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Content

Content

HOW TO CHEAT THE AI IN SELF-DRIVING VEHICLES?

Kiss Gabor[1]

Abstract

There is a growing number of vehicles on the road that are either equipped with driver assistance devices or, in certain circumstances, are capable of fully autonomous driving. Meanwhile, self-driving vehicles with different capabilities are being tested in countries around the world. In the later stages of development, self-driving vehicles capable of self-driving in all conditions will also be on the road. At first, conventional vehicles with full driver attention and fully autonomous vehicles will coexist, but in time we should expect to see self-driving vehicles on the roads. Our aim is to point out the situations and safety issues that we recommend vehicle manufacturers test before we reach the stage where only autonomous vehicles are on the road. The use of self-driving vehicles is expected to result in a lower risk of accidents, as most road accidents are caused by human error, but it is worth taking a look at which situations could be dangerous in the case of fully autonomous transport.

Keywords

cheat, Artificial Intelligence, self-driving, vehicle, auto, autonomous

1 Introduction

People are always dreaming about things that are unattainable in their lives. As part of this, fantasies about technical devices and possibilities that are not feasible in their time may appear. Thanks to human ingenuity, some of these will actually come true in time.

Many of the 108 inventions and plans in the books of Gyula Verne, a 19th-century inventor, have now been realized, for example, landing on the moon or exploring the depths of the sea.

Science fiction literature of the 20th century is often concerned with the complete replacement of human labour by robots. Some of these ideas have already been realized thanks to technological advances made possible by human ingenuity, such as the assembly plants of car manufacturers. Some of the fantastic literature contains references to fully autonomous vehicles and the way they will be driven in the future.

Thanks to the technical progress of mankind, it is now natural to see vehicles on the roads that incorporate various driving support systems, and tests are constantly being carried out in various countries on completely non-driving vehicles (Favarò F. et al, 2018) (Galen E. et al, 2017). Our aim is to identify the circumstances and incidents that pose a safety risk in the world of self-driving vehicles.

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2   The conditions for autonomous vehicles

The Society of Automotive Engineers (SAE) International laid down the categories of self-driving vehicles in its 2014 standard J3016 "Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems", which was updated in 2016 in response to circumstances and is currently used by automotive industry stakeholders in J3016_201609. The standard distinguishes six levels of self-driving vehicles.

Level zero is for vehicles without any self-driving function or driving assistance system, and the highest level 5 is for vehicles that are fully capable of autonomous driving without a driver, where the occupants are only passengers and all driving is done by the system.

Full self-driving can be achieved soonest on motorways, where there is no oncoming traffic, lane markings are clearly visible and lanes are wider than in the city. It's not for nothing that more and more car manufacturers are promising this feature in their upcoming vehicles.

Here, the system has fewer things to watch out for than in urban traffic, with its intersections and frequent lane changes, where buildings sometimes make it impossible to monitor traffic at a greater distance.

The majority of vehicles on the roads are currently classified by SAE International as level 0, i.e. with no driver assistance systems at all, and the proportion is higher in poorer countries.

New cars, on the other hand, are already equipped with support depending on their equipment level, i.e. they are at least SAE level 1. One of the most common lower levels is urban braking assistance, which intervenes in the event of sudden braking or driver inattention, using cameras to monitor traffic ahead. The other common tool is to assist lane-changing by using UH sensors to monitor traffic behind and warn us if there is a vehicle too close or faster than us within a given distance. At a higher level, there is cruise control, which uses radar and cameras to adjust the speed of the vehicle in front, and lane-keeping electronics, which uses cameras to keep the vehicle in its lane. Both solutions only work properly under certain conditions, e.g. weather conditions are good, lanes are clearly visible.

