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PANEURÓPSKA VYSOKÁ ŠKOLA

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Editorial office address

Faculty of Informatics, Pan-European University, Tematínska 10, 851 05 Bratislava, Slovakia
juraj.stefanovic@paneurouni.com

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Contents

Editorial

Dear readers,

this issue contains articles where virtual and mixed reality supports processes of disease diagnostics and therapy, which is a new domain of information technologies application. Image recognition is a widespread technology under development for various purposes – here a contribution is presented about the experimental construction of car assistance system. Popular mobile technologies are used as an environment for kid´s play and learning, an article reports here about experimental game application. Last but not least, constant growth of administration brings the necessity using proper information technologies to keep consistent data and documentation – last contribution reports about database application, which was created for real and practical purposes.

Ing. Juraj Štefanovič, PhD.
ITA Executive editor

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VIRTUAL REALITY SYSTEM FOR REHABILITATION - CASE STUDY

Eugen Ružický, Ján Lacko, Tomáš Kubinec

Abstract:

Nowadays, the number of patients with spinal pain is increasing. This paper presents research on a virtual reality system for patient rehabilitation with feedback during home exercise. The aim of the feasibility study of the proposed system was to analyze the accuracy of the exercise with tracking the patient's face and using the patient's avatar to provide the physician with an overview of the progress of the exercise quality. The virtual reality system will alert the physician in a timely manner if the patient experiences more pain during the home exercise. The use of the proposed system on a smaller sample of patients confirmed the hypothesis that patients with regular exercise experienced progressively less pain during exercise over a 4-week period.

Keywords:

Virtual reality, face tracking, HTC Vive Pro Eye, rehabilitation.

ACM Computing Classification System:

Virtual reality, Information visualization, Visual analytics.

Introduction

Virtual reality (VR) and augmented reality (AR) are promising platforms and technologies to support applications in areas such as healthcare. A head-mounted display (HMD) is a display device that is worn on the user's head in virtual reality. Techno-logical advancements in sensors, imaging techniques in HMDs, and their affordability have contributed to the increased interest in patient rehabilitation. VR has several advantages that can be used in rehabilitation: increased engagement in repetitive tasks, real-time monitoring of the patient's rehabilitation process, and interactions to enhance motor learning [1].

The rehabilitation program is carried out in a clinical setting under the supervision of a physiotherapist who continuously provides feedback on the correctness of exercises such as movement and posture to achieve the best outcome with effectiveness in both the short and long term. Feedback on the correctness of the exercise during or after performing the movement is very important as it promotes motor learning and its retention, thus minimizing possible side effects on health [2].

For proper feedback, it is necessary to ensure that the sensors are accurate enough to capture the movement. Vicon's precision motion sensing system is based on body tracking using markers on the body. Using the Vicon Tracker system, they tracked the limb movement of post-stroke patients in real-time using 15 markers tracked by 6 Vicon motion capture cameras [3]. Kinematic data of the participants were collected at a frequency of 120 Hz using the Vicon Tracker system. The overall results showed that avatar-based real-time feedback can be used as an intervention to improve gait asymmetry after stroke.

Leap Motion is another low-cost optical motion sensing device that is advantageous in upper limb rehabilitation programs to support natural interaction, where users' gestures and hand movements can be tracked with high accuracy. Another inexpensive motion-sensing device is Microsoft's Kinect, which incorporates depth cameras that allow full-body tracking without markers.

The study analyzed the impact of the motion system and compared it with results obtained from rules, templates, and clinical evaluation [4]. Doctors selected exactly five physical exercises for back pain. For each exercise, a set of data and functions were recorded that were specifically defined by the physicians and that described its scope. The system analyzed and compared the results obtained based on the defined rules from a large set of 78 subjects divided into 2 groups with 44 healthy subjects and 34 subjects with movement dysfunctions. This database allows the use of real-time control of the movement of the exercising person. For example, a dedicated software system 2Vita-B Physical for home rehabilitation was developed in Italy, which included motion tracking using Microsoft Azure Kinect [5]. The system was able to automatically assess the accuracy of the design of re-habilitation exercises. A preliminary study of rehabilitation plans achieved an average accuracy of over 85%.

The aim of the Horizon2020 project SenseCare was to develop a platform to analyze and visualize the data collected during the care of the elderly. Based on this platform, some rehabilitation-oriented applications were designed. In a prototype implementation, convolutional neural network methods were used to recognize psycho-somatic states while monitoring patients using Kinect, a microphone and a face-tracking camera [6].

Over the past 10 years, research on telerehabilitation technologies in post-stroke rehabilitation has developed rapidly [7]. Both the technology base and the improved quality of research have demonstrated that the efficacy of telerehabilitation is superior or equivalent to traditional rehabilitation methods, but new approaches still need to be found. Another study reviewed publications according to the methodological quality of physiotherapy evidence databases and showed that, compared with conventional rehabilitation, telerehabilitation using VR has comparable outcomes in upper limb function and balance in patients after stroke [8].

In this section, we discuss the use of immersive VR in rehabilitation. The global immersive reality (iVR) market, which includes augmented and mixed reality in addition to virtual reality, was worth $29.3 billion in 2022 and is expected to grow to over $100 billion by 2026 [9]. In iVR virtual environments that use mirroring of the exerciser's movements, a virtual proxy of the exerciser needs to be visualized. The role of avatars in iVR environments is to mediate the persons perception, identification, representation and visualization of actions. In the case of iVRs with eye and facial expression tracking sensors, the avatar can additionally display the emotions of the users, which can be used to identify negative or positive emotions of the persons during the exercise. In many studies, the DeepFace algorithm has been used for face recognition and trained on more than four million images of identified facial emotions [10]. In interpersonal communication, facial expression is one of the most important information channels, so in our study we also followed the evaluation by similar algorithms using 6 basic types of emotions according to Eckman.

Immersive stimuli using iVR are the key to influencing user-body behavior because they have the ability to provide a sense of presence and engage emotions in the virtual-world [11]. The potential benefits of acting on a person's feedback using their avatar-ra open up new possibilities for rehabilitation [12].

The study extensively searched publications focusing on VR applications in exercise and concluded that iVR in conjunction with stimuli and biofeedback is a new area that is under-researched [13]. An interesting study investigated intensity ratings of different emotions in iVR [14]. Participants in the study tried several iVR games and reported their emotional experiences in a questionnaire. The analysis confirmed intense responses in several emotion components. The analysis supported the hypothesis of the multi-component nature of the elicited emotions and grouped them into differentiated patterns, with fear and joy being the most strongly represented emotions as in Eckman's study.

Rehabilitation programs in VR have many advantages because they create greater presence, better control over the exercise, and engagement of the practitioner. Our research and clinical studies have highlighted various innovative uses of VR in healthcare, with one of the interesting applications of VR being emotion detection in nano-arthroscopic surgery [15]. The proposed VR Training with Avatar program followed a movement activity mainly focused on training adepts using emotion tracking.

1 Materials and Methods

In this section, we describe the equipment used to apply the training system, the selection of subjects to test the exercise recording, and the overall design of the Training program. An important part of the system is tracking the eyes and face of the subject in order to evaluate the emotions experienced by the patient as pain.

1.1 Technological equipment

To test the hypothesis of the effect of VR rehabilitation on reducing spinal pain, it was preferable to use the HTC Vive Pro Eye along with the Facial Tracker device, which provides better information to assess the patient's emotions and a more realistic exercise environment, although it requires a more challenging technical environment. The HTC Vive Pro Eye provided a resolution of 2880 × 1600 (1440 × 1600 pixels per eye). The required hardware configuration was implemented based on the available HW in our laboratory. The software solution is also optimized for use with other types of HMDs supporting eye or face tracking (Oculus Quest2 and Meta). We used high-performance computers with a Core i9 processor, 32 GB of RAM and NVidia RTX 2070 graphics card, 1 TB SSD. For rehabilitation of patients at home, we rented them high-performance laptops with Intel Core i5 12500H processor, 32 GB DDR5 RAM, NVIDIA GeForce RTX 3060 6 GB graphics card, 1 TB SSD.

HTC Trackers were used to track a person's upper and lower limbs, and body. The HTC Tracker is a device that is used to extend the virtual reality capabilities of the HTC Vive. Its main purpose is to track physical objects in the real world and transfer their movement into virtual space. HTC Trackers have been paired with the HTC Vive system and transmitted their movement data to Steam VR and further to the Unity development environment. The HTC Vive device itself provided enough data to reconstruct a good full-body avatar in the apps. Motion tracking accuracy in such a setup ranged from 1 to 2 millimeters.

1.2 Sensor-based avatar animation

For sick patients, wearing many sensors would be uncomfortable and could restrict movements, which is undesirable in a rehabilitation application. To reduce the number of sensors, we do not track every movement or rotation of every bone and joint. Instead, we only track the position and rotation of a specific part of the body, called the end effector, i.e., the head, arms and legs, and waist area. To determine the position and rotation of the remaining body parts, we have to solve the problem using inverse kinematics. After calculating the position and rotation of the remaining (unmeasured) body parts, these values are set as the positions and rotations of the avatar in VR. This computation is done in real time, thus ensuring the animation of the avatar in the virtual reality environment.

The skeletal data (i.e., the trajectory of the positions and orientations of the virtual joints) is computed post-power by a modified algorithm proposed in [10]. Sufficient trained intelligence is stored in the system to analyze what it sees and evaluate it with the stored collection of skeletal structures to interpret the movements. The avatar information is anonymized person data and therefore can be stored in a database of patient skeletal movements with eye movements and facial gestures according to defined values as data for exercise analysis in the cloud.

By having the physician or rehab worker download this information about a particular patient from the exercise database, they can link the patient's actual physique, face, and eyes on computer, what allowing them to better monitor and evaluate the selected patient during the exercise who previously saw at the rehab facility. In (Fig.1) we see an example of an HTC Vive with a device to track a person's face and their avatar.

HTC VIVE Pro Eye in HMD generates various data related to eye gestures. We used the EyeDataManager class from the SRanipal wizard [16] to extract eye gesture data and in a study on creating avatars from sensed data [17]. The maximum sampling rate of the eye tracker was 120 Hz, based on which we processed the extracted data. We processed the received data and then extracted eye data related to openness, pupil size, blinking, eye position, expression, and gaze target.

(**a**) (**b**)

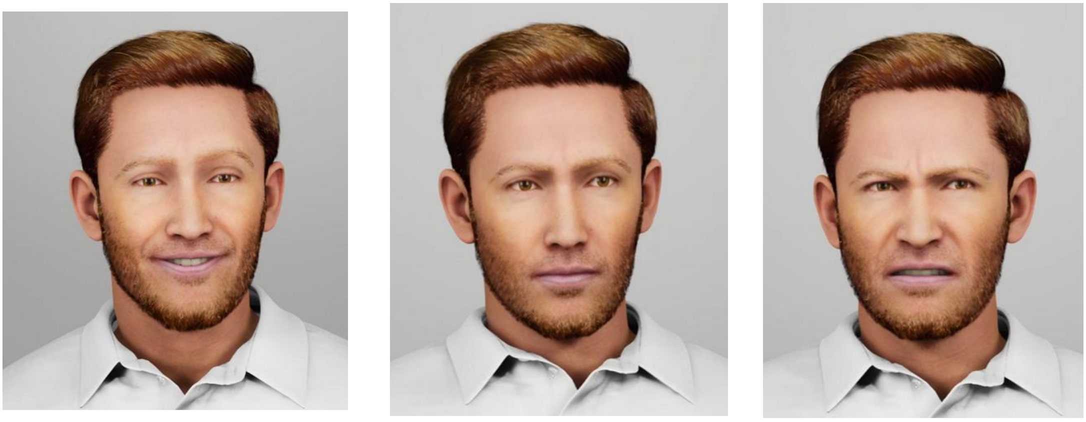
Fig.1. This image shows facial expressions: (a) capturing facial expressions with the HTC VIVE Pro Eye and Facial tracker; (b) MetaHuman avatar showing captured emotions.

The VIVE Facial Tracker was connected to the HTC VIVE Pro Eye using a USB-C cable. We used the FacialDataManager class to capture data from the sensor, following the same steps as for eye sensing. The Facial Tracker API captured data according to a defined sampling rate of 120 Hz. The received data contained 38 data items related to jaw, mouth, tongue, face, and sensor status. A more detailed description of the eye and face tracking signals using the HTC VIVE is given in the Vive SRanipal Unreal SDK manual [16] and similarly as given in reference [17].

Based on the data captured from the human eyes and face also transferred to the avatar, we defined neutral, positive, and negative states similarly to the study in [15]. (Fig.2) shows 3 facial emotional states, the first one corresponding to joy and the other two to neutral and negative expressions according to Eckman's basic emotions.

1.3 Selection of persons and exercises

We selected five exercises commonly used in rehabilitation programs for spinal pain. The procedure was modified to exclude VR patients who have vision problems (too strong diopters, strong squinting, problems with 3D perception in VR) or dizziness (vertigo, loss of balance from high altitude, inner ear or vestibular nerve disease). A VRSQ value of less than 9 is recommended for VR use. The VRSQ questionnaire presented here comes from a study [15] with VRSQ values ranging from 0 to 27. In designing our system and exercise database, we followed a similar procedure as in that study [4] and recruited 5 healthy control patients (HC), 6 post-stroke stroke patients (STR), and 4 Parkinson's disease (PD) patients to test the system. The initial phase was conducted in a rehabilitation facility for 6 days to ensure that each patient became sufficiently familiar with the HTC device, even with the help of a family member. After 6 days, the physician assessed the patient's condition, and the therapist evaluated the person's experience with VR. (Tab.1) shows basic information about the patients such as gender, age, height, VRSQ score at the beginning of the exercise, and VR experience after 6 days in the rehabilitation facility.



(**a**) (**b**) (c)

Fig.2. This figure shows facial expressions using Eckman's representation: (a) positive emotion; (b) neutral emotion; (c) negative emotion.

Table 1. Basic parameters of selected patients for VR rehabilitation
(STR - stroke, PD - Parkinson's disease, M - Male, F - Female).

N.	**Patient**	**M - F**	**VRSQ**	**Age**	**Height in cm**	**VR exp.**
1	STR	M	7	68	168	7
2	STR	M	2	39	170	3
3	STR	F	3	44	165	4
4	STR	M	2	37	180	2
5	STR	M	3	41	178	2
6	STR	F	4	62	169	3
7	PD	M	3	50	179	3
8	PD	M	5	55	155	3
9	PD	F	4	56	163	5
10	PD	F	5	67	159	7

We also used data from the KIMORE database and designated exercises as Ex1 to Ex5 [4]. The designed rehabilitation exercise system allowed the physician and therapist to make evaluations of the exercises. We designed exercise quality in a way that searched from defined skeletal exercise points during the course measured from the average from the HC group in selected positions, for example, at the beginning and at four to eight phases of one exercise cycle.

From the deviation from both the skeletal points and the end angles marked as in the KIMORE database, we calculated the exercise quality of each exercise Ex1 to Ex5. A brief description of each exercise Ex1 - Ex5 from publication [4]:

- Ex1: Lifting arms
- Ex2: Lateral tilt of the trunk with the arms in extension
- Ex3: Trunk rotation
- Ex4: Pelvis rotations on the transverse plane
- Ex5: Squatting.

1.4 Initial exercise phase and accuracy assessment

The patient exercise procedure in the Training system was designed with the help of doctors and rehabilitation staff of Rehamed Piestany. Each exercise was repeated 5 to 25 times, with 3 breaths in and 3 breaths out between each exercise Ex1 to Ex5. After the five exercises Ex1 to Ex5, the doctor suggested two short stretching exercises, which were part of the rehabilitation, so that the total time did not exceed 15 minutes. The speed of the exercises and the number of repetitions at home were determined by the physician individually for each patient. After one cycle of exercise, a short 0.5s break was always taken as a time reserve for possible delays in home exercise. The initial phase took place in the rehabilitation facility 6 days, during which 10 patients trained using VR Training system. After the first initiation week, patients were asked to exercise at home in the VR system for at least 2 weeks. After two weeks, a one-day review of the exercises was conducted at the facility to repeat the acquired stereotype and to check exercise accuracy with the physiotherapist.

Training System was prepared with the help of the 5 therapists so that their average movement during a single exercise at certain time intervals determined the basic framework for assessing the exercise accuracy of the patients. The height of the exerciser determined the normalized skeletal points for comparison. For each ExK exercise, one time cycle and a certain number of intermediate IK phases were determined according to the exercise K (e.g., for Ex1, 4-time intervals were taken for the full arm lift and their skeletal points (j) were converted to normalized height). For 6 days, the data set of normalized skeleton points at given time intervals (i) of phases was determined as ExK_HC(i,j) for the average of healthy (HC) according to their height for ExK. For each patient N on the ExK exercise on a given day, we can determine the error rate (FR) according to the difference from the normalized healthy dataset, which we denote by FR(K, N).

$$FR(K,N) = \sum_{i=1}^{IK} \sum_{j=1}^{Scelet} Distance(\mathrm{ExK}(i,j,N), \mathrm{ExK\_HC(i,j)}) \qquad (1)$$

In order to have a normalized scale for graphical display, we determined absolute values for ExK. We defined the maximum failure rate (AbsFR) for all ExKs and all patients. This value was given by the relation:

$$MaxFR = Max\ (FR(K,N)),\ pre\ N = 1,..,10\ a\ K = 1,..,5. \qquad (2)$$

The absolute error rate (AbsFR) for exercise K and patient N is given by the percentage error rate of the exercise to twice the maximum normalized error rate.

$$AbsFR\ (K, N) = FR(K, N)/(2*MaxFR). \qquad (3)$$

(Tab.2) shows the mean values with standard deviations for VRSQ, age, height and absolute error rate AbsFR(K, N) of exercise K for healthy and diseased subjects. The above table shows that in our sample of healthy and sick subjects, the absolute error rate was lowest for the first exercise Ex1 and highest for the third exercise Ex4.

