONAL STRUCTURE OF EMPLOYEES
IN THE ZP, A.S. (OWN ELABORATION, 2016)

The educational structure in the ŽP, a.s. (2003 - 2015) (in %)				
Year	Complete secondary education	Secondary education	Higher education	Basic education	TOGETHER
2003	47	37	9	7	100
2004	47	37	9	7	100
2005	47	37	9	7	100
2006	48	38	8	6	100
2007	49	37	8	6	100
2008	48	37	9	6	100
2009	48	37	10	5	100
2010	49	36	10	5	100
2011	49	36	10	5	100
2012	50	35	11	4	100
2013	51	35	10	4	100
2014	51	35	10	4	100
2015	52	33	12	3	100
AVERAGE	49	36	10	5	100

Annual accretion of young professionally educated graduates prepared for employment manifests the positive trend in educational trend. Established system of dual concept education has positive influence on educational structure within enterprise and increase employees quality and proficiency.

IV. VISIONS AND TRENDS IN EDUCATION

Situation on the employment market reflects the fact that industrial enterprises cannot expect any essential help from schools in wider highly qualified employees offer. Dual education concept should deliver improvement not only in increase number of graduates with theoretical knowledge but also with work experience. Positive information in dual education concept is its awareness and potential contribution knowledge on business side within enterprises [12].

A. Research of enterprises in the field of education

The research sample covered 75 enterprises. The following figures answer the question:
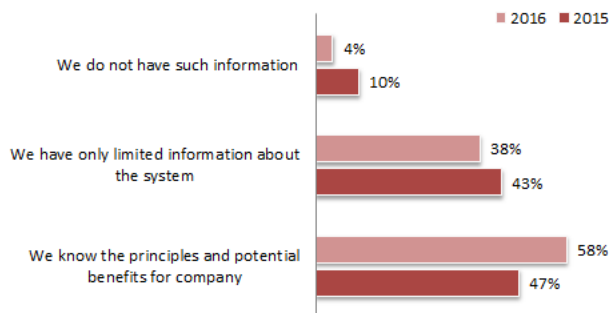

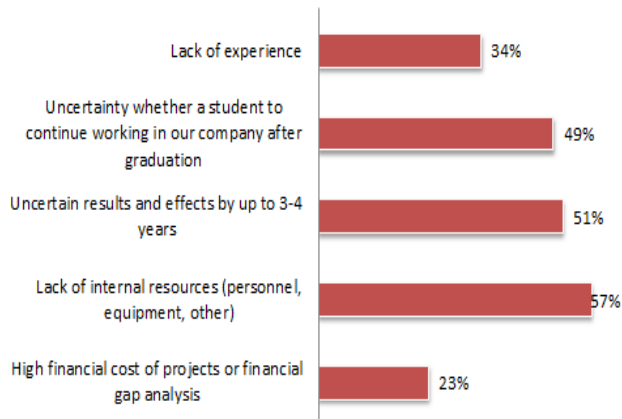Figure 3. What is your awareness about the launch of the dual education system (training)? [12]

Figure 4. What, in your opinion, are the greatest obstacles to the participation of enterprises in the dual education system? [12]
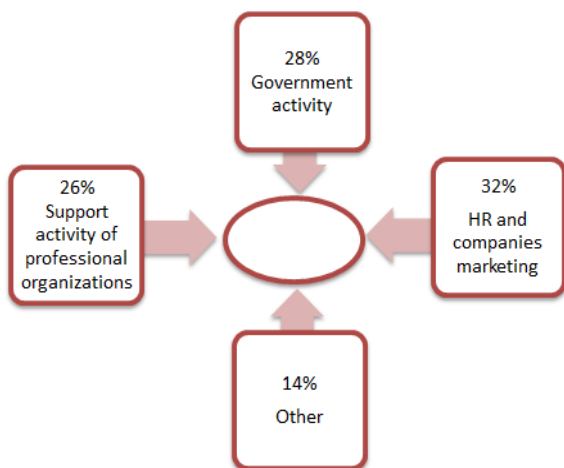