We now have SAE Level 2 vehicles on the roads, albeit in relatively small numbers. Tesla introduced the first commercially available car with self-driving functionality, available in the Tesla Model S in October 2014, Tesla Autopilot 1 used a single forward-looking camera, radar, and 12 ultrasonic rangefinders with a range of 5 meters. Alongside this, a growing number of manufacturers have introduced Level 2 self-driving systems - Cadillac Super Cruise, Audi Traffic Jam Pilot, BMW Traffic Jam Assistant, Volvo Pilot Assist, and Mercedes Distronic Plus - and other manufacturers are working on their own systems. Typically, Level 2 systems assist in parking, tailgating in traffic jams, and in motorway environments when the system requires conditions (clearly visible lanes, suitable weather, and visibility conditions) to help the driver to move quickly. Here, it is sufficient to detect the vehicle's immediate surroundings. The driver can temporarily let go of the steering wheel but must be ready to take control at all times if necessary. If the conditions for Level 2 self-driving are not present, the vehicle may not take over control from the driver. Of course, with software upgrades, these systems can be used in increasingly complex situations, allowing better and more precise control within the limits of their capabilities. Level 2 vehicles are now also appearing in urban traffic, where the extra challenge is to recognize, among other things, more complex urban traffic and traffic lights.

In March 2018, Nissan unveiled the new Nissan Leaf, a test car with Pro Pilot, which is already capable of fully autonomous urban driving with 12 cameras and 4 LiDARs (https://youtu.be/cfRqNAhAe6c). This service could be fully standard in cars by 2020, according to Nissan. Tesla's Autopilot 2 system is already good at recognizing traffic lights, city traffic, and parking spaces on the latest software, but full self-driving is promised for 2019.

With Level 3 self-driving, the driver can let go of the steering wheel for extended periods, but still, be ready to take back full control of the vehicle almost immediately. At this level, the use of LiDAR is already required, as well as the ability to process the computational task required to perform a complex maneuver. This feature was first introduced on the AUDI A8 in the summer 2017 and was then introduced as a feature on the Audi A6 in early 2018. LiDAR is also used in the Audi, alongside radars, cameras, and ultrasonic sensors, but the laser scanner is not on top of the vehicle but in the grille below the number plate, so it can only see 145 degrees ahead. The A8's self-driving mode can only be used when physically separating oncoming traffic, but even then the feature only works up to 60km/h. If the car is traveling faster than this, it returns control to the driver; if it doesn't, it emits an audible and light signal and after a while applies the brakes. If the driver still fails to take control, the hazard warning lights are activated, the car stops and an automatic emergency call is made. Level 3 is not a very big improvement on Level 2, so many manufacturers and developers are skipping this level. From 31 March 2018, only new cars that initiate an emergency call and send the vehicle's coordinates to the competent authority in the event of an accident will be allowed on the EU market.

At level 4, the driver can sleep during the journey but must be ready to drive if necessary. In such a case, the car will drive itself out of traffic and wake the driver, allowing the journey to continue. At this level, the car is not yet capable of driving autonomously on, for example, dirt roads. At this level, there is already a need for the vehicle to have information about the distant environment, making it possible to plan the journey in advance for longer distances.

Level 5, where the driver is now fully a passenger, there is no way to intervene as necessary to avoid an accident. From an information security point of view, it is precisely for this reason that this level is the most vulnerable. Tesla, unlike other manufacturers, does not use the LiDAR used in Google cars in its Level 5 self-driving cars, The newer version inherits the first radar from the previous version, 12 ultrasonic sensors and the previous 1 camera is supplemented by 7 additional cameras around the car

3   The questions of decision-making of AI in a self-driving vehicle

3.1   *Cheating based on humans*

Imagine a situation where there are people standing/seated on the road or at a pedestrian crossing so far apart that they cannot be avoided. Then, urban traffic dominated by autonomous vehicles, if the driver has no possibility to intervene in the control, could be stopped, causing congestion, or exploited for serious damage. How should the vehicle decide in such a case?

Cyclists cause an even more serious problem because they are able to move faster and therefore have to react to any change of direction from a distance. In many cases, there is no separation of cyclist traffic from vehicle traffic, only a painted lane marking the cycle lane, and in most places no lane at all. In the case of cyclists, all it takes is an unexpected crosswind to cause a change of direction or a drunk cyclist on his way home from the pub not fully in control of the situation and who wobbles around the road, possibly even falling. The cyclist's movements can be used by artificial intelligence to detect possible alcohol intoxication and the vehicle can prepare to swerve out of the way in a larger arc or pass more slowly due to lack of space, but sudden changes of direction are not expected if the cyclist is moving in a regular manner.

In another imaginary situation, a cyclist stops in front of the vehicle and next to or behind it, e.g. waiting at a red light. It is therefore not possible to avoid them without driving one of them over. What happens? The car remains stationary waiting for the room to swerve. The cyclists have trapped the vehicle!