Table 2. Averages for age, height and AbsFR for exercise.

	Age	Height	Ex1	Ex2	Ex3	Ex4	Ex5
Average of therapists	35	172	2.1%	3.5%	4.1%	3.6%	3.9%
Average of patients	55	165	45.3%	48.5%	51.7%	52.8%	51.7%

2 Designed Training System

In this section, we describe the main features that are built into the Training System: pre-practice and save exercise, demonstration of correct exercise, the exercise itself with feedback, tracking the patient after the exercise at home offline, and tracking the patient at home online. (Fig.3) below shows a diagram of the above functions and modules. The system was also implemented for MS HoloLens, in which the patient was displayed to the physician using a hologram.

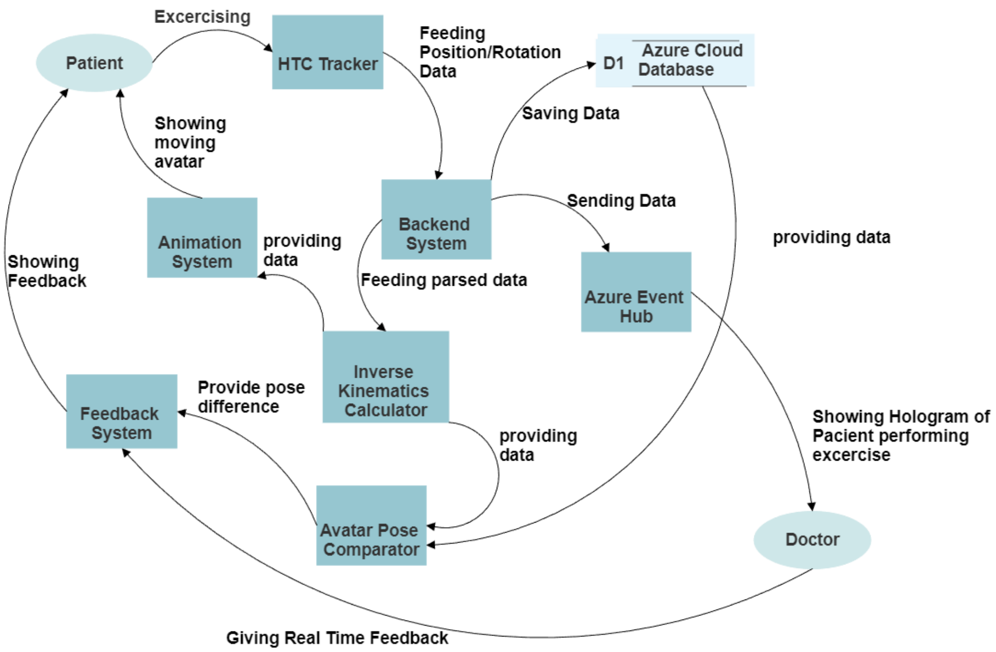


Fig.3. Diagram of the main functions of the Training system

2.1 Preparation and recording of the exercise

The application is divided into modules for recording exercises and the exercises themselves. The recording of the exercises is done by the physiotherapist according to a template selected and designed by the physician. The pro-process consists of practicing one repetitive exercise, which is saved as a template to be practiced by the patient. This pre-practiced exercise is then available to the patient in the exercise app. The exercises are stored in json format in the Azure cloud in the Blob storage. (Fig.4) below shows a physiotherapist practicing the lifting arms exercise (Ex1).

2.2 Exercise module

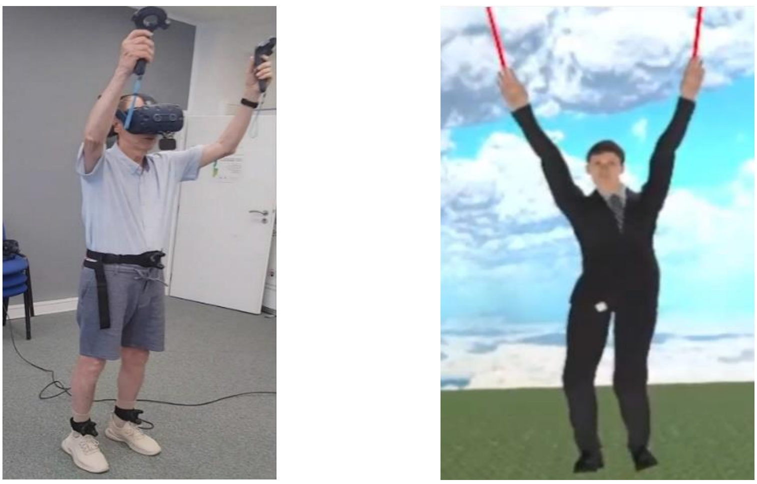
In Exercise module, the patient can see how to perform a specific exercise. After selecting this module and the selected ExK exercise, the avatar of the physiotherapist appears next to the patient's avatar in the virtual reality.

After one cycle of the physiotherapist's exercise, the patient repeats the exercise according to the physiotherapist to maintain the selected rhythm and accuracy of the exercise.

(a) (b)

Fig.4. Create template for Lifting arms exercise:
(a) physiotherapist performing the exercise; (b) view in the Training system.

During incorrect exercises, the patient receives feedback via red arrows that are placed at limb. If the position or rotation does not significantly match the physiotherapist's exercise, then a red arrow is dynamically displayed in the direction of the change in movement. (Fig.5) shows a patient performing the lifting arms exercise. The red arrows at the end of the arms indicate that the patient should lift the arms higher.



(a) (b)

Fig.5. The picture shows the patient during lifting arms exercise Ex1:
(a) as he lifts his arms during the exercise; (b) as an avatar in the Training system.

2.3 Offline patient monitoring

Patient performance is sampled every 0.1 seconds and all necessary information is stored in the operating memory in the background. When the patient completes an exercise, this exercise is transferred in json format to the Azure cloud to the Blob storage and stored using a unique GUID. This identifier is paired with the patient's account. It is the only link between the patient and their exercise data from which the patient's unique identity cannot be determined. This allows an anonymous playback of the patient's exercises using an avatar that shows the patient during the exercise, thus allowing the physician to analyze the patient's performance during the exercise.

2.4 Online patient monitoring

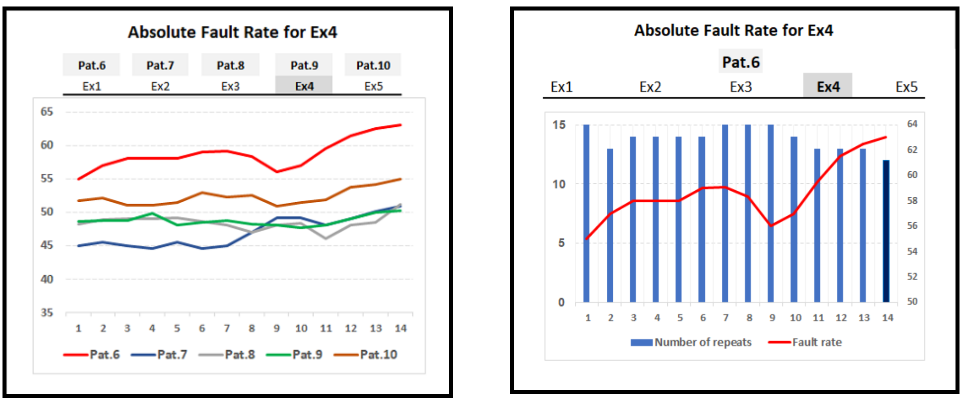
The application enables real-time transmission of exercises to a remote device. This feature allows the patient to be monitored as a virtual reality avatar during exercise at any distance and provides the ability to provide instant voice feedback to the patient during rehabilitation.

3 Results of the Case Study

In this section, we present the results of the visualization and analysis of the evaluation of the training system for monitoring patients exercising at home. The summaries presented were intended for physicians and physiotherapists. We divided them into 4 parts: exercise accuracy analysis, facial monitoring analysis, pain analysis, and questionnaire analysis.

3.1 Exercise accuracy analysis

The physician and physiotherapist could get a quick overview of how the exercise had evolved in the last days. The training system allows to view different summary visualizations of the patients' exercises over time, down to a detailed view of the patient for a given exercise in weeks. The visualization is similar to systems using Business Intelligence. For example, after selecting multiple patients Pat.6, Pat.7 to Pat.10 during an exercise, a graph of the AbsFR error values by selected exercise Ex4 was displayed (Fig.6a), and after selecting patient Pat.6, for example, additional information about the number of repetitions of the exercise was displayed (Fig.6b).



(a) (b)

Fig.6. a) Visualization of AbsFR for Ex4 exercise of selected patients Pat.6 to Pat.10 over 14 days; b) the blue bars are the repetitions for Ex4 exercise of patient Pat.6 and the red line is his AbsFR error rate.

For exercise assessment, the training system allowed the physician and physiotherapist to monitor longer time intervals ranging from 2 to 8 weeks. This allowed patients' exercise performance to be monitored and compared and any errors to be identified even over longer time intervals.

3.2 Face tracking analysis

We tracked the movement of both eyes at 120 Hz while the patient was exercising using the HTC Vive Pro Eye. We counted the number of saccades at the edge of the projected portion in the HMD similarly to the study [15]. To assess emotion, we recorded the number of eye movements at the edge of the projected portion in the HMD for 25 ms. Similarly, we tracked facial emotions determined using the Facial Tracker attachment at 120 Hz.

We experimentally verified negative emotions and finally determined the following algorithm. We considered negative emotions when the eyes were withdrawn for 1 second, or when the eyes moved rapidly (saccade) within half a second outside the edge of the projected part, or when the patient's gaze remained 2 seconds outside the view of the avatar in the HMD, in which case we assigned only half the value of the negative emotion. In addition, we determined the negative facial emotion from a selection of faces determined by the Facial Tracker device from the 38 defined from the SRapinal Facial Tracker manual [16], which were aggregated and evaluated together with the emotions from the eyes when necessary.

For graphical display purposes, we normalized the data by exercise duration. We adjusted the time interval to 20 units (as for the average exercise duration) and transformed the maximum number of normalized emotions for the patient to 10 units. For each patient N on an ExK exercise on a given day, we can determine the number of negated emotions (Emo) during his or her ExK exercise, which we denote Emo(K, n), during the retention time Itime that we determined for each exercise.

$$Emo(K,N,day) = \sum_{i=1}^{Itime} \mathrm{Emo(K,N,day,i)} \tag{4}$$

To have a normalized scale for graphical display, we determined the absolute ExK values during exercise from the first 6 days. We defined the measure of negative emotion during ExK exercise as the percentage of emotion that is twice the maximum normalized value calculated from the initiation phase of 6 days of exercise in the rehabilitation facility:

$$Emo(K,N) = \sum_{day=1}^{6} Emo\ (K,N,day) \tag{5}$$

$$MaxEmo(K) = Max(Emo(K,N), for\ N = 6,\ldots,10. \tag{6}$$

We defined the emotion measure for exercise ExK and for patient N on a given day from calculations (4) and (6):

$$EmoRate(K,N,day) = Emo(K,N,day)/\ (2 * MaxEmo(K)) \tag{7}$$

The results also show, on a smaller sample of patients, how appropriate visualization can be selected for rapid analysis of patients. (Fig.7) shows the data in normalized emotional values from the eye and face for patient 6 during the pelvic rotation exercise in the transverse plane (Ex4 exercise).

3.3 Pain analysis

Through the facial tracking features in the system, the values of the morphological shapes of the avatar can be animated by moving mainly the lips of the person, as described in the SRanipal manual [16]. The avatar of a person has 38 shapes defined corresponding to face and lip tracking. Of these morphological avatar faces, the closest approximation to pain is the squinting of one eye and the simultaneous lifting of the right or upper lip towards the squinted eye or the simultaneous lifting of the lips with the squinted eyes. The recorded values were summarized for a single exercise with a frequency of 0.1 seconds. Figure 8 shows the basic avatar corresponding to the pain from SRapinal.

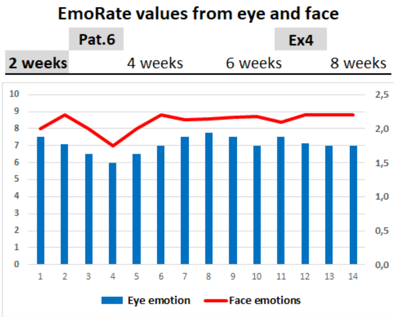


Fig.7. EmoRate values from the eye and face for patient Pat.6 during Ex4 exercise.

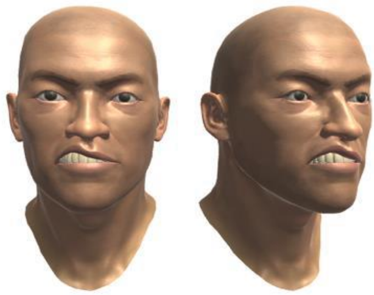


Fig.8. Avatar face with upper lip raised from the SRapinal Unreal SDK guide (Mouth_Upper_UpRight and Mouth_Upper_UpLeft) matching the experience of pain.

The clinician could view a video of each day's exercise of the selected patient offline, which was displayed as an avatar (see Fig.9). An alarm signal was prepared in the exercise database to alert the physician if the patient significantly exceeded the tolerable error threshold compared to the mean (i.e., FR(K, n)/MaxFR>0.7). In such a case, the physician could immediately review the patient's video recording offline and, in case of obvious deficiencies, discontinue the home exercise or call the patient for a follow-up examination.

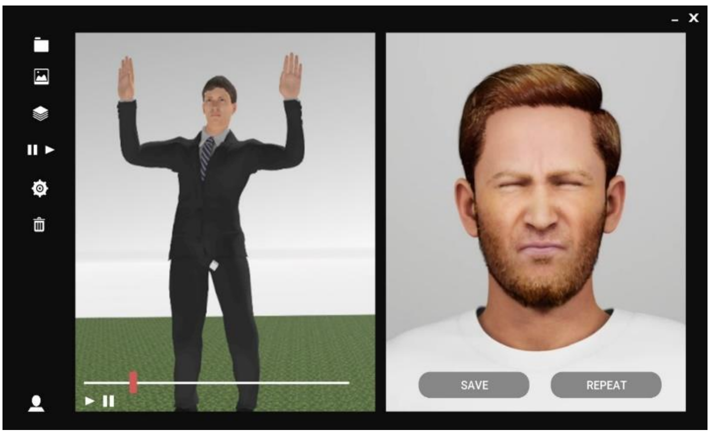


Fig.9. Video of a patient showing him as an avatar during the exercise: (a) the video can be paused; (b) the corresponding detail face of the patient avatar at that moment.

(Fig.10) shows the mean pain values recorded in patients by group (STR and PD) during exercise using facial tracking, the x-axis is the time axis for 24 days and the y-axis is for the normalized pain values. The R2 value shows how closely the estimated values of the trend line fit the actual data. In our case, for stroke patients R2 =0.9448 and for Parkinson's patients R2 =0.8771, which is a very good fit to the data.

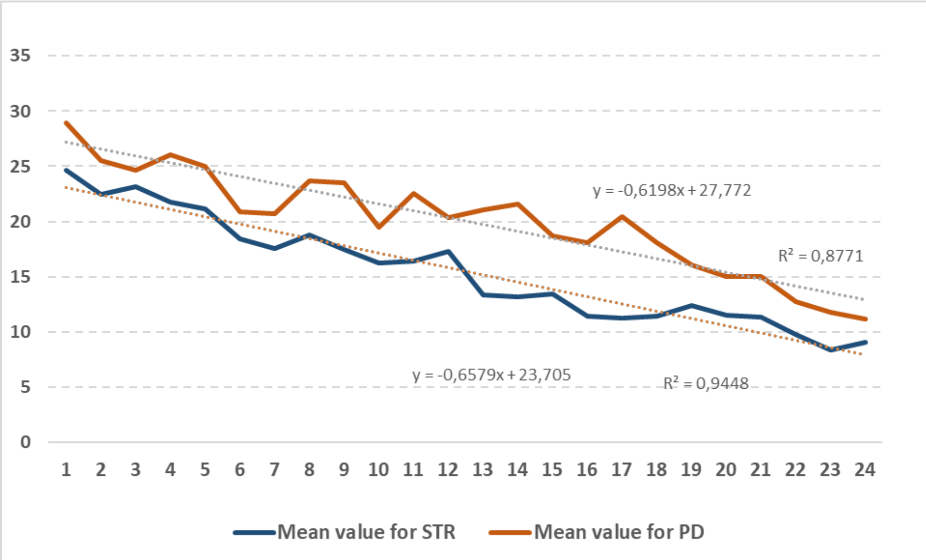


Fig.10. Line graph of mean pain in patients over 4 weeks (24 days) with a linear trend. The blue line shows the mean pain values in patients after stroke and the red line shows the mean pain values in patients with Parkinson's disease.

4 Discussion

According to the results to date and a review of publications from the IEEE, PubMed and SCOPUS databases, this is the first case study that enables rehabilitation in a home setting using anonymized cloud-based data logging with face tracking. The training system allows online or offline exercise tracking using the patient's avatar and anonymized face, providing the physician with a quick overview of the patient's exercise quality progress and timely post-exercise alerts to the physician if the patient experiences significant pain during exercise. Comparison of the pain monitoring results from the face in Section 3.2 (Fig.10) showed a correlation between the different conditions and also a gradual reduction in pain during exercise. If more patients undergo VR rehabilitation at home according to the proposed scenario, we plan to investigate this study in detail using the statistical methods described in the publication [18].