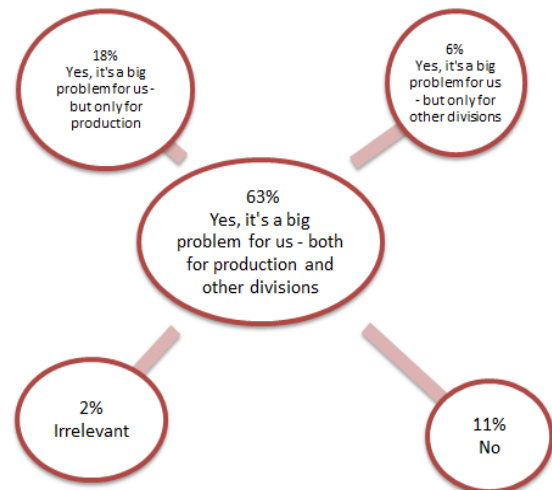Figure 5. What do you think would improve / increase the interest of students in dual education? [12]

Figure 6. Represents the availability and quality of skilled manpower problem for your enterprise? [12]
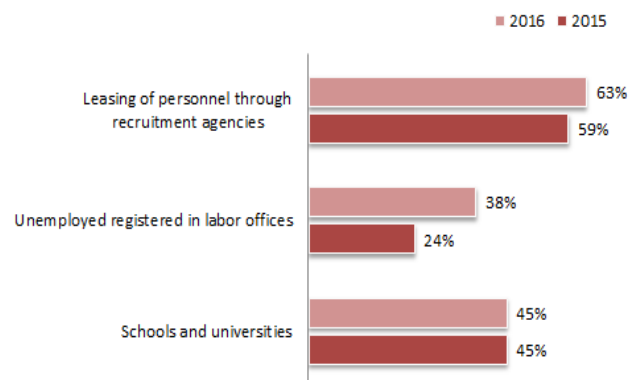
Figure 7. What are the main sources of new employees? [12]

From the research the authors of the paper can conclude that employers compared to 2015 have a higher awareness of dual education. The biggest barrier is lack of internal resources in enterprise. The employers have problem in finding enough skilled workforce on labour market and use schools and universities as a source of new employees. From this research can be stated the necessity and importance of dual education, its expansion and recommendation for employers to acquire it in order to maintain the functioning of their enterprise.

B. Goals Proposal - National Program Expansion for Education

Slovak Republic is aware of the need to develop education and training and therefore has set targets for the years 2016 – 2020 [13] These include following:

- The Slovak government supports not only formal education but also home upbringing, expansion of non-formal education and learning, and ensures the conditions for different ways of knowledge acquisition. It is rolled out number of alternative educational channels, many non-formal institutions started their education and the scholars have many chances for non-formal learning.

Government should not only respect and know but also actively promote various educational ways supporting children and adults erudition and build up the competence recognition method obtained differently from formal education.

• Consistent system for vocational education and young man power preparation is formed by synopsis local and international experience (new synthesis with German, French and Anglo-Saxon best practices application) – in vocational education and preparation system is necessary to continue in the following areas:

- The balance in carriers advising implementation system and certification of non-formal education results and in-formal learning process (France).

- Dual education introduction (Switzerland, Austria, Germany) – being alternative in work education environment, attractive for enterprises interested in education their own man power.

• The portion of education in working process increases via dual contracts conclusions between schools and employers or via dual education – it is necessary to develop grant scheme for schools and enterprises educational cooperation during working process and include the dual study concept, to support institution of enterprise school – the school established by the enterprise and offering practical teaching in working environment. Adopt 3,5 years dual education study and allow in the final phase of half-year vocational expansion increase scholar proficiency and compensate a part of enterprise investment to the scholars study. Arrangement could increase attractiveness of dual study concept also for smaller enterprises. In final half-year study phase would scholars become a part of enterprise production process and they would be financially attractive for enterprise. However, it also offers opportunity for scholars professionalization. The study itself would be linked up to 1,5 years extension of post-secondary vocational program education.

• Employees involved in teaching process need professionalization and further education process – reaction to required technology progress and reaction to labour market needs – it is necessary to increase offer and availability of continual education for vocational education masters and dual study instructors. It is important to stabilize position of vocational masters and instructors – they have determining influence on practical scholar skills at vocational secondary schools. There is need for licensed master institute and licensed masters – experts – especially educated in handicrafts connected to tradition of guild activities. In Germany are at the same level with bachellors (grade 6 under the European classification ISCED). Licensed masters have unsubstitutable role in secondary scholars further education – the final examinations improvement, the qualification exams, long life education as well as the labour market education.