The same situation can be imagined with pedestrians. With a level 5 self-driving vehicle, it is planned that there will be no steering wheel, pedals, etc., and the occupants will be passengers only, with no possibility to intervene in case of emergency, which the vehicle will have to avoid and solve. The situation can be exploited to cause damage, even if only deliberate delay to the vehicle's occupants.

The situation can also be used to attack the vehicle, e.g. to steal property carried in the vehicle. In the case of being surrounded by pedestrians or motorcyclists, the vehicle is standing still without giving the occupants a chance to escape to the protection of the vehicle, which a non-self-driving vehicle allows the driver to do. A motorcycle team can even force a self-driving vehicle to change direction and stop while driving by circling around and gradually slowing down, again taking advantage of the opportunity to cause deliberate damage. What could be the solution? Recognizing the situation, could the occupants of the vehicle override the programming of the self-driving vehicle, encouraging it to break free of the situation, even by swerving past pedestrians or motorcyclists, and continue on its original route?

Is it a good idea to include such an option? Can't we use it to deliberately damage the side of the vehicle/causing an accident by driving into pedestrians, even on the pavement? Can vehicles carrying and accompanying prominent people from certain countries ever be fully self-driving vehicles without a break-away function, offering the possibility of being captured?

In the situations described above, what decision should the self-driving vehicle make when replacing pedestrians, cyclists, and motorcyclists with animals? In urban traffic, should the life of a dog or cat that suddenly runs out onto the road be given the same weight in avoiding an accident as that of a human pedestrian? What should the self-driving vehicle do if, for example, it is surrounded by dogs, trapping them, even to give the attackers enough time to get close enough and take up the necessary position?

If the vehicle favors the occupants e.g. in a dangerous situation, would the demand for self-driving cars increase in the direction of the vehicle? e.g. pedestrian jaywalking, would it be hit if otherwise, the occupants would be in danger? In such cases, the at-fault is punished and the legal situation could be simpler. How would the social perception of vehicles change if, for example, a child ran out onto the road after his ball could be hit?

In the case of animals, up to what size should a vehicle be allowed to hit to avoid a major accident? Cats yes, dogs no? Should the AI assess what size does not yet cause damage to sensors at a bumper height so that the journey can still be continued safely in self-driving mode?

We have seen how humans and living creatures can cause a disturbance, either unknowingly or deliberately, to the decision-making of a self-driving vehicle, creating the potential for the occupants to be restricted in their progress. In light of this, it is worth considering from the manufacturers' perspective whether the occupant should have the right to override the vehicle's decision, giving them the chance to escape from a dangerous situation by forcing the AI to stop the vehicle, thus trapping it, or to change direction to guide it to a more advantageous location for damage.

3.2   *Cheating based on sensors*

We mentioned earlier that self-driving vehicles inherit functions that today are still only provided by driver assistance systems, sometimes with improved hardware, and given the right conditions (weather, lighting, good quality pavement signals, etc.), a well-programmed autonomous system should not make a bad decision based on the data they provide. However, this requires a good quality infrastructure (pavement, pavement signs, traffic signs, etc.), which is not always the case in many countries. However, the introduction of self-driving vehicles with higher and higher SAE levels is driven by manufacturers' competition for first mover and customer markets, so that when these vehicles are widely deployed on the roads, the

infrastructure will still not fully provide the conditions necessary for perfect operation everywhere.

Let's look again at some situations that pose a serious challenge to vehicle decision-making.

It can be a problem if one of our sensors is disturbed by different conditions due to the time of day. During the day, in-vehicle cameras can produce high-quality images to support decision-making, if the surrounding vehicles do not obscure road markings and signs, the images produced can be processed by radar and any LiDAR data used to support good decision-making. Although the processing of data from multiple sources becomes redundant information, placing a burden on the central unit, it can still help the system to make a more relevant decision.

When the sun is low, light reflected from the pavement can negatively affect the visibility of pavement markings, and if it blinds the camera, it can even interfere with the reading of the signs, temporarily removing the data and information from the redundant system by temporarily removing the data and information from one of the most important elements from the decision support.