These results suggest that pain assessment in post-stroke patients also had a positive impact on treatment in terms of pain survival. Similar findings were also reached in a previous project focusing on exercise for post-stroke patients using VR games [19]. The aforementioned method of pain sensing using facial monitoring allows patients' pain to be objectified and can be used in other virtual reality exercises and tested to monitor patients during exercise.

In a study, a system was designed to monitor post-stroke patients without a therapist present using a color feedback system in which patients could self-correct their exercise during exercise [20].

Instructions on the degree of difference in joint orientation between the patient and the template were generated from Kinect or camera images, which could be used to create a skeleton of the patient. A drawback of the system was that it did not support the uploading of patient videos due to GDPR privacy concerns. Our training system displays an anonymized patient using their avatar (see Fig.9).

Our findings confirmed that patients exercised at home with more breaks than in the rehabilitation facility and switched between real and virtual worlds between exercises, similar to the study reported in [21]. On average, exercise accuracy at home deteriorated over time, and therefore exercise monitoring at the rehabilitation facility should be repeated after 2 to 3 weeks on an individual basis depending on the patient.

When using immersive VR in people with spinal pain, it is important to monitor them after exercise and make sure that the rehabilitation is being performed accurately enough as instructed by the physiotherapist. Therefore, it is good when the clinician has the ability to monitor appropriate summary information about the rehabilitation during home exercise using visualization and can draw conclusions from offline assessment of patients. Future research needs to expand the list of different types of exercises to include as wide a range of limb and whole-body exercises as possible, and also to establish more detailed correlations for a sufficient number of patients.

Conclusion

The implementation of our Training system has been done in such a way that it can be adapted to new prospective VR devices that will be developed in the future. A standardized technical specification for training implementations has not yet been widely adopted, and existing implementations rely primarily on proprietary technologies. An important avenue for further research will be to investigate in detail how adaptation to altered movement-sensory environments in a rehabilitation facility affects exercise at home, and what kind of virtual home environment is best for each individual patient, in which artificial intelligence may also play an important role.

Acknowledgement

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References

[1] Ferreira, B., Menezes, P. (2022). Gamifying motor rehabilitation therapies: Challenges and opportunities of immersive technologies. Information 2022, vol. 11, no. 2, 88.

[2] Albuquerque, M.R., Lage, G.M., Ugrinowitsch, H., Corrêa U.C., Benda, R.N. (2014). Effects of knowledge of results frequency on the learning of generalized motor programs and parameters under conditions of constant practice. Perceptual Motor Skills 2014, vol. 119, no. 1, 69-81.

[3] Liu, L.Y., Sangani, S., Patterson, K.K., Fung, J., Lamontagne, A. (2020). Real-time avatar-based feedback to enhance the symmetry of spatiotemporal parameters after stroke: instantaneous effects of different avatar views. In IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2020, vol. 28, no. 4, 878-887.

[4] Capecci, M. et al. (2019). The KIMORE Dataset: KInematic Assessment of MOvement and Clinical Scores for Remote Monitoring of Physical Rehabilitation. In IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2019, vol. 27, no. 7, 1436-1448, doi: 10.1109/TNSRE.2019.2923060.

[5] Antico, M., Balletti, N., Ciccotelli, A., Ciccotelli, M., Laudato, G., Lazich, A., et. al. (2021). A Virtual Assistant for Home Rehabilitation: the 2Vita-B Physical Project. Paper presented at the 2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC / I&CPS Europe), 2021.

[6] Hadjar, H., Maier, D., Mayer, G., Mc Kevitt, P., Hemmje, M. (2021). Video-based emotion detection analyzing facial expressions and contactless vital signs for psychosomatic monitoring. In Collaborative European Research Conference, September 09–10, 2021, Cork, Ireland.

[7] Li, L., Sun, Y. (2023). Research hotspots and trends of the tele-rehabilitation for stroke survivors based on CiteSpace: A review. Medicine (Baltimore). 2023, 102(13):e33398. doi: 10.1097/MD.0000000000033398.

[8] Hao, J., Pu, Y., Chen, Z., Siu, K.C. (2023). Effects of virtual reality-based telerehabilitation for stroke patients: A systematic review and meta-analysis of randomized controlled trials. Journal of Stroke and Cerebrovascular Diseases 2023, 32(3), 106960. doi:https://doi.org/10.1016/j.jstrokecerebrovasdis.2022.106960

[9] Alsop. T. (2023). XR market size 2021-2026. Extended reality (XR) market size worldwide from 2021 to 2026. Technical report, Statista Research.2023. https://www.statista.com/statistics/591181/global-augmented-virtual-reality-market-size/

[10] Taigman, Y., Yang, M., Ranzato, M., Wolf. L. (2014). Closing the gap to human-level performance in face verification. deepface. In Proceedings of the IEEE Computer Vision and Pattern Recognition 2014, 5, p. 6.

[11] Chittaro, L., Sioni, R., Crescentini, C., Fabbro, F. (2017). Mortality salience in virtual reality experiences and its effects on users' attitudes towards risk. Int. J. Hum. Comput. Stud. 2017. 101, 10–22. doi: 10.1016/j.ijhcs.2017.01.002

[12] Tieri, G., Morone, G., Paolucci, S., Iosa, M. (2018). Virtual reality in cognitive and motor rehabilitation: facts, fiction and fallacies. Expet Rev. Med. Dev. 2018, 15, 107–117. doi:10.1080/17434440.2018.1425613

[13] Elor, A., Kurniawan, S. (2020). The Ultimate Display for Physical Rehabilitation: A Bridging Review on Immersive Virtual Reality. Frontiers in Virtual Reality. 2020, doi:10.3389/frvir.2020.585993.

[14] Meuleman, B., Rudrauf, D. (2021). Induction and Profiling of Strong Multi-Componential Emotions in Virtual Reality," in IEEE Transactions on Affective Computing, 2021, 12, 1, pp. 189-202, doi: 10.1109/TAFFC.2018.2864730.

[15] Ružický, E., Lacko, J., Mašán J., Šramka, M. (2022). Use of Virtual Reality for Stress Reduction in Nanoarthroscopy. In Cybernetics & Informatics (K&I) 2022, Visegrád, Hungary, 2022, 1-6, doi: 10.1109/KI55792.2022.9925963.

[16] Vive Developers. (2021). Facial tracking. https://developer.vive.com/resources/vive-sense/eye-and-facial-tracking-sdk/

[17] Moon, J., Jeong, M., Oh, S., Laine, T.H., Seo, J. (2022). Data Collection Framework for Context-Aware Virtual Reality Application Development in Unity: Case of Avatar Embodiment. Sensors 2022, vol. 22, no. 12, 4623.

[18] Stehlikova, B., Tirpakova, A., Pomenkova, J., Markechova D. (2009). Metodológia výskumu a štatistická inferencia. Research methodology and statistical inference. Brno: Mendelova univerzita in Brno, 2009.

[19] Sramka, M., Lacko, J., Ružický, E., Masan, J. (2020). Combined methods of rehabilitation of patients after stroke: virtual reality and traditional approach. Neuroendocrinol Lett, 2020, vol. 41, no. 3, 101–111.

[20] Kanade, A., Sharma, M., Muniyandi, M. (2023). Tele-EvalNet: A Low-Cost, Teleconsultation System for Home Based Rehabilitation of Stroke Survivors Using Multiscale CNN-ConvLSTM Architecture. In: Computer Vision – ECCV 2022 Workshops. Lecture Notes in Computer Science 2023, vol 13806. Springer, Cham. https://doi.org/10.1007/978-3-031-25075-0_50.

[21] Clark, R.A., Szpak, A., Michalski, S.C., Loetscher, T. (2021). Rest Intervals during Virtual Reality Gaming Augments Standing Postural Sway Disturbance. Sensors 2021, 21, 6817. https://doi.org/10.3390/s21206817

Authors

Assoc. Prof. RNDr. Eugen Ružický, PhD.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
eugen.ruzicky@paneurouni.com
His research interests include applied informatics, virtual reality, modelling, visualisation and applications in medicine.

RNDr. Ján Lacko, PhD.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
jan.lacko@paneurouni.com
His research interests include digitization of objects from the field of cultural heritage, healthcare, industry, urban planning. and their display by various techniques, including virtual and augmented reality.

Mgr. Tomáš Kubinec
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
xkubinec@paneurouni.com
His research interests include virtual and augmented reality and its application in industry and humanitarian sciences.

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SAFETY ASSISTANCE SYSTEM USING CONVOLUTIONAL NEURAL NETWORKS

Ján Cigánek, Filip Žemla

Abstract:

The aim of this paper is to create a safety assistance system for a vehicle that is able to recognize dangerous situations while driving using the front camera. In addition to the detection of these events, the system is able to warn the driver using sound and visual effects to prevent a possible accident. The main principle of the work consists of creating and training a convolutional neural network that will be able to detect a set group of objects in images, videos or camera images captured in real time and to visualize these objects in the created application.

Keywords:

Neural network, security, vehicle, detection, assistance system, application.

ACM Computing Classification System:

Computing methodologies, Artificial intelligence, Computer vision, Image and video acquisition, Active vision.

Introduction

Various safety systems have been implemented in vehicles for several years. These systems are constantly innovating and coming up with new improvements. It is a trend whose main task is to increase the safety of the vehicle crew, but also to increase comfort during driving. This is an area of automotive technology that will constantly advance and will be implemented to a greater extent, especially in autonomous vehicles, the development of which is currently on the rise. In this area, safety systems that are able to detect dangerous situations and to assist in driving the vehicle are a key factor.

The most common risk when driving a vehicle is a collision with another object. In 2021, up to 64% of collisions from the total number of traffic accidents were caused by this reason. If safety systems used in vehicles were not developed, this number would increase every year due to the ever-increasing number of vehicles on the road [1].

The main task of this paper is to create a security system that will be able to detect objects around the vehicle while driving: that could endanger the vehicle; or objects that could be endangered by the vehicle itself. The system has to recognize the danger in real time and inform the vehicle driver about the detected problem. This warning consists of two parts: a visual part, which can be represented by a warning inscription depending on the type of detected object on the display in the vehicle or the monitor of the additional device; the second part of the driver's warning is an audio signal that sounds immediately after recognizing a dangerous object. Both warnings (warning text and warning sound signal) differ according to the type of danger.

This paper serves as a tool and demonstration of a security system based on convolutional neural networks used in the control unit of vehicle. It can also serve as a basis for later work, which would further develop and improve it according to current requirements.

This action could be performed thanks to a relatively simple extension of the system, which would be able to detect a larger number of objects or would contain other security elements.

1 Safety Assistance Systems in Vehicles

An important element on which great emphasis is placed in the development and production of cars is also their safety and the security systems associated with it.

Individual systems are required not only by customers, but also by laws in the countries for which the cars are manufactured. The main goal of introducing such systems is to protect the health of the driver and the entire car crew, but also to protect people who are around the vehicle.

Various types of safety systems are implemented in automobiles to achieve safety requirements. They are generally divided into two categories: active vehicle safety features and passive vehicle protection features [1, 2].

Active safety elements include the following systems [1, 2]:

- Good driving characteristics and optimal traction,
- Quality brakes and precise steering,
- ABS – a system preventing the wheels from locking when braking,
- ESP – helps stabilize the vehicle,
- BAS – braking effect assistant,
- Autonomous emergency braking,
- Driver fatigue monitoring,
- Lane keeping assistant,
- Airbags.

Passive safety elements include the following systems [1, 2]:

- Seat belts,
- Seat belt pretensions,
- Laminate and polycarbonate glasses,
- Active head restraints,
- FPS – a system interrupting the supply of electrical energy during an accident,
- Emergency rescue call.

Currently, the automotive industry uses a wide range of systems that are used to detect objects located either in the near or far vicinity of the vehicle. These systems are specially designed for different conditions such as fog, rain, driving at night or, conversely, high intensity of ambient light.

Initially, these systems were designed with the aim of increasing traffic safety, but with the advent of autonomous vehicles, their use has expanded even further. Without their use, the functioning of autonomous vehicles would be almost impossible, or very dangerous. Thanks to these systems, it is possible to use functions such as adaptive cruise control, lane control, reading traffic signs, automatic parking, a bird's-eye view of the car or automatic braking in front of an obstacle [3, 4].

We use the following systems to detect objects:

- Infrared systems (Fig.1),
- Radar systems (Fig.2),
- Camera systems.

Fig.1. Detection of people on the road using an infrared camera [4].

Fig.2. Demonstration of the operation using radar systems [2].

Despite the fact that every car manufacturer uses the same safety systems, such as reversing cameras, object detection, night vision or parking assistant, these systems differ from each other in many elements. This is due to the fact that most car producers or concerns develop their own systems and methods of how these systems work. Even in the case of using components from suppliers, which several car manufacturers may have the same, these systems often differ in the used software.

2 Neural Networks

Nowadays, there are many operations and situations that various devices and computers handle better than humans. These are, for example, complex mathematical calculations, creation of various animations or simulations. However, when it comes to ordinary thinking, imagination and thinking, humans are still ahead of computers. It is thanks to the inspiration of the human brain that artificial neural networks provide solutions that make computers more and more like people, and often these systems come up with their own solutions to problems.

Artificial neural networks are massively parallel computing models built on the basis of the properties and structures of biological neural networks. They have the ability to store information, which allows for further processing, while mimicking the human brain in gathering knowledge in the learning process. It can be said that it is a kind of artificial simulation of the brain.

Their goal is to arrive at a decision or final result based on a certain amount of input information. The ability to learn is a fundamental aspect of intelligence.

However, with artificial neural networks, learning cannot be understood in the same sense as with humans, but it is a continuous solution to a given problem, during which the knowledge of the network increases and its ability to solve the problem constantly increases [5].

Artificial neural networks consist of a large number of interconnected individual elements called neurons that work to solve a problem. These are groups of algorithms designed for recognizing and distinguishing various patterns and structures. Individual patterns and structures such as images, sounds or text are converted into the forms of numbers and vectors. In some cases, networks consist of several hidden layers in which data is processed, allowing this data to be explored in depth and to make connections between the acquired experiences of the network. The number of hidden layers can vary from one for normal neural networks to 200 or more hidden layers, in this case they are called deep neural networks [6].

The basic element of an artificial neural network is **a neuron** (Fig.3). It generally has several inputs from other neurons and only one output. The process of a neural transformation (inputs into outputs) is relatively simple, but a complex activity occurs in the connection of many neurons into one network.

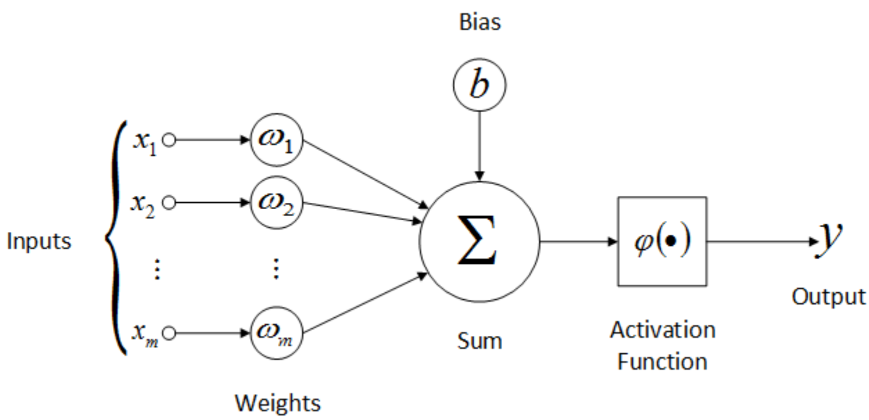

Fig.3. Model of a neuron [6].

In the vast majority of neural networks, neurons are arranged in individual layers. Such a division facilitates program implementation and also enables a mathematical description of the activity of the neural network. In practice, they are divided into two main groups according to the direction of signal propagation:

- **Forward neural networks** - called Feed-forward in English. The main essence of these networks is that the information and thus the signal spreads in only one direction, from the neurons of the input layer to the neurons in the hidden layers to the neurons located in the output layer.
- **Recurrent neural networks** - unlike forward ones, here the signal can also propagate from the neurons in the output layer to the neurons in the hidden layers and even to the neurons located in the input layer. In general, recurrent neural networks are much more complex than feedforward ones.

A. Perceptron

Perceptron is the simplest model of artificial neural network consisting of only one neuron and therefore it has one layer. It is a supervised learning algorithm that allows neurons to learn new knowledge based on input data. It belongs to the group of feed-forward neural networks [6, 7].

The most common implementation of the combination of feed-forward neural network with supervised learning is **Multi-layer perceptron** (MLP). The structure of such a network (Fig.4) consists of one input layer, one or more hidden layers and one output layer. A typical feature and at the same time the reason for their frequent connection and usage is the relatively simple implementability and versatility of using such a network.

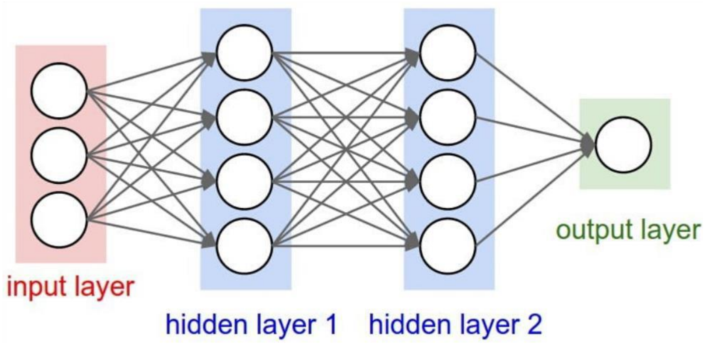

Fig.4. An example of MLP network with two hidden layers [7].