Described goals of Slovak government are chosen as most relevant to dual education concept. Not only enterprises, also government is aware of the necessity of this education type and notice a large gap in the qualified man-power shortage.

In fact, there is an investment required for the dual study concept establishment but it returns to enterprises by having highly qualified new man power and the current problem would be solved. For enterprises it is important in connection with negative demographic advancement (society ageing process) to implement the dual education concept so quickly as possible to help to decrease average age in society and ensure their prosperity and the market share, too.

V. SUMMARY

The authors of the paper consider the human factor as one of most important factors connected with each society success. The employees are integral part of each enterprise and participate in enterprise results. The enterprise culture is formed by them and it is mostly given by educational level and age average. The research part of the work points to employee age variety of successful enterprise ZP, a.s. and to positive advancement trend in educational employee level.

Based on the results obtained, the authors of the paper can declare that there is a dependency between education and age structure. The authors of the paper prove that thanks to dual education, the influx of young employees into the enterprise is ensured, despite the unfavourable demographic situation of society.

The authors of the paper also point to the use of age-old employees when passing experiences to younger colleagues. Finally, the authors of the paper are persuaded that the results adequately point to the importance but also to the topicality of the processed issue and that the mathematical calculations and graphical representations show the positive trend of the development in ZP, a. s.

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Training and Development Tool for the Open Innovation Quality Management System

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Abstract— **The purpose of the paper is to contribute to learning, knowledge creation and knowledge transfer obtained through a web-based role-play simulation environment as a training and development tool for the new phenomena of Open Innovation (OI) concepts of organizations. This paper is based on the survey realized within the OI-NET project. Learning objectives for OI course were chosen by the expert team of the project. A new approach to education using OIMS-RPS has been tested on a sample of PhD students from different study fields at the University. The study is limited by the complexity of the actual Open Innovation environment, measurability of any real enhancement achieved and the possible verification of empirical results.**

I. INTRODUCTION

The new course related to innovation engineering and management for PhD study programs were created in the frame of the OI-NET – Open Innovation Network project.

Specific knowledge and skills were identified within the research in the project, which should be achieved in the course. The part of the course, which relates to Quality management system in OI environment uses the Role Play Simulation (RPS) methodology with which the Technical University of Kosice (TUKE) has experiences.

The Management System Role Play Simulation (MS-RPS) aims to contribute learning, knowledge creation and knowledge transfer obtained through a web-based role-play simulation environment as a training and development tool [1], [2].

The new version of the MS-RPS, which was developed for the course, provides students and other interested parties possibility to experiment with the selected Open Innovation strategy. Students under the direction of moderator create variant solutions in situations that mimic reality.

The first version of the role-play simulation developed at the Technical University of Kosice [3], took the form of paper playing cards accompanied by a user guide and have been focused on quality management systems (QMS) training and development. Since then, the understanding of business models (BM), management systems (MS) and value creation (VC) has changed and developed considerably. Markets, industries and also society are proclaimed to be in transition [4]: from local to global [5]; from product-oriented to process-oriented [6], [7]; from analog to digital [8]; from supply-side driven to demand-side driven [9]; from closed to open [10].

Open Innovation is a concept originated from Henry Chesbrough, 2003 that falls directly in the gap between business and academe [10]. According to [10], OI is a more distributed, more participatory, more decentralized approach to innovation. Based on the observed fact that useful knowledge today is widely distributed no matter how capable or how big, could innovate effectively on its own [10]. Chesbrough defines Open Innovation as "the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively". According to Chesbrough book [11], Open Innovation can be understood as the antithesis of the traditional vertical integration approach where internal R&D activities lead to internally developed products that are then distributed by the firm.

Those facts and new knowledge from the OI-NET project led us to develop the new version of MS-RPS, named Open Innovation Management System Role-Play Simulation (OIMS-RPS). This game became a supporting material for the teaching of Open Innovation for PhD students.