In the dark, road signs and markings are illuminated by the vehicle itself, thus supporting the quality of the images that can be taken by the cameras, but what happens if the bulb on one side burns out (a less common phenomenon in the case of vehicles with Led lighting), then only the light from the other side of the vehicle helps, thus reducing the distance at which a good quality image can be taken. If you are driving alone on the road, you can't even expect the lights of those around you to help you temporarily. And if the lights on both sides go out, we can only rely on radar and any LiDAR that may be installed.

Intentional damage has already been covered as a source of danger caused by people and animals in traffic. We will now consider the potential for deliberate tampering with sensors. Today's modern cars are equipped with a sign recognition system, displaying the recognized sign on the dashboard, possibly on the windscreen. It can be used to warn the driver of speeding, no parking, etc. For example, a yield sign is moved from its top to its base. The question is, what kind of sign does the system recognize it as? A warning sign missing the exclamation mark in the middle, a wildlife hazard missing the leaping deer? Of course, the map software in the vehicle knows the original function, but in self-driving vehicles, the data detected has a higher priority for decision-making than previously known, which is good if there is a change in e.g. the number of lanes for a road resurfacing, which the map does not yet have information about, but in this case it creates uncertainty.

4   Conclusion

As we have seen above, there are many areas where autonomous vehicle developers need to pay attention. We have listed a number of situations for which systems should be prepared. Whether intentional or accidental, a decision situation can arise that the system may not be prepared for and therefore may not handle properly.

Care should also be taken to ensure that an autonomous vehicle cannot be trapped, deliberately forced to take a new route, and to be prepared for situations arising from infrastructure problems.

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Differential Safety Technique of
MOBILE ROBOT SYSTEM

Safa Jameel Al-Kamil [1]

Abstract

Mechatronics and robotics have progressed rapidly and offered a variety of solid technologies for application in industry and beyond; such progress is expected to have an even higher impact shortly by making mechatronics and robotics permeate our daily life. Robots are the future of the industry. However, deploying these robots in industrial environments, particularly in assembly, still comprises several challenges, one of which is skills-based task distribution between humans and robots. Designing artificial equipment so that its motion functions match the ones of the natural system, and forming a human-mechatronic system, is still challenging. Nevertheless, Mobile Robots (MR)are generally used to perform unsafe, hazardous, repetitive, and complex tasks. No optimal standard techniques provide safety regulations for MR in these environments. The MR must understand the dangers of a mission to themselves and the surrounding environment and analysis of fault detection directly; this paper will propose a new method of safety technique that improves the navigational system of MR, especially path planning and localization modules to use probabilistic in combination with a robust obstacles avoidance and safety hazard. Furthermore, we will develop the performance of the drive train of MR with different types of differentials that make the MR more efficient and safer.

Keywords

Mobile Robot, Safety, Industry, Motion

1. Introduction

Robotics in general has gained growing interest in the past years especially with the exciting advances in artificial intelligence technology, which could enable various valuable applications ranging from manufacturing to safety and healthcare. (Rosso et al., 2006) (Morales et al., 2014), However, the boundary between robots and humans remains hazardous (Saigo, et al., 2019), as the modern-day hard robot requires a lot of precise control (Shiva, et al., 2016), rigid interconnected links that can move in predetermined environments, and typically heavy and expensive. Autonomous mobile robots (AMR) becoming more use in industrial environments for logistical and manipulating tasks. Until now, a standard for mobile robots does not exist (Papa, et al., 2018)

Differential wheels are commonly employed in the construction of autonomous mobile ground robots. Achieving full autonomy requires addressing various features such as sensing, path planning, trajectory tracking, control, and self-localization. One key aspect of this development is the control and navigation of differential drive robots and vehicles (Safa J.D. Al-Kamil, Tamás Szakács, 2021), particularly with respect to ensuring safety and comfort for human interactions. Safety is achieved by avoiding collisions with humans or other obstacles,