B. Artificial Neural Networks

Hopfield neural network - this type of network is created by a combination of recurrent neural network and supervised learning method. It uses a completely different network structure than MLP. Individual artificial neurons are both input and output and are connected to all other neurons. Such type of neurons is called dual. All neurons are located on the same layer and thus there is no input, hidden or output layer in such a topology [6, 7].

Convolutional neural networks (CNN) are the main type of artificial neural networks used in the field of computer vision. Specifically, it involves the detection and recognition of objects in images, videos or the classification of images into different groups. It involves recognizing human faces, animal species, handwritten text, dangerous driving situations and a large number of other uses. Individual operations are part of almost every CNN and they are always performed in a strictly defined order. The method of their use will be described on the following task example, where the assignment would be to determine which object is in the picture (Fig.5).

An image containing one or more objects would be fed to the input of the network. Subsequently, operations one to three would be run several times in a sufficient amount of repetitions so that the network managed to extract all the necessary information from the input image. All the findings are then combined into one so-called symptom map within fully connected layers. The map created in this way is processed by the last operation - classification, in which it reveals individual objects. The output of the network is a list of detected objects, often together with the percentage success rate of their detection [7, 8].

Fig.5. Simplified CNN operation procedure [8].

Since **convolution** is the first operation of the network, it works with the original input images. Its first task is to determine the dimensions of the image such as height, width and depth. In most cases, the input images are colored and therefore in RGB format their depth is 3. Width and height are the basic data about the image. For example, a color image would be loaded as an 8x8x3 array of matrices, and a black and white image as an 8x8x1 array of matrices. The first layer is the input layer, which usually has specified exact dimensions, but it is not a condition for the correct functioning of the network.

The next layers are convolutional layers, of which there are several dozen in the network. These layers consist of a set of filters used to extract all the necessary information and elements from the image. This process takes place by storing the values of all pixels in matrices. The matrices are then multiplied by the values of the individual filters, which are also placed in the matrices, and the output is a matrix in which the output values of this operation are found separately for each pixel. Within one layer, a larger number of different filters are applied to all pixels of the image. The output of the convolution is the matrix of output values for individual pixels and the black-and-white form of the input RGB image. The important information is that it is the individual values of the filters that are important in the learning process and based on these values KNS learns to detect objects [7].

Just like the previous operations, **classification** can be performed using different methods. One of these methods is the Softmax function. Let's imagine that the network should be able to detect a certain number of classes, which we denote as n, while they can be, for example, classes such as a person, a vehicle, a road sign or an animal. This function assigns to each of the classes the probability with which the object in the image belongs to one of the classes. The sum of the probabilities of all classes must always equal one. Subsequently, the probability for each class is calculated using formula 1, where N is the total number of classes and z is the output vector from the previous layer:

$$S(z)_j = \frac{e^{-z_j}}{\sum_{n=1}^{N} e^{z_n}},\ j = 1,2,3, \dots N \qquad (1)$$

This equation calculates for each class the probability that the object in the image belongs to it. This value ranges from 0 to 1. The last step is to select the class with the highest probability value. This value can often be seen next to the description of the detected object in the image [7].

3 Methods for Detection of Objects in the Image

Computer vision is a field of artificial intelligence that has been gaining more and more prominence in recent years and is beginning to develop. This development began with the creation of convolutional neural networks and the production of autonomous vehicles.

Object detection is an important part of computer vision. Currently, there are many approaches, algorithms and solutions to detect individual objects. The difference between object detection algorithms and classification algorithms, which are also used in other areas of artificial intelligence, is that object detection algorithms draw bounding boxes around detected objects, thereby visually signaling individual points of interest. Their number in the examined image is not limited by anything and there may be several dozen of them depending on the number of objects in the image.

The reason why standard convolutional neural networks using fully connected individual layers are not used for image object detection is that the length of the output layer is variable and therefore not constant. This is because the detection of individual objects does not decide which category the image as a whole belongs to, but which category the objects in the image belong to. For this reason, there can be a large number of given outputs. Therefore, for this case, standard convolutional networks were modified to meet all requirements and could also be used in this area. Specific types of these solutions will be described in the following part of the work.

R-CNN (Region-Convolutional Neural Network) is one of the methods used to detect objects from input images. This method uses the so-called selective search algorithm, which divides the input image into 2000 regions, which are then further processed. In this way, it proposes the aforementioned 2000 candidate areas where potential objects could be located [9].

Fast R-CNN method was created by the same author as the classic R-CNN network. Compared to this version, it brings a significant improvement in the duration of object detection (Fig.6).

The essence of this network is similar, but instead of sending individual 2000 regions to the convolutional network, the whole image is directly sent to this part, which is not divided in any way in this step [9].

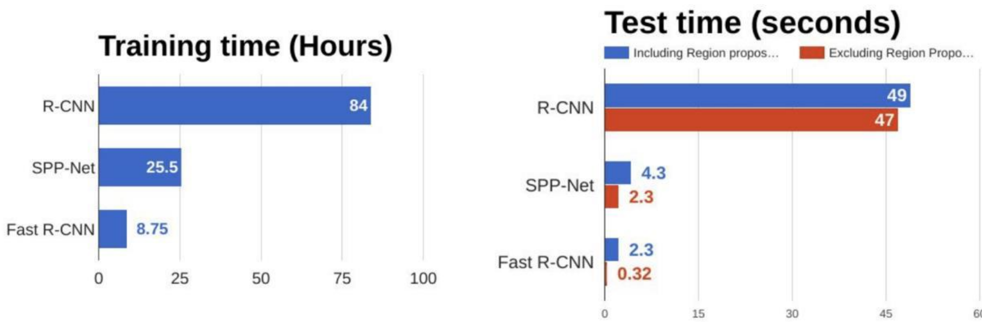

Fig.6. Comparison of Fast R-CNN and classic R-CNN network speeds [9].

YOLOv3 is a fully convolutional neural network (FCNN) that is used to detect objects in an image. This is already the third version of this algorithm, which has been constantly evolving over time. Currently, *YOLOv3* is one of the fastest detectors of objects in the image among all the systems used in this issue [10].

The most striking element that distinguishes *YOLOv3* from other object detection methods is the processing of the entire image in one step. For a better idea of the processes involved in image processing and object detection, the R-CNN and Fast R-CNN functions were described in more detail in the previous two subsections. The fact that the entire process takes place in a single step has the most significant impact on reducing the overall detection time [10].

Another advantage is that this method does not require an exact and uniform size of the input image. This facilitates the process of training the network, there is no need to take into account the size of the photos in the input dataset, as well as the images on which we want to perform object detection. As a result, there is one less operation in the image processing process compared to other methods, as there is no need to additionally adjust the size of the candidate areas. This feature also makes the network faster [10].

The architecture consists of 2 parts. The first part of this architecture is *Darknet-53*. It is a block that acts as a flag extractor. This block consists of 53 convolutional neural layers. After the aforementioned *Darknet-53* block, there are several more interconnected convolutional layers within the network. The output from these layers is directed directly to the next part - the output layer. In this part, grids of different sizes are applied to individual images. These grids fall into three different categories, depending on what objects they target [10].

Individual types of outputs according to the used grid are divided into:

- Outputs for large objects – large objects are detected first within frames.
- Outputs for medium-sized objects – after processing several convolutional layers from the time of detection of large objects, the detection of medium-sized objects comes next.
- Outputs for small objects – here the same procedure as for the detection of medium-sized objects is applied, so the image goes through several convolutional layers again, and small objects on the given image are detected last.

During the entire process of detecting objects of different sizes, *Upsample* is used to combine information from previous detections and to obtain better results in the currently performed detection.

In Fig.7 a simplified procedure of the entire process of detecting objects with different sizes is shown (from large to small objects).

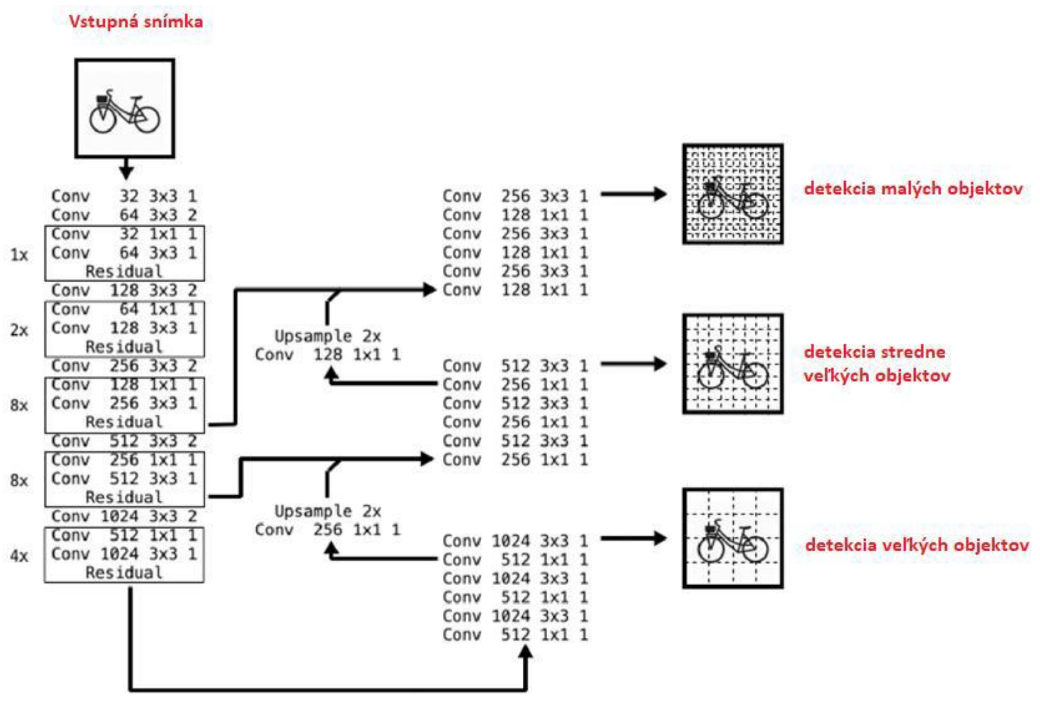

Fig.7. The process of detecting objects with different sizes [8].

4 Case Study

In this chapter, the complete process of creating the entire practical part will be described. The first step was the selection of a suitable algorithm for creating the CNN. This selection consisted of a survey of individual algorithms and approaches to the creation of neural networks. Another criterion was the systems that are currently used in the area of car safety. Algorithms used for image processing and subsequent object detection are constantly evolving and increasing their object detection accuracy along with shortening the time required for detection. From the currently used algorithms we chose the ***YOLOv3*** algorithm.

The second very important part of the work was the installation of necessary software for training and testing the neural network. The entire work is created in the ***Python 3.9*** programming language. ***Miniconda*** and ***pyCharm*** were chosen as the environment in which we developed the algorithm. In the field of computer vision and machine learning, we used the ***OpenCV*** tool. To create our own image annotations we used ***LabelImg***, which creates data for training of neural networks from our own images. We used the ***OIDv4 Toolkit*** to obtain thorn data. Next, we used the ***Darknet*** framework to use the performance of the graphics card to train the neural network and to configure YOLOv3 algorithm. The last tool we used was ***PyQt5m***, which enables the creation of user applications.

A. Photo dataset

In this phase of the work, it is necessary to know what kind of specific objects should be detected by CNN and to divide them into groups. In our case, CNN will be able to detect following 7 different types of objects:

- Vehicles,
- People,
- Animals,
- Traffic signs: prohibition, information, warning and command.

The total number of used photos is 4400 and they are divided into 1100 photos of cars, 1100 photos of people, 1100 photos of large animals and 1100 photos of individual types of traffic signs. The objects in the individual photos are photographed at different angles, under different lighting conditions and also from different sides.

At the same time, the individual objects in the photographs are captured in such a way that they do not resemble each other too much. There were used pictures of vehicles of different sizes and brands, and people of different ages, genders or races.

Since it would take a very long time to acquire our own data for training, and ultimately the data would not be completely suitable for training due to the expected low variety of captured objects, we used already created photos for training the network, which are directly intended for training of neural networks. We used the ***OIDv4*** tool to retrieve photos from two different sources:

- German Traffic Sign Detection Benchmark (GTSDB) – the official list of traffic signs for the European Union,
- storage.googleapis.com – a repository with a large number of photos for neural network training.

The second option was to create these photos manually along with marking the objects in the picture. For this operation, we will use the already mentioned ***LabelImg*** tool. The first step is to load the photos. The second step is setting the format of preparing photos. In our case, we used the YOLO format. Next, it was necessary to mark the objects and to name them (Fig.8). The output of the entire process is text files with data about objects.

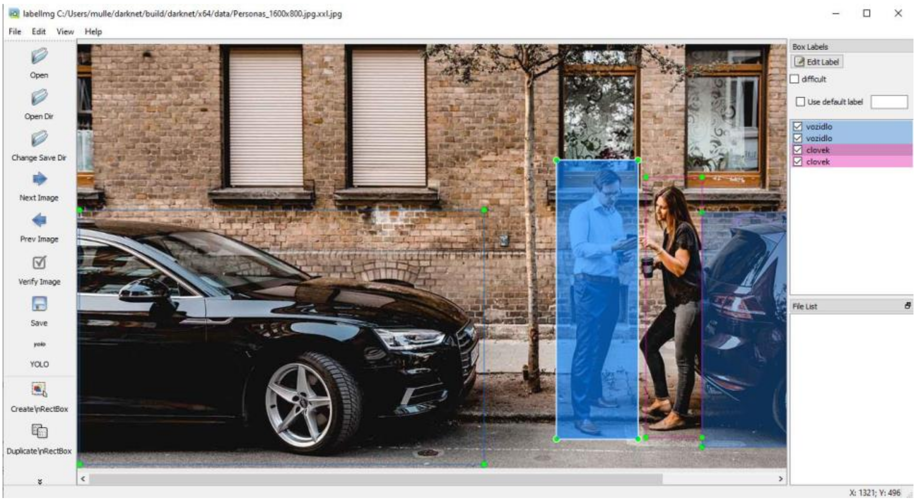

Fig.8. *LabelImg* user interface.

B. Neural Network Training

This is the most important part of the work, in which the main goal is to train own neural network based on actually assembled input images. After successful completion of this step, it will be possible to use the neural network to detect objects either in photos or on video. There are many ways to train a neural network, and the individual procedures differ in terms of difficulty and duration of the training itself. In general, two training procedures are known:

- using the processor and thus a CPU,
- using a graphics card and thus a GPU.

In our case, we started by training the neural network using the processor. Such training is suitable in the case of a small number of input images on which the given neural network is to be trained. But in the case of a larger dataset it is almost unrealistic to achieve the best possible results with this procedure (using a processor). The main disadvantage is too long training time, as the processing power of the processor is too low even in the case of high-performance processors. However, this is a simpler method, as there is no need for the difficult installation of additional software, which is required for other types of training.

The second chosen procedure was to train the neural network using a graphics card, in our case *NVIDIA GeForce GTX 1050 Mobile 2GB*. To train a neural network using a graphics card, installation of *CUDA* package is required. The advantage is that the computing power of the graphics card is not only used during the training of the neural network, but also during its subsequent usage and object detection. The usage of the graphics card is many times faster compared to the processor.

Despite the higher speed of training using the graphics card, the estimated time of the overall training process was estimated to be several days of pure time. It was due to the setting of a large number of iterations and also not too high performance of the graphics card. Despite investing a relatively large amount of time to install the required software and create all the necessary adjustments and settings, we decided not to continue with this method of neural network training.

The method we eventually chose and successfully trained our own neural network with was the graphics card trained version. But it was not a graphics card directly on our laptop, as in attempt number two, but a virtual graphics card offered by Google. This is a *Tesla K80* graphics card, which is physically located on the side of the provider of this service. The entire training process took place using the *Google Collaboratory cloud service*. It is a service focused on creating your own projects in *Python* with the possibility of using various libraries such as *Keras*, *TensorFlow*, *PyTorch or OpenCV*. The great advantage of this service is that it provides very high processing power absolutely free! The only limitation is the usage time of this graphics card for a period of 8 hours. Therefore, it was necessary to save the progress and, after the specified time, start the whole process again, when we reconnected to the graphics card and had it available for another 8 hours. Thanks to the saving of interim results, we could always continue at the point where the training of the network ended. Even before starting work in *Google Collaboratory*, we saved the entire dataset of photos together with their annotations and remaining text documents on *Google Drive* (Fig.9).