Learning objectives for Open Innovation course were chosen by an expert team of the project consisting of 52 representatives of 32 countries. The whole process started with the construction of the list of learning outcomes from other disciplinary areas (other than Open Innovation), combined with Open Innovation training. This list was distributed and comments were collected to critically assess the whole list to remove unnecessary items and to consolidate or discard unnecessary items. Learning Objective (LO) wording should observe Bloom taxonomy to be clear and appropriately structured. A short questionnaire which included several itemized questions like methods of teaching, additional comments, website references and methods of assessment were distributed among experienced innovation lecturers across Europe to get relevant information on each item. The 1st list started with about 189 LO, which was further refined and reduced to a final number 98, where quality management and engineering have been related to LO [12].

In the next step teachers who participated in the OI-Net survey were asked the question: "If you had the opportunity to invest in teaching skills, knowledge, tools and/or conditions to improve European education in OI, how would you use this budget?".

The highest number of hits targeting (1) improving teaching skills; (2) improving experience; (3) creating games is on third position [13].

II. DESCRIPTION OF THE OPEN INNOVATION MANAGEMENT SYSTEM ROLE-PLAY SIMULATION

The OI version of MS-RPS aims to provide any interested parties with the possibility of experiment with the selected Open Innovation organization's management system model under the guidance of a moderator and to create variant solutions in situations that mimic reality.

This version is designed on the base of survey results and joint experience of the authors of this methodology, along with designers, programmers and the team of international teaching and research staff, as well as information from the satisfaction surveys of the players and direct interviews with the facilitators, players and programmers.

Software for the web environment of the role-play simulation was created using the Hypertext Preprocessor (PHP) script language. Open source relational database management system (MySQL) used for the database and the OI version includes:

- Basic types of business model;
- Basic types of organization structures;
- Basic terms of reference model for roles and responsibilities in project structure;
- Narrative description and graphical models of the main and secondary processes of organization, with the possibility of linking to the process designer software [14];
- Narrative description of MS processes according to ISO 9001:2015 [6] and ISO 21500:2012 [15];
- Basic (empty) forms for documented information;
- Questionnaire for management system audit;
- Questionnaire for identifying risks;
- Case studies created in previous role-plays;
- Basic indicators of product and process quality and performance, and organization efficiency indicators, with the possibility of linking to the Balanced Scorecard performance management software [16].

The database stores the language versions of the role-plays in Slovak and English. The role-play can run concurrently in both languages for different players, which is important for international teams. Part of the role-play also contains a glossary, which supports teaching based on keywords and definitions – that is, glossary-based learning.

Predefined processes in the database enable to create variant solutions for integration of several management systems. New processes can be also added to the database and new forms for new business models can be created.

The purpose of experimenting with the pre-selected business model and management system model is to allow better workflow in the organization, the acceptance of processes created by the new or changed model by the players, the creation of documented information and the testing of its operation.

The moderator chooses at the beginning whether the role-play will be for the organization that does not have a management system implemented according to ISO standards but desires to design and apply it, or for for the organization, which has an established system and wants to change it according to the requirements (transition) of the new ISO standards [6], [17]. Also, Open Innovation model must be selected from the list of business models.

The following illustrations (Figure 1 and Figure 2) show examples of two Open Innovation models used in OIMS-RPS.

The sequences of steps in the role-play simulation for the version of the simulation when the organization wants to apply Open Innovation business model is described in Tab. 1.

III. OUTCOMES

Our task in the project was the development of scenario and requirements for software and database adjustment based on the results of the survey. The OIMS-RPS version includes: (1) basic types of business model; (2) basic types of organization structures; (3) basic terms of reference model for roles and responsibilities in project structure; (4) narrative description and graphic models of the main and secondary processes of organization, with the possibility of linking to process designer software [14]; (5) narrative description of MS processes according to ISO 9001:2015 [6] and ISO 21500:2012 [15]; (6) basic (empty) forms for documented information; (7) questionnaire for management system audit; (8) questionnaire for risks identification; (9) case studies created in previous role-plays; (10) basic indicators of product and process quality and performance, and organization efficiency indicators, with the possibility of linking to the performance management software [16].
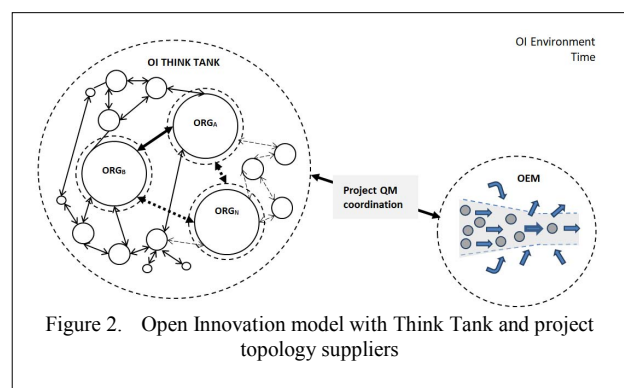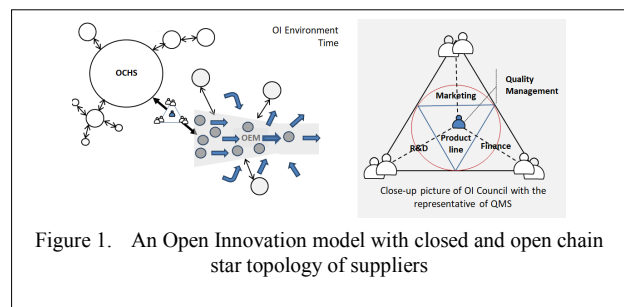