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while comfort is ensured by maintaining a safe distance and slowing down in proximity to humans (Robins Mathew, Somashekhar S Hiremath, 2016). In traditional motion-planning, obstacles are typically assumed to be stationary, but in the case of human motion, it is highly unpredictable. While a robot follows a pre-determined path or moves at a slow pace, it's motion can be predicted and measured. However, humans tend to move at a similar speed as the robot and their motion is difficult to predict. Therefore, a motion-planning algorithm for dynamic environments, such as human interactions, should be able to adapt and replan efficiently to ensure a collision-free trajectory for the entire motion of the robot. One potential solution for dealing with the unpredictability of human motion and the complexity of replanning is to utilize RRTX. (Liu, et al., 2022), allowing to repair of unfeasible graph parts and introducing a prediction of human motion that, under mild assumptions, holds for brief time windows.

probabilistic algorithms, such as "Mobile Industrial Robots (MiR)" (MiR, 2017) and "Kuka KMR iiwa" (KUKA, 2018), are commonly utilized by mobile robots designed to work in industrial settings alongside humans. These robots often employ Light Detection and Ranging (LiDAR) technology for safety. However, the absence of widely accepted standards for mobile robots in industrial environments is a drawback of this approach. Studies, research, and developments in the field of motion planning for mobile robots are considered as related work in this area. The use of probabilistic algorithms in mobile robots operating in industrial settings not only improves safety but also enhances the overall performance of these systems. For example, the integration of LiDAR technology enables real-time mapping of the environment and dynamic obstacle avoidance, allowing the robot to navigate safely and efficiently. Additionally, the application of motion planning algorithms, such as the PRM planning algorithm and the Pure Pursuit controller, enhances the ability of the robot to generate optimal paths in complex and unpredictable environments.

Despite these advancements, the absence of widely accepted standards for mobile robots in industrial settings remains a major challenge. This has led to the need for continuous research and development in the field of motion planning for mobile robots. The goal is to establish best practices for these systems and ensure their safe and effective integration into industrial environments.

Overall, the development of safe and effective mobile robots for industrial applications is a rapidly evolving field that requires interdisciplinary collaboration and a strong focus on motion planning and control algorithms. The related work in this area has the potential to greatly improve the efficiency and safety of industrial processes and have a significant impact on the future of manufacturing and other industrial applications.

2. Related work

Recent evaluations of path planning do not provide a complete examination of most of the existing path planning solutions. The Differential-Drive Mobile Robot (DDMR) is a commonly used option due to its uncomplicated design and simple control. (N. Leena , K. K. Saju, , 2016) (Alves, et al., 2018). The control of DDMR has been a subject of much research in robotics. (S. He, 2005) (H. Wang, et al., 2021) The primary challenge in DDMR is to precisely control its fast movement and make it follow the desired trajectory (L. Kinam, et al., n.d.). Smoothing out sharp turns to prevent sudden changes in the robot's speed is a problem that needs to be addressed in the robot's trajectory. There are multiple methods currently used in research to address this problem, such as using arcs to fillet folded segments (Samson, 1995), B-spline for path planning (M. Eghtesad and D. S. Necsulescu, 2006) (Sun, et al., 2021), Clothoids for path smoothing (M. Brezak and I. Petrović, 2011), or Bézier curve continuity (Scheiderer, et al., 2019). Path planning for the UAVs conducting autonomous 3D flights also is an emerging issue today. Especially, for multirotor UAVs 3D paths were proposed for take-

off and landing. (Szabolcs, 2020.) (Szabolcsi, 2020). For fixed-winged UAVs different flight paths has been designed for low altitude flights, like landing and flare. (Szabolcsi, 2020). Computer-aided simulation and design of the 3D flight path is supported by (Szabolcsi, 2020). In our work, we have chosen to use NURBS curve to design the desired motion trajectory of the robot, as it has been found to be effective in preventing sudden changes in the robot's speed (N. H. Thai and T. T. K. Ly, 2021) (Rogers, 2001).

This article includes developing different types of motion planning algorithms, sampling-based and optimization-based, and their comparison and evaluation in various environments. Moreover, it includes the integration of motion planning with other subsystems, such as localization, perception, and control, to improve the overall performance of the robot. Additionally, using machine learning techniques for motion planning, the results of these studies are highly encouraging, demonstrating remarkable improvements in the accuracy and robustness of the proposed navigation system

3. Research methodology

3.1 Navigation system

The proposed model for navigation involves three main stages: path planning, control, and simulation. The path is generated using a probabilistic road map (PRM) planning algorithm (mobileRobotPRM). The Pure Pursuit controller block is then used to generate control commands for following the generated path. The robot's motion is simulated using a differential drive kinematic motion model. The model is created using the "Differential Drive Kinematic" block in MATLAB Simulink, which simulates simplified vehicle kinematics by taking in linear and angular velocity commands from the Pure Pursuit controller block and outputting the current position and velocity states of the robot.