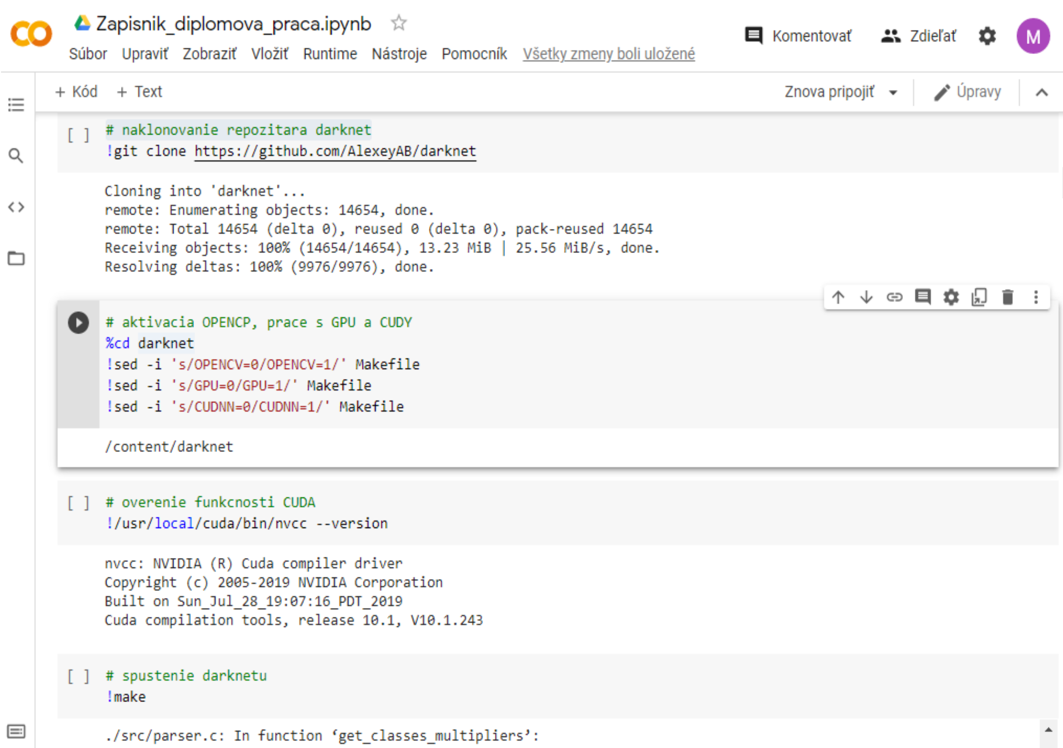

Fig.9. A preview of *Google Collaboratory* user experience.

The total training time of the neural network was 32 hours of pure time and the result is several files. These files were always created after performing 1000 iterations. From among all these files, we then had to choose the one that would provide the best results. As expected, it should have been one of the last files created. The file that reached the highest value of the so-called mean average precision was the most suitable. To find this value for individual weight files, we used a function provided by *darknet*. We used this function for individual files with weights and found that the weights in the last file reached the highest value. This file contains the trained final convolutional neural network, which we will subsequently work with in object detection.

C. User Application

We created the entire user application using *Qt Designer library* using the *PyQt5* tool, which enabled the entire application creation process to be performed in *Python* programming language. We have created two different applications, for detecting objects in images and for detecting objects from video captured in real time using a webcam. The creation and work with the application for object detection from video captured in real time will be described in detail.

The application environment consists of the following parts:

- Button to start the camera - after starting the application, the webcam is turned off by default for security reasons. The user can turn it on at any time and then turn it off as needed. The button called "Launch camera" is used for both of these actions. The button is located at the bottom of the screen and is of the Push Button type.
- Display area - this part of the application is used to display captured video from the webcam. If the video is running, this area occupies the majority of the entire application. It is also used to mark detected objects and thus the driver can spot objects that he could miss under certain conditions. It is located in the middle part of the screen and is of the Label type. In Fig.10, its area is marked with blue squares.
- Control of safety systems – this section is used to turn on and off individual warning safety systems. In the basic state, all warning safety systems are switched off, so the driver can switch them on as needed. These are the following systems:
    - Vehicles – if this security system is activated and CNN detects a vehicle in the captured images, an audio warning will be triggered and the system will play the sound "car car car..." and a visual warning with a large inscription "CAUTION" will also appear on the display.
    - Signs – if this security system is activated and CNN detects a traffic sign on the captured images, an audio warning will be triggered and the system will play a message based on the type of traffic sign. If it is a prohibited road sign, the warning message will be "prohibited prohibited prohibited...", if it is an informational road sign, the warning message will be "information informational informational...", in the case of a warning road sign, the warning message will be "warning warning warning ..." and the last kind is a command traffic sign, for which the message will be "command command command...". At the same time, a visual warning with a large inscription "WARNING" will also appear on the display.
    - People – if the system detects a person in the vicinity of the vehicle and the people warning safety system is activated, the audible warning sign "person person person..." will be triggered. Along with this sound signal, the warning text "CAUTION" is also displayed on the display.
    - Animal - the last safety system that can be turned on is a warning to the driver in case of detection of large animal in the vicinity of the front part of the vehicle. If there is a tall animal on the image captured by the camera and the CNN successfully detects it, the sound warning message "animal animal animal..." will start and the warning text "BRAKES" will appear on the display.

Starting and turning off individual security systems is carried out through check boxes and is located on the upper right side of the screen within the application.

- Area for warning text – a warning text is written in this place in case the CNN detects one of the target objects. Under normal circumstances, this place on the desktop is. The text displayed here is always displayed in red capital letters. Its goal is to attract the driver's attention so that he can react in time to a threatening event. The text is displayed here if one or more security systems are activated at the same time. The individual warning texts that can be displayed here are "CAUTION", "WARNING", "BRAKES" or, if several safety systems are activated at the same time, they are "CAUTION/WARNING". This field is located in the upper left part of the screen and is of type Label.
- Main title – this is the name of the application, at the same time it indicates what activity the application is intended for. It is located in the upper part of the area.

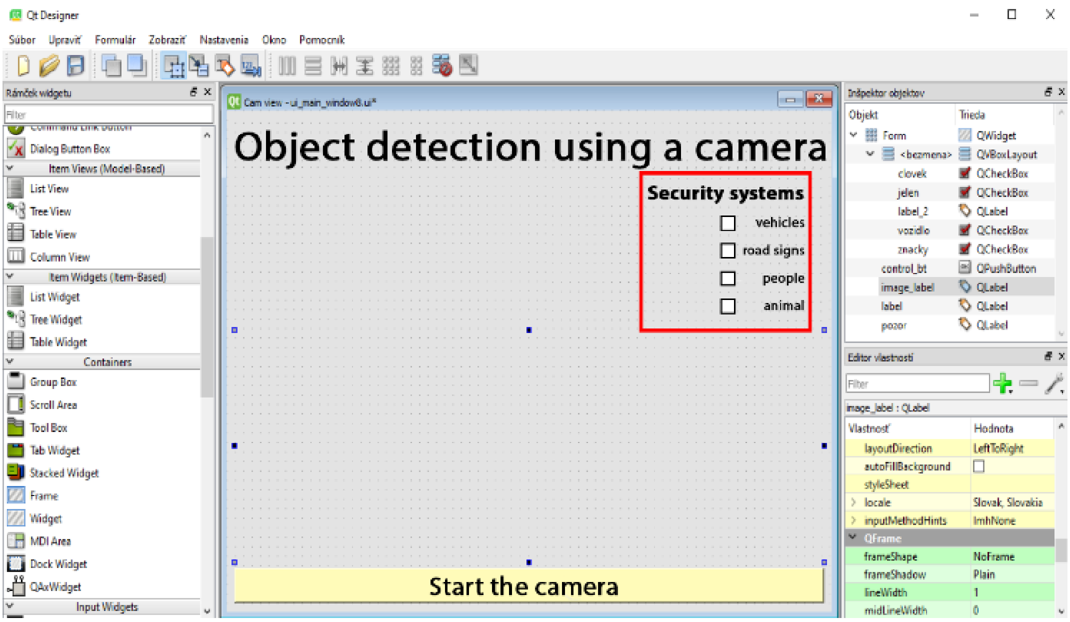

Fig.10. Creating an application in *Qt Designer program.*

The next step was the creation of a *Python* script that serves to connect the user environment with the already trained neural network. This script is called "*detekcia_webkamera.py*" and at the same time it is the main script from which the entire application is launched. For the sake of clarity, we have created a folder named "*functionalAPP_webcamera*", which contains all the necessary files for the proper functioning of the application:

- A folder called "detective" - in this folder there is a text document called "classes.names", which lists the names of all objects that CNN works with. Furthermore, it is the final output of the network training process "yolov3_custom_final.weights", which contains the weights of our CNN, which are used for object detection. The last file in this folder is the configuration file "*yolov3_ train.cfg*".

- Script called "*detekcia_webkamera.py*" - as already mentioned, it is a script used to connect the user environment with an already trained neural network and at the same time to start the entire application.
- Script named "*user_forecourt.py*" - the appearance and layout of all elements of the user environment, which was created in Qt Designer program, can be found here.
- Audio recordings – these are 7 audio recordings in .mp3 format. These recordings are used to soundly warn the driver in case of danger.

Fig.11. Person detection using a real-time object detection application.

The very process of creating this application was in many steps similar to creating an application for object detection from video. The user interface has a similar appearance and was also created using *Qt Designer*. The script itself, which is intended for object detection, is different, as the procedure for processing photos and video is different. In the case of this application, the user is able to choose any image on which he wants to perform the detection. He performs this action by pressing the "Select image" button, after which a window will open with the possibility to browse individual directories on the computer in order to select a specific photo. Even in this case, there is the possibility to turn on and off the individual safety systems (Fig.12), where the safety system is turned on to warn the driver in the presence of people.

Compared to an application designed for object detection from video, this application contains several pieces of information provided to the user:

- Total time duration in seconds of objects detection from the selected photo.
- The second value is the total number of detected objects. It is a figure that represents the number of objects before the unification. This information tells how many objects from the given classes are in the picture in total.

- The last value is the total number of detected objects after unification. This information tells how many bounding-boxes are drawn on the selected image.

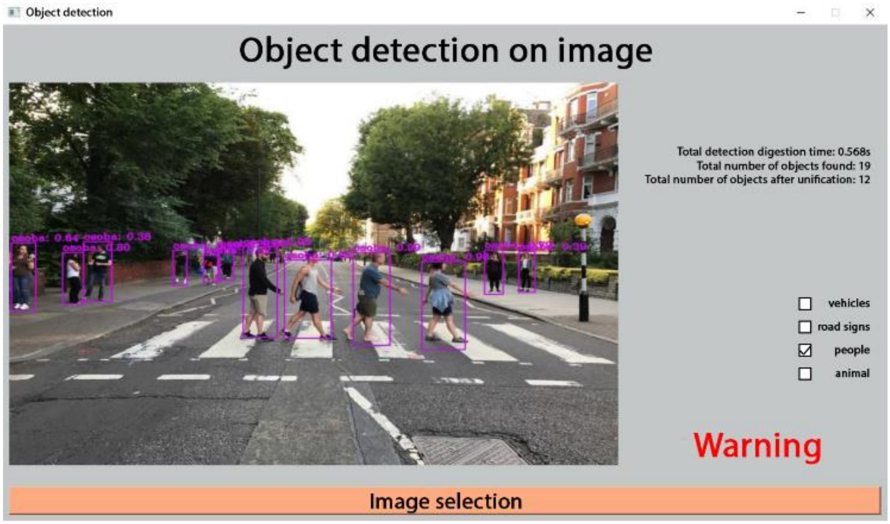

Fig.12. Creating an application in *Qt Designer* program.

Conclusion

The task of the paper was to create an assistance safety system for the driver of the vehicle, which will detect not only a certain group of objects representing a risk when driving the vehicle, but also vertical traffic markings. The condition was the usage of a convolutional neural network, which will be used to detect these objects. The task was to create, train and test our own convolutional neural network, which will be able to detect selected objects from images captured by the camera. The second main task was to create a user application that will be used to work with an already created convolutional neural network and at the same time control individual security elements.

We have successfully trained our own convolutional neural network that can detect and recognize 7 different objects. We verified the functionality of the network on different types of input data, such as photos and videos directly from real traffic or from video captured in real time using a camera. The success of the detection of individual objects depends on the quality of the resolution of the input images, the lighting and the environment in which the objects are located.

We have also successfully created two user applications. The first application is used to detect objects in selected photos. At the same time, it provides the possibility of activating the security system for warning in case of detection one of the threatening objects or vertical traffic markings. The application provides basic information about the detection process, such as the total detection time or the total number of detected objects in the selected photo.

The second application is used to detect objects from video that is captured in real time using a camera. The user has the option to turn the camera on or off at any time. It can also activate any number of security systems that work together. If one of the threatening objects is detected, an audio warning will be triggered along with a warning text statement directly in the application. During the whole time, the user has the opportunity to watch the image captured by the camera directly in the application, at the same time, individual objects are marked in the captured image if they are located in the vicinity of the vehicle.

Acknowledgement

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References

[1] European commission (2022). *2021 road safety statistics: what is behind the figures?* Retrieved online, January 10, 2024, https://transport.ec.europa.eu/background/2021-road-safety-statistics-what-behind-figures_en

[2] Martin, D. (2022). *Appen Delivers High-Quality Training Data for Autonomous Vehicle Manufacturers.* Retrieved online, January 10, 2024, https://www.unite.ai/appen-delivers-high-quality-training-data-for-autonomous-vehicle-manufacturers/

[3] Holts (2018). *A Guide to Your Car's Safety features*. Retrieved online, January 10, 2024, https://www.holtsauto.com/holts/news/guide-cars-safety-features/

[4] Procházka, J. (2014). *BMW Night Vision 3rd generation sees for you (In Slovak).* Retrieved online, January 10, 2024, https://techbox.dennikn.sk/bmw-night-vision-3-generacie-vidi-za-vas/

[5] Hardesty, L. (2017). *Explained: Neural networks.* Retrieved online, January 10, 2024, https://news.mit.edu/2017/explained-neural-networks-deep-learning-0414

[6] Snives, J. (2018). *SimpleNeuralNetwork*. Retrieved online, January 10, 2024, https://github.com/snives/SimpleNeuralNetwork

[7] Cybiant (2020). *An introduction to Artificial Neural Networks*. Retrieved online, January 10, 2024, https://www.cybiant.com/knowledge/artificial-neural-networks/?v=13dd621f2711

[8] Muráň, J. (2019). *Introduction to convolutional neural networks (In Slovak)*. Retrieved online, January 10, 2024, https://umelainteligencia.sk/uvod-do-konvolucnych-neuronovych-sieti/

[9] Gandhi, R. (2018). *R-CNN, Fast R-CNN, Faster R-CNN, YOLO — Object Detection Algorithms*. Retrieved online, January 10, 2024, https://towardsdatascience.com/r-cnn-fast-r-cnn-faster-r-cnn-yolo-object-detection-algorithms-36d53571365e

[10] Orješek, R. (2020). *YOLO architecture for object detection (In Slovak)*. Retrieved online, January 10, 2024, https://umelainteligencia.sk/architektura-yolo-pre-detekciu-objektov/

Authors

Ing. Ján Cigánek, PhD.
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology in Bratislava, Slovakia
jan.ciganek@stuba.sk
He was born in 1981 in Malacky, Slovakia. He received the diploma and PhD. degree in Automatic Control from the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology (FEI STU) in Bratislava, in 2005 and 2010, respectively. He is now Assistant Professor at Institute of Automotive Mechatronics FEI STU in Bratislava. His research interests include optimization, robust control design, computational tools, SCADA systems, big data, and hybrid systems.

Ing. Filip Žemla
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology in Bratislava, Slovakia
filip.zemla@icloud.com
Currently a student of doctoral studies at Slovak University of Technology in Bratislava. The main focus of his studies is oriented to virtualization and optimization modern manufacture processes. His main skills are SCADA systems, database systems and front-end programming.

THE USE OF VIRTUAL REALITY FOR THE DETECTION OF EARLY SIGNS OF ALZHEIMER'S DISEASE

Richard Hasaj

Abstract:

Alzheimer's disease is a neurodegenerative disorder that affects millions of people worldwide. Early detection and treatment can help to slow down the progression of the disease and improve the quality of life for patients. Virtual reality (VR) is a promising technology that has been increasingly explored as a tool for detecting early signs of cognitive decline in individuals. This paper examines the potential use of VR in detecting early symptoms of Alzheimer's disease, such as memory impairment and spatial disorientation. It also explores how VR can be used to slow down the deterioration of cognitive functions in Alzheimer's patients by providing cognitive and physical stimulation. The potential benefits of VR in Alzheimer's disease are vast, including earlier diagnosis, more accurate assessment of cognitive functions, and improved patient outcomes. Furthermore, the use of VR can help to reduce the stigma associated with Alzheimer's disease and increase awareness and understanding of the disease among the public. As VR technology continues to evolve, it is likely that it will become an increasingly valuable tool in the diagnosis and treatment of Alzheimer's disease. Its potential applications in various areas of life, such as healthcare, education, and entertainment, make it an exciting field for future research and development.

Keywords:

Alzheimer's disease, dementia, virtual reality, early symptoms, prevention.

ACM Computing Classification System:

Human-centered computing: Human computer interaction (HCI), Assistive technologies for persons with disabilities; Computing methodologies: Artificial intelligence, Simulation and modelling; Human-centered computing: Virtual reality; Applied computing: Healthcare information systems, Interaction paradigms, Empirical studies in HCI.