Figure 1.   An Open Innovation model with closed and open chain star topology of suppliers

Figure 2.   Open Innovation model with Think Tank and project topology suppliers

TABLE I.
TYPE SIZES FOR CAMERA-READY PAPERS

Stage	Objective of the OIMS-RPS© phase
Learning	0th phase: Familiarization with the organization's current state: • Identification of an organizational culture; • Familiarization with the value-added main processes and MS existing documentation; • Gap analysis.
Knowledge creation	1st phase: Finding the right place for the right people in the organization: • Familiarization with the organizational culture; • Enforcement of the OI organizational structure; • Acceptance of position in an OI organization.
Knowledge creation	2nd phase: Experimentation with processes of the selected MS: • Selection from randomly distributed processes; • Acceptance of assigned processes; • Taking responsibility for selected processes.
Knowledge creation	3rd phase: Definition and modelling of the processes of the selected MS and its simulation (re-assessment): • Selection from randomly distributed processes; • Modelling of processes; • Simulation of processes.
Knowledge transfer	4th phase: Experimenting with inputs and outputs of MS processes: • Selecting from randomly distributed outputs; • Acceptance or rejection of distributed data inputs from documented information; • Evaluation of the practical comparative value and creation of quality policy.
Knowledge transfer	5th phase: Experimenting with MS support • Selecting from distributed resources; • Acceptance and awareness of resources; • Creation of communication channels.
Knowledge transfer	6th phase: Creation of quality plans and risk assessment • Identification of the risks and opportunities associated with the process; • Creation of the quality plan; • Creation of quality objectives.
Knowledge verification	7th phase: Preparation of the MS documented information manual • The extended description of managerial tasks with new responsibilities; • Defined and modelled processes of the organization's MS; • Responsibility and competence matrices in the organization MS.
Knowledge transfer	8th phase: Internal auditing of MS • Obtaining evidence of audit; • Evaluation of the audit evidence; • Audit findings and the creation of conclusions.
Knowledge verification	9th phase: Experimenting with the functioning of the MS • Analysis of problems on modelled situation; • Finding process owners; • Acceptance of responsibilities.
Knowledge verification	10th phase: Improvement • Finding nonconformities • Definition of corrective actions • Proposal for improvements

IV. CONCLUSIONS

A new approach to education using OIMS-RPS was tested in the frame of project OI-NET on a sample of 16 PhD students from different study fields at the Technical University of Kosice.

Student evaluation of OI-Net Pilot lecture with OIMS-RPS was realized through a questionnaire. From total 16 participants, 10 students responded (4 female, 6 male). The questionnaire consisted of six criteria with were assessed through closed questions (first five criteria), and the rest criteria were assessed through open questions. Open questions related to general feedback were answered as follow (3 most interesting answers):

- The presentation highlighted the basic definitions, principles and concept of Open Innovation, while appropriately linking the issue with companies where this concept works.
- High proficiency, excellent clarity of the provided information.
- Meaningful, straight, clear and needed.

Summarization of answers related to the OIMS-RPS:

- helped students to remember better the terminology;
- the case studies supporting the role play promoted the understanding of fundamentals and context in management systems of Open Innovation organization;
- contributed to applying a process approach in real OI organization situation;
- developed the critical thinking and creativity of students.

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