Introduction

Alzheimer's disease (AD) is one of the most widespread neurodegenerative diseases in the world. Dementia is one of the most common symptoms of AD and accounts for 50% to 75% of all cases. In 2015, approximately 46 million people worldwide suffered from dementia, 55 million in 2020. It is estimated that 78 million may suffer from it in 2030 and up to 131.5 million people may suffer from it in 2050. Of this number, up to 60% of people will come from low to middle-income countries. As a result of demographic aging, which is caused by improving health care and increasing people's living standards, the proportion of elderly people is increasing in the world. Older people are more susceptible to dementia, but cases of dementia begin to occur in the world before the age of 65. [1] Dementia has a large economic impact, it is estimated that in 2015 the global cost of dementia was USD 818 billion, which represented approximately 1.09% of global GDP. These costs rise sharply as the disease spreads. The current cost of dementia is approximately 1.3 trillion USD and is expected to increase to 2.8 trillion USD in 2030. In high-income countries, around 20-50% of dementia cases are recognized. One study from India suggests that up to 90% of cases remain undetected or undiagnosed. If these results were applied to other countries, it is estimated that up to 75% of people with dementia would not been diagnosed and would not have access to treatment. [2]

1 Current Diagnosis of Alzheimer's Disease

The aim of my paper is to describe the theoretical possibilities of using virtual reality (VR) in the detection of early symptoms of AD, to assist in the treatment and training of patients with AD. We analyzed publications dealing with AD such as diagnosis, early symptoms, progression of the disease, and later stages of the disease. I also focused on alleviating symptoms and helping patients with treatment. AD is a progressive disease, the symptoms of which are loss of short-term memory, disruption and decline of memory functions, loss of orientation, reduced abstract thinking, personality changes and disruption of emotional expression. The initial stage is difficult to detect. It lasts approximately 2 to 3 years. Typical forgetting is difficult to distinguish from the normal forgetting that occurs in the elderly. In these people, plaques containing amyloid and neurofibrillary tangles can already begin to form in the brain. These clumps are durable and can persist in the brain even after the neuron has died or disintegrated. Plaques are small and flat areas formed by the accumulation of degenerated nerve terminals, scattered around a central core formed by amyloid β-protein. These plaques are found in the cerebral cortex and are associated with intellectual functions. Small amounts of balls and plaques can be found in the brains of healthy people who show no abnormalities. The number of these plaques and clumps is involved in the intellectual decline that occurs in AD. [3] (Tab.1), adapted from [4], briefly describes the stages of AD.

Table 1. Stage of Alzheimer's disease

Stage of AD	Definition	AD diagnostic options
Preclinical stage	A clinically asymptomatic patient with signs of beta amyloid deposition or (phospho) tau protein in the brain	Biomarkers (research concept, without immediate clinical use)
Mild cognitive impairment	The patient has detectable new-onset cognitive deficits due to AD pathology, but is still fully self-sufficient	Detailed neuropsychological examination combined with imaging methods (especially MRI and PET) and biomarkers
Dementia	A patient with a new-onset long-lasting cognitive deficit caused by AD changes and causing difficulty in daily activities	Anamnesis, indicative neuropsychological examination, MR and PET, possible confirmation using other biomarkers

AD, which begins at an earlier age, has been shown to be associated with the mutation of at least three genes. (APP gene on chromosome 21, PS1 gene on chromosome 14, and PS2 gene on chromosome 1). An example is the observation of patients with Down syndrome. In people with Down syndrome who lived to be 50 years old, all developed pathological features of dementia.[3]

In the second stage, the patient has a greater cognitive deficit (they forget more, it is more difficult to orient themselves), but they can still be independent. A detailed neuropsychological examination in combination with magnetic resonance imaging (MRI) or positron emission tomography (PET) can already reveal the disease. In the third stage, the patient can no longer be independent and needs the help from others. They often forget, do not know why and where they are, have sudden mood swings and can be aggressive.

Currently, AD is an incurable disease for which there is no drug or treatment that can completely suppress the disease. Various research is currently being conducted on how to prevent the formation of balls and plaques in the brain and what causes it.

2 Possibilities of Using VR in the Detection of AD Symptoms

The Montreal Cognitive Assessment (MoCA) and similar tests are used in the current diagnosis of AD by a psychologist. The tests are based on testing the patient using verbal tasks given orally and worked out by the patient orally or on paper. Such testing can detect memory abnormalities, attention problems, reduced abstraction, visual-spatial executive functions, and much more. With the help of VR, however, we can create an environment for the patient in which we can simulate life events. This allows us to get an idea of how the patient will react and whether they are able to perform the activity independently according to their own judgment or which was assigned to them. To create VR, you need a device that will simulate this environment. The device usually consists of a head-mounted display (HMD), controllers, position sensors and a powerful PC. There are already stand-alone devices on the market that no longer need a PC or external position sensors. We also need software (SW) with which we can create and program the given environment. There are certain rules to follow when using VR. These include:

- There should be no other objects on the area intended for VR.
- VR should not be used by pregnant women, children under the age of 12, people under the influence of alcohol, narcotics, and addictive substances.

The use of VR will not be possible for all patients. There are some health risks when using VR, such as:

- Seizures – rapid flashing of the screen, alternating colours and patterns can cause an epileptic seizure in some people. People suffering from seizures should not use VR at all.
- Anxiety – when fully immersed in VR, depending on what the scene is, it is possible to create different waves of emotion. It takes some time to overcome this anxiety, but it will not be possible for some patients.
- Nausea – when moving in VR, it is possible that the patient may experience nausea. This nausea can be caused by a poorly adjusted HMD (focal length, eye distance), a bad way of moving the patient in VR, or the patient has nausea just from putting the HMD on their head. It is recommended to take breaks when using VR and not to use VR for a long time in one time sequence.
- Eye strain – the HMD contains a screen that emits high doses of light and heat. Human eyes are not adapted to such doses of light and therefore it is necessary to observe the time intervals and have a correctly adjusted HMD. Eye strain can cause a headache. [5]

Because of these risks, it is necessary to ask patients about all medical complications and conditions that preclude the use of VR. If the patient has no complications, we can explain the principle of movement, orientation, and interaction in VR. It is necessary to create a simple scene in VR where the patient can try movement, orientation, and interaction with objects. With this test, we can detect or find out whether the patients have some problem and whether they are able to use VR. If we find that the patient can move, orient themselves and interact with objects in the VR scene without problems, then we can continue the test. We will then fill out a simple questionnaire about the anamnesis. Here we find out age, gender, psychological problems, head injuries and operations, other head and brain diseases, currently used medications, education level. In this way, we will obtain the necessary information that could affect the testing of the patient.

Subsequently, the patient receives a printed map of the scene (Fig.1), which they will try to remember, and their task will be explained to them. Their main task will be to get from the starting position at the big lake, to get to the other side of the scene, to the smaller lake. Along the way, they will have 10 tasks, with which we can test certain abilities of the patient. The map will have all possible routes to reach the destination marked. These paths will branch and connect in different ways. These intersections and points will be marked sequentially 1-A-2-B-3-C-4-D and so on. The patient will have to follow this order.

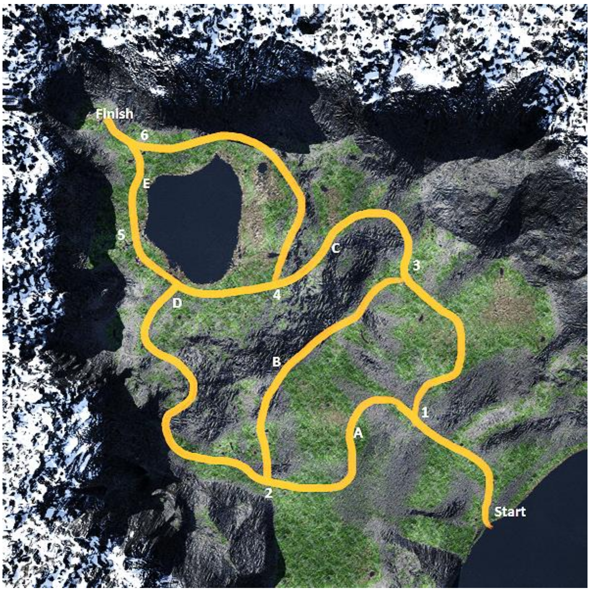

Fig.1. An example map showing the start, finish, all roads, and intersections.

This allows us to test the patient's orientation and visual-spatial abilities. We will measure the patient's time, how long it will take. A natural environment surrounded by hills and a lake was created as the main test scene (Fig.2). This ensures that the patient does not escape from the scene. The scene tries to imitate the real environment and tries to be as photorealistic as possible to simulate the real environment. Real objects such as trees, rocks, animals, and other objects are placed in the scene. The roads and the surroundings of the stations are marked as zones in which the patient can move. The patient cannot get to other places. To separate the positions so that the patient is not distracted by other objects, I used height differences on the map and objects such as: trees, rocks, and other natural obstacles.

On the way from the start to the finish, there will be a total of 10 stations where the patient will perform various tasks, described in the table below (Tab.2). For half of the tasks, the patient will be told to remember what was on the given statement.

These objects (Fig.3) must be placed on the marked path in such a way that the patient notices them immediately. Some positions will need to be in the scene more than once to ensure that the patient can perform all the tasks in case, they take a wrong turn and goes the wrong way. The patient's entire procedure is recorded in a prepared form, where answers and selected paths are recorded. If the patient answers the last question, we stop the measured time, which is marked. Subsequently, we ask the patient about all the tasks he did. The questions will be more focused on objects that they named, supplemented or on some property. In this way, we can compare memory performance. All the patient's answers are marked and evaluated with the corresponding number of points (Fig.4).

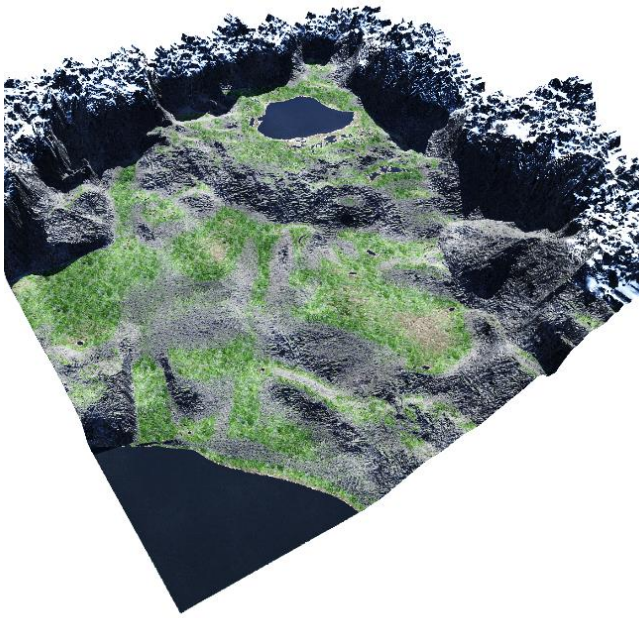

Fig.2. Test scene in VR. Display of basic terrain without plants and other objects.

Table 2. Positions and given tasks.

Object no.	Object or position	Question for the patient	Said command to remember it	Solution
1	Enclosure with animals	What animals are in the enclosure?	No	Sheep, horses.
2	Field	What colour is the tractor?	Yes	Blue.
3	Flagpole	What geometric shapes are on the flag?	Yes	Square, triangle, circle.
4	Clock tower	What time is it on the tower?	No	Twenty minutes after one.
5	The camp	What's wrong there?	Yes	Wrong number order.
6	Spring/well	Name the objects on the boards.	Yes	Car, bicycle, plane.
7	Mine	Complete the geometric sequence.	No	The square/rectangle is missing.
8	Wood saw	Say the similarity of the given objects.	Yes	Bread, apple - food, T-shirt, cap - clothing.
9	Wooden perch/watchtower	Build a tower out of blocks.	No	The patient has to Build a small tower from 6 cubes.
10	Cottage	What is illogical/bad about Cottage?	No	Instead of a door there is a window and instead of windows there is a door.

Fig.3. Example of the test task "Name the objects on the board".

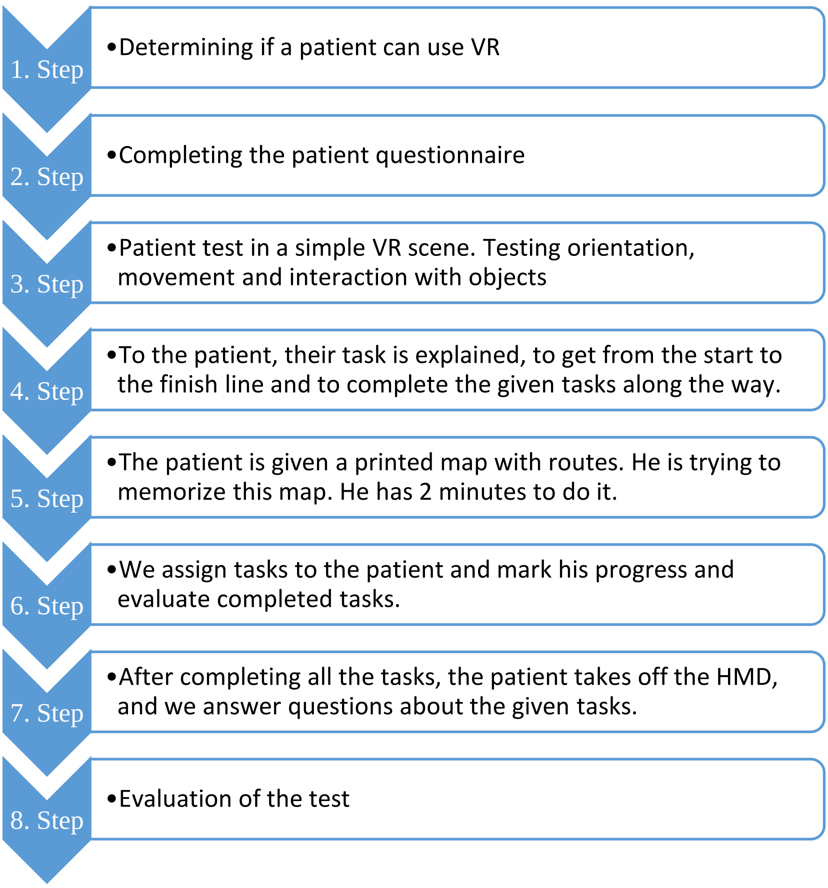

Fig.4. Patient testing procedure.

3 Possibilities of Using VR in the Training of Patients with AD

In lighter stages, the decline of cognitive functions can be partially influenced and slowed down. This can be achieved by regular memory training, regular and equally long sleep, a high-quality and varied diet, sufficient hydration, exercise and being in the fresh air. Many patients no longer enjoy the same training sessions and become passive. This passivity, in turn, has a negative impact on their health and can in turn accelerate the worsening of AD symptoms. Using VR, we can create different scenes for patients and try to induce some positive emotion in them, which will start the production of hormones such as: serotonin, oxytocin, dopamine and endorphins. There are studies that show that these hormones can slow down the progression of AD. It is currently neither confirmed nor denied. An example would be "virtual fishing". We assume that the patient liked to go fishing, but his current condition does not allow him to do so. However, you must be very careful with such scenes, because we can also create the exact opposite and throw the patient, or even cause them trauma.

Another possibility of use is the creation of a patient's home environment in VR, in which they are able to practice typical activities. In a hospital or specialized centre, where the patient is temporarily accommodated, it is possible to train the patient in the home environment and test whether they are still able to live independently.

Based on the patient's points obtained from the test, we can compare the results with other patients. With the help of these deviations, we can determine whether the patient has a weaker memory, a problem with orientation or another problem. However, to be able to make these comparisons, a larger sample of patients is needed, which will be healthy but also those who will already have some symptoms of AD

Conclusion

The use of VR shows promise in the detection and treatment of neurodegenerative diseases such as Alzheimer's, further testing is needed on a larger sample of healthy individuals and patients with mild AD symptoms to obtain reliable data and individual conclusions. While VR has already proven its effectiveness in training various occupations and in surgical procedures, the technology continues to evolve. HMDs are becoming smaller with higher resolution, refresh rates, and longer battery life. We cannot predict where the development of VR technology will lead us in the future.

There are potential risks and limitations to consider as well. It is possible that patients with AD may become lost or confused in VR, making it difficult or impossible for them to use the technology. Therefore, caution and careful monitoring should be exercised when introducing VR to Alzheimer's patients.

Despite these uncertainties, VR holds immense potential for improving the lives of individuals with Alzheimer's disease, and continued research and development in this area is highly encouraged.

References

[1] Alzheimer's Disease International. (2015). Numbers of people with dementia worldwide, An update to the estimates in the World Alzheimer Report 2015. Retrieved April 2023, https://www.alzint.org/resource/numbers-of-people-with-dementia-worldwide/

[2] Dementia statistics (2023). How many people have dementia worldwide? Are the numbers increasing? What is the cost of dementia care? Retrieved April 2023, https://www.alzint.org/about/dementia-facts-figures/dementia-statistics/

[3] Ivan Hulín, et al. (2009). *Patofyziológia,* SAP – Slovak Academic Press, spol. S.r.o. p.1165-1168, ISBN 978-80-8095-043-9

[4] Časná diagnostika Alzheimerovy nemoci ve světle nových diagnostických kritérií (2012). Retrieved April 2023, https://www.alzint.org/about/dementia-facts-figures/dementia-statistics/
[5] HTC, *Verifying your setup*. Retrieved online, April 13, 2023, https://www.vive.com/uk/support/vive/category_howto/verifying-your-setup.html

Author

Bc. Richard Hasaj
Student at the Faculty of Informatics, Pan-European University, Bratislava, Slovakia
E-mail: hasaj.richard@gmail.com

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MOBILE GAME ABOUT SPACE FOR KIDS

Barbora Jurkovcová

Abstract:

This scientific article presents an educational application focused on space exploration. The goal of this application is to improve students' understanding of astronomy and encourage their interest in science. The methods used in the development of this application included collaboration between astronomy experts, educators, and app developers. The results of the application showed increased engagement and interest in astronomy among students who used it. The application includes interactive features such as virtual tours of the solar system and educational games. The conclusion is that this educational application is an effective tool for enhancing students' understanding of space and can contribute to their interest in pursuing careers in science.

Keywords:

Android, app, Kotlin, GitHub, Android Studio.

ACM Computing Classification System:

Information system, Sofware engineering.

Introduction

Teaching science with computer games and simulations goes back to the 1970s and early 1980s, where the ability of games and simulations has been widely explored as a new teaching method [1]. This study investigated the use of serious games for science education, focusing on the role of virtual reality (VR), artificial intelligence and augmented reality (AR) games in physics teaching. Teaching science using computer games and simulations dates back to the 1970s and early 1980s, where the power of games and simulations was widely explored as a new teaching method [2].

Space has always been a topic of fascination for humans. We have been exploring and learning about the vast universe surrounding us for centuries. With the advancement of technology, it has become easier for us to visualize and understand the mysteries of space. The popularity of space-themed movies, books, and TV shows is a testament to our endless curiosity about the cosmos. In recent years, the gaming industry has also embraced space as a popular theme for games. Games about space offer players a chance to explore the unknown and experience the thrill of space exploration. However, creating a game about space is not an easy task. It requires a deep understanding of the scientific concepts involved, as well as a creative approach to designing the gameplay.

Virtual reality is not yet so widespread for younger children, so we developed a mobile application about the universe, which we want to later modify for VR Oculus Quest2. The system design for VR will be similar, using 3D scenes designed on the Unity Engine game platform. Our mobile game offers children a unique opportunity to learn about the universe in a fun and educational way.

By leveraging the power of modern mobile devices, we have created a platform that is accessible to children of all ages, regardless of their access to traditional educational resources. With our game (Fig.1, 2, 3), children can explore the solar system, learn about the different planets and their features, and even discover new and exciting space phenomena.

1 Educational Game Design

This process is crucial for mobile game development and must be considered early in development. When designing the design, not only the visual impression, but also the functionality and usability of the game must be taken into account. In order to start creating the game's graphical content, we first had to design a wireframe, a sketch of our mobile interface. The wireframe served as a blueprint for our application and helped us determine how the application would look and function.

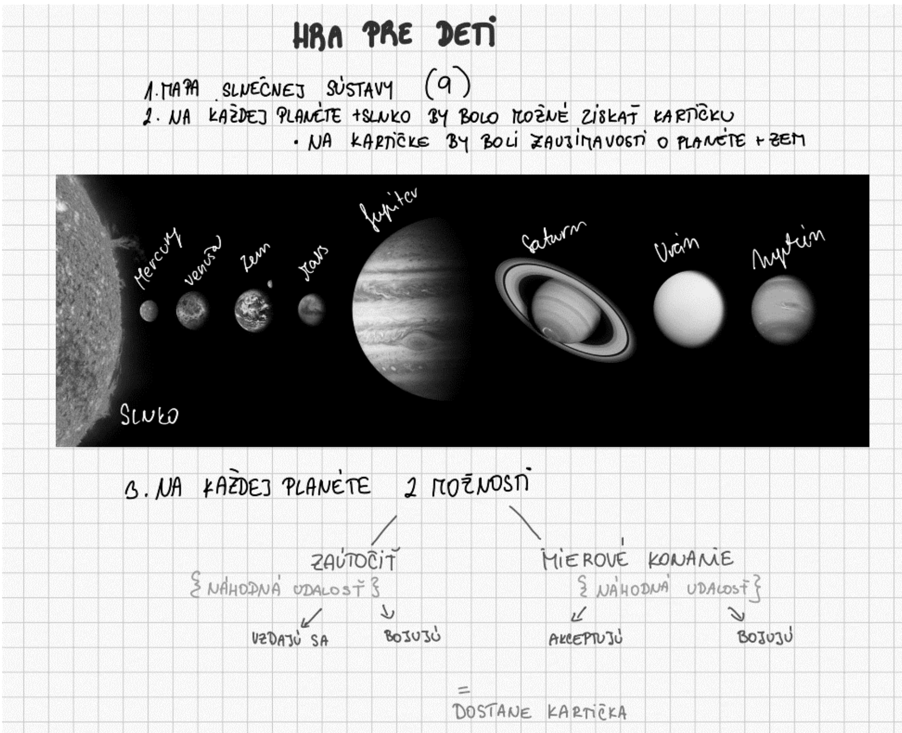

Fig.1. Initial notes for the game Universe: decision tree what to do in play.

When designing our game, we tried to create a pleasant environment for children, which will motivate them to learn and have fun at the same time.

We chose a simple, but at the same time modern and colorful design that will be accessible to all age groups. Our goal was to create an interactive game that would allow children to learn more about the universe and its objects. In the game, we focused on visual elements that would be simple and understandable for children, but at the same time attractive for their sense of aesthetics. When creating graphic elements, we were inspired by real photos of the solar system, planets and stars.

We chose bright colors and simple shapes to show players important features of each planet, such as size, number of moons, and temperature.

In addition, we also took into account the interactive elements of the game, such as buttons for War and Peace and communication elements between the player and the alien. We designed these elements to be understandable and easy to use for players.

Design is very important for mobile games because it directly affects the usability and overall feel of the game. When designing the design, it is important to think about the needs of the users and ensure that the game is easy to control and can be used without any problems.

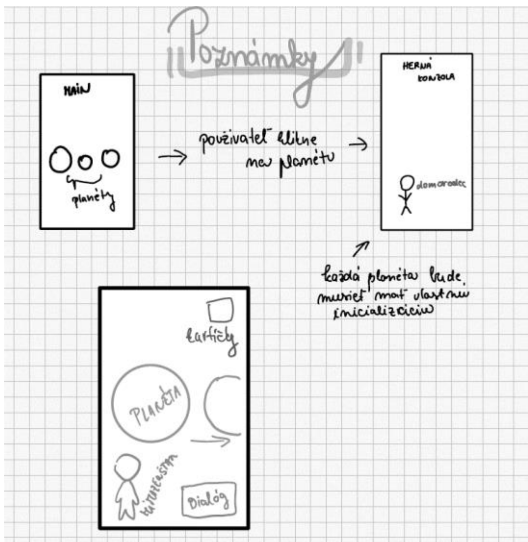

Fig.2. Wireframe of solar system Activity: mobile phone display design.

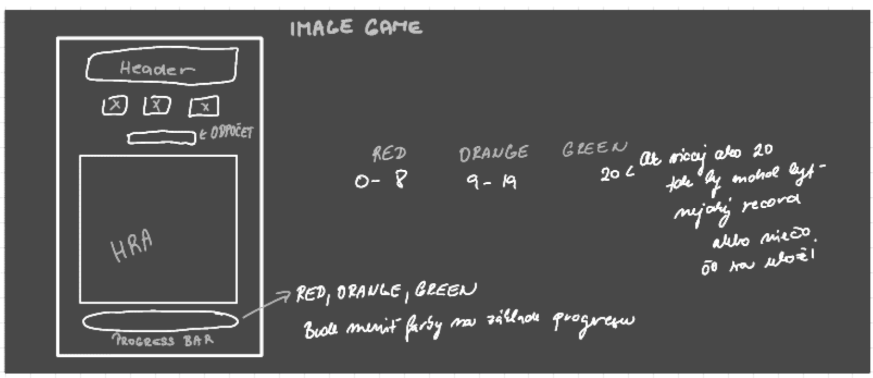

Fig.3. Wireframe of mini game.

2 Implementation of the Game Universe

Our priority was to create fun and interactive elements that would motivate children to learn and discover new knowledge about space and space objects.

To achieve this goal, we used the Kotlin programming language and the Android Studio platform. Thanks to this technology, we were able to create an engaging 2D solar system environment that is interactive and allows the player to move around it. This allows the player to see the exact location of each planet relative to the other bodies and gets a better sense of their relative sizes.

Our programming allowed children to get to know the universe not only visually, but also through informative text about individual planets and space objects. Children can simply click on a particular planet to see more information about it.

When the player clicks on a planet, there will be shown information about that planet and images that they can navigate through. The text is displayed in the ScrollView element sequentially based on which questions the player decides to ask first. The War and Peace buttons are not made available to the user until all questions have been asked. As soon as the player asks three questions, the War and Peace buttons are colored and the player can click on them according to their choice. When the player chooses one of the options, the algorithm starts generating 1 or 0. If it is 0, the Quizz Activity is started, which means peace. If a 1 is generated, the ImageGame Activity starts, meaning a fight.

We have created a game that contains mini-games and challenges that children must solve in order to progress further in the game.

The first mini-game that introduces combat focuses on children's reflexes and their ability to quickly react to changes in the game environment. In addition to reflexes, this minigame also focuses on the player's ability to focus and maintain focus in a rapidly changing environment. The player will have to give full concentration and be able to react quickly and accurately to every movement of the opponent. Thus, this mini-game helps to develop not only motor skills, but also cognitive abilities of children. Aliens are randomly displayed to the player on a 3x3 field, and the player must collect them within the time limit or as quickly as possible. At the same time, he has to be careful not to depress the bomb that takes his lives. The game lasts 30 seconds and is counted down using the CountDownTimer class, which allows programmers to implement countdown timers in Android applications. To use, you first need to create an instance and specify the time interval for which the timer should run. The start() function is executed first, which starts the timer. The CountDownTimer then counts down to the specified interval and calls the onFinish() method when the timer expires. In our case, after the countdown, the timer evaluated whether the user collected the necessary number of aliens to complete the level.

But if the player pressed the bomb 3 times during the game, the game is automatically ended and the player has lost. This was done in the setGame() function, where it looks to see if the image contains the "alien" tag. The setGame() function has one input parameter and that is the imageView element, i.e. the image that was clicked. If it didn't contain this tag, the function looked at what the player's health score was. If the player reached the last life, it was game over for him and he lost. If he had more than one life, the life was counted and the game continued.

The setGame() function then calls the playGameAgain() function, whose input parameter was the same as for the setGame() function. For all images in the ArrayList element, the tag indicating whether it is a bomb or an alien has been deleted, and the number of captured aliens has been added to the UI.

The game() method was then called, with a random number as its input parameter. This random number determined which field would appear and whether it would show a bomb or an alien. Based on this, the correct tag was assigned to determine what the player clicked on.

It was important to design the game so that if the player did not click on any image, the images would continue to be randomly generated. We achieved this again with the help of the CountDownTimer class, which counted down until the end of the image. If the player managed to click within the specified time window, the timer was restarted.

If the player chooses peace, a mini quiz will start, consisting of 3 randomly generated questions. First, it detects which planet is currently being played and loads all the questions about this planet from the Excel file into separate objects of the QuizzClass class. All these objects are added to an ArrayList element named list: ArrayList<QuizzClass>.

Then the three RadioButton elements are added to another ArrayList element named radioButton: ArrayList<RadioButton>. These ArrayList elements are then sent to the createRandomQuestion() function. This function first checks how many questions have already been asked, and then generates more questions and assigns them to the RadioButton elements, shuffling them in random order. Questions are also randomly selected from the ArrayList element and assigned to the radioButton element. When a question is asked, it is deleted from the list so that it is not repeated.

RadioButton3 always contains the correct answer, so when the user presses the next button, the application evaluates whether the player answered correctly or not and colors the answer accordingly.

```
// Generuje sa dalsia otazka

// Z listu sa vytiahne random otazka
val randomNu = (0 ≤ until < list.size).random()
currentQuestion = list.get(randomNu)

// Cistenie a nahodzanie otazok
binding.radioGroup.clearCheck()
binding.radioGroup.removeAllViews()
binding.question.text = currentQuestion.question
binding.radioButton2.text = currentQuestion.answer1
binding.radioButton3.text = currentQuestion.answer2
binding.radioButton4.text = currentQuestion.correctAns

//OTAZKA sa vymaze zo zoznamu, aby sa neopakovala
// random prehodenie otazok
list.removeAt(randomNu)
radioButton.shuffle()

for (radio in radioButton) {
    binding.radioGroup.addView(radio)
}
numberOfQuestions++
```

Fig.4. A method for loading a random question and assigning the question and answers to a radioButton.

3 Testing

Testing is an essential part of the software development process. It helps in identifying defects or bugs in the software, which can be corrected before the software is released.

To ensure that our game is of high quality and provides an excellent user experience, we used a combination of manual and automated testing. Manual testing involves having testers, who were both adults and children, play the game to identify any issues or bugs that may arise during gameplay.

Fig.5. Implementation of the Milky Way.

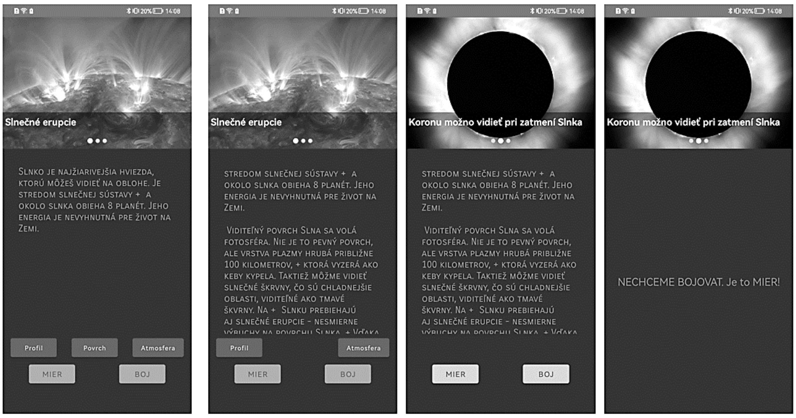

Fig.6. Implementation of the description of the planets.

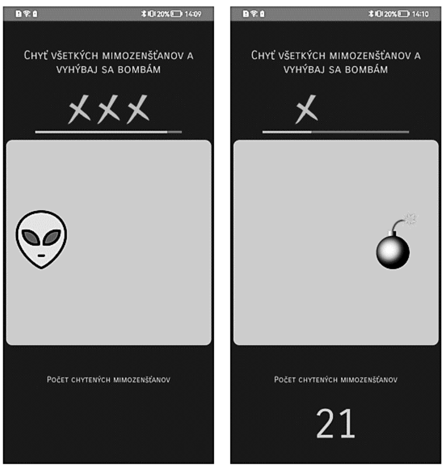

Fig.7. Implementation of the mini game.

The testers were provided with a set of instructions and asked to complete certain tasks within the game, while we monitored their actions and took note of any issues that arose. We also used automated testing, which involved using a software program to run a series of tests on the game. These tests were designed to check specific functions or features of the game, such as checking the accuracy of the planet positions or ensuring that the activity was run successfully.

Automated testing helped us to identify any bugs that may not have been caught during manual testing. We used various tools for automation such as Java for unit testing and Appium for UI testing. With unit testing, we examine individual components and classes of the application to see if inputs and outputs are handled correctly. Using the Java JUnit framework, we wrote and ran test scenarios that verified the correct functioning of the code. In addition, we used the Appium tool to test the user interface. This tool allowed us to simulate user interactions with the app and test them on different devices. That's how we made sure that the app works properly even on different platforms and devices. During the testing phase, we identified several issues that needed to be addressed. These issues ranged from minor bugs, such as a button not working correctly, to more critical issues, such as crashes or freezes during gameplay. We used a bug tracking system to keep track of these issues, and once they were identified, we worked to fix them promptly.

One of the significant benefits of testing was that it allowed us to receive feedback from our testers. This feedback helped us to identify areas of the game that needed improvement, and we used this information to make changes to the game. For example, one of the testers pointed out that the font used in the game was difficult to read, so we changed the font to make it more readable.

4 Discussion

We described a mobile educational space game that we developed to help children learn more about space. During the development of the game, we encountered several programming problems.

One of the main problems was the difference between the requirements of the user and the programmer. Users expect intuitive controls and attractive design, while programmers focus on functionality and code efficiency. We had to find a compromise to meet user requirements while ensuring the app works properly. Another problem was testing the application. Even though we used automated testing, manual testing was still required. We had to make sure to catch all the bugs and make sure the game runs smoothly. Finally, we faced the challenge of optimizing game performance. The game has been designed to work on different mobile devices with different operating systems. We had to make sure that the game works on all these devices while trying to maximize its performance. We had to ensure a responsive display so that the game works on all smartphones and tablets while providing maximum performance. Currently, the final version is being approved for Google play, which will be free for everyone. We are preparing an English version of the game so that students can improve their English.

We adapted the design and development of the game so that it could be easily modified for the design of a similar game, for example for education about atoms and molecules by focusing on the periodic table of elements. In the future, we would like to focus more on optimizing game performance and improving the user experience for similar educational games.

Conclusion

Based on our research, we developed a space-focused mobile educational game for children. The game contains several mini-games that help children improve their knowledge about space and space objects. In this discussion, we will look at the advantages and disadvantages of using mobile games in the educational process, as well as potential areas for further research in this area.

The advantages of using mobile games in the educational process are multiple. The first advantage is their accessibility. Mobile devices are widely available and playing games on these devices is natural for children. Games can be adapted for different age groups and can be designed to be fun and educational. Memorization of the subject matter is also improved, as the players learn in an interactive way and remember the subject matter better. The disadvantages are related to the dependence on technology and the risk of inappropriate content. Children should be supervised while playing games and games should be designed to be meaningful and safe.

Our research has shown that mobile educational games can be an effective way to engage children and improve their knowledge of a given topic. Automated testing allowed us to detect and fix bugs in the game. Further research could also include investigating the effectiveness of mobile educational games compared to traditional learning methods, as well as the inclusion of more challenging game mechanics that would further engage children in the learning process.

In conclusion, we would like to emphasize that our mobile educational game was successful in attracting children to space and space objects. Using automated tests, we were able to detect and fix bugs, thus achieving a high quality game. Mobile educational games have great potential in the educational process. This project could also be applied in other fields, such as chemistry or biology. Further research could demonstrate the effectiveness of mobile games in other educational areas and help provide new approaches to teaching.

Acknowledgement

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References

[1] Ulah M, et al. Serious Games for Science Education: A Systematic Review of Research Trends and Patterns. Vol. 4, N. 3, 2022, pp. 189-209, ISSN 2096-5796

[2] Ellington H, Addinall E, Percival F. Games and simulations in science education. 1981R

Authors

Barbora Jurkovcová
Pan European University, Bratislava, Slovensko
xjurkovcova@paneurouni.com

DESIGN OF THE INFORMATION SYSTEM FOR MONITORING THE QUALITY OF THE UNIVERSITY

Michal Drobný

Abstract:

This article further analyzes the requirements for evaluating the internal quality system at Pan-European University (PEU), which are defined by PEU internal directives based on the conditions described in Act no. 269/2018 ensuring the quality of higher education and amending Act no. 343/2015 Coll. on public procurement and the amendment of specific laws as amended and based on this analysis, design and implement the information system that will serve to manage the internal quality system at PEU. The following chapters describe the entire process of creating this information system, from analysis, through implementation and testing to deployment in production and use at PEU, as well as how the system's future development should be managed.

Keywords:

Information system, a system of quality, evaluation of quality.

ACM Computing Classification System:

Software and its engineering. Software creation and management.

Introduction

The beginning of the 2022/2023 academic year brought the task for universities in Slovakia to adapt their existing study programs (hereinafter referred to as "programs") as well as habilitation and inauguration procedures (hereinafter referred to as "procedures") to the new Higher Education Act and the Quality Act. At the same time, it is necessary to prepare for a new method of accreditation of programs and procedures by universities.

Since this obligation arose for universities, an initiative was created at Pan-European University in Bratislava (hereinafter referred to as "PEU") to manage this process at PEU and its faculties more sophisticatedly compared to the circulation and approval of paper forms.

After processing the requirements for the management of this process, it was decided to create a custom information system that would reflect the needs associated with this process and, at the same time, be wholly owned by PEU.

The quality system defines how the university will ensure systematic and structured care for the quality of education, related creative activities, and maintenance and improvement. However, a recent change in legislation is changing the current way of managing and evaluating the quality of higher education. This change is directly related to the accreditation of study programs and procedures.

Law no. 269/2018 on ensuring the quality of higher education and amending Act no. 343/2015 Coll. on public procurement and on the amendment of specific laws as amended (hereinafter referred to as "Act No. 269/2018 Coll.") brought with it the creation of the Slovak Accreditation Agency for Higher Education (hereinafter called the "Agency").

This Agency oversees assessing the internal quality systems of individual universities and, based on this assessment, accrediting individual programs and procedures. It also complements the legislative framework, as determined by Act no. 269/2018 Coll.

The quality system at PEU is governed by the following internal directives and decrees, created upon legislation need based on Act No. 269/2018 Coll. Their directives are:

- Directive no. 1/2022 - Statute of the board for internal quality system evaluation
- Directive no. 2/2022 - Internal quality assurance system
- Directive no. 3/2022 - Evaluation of educational activity by students and graduates
- Directive no. 4/2022 - Rules for creating and implementing study program adjustments
- Quality indicators and their calculation

A new body, the Quality Council, was created to evaluate the internal quality system of PEU. The competence of the council is determined by Act no. 269/2018 Coll., the Agency's standards, the PEU statute, and its internal regulations, which are listed above. "The quality council has at least seven members". [1, p. 4] Only a person who is a recognized professional authority, a graduate, or a student who has achieved good academic results during their previous studies at PEU can be appointed as a member of the Quality Council.

For harmonizing programs and procedures, these programs are evaluated by a recognized external authority (hereinafter referred to as "an evaluator"). Their evaluation is part of the quality evaluation, and the documents created by the evaluators are an integral part of the documents, defined as self-assessment reports. This report is the basis for the responsible Agency in the accreditation process of individual programs and procedures. On its base, the university and individual faculties are granted accreditation for individual programs and procedures.

The following chapters describe the process of introducing process of creating the information system that serves quality management at the PEU.

1 System Design

The new information system for quality approval (hereinafter referred to as "the information system") was designed based on legislative requirements already mentioned in this article's introduction chapter. The proposal also included requirements from the future users of the information system.

The design of the information system should reflect these requirements and be implemented into one functional unit so that this system not only meets expectations but is also expandable and sustainable in the future.

1.1 Timetable

At the latest, PEU and its faculties had to harmonize their programs and procedures with legislative requirements by August 31st, 2022. Since the deadline that PEU had to meet was precisely defined, the schedule for implementing the information system was also subject to this deadline.

The university amended its internal directives, which created a prerequisite for fulfilling the legislative requirements as of April 1st, 2022. Subsequently, the Quality council was established to supervise the quality approval process. Individual faculties have started preparing the necessary documentation for unique programs and procedures.

In April 2022, a functional specification was created describing the process of approving programs and procedures by the Quality Council and the body of evaluators, as it should have been implemented in the information system.

This specification also describes individual functional elements of the information system users will work with. Great importance was placed on the security of the information system and its auditability. The implementation of the information system began at the beginning of May 2022. The first version was made available to users and testers at the end of May 2022.

During June 2022, the change requirements resulting from testing were implemented into the system, and bugs were fixed so that the system was ready for production launch on June 23rd, 2022 when the first official meeting of the Quality Council at PEU took place.

The following picture (Fig.1) describes the implementation timetable in main milestones.

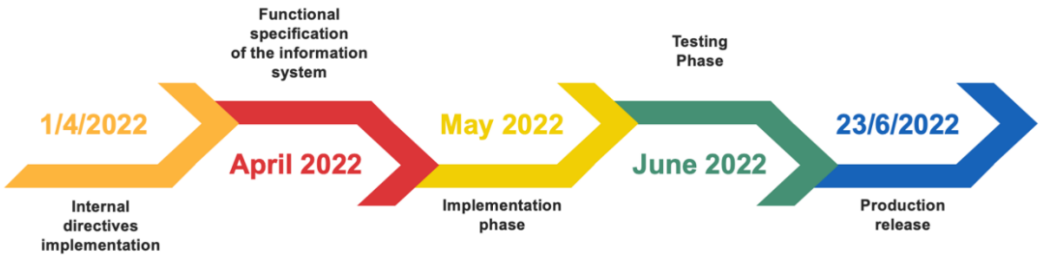

Fig.1. Implementation timetable.

1.2 Choice of Technology

Developing any information system involves making critical decisions about the technology stack used throughout the project. A well-thought-out decision process ensures that the chosen technologies align with the project's goals, meet the requirements, and contribute to the application's long-term success. In this section, we outline the decision-making process that led us to choose **PHP** with the **Laravel** framework and **MySQL** as the database for the information system.

Understanding the project requirements

Before evaluating different technologies, it is crucial to understand the project requirements clearly. Our information system needed to be scalable, secure, and easy to maintain while offering excellent performance. Additionally, we had a relatively short development timeframe.

Comparing various technology options

We compared several popular programming languages, frameworks, and databases to understand their suitability for our project. The contenders included Python with Django, Ruby with Rails, JavaScript with Node.js and Express, and PHP with Laravel. We also considered databases such as MySQL, PostgreSQL, and MongoDB.

Evaluating the PHP and Laravel combination

PHP is a widely used, open-source scripting language designed for web development. It offers several advantages, such as:

- **Mature ecosystem** (long history with extensive libraries and resources)
- **Affordability** (thanks to open-source code and wide availability of qualified developers)

- **Compatibility** (with different web servers and operating systems which facilitates deployment and integration with other technologies)

Laravel is a robust PHP framework that simplifies development by providing a clean and elegant syntax. It offers several benefits, such as:

- **Rapid development** (built-in tools and libraries such as Artisan, Eloquent ORM, and the Blade templating engine help speed up the development process)
- **Scalability** (horizontal scaling through queuing and buffering mechanisms that ensure our application can handle growing traffic demands)
- **Security** (robust security features such as protection against SQL injection and cross-site scripting, which ensure the security of our application)

Choosing MySQL as the database

“MySQL is a popular, open-source relational database management system (RDBMS)” [2, 2023]. It is known for its reliability, performance, and ease of use. We chose MySQL for the following reasons:

- **Compatibility** - MySQL is highly compatible with PHP and Laravel, making integrating with our chosen technology stack easy.
- **Cost-effective** - MySQL is an open-source solution with many cost-effective hosting options.
- **Performance** - MySQL offers excellent performance with indexing and caching mechanisms, ensuring quick data retrieval and storage for our application.

After thoroughly evaluating different technologies, we concluded that PHP with the Laravel framework and MySQL as the database was the optimal choice for the information system. This combination offers a cost-effective, scalable, and secure solution that aligns with our project requirements and ensures a smooth development process.

1.3 Data Model

Having decided to use a MySQL database for the information system, the clear choice was implementing the relational data model. This model allows us to efficiently organize and manage structured data in the database using tables consisting of rows and columns. The relational model also allows us to represent relationships between data entities using primary and foreign keys. This enables efficient querying and manipulation of data using a declarative language, such as Structured Query Language, represented via ORM integrated with Laravel Framework.

With this approach, we can achieve higher consistency, integrity, and normalization of data, which is essential for various applications, such as transactional systems, reporting, and data warehouses. As a result, implementing the relational data model in the information system will enable better data management and optimization.

Since our data model is pervasive, for this article, we will only summarize the most crucial data entities:

- **Academic titles** store information about academic titles, such as professors or assistant professors.
- **Activity log records** user activities, such as login/logout, page views, and other actions taken on the system.
- **Audit logs record** audit logs, such as changes to user roles, permissions, or access.

- **Document templates** store document templates indented from the documents necessary for the accreditation process.
- **Documents** store documents uploaded to the system.
- **Document versions** store document versions of uploaded documents.
- **Form of studies** stores information about forms of study, such as external or daily.
- **Hip approvals** record approvals for procedures accredited in institutions.
- **Hips** store information about procedures accredited in institutions.
- **Institutions** store information about educational institutions such as universities and faculties.
- **Level of studies** stores information about levels of study, such as undergraduate or graduate.
- **Field of studies** stores information about fields of study.
- **Self-assessment report approvals** record approvals for self-assessment reports.
- **Self-assessment reports** store self-assessment reports.
- **Study program approvals** record approvals for study programs.
- **Study programs** store information about study programs.
- **Fields of study** store fields of study accredited in instructions.

Overall, this data model is designed to support the management of the information system and all required functionalities specified in the functional specification.

2 Implementation

In the implementation phase of the development, we focused on turning the design and plans into a functioning system. We wrote the necessary code, created and integrated databases, and implemented all the required features and functionality.

We also conducted extensive testing and debugging to ensure the information system worked as expected. Once the information system was ready, we deployed it to production and made it available to the users. In the following part of the article process of implementing REST API and user interface will be explained in more detail.

2.1 REST API

REST API is considered a best practice for API communication in Laravel because it follows principles that make it more efficient and effective for exchanging data between systems. These principles include a stateless, client-server architecture, standardized HTTP methods for accessing resources, and the use of URLs to identify resources as stands in "What is REST API" [3, 2023]. This design provides a more organized and predictable way to communicate between systems and allows for greater flexibility in the types of requests and responses that can be used.

In the application, we used a REST API because it allowed us to easily create endpoints for different types of resources and utilize standardized HTTP methods for accessing and manipulating data. This allowed for more consistent and predictable interaction with our backend system, making developing and maintaining our application easier. Additionally, the use of REST API allowed us to easily integrate with other systems that also utilize this design, making it easier to expand and grow our application in the future.

The naming convention used in our application was modified, and we did not use the standard naming convention for REST APIs. The main reason for modifying the naming convention was code readability for future development. Our backend also modifies the data processing to make the REST API usable with the front end, to provide all data for blade templates, and to be used when changing the frontend framework in the future.

2.2 User Interface

The user interface was divided into two parts: user and administrative. Each part was designed independently to meet the requirements specified in the functional specification. The user interface was designed with a focus on ease of use and providing a positive user experience, while the administrative interface was designed with a focus on functionality and ease of management. This approach allowed us to tailor each interface to the needs of its respective user group, ultimately leading to a more effective and efficient system. Additionally, it facilitated easier maintenance and updates in the future, as changes to one interface would not impact the other.

User interface

For the user interface, we have decided to use Laravel Blade. Implementing an interface with Laravel Blade involves creating and structuring views that are returned as HTTP responses to user requests. Laravel Blade is a templating engine that provides a simple yet powerful way to create reusable HTML and PHP code. Blade templates use a special syntax that enables us to define layout files, include partial views, and pass data to views.

One of the advantages of using the request-response way of implementing UI instead of asynchronous JavaScript calls is that it enables us to easily create reusable UI components with no strict binding to any browser-side rendering. These components can be defined as Blade templates and included in other views, making it easy to create a consistent look and feel across our application. Additionally, Blade templates can be extended to create master layout files that define the overall structure of an application's UI. As our user interface is mainly structured as an Admin Template, usage of Master Layout was the right way how to structure our Frontend application.

Overall, implementing a user interface with Laravel Blade provided us with a powerful and flexible way to create reusable UI components, define master layout files, and generate clean and semantic HTML. These benefits, along with Laravel's robust routing and controller features, helped us implement a flexible user interface with a high focus on development speed.

Admin interface

We have decided to use Laravel Nova for generating the administration interface due to the pervasive data model that our information system is using. This decision allowed us to generate CRUD for all data entities implemented in the application and enable their fulfillment through the administration interface. Thanks to CRUD, it is possible to modify and delete these entities according to the needs and functional specifications of the application.

Laravel Nova provides an easy-to-use and customizable interface for managing data entities. It allows us to create, read, update, and delete records in our database. Additionally, it will enable us to manage relationships between entities and provides a search functionality that makes it easier to find specific records.

Using Laravel Nova for the administration interface provides several benefits, including reducing development time and increasing productivity. With Laravel Nova, we did not have to spend time creating custom administration interfaces for each entity. This allowed us to focus on other vital parts of the application, such as the user interface.

In summary, using Laravel Nova for the administration interface has been a wise decision for the information system. It allowed us to generate CRUD for all data entities, easily manage relationships, and access valuable features like metrics, custom filters, and custom actions. Additionally, it has helped us reduce development time and increase productivity, allowing us to focus on other essential parts of the application.

3 Testing

Our framework of choice, Laravel, provides several possibilities for automated testing, including Unit tests and Feature tests. Unit tests, when PHP Unit or PEST is used, allow for testing of individual methods and classes, while Feature tests allow for testing of functionality across multiple methods or classes.

One of the primary reasons we chose PEST as our testing framework and not PHP Unit tests is its simplicity and ease of use. PEST provides a more readable syntax and allows for faster writing of tests, as can be seen in (Fig.2) vs. (Fig.3).

```php
<?php
namespace Tests\Unit;

use PHPUnit\Framework\TestCase;

class BasicUnitTest extends TestCase
{
    public function basicTestCase()
    {
        $this->assertTrue(true);
    }
}
```

Fig.2. Basic PHP Unit Test.

```php
<?php

test('is true')
    ->expect(true)
    ->toBeTrue()
```

Fig.3. Basic PEST Test.

It also integrates well with Laravel and supports Laravel's testing helpers, such as actingAs(), assertDatabaseHas(), and assertSee(). PEST also provides a test suite feature, which allows for the grouping of related tests and easier management of tests as the application grows.

Another benefit of using PEST is that it provides more helpful error messages, making it easier to identify and fix issues in the code. PEST also allows for parallel testing, which can significantly speed up testing times on larger projects.

PEST supports test-driven development (TDD) by providing a built-in --watch flag that automatically runs tests as changes are made to the code. This feature encourages developers to write tests before writing code, making it easier to identify issues early in the development process; even TDD was not used while developing the information system, this development pattern can help us, if used, with implementing new features without worrying about introduction of complex bugs into the information system.

The user interface underwent primary testing through manual methods. Users who were involved in the project were given the application for testing after the implementation of all functionalities. Complex test scenarios were excluded from the testing process.

The purpose of this approach was to identify any potentially poorly designed processes. By focusing on manual testing, users could better examine the environment and its functionality in a more natural setting.

As a result, this testing method allowed for a more comprehensive understanding of the user interface. By working within the environment and interacting with its features, users were able to uncover any flaws or issues that might not have been apparent during more complex testing scenarios.

4 Discussion

During the design and development of the information system, it was discovered that it is essential to include all materials processed in the system in the electronic form to streamline the entire approval process. The implementation of electronic documents brought many benefits, particularly in the speed and efficiency of information processing.

Each document that must undergo the approval process retains a detailed history of what happened to it and who commented on it. This digital trail ensures transparency and traceability of operations, leading to improved communication and collaboration among involved parties.

The digitization process brought significant improvements to the speed of the approval process for programs and procedures and time savings for the PEU. This acceleration allowed for the streamlining of work for employees, the Quality Council, and Approvers, leading to better resource utilization and an increase in the quality of services provided by the information system itself.

Conclusion

The implementation of the application has brought significant benefits to PEU, including the alleviation of paper bureaucracy. This digital transformation of the quality monitoring process has streamlined processes and improved efficiency while also providing a more user-friendly experience for approvers, the Quality Council, and all personnel involved in the approval and accreditation process.

The application will continue to be expanded, adding new functionalities to enhance its capabilities. Future developments include the implementation of AI to optimize processes and creating documents for programs and procedures directly within the application. This innovation will allow for even more significant time savings and resource optimization.

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References

[1] Pan-European University, Directive no.1/2022, 2022
[2] Craig S. Mullins, July 27th , 2015, accessed April 29th, 2023. https://www.techtarget.com/search-datamanagement/feature/MySQL-open-source-RDBMS-overview
[3] What is a REST API? 2023, accessed April 29th, 2023, https://www.ibm.com/topics/rest-apis

Authors

Michal Drobný
Pan-European University/Faculty of Informatics, Bratislava, Slovakia
xdrobny@paneurouni.com

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