3.2 Localization of Mobile Robot

A robot that moves around uses odometry to track its movement in a known environment. However, odometry can be imprecise, making it challenging for the robot to accurately determine its current location. To overcome this, the robot uses data from its sensors, such as lasers, cameras, and ultrasonic sensors, to calculate its position relative to a map of its surroundings (Prabin KumarPanigrahi, Sukant KishoroBisoy, 2022). This helps to limit the uncertainty of the robot's position. The robot's belief represents this information, and the process of updating the robot's position involves two steps: updating the prediction and action and updating the perception, measurement, and correction.

3.2 Map Building Process

The path planning algorithm for mobile robots is based on the Probabilistic Road Map (PRM) method. The PRM algorithm can find a path that avoids collisions and connects a starting point to a goal point, using a roadmap constructed by randomly placing nodes in the free configuration space. The PRM process has two stages: learning (preprocessing) and query. In the offline learning stage, many robot poses are randomly sampled, and connections are established between neighboring nodes to construct a roadmap. In the online query stage, a heuristic search algorithm is used to find a feasible path from the starting point to the goal point, using the roadmap information.

3.3 Learning Stage

The offline learning stage, which is the process of con structing the path network graph, is the main part of the PRM algorithm, so the nature of the algorithm determines whether it is used in static environments or when the randomness of environment variation is little. An undirected path network map G = (V, E) is constructed, where V represents a random set of points, E represents the set of edges between all possible two points. The pseudo code for the construction process is as follows.

Algorithm 1   PRM

1: V←∅
2: E←∅
3: loop
4:    q ← a randomly chosen free configuration
5:    V_q← a set of candidate neighbors of q chosen from V
6:    V← V{q}
7:    for $q' \in V_q$, in order of increasing, (q, q'), do
8:    if E =same− connected − component $(q, q') < |$ (q, $q')|$ then
9:         E ← E ∪ {(q, q')}
10:        update E's connected components

Steps 1-2: Initialize the two collections, one for the set of nodes and another for the set of edges connecting the nodes.

Steps 5-8: Select a series of neighboring nodes for the current node q. Use a local planner for path planning between the current node and each of its selected neighbors.

Steps 9-10: Add the boundary (q, q) of the feasible path to the set of edges and remove any paths that result in collisions. The specific process considers the following four key issues:

(1) Random Sampling (Pseudo Code Step 4): Ensure that the random point is within the free space and does not collide with any obstacles.

(2) Regional Planner Construction (Pseudo-code Step 8): Ensure that the regional planner is reliable and efficient. Minimize the time spent in a single call and the total number of calls. Discretize the local path and perform collision avoidance checks.

(3) Neighborhood Point Selection (Pseudo-code Step 5): Use a rule to select neighborhood points that are within a specified distance range from the current node.

3.4   Query stage

In the offline learning phase, an undirected path network G = (V, E) is constructed. During the inquiry stage, a path is selected based on the set starting position (qs) and target position (qg) by connecting the qs and qg points to two points (q1, q2) in the path network graph, and finding the path between q1 and q2 in the undirected network graph. This results in a global path connecting the initial and target positions. Once the global path is obtained, a smooth method can be applied to find the shortest path.

Algorithm 2 PRM

1:      Open←∅;
2:      Closed←∅;
3:       Open← q_s;
4:    **while** Open =∅
5:        q_0← arg min f(x);
6:         REMOVED (Closed, q_0);
7:       (Closed, q_0);
8:          **if** q_0 == q_g then
9:             **return** Reconstruct PATH (q_s, q_g , Closed);
10:        S←NEIGHBOURS (q_0);
11:    **for all** $q' \in S\ do$
12:        g←g(P');
13:        h←D (q_0, P');
14: $f ←$ g + h;
15:              **if** $q' \in Open \wedge f\ (q_0) < f(q')$ then
16:           **return**
17:           **elseif** $q' \in closed \wedge f\ (q_0) < f(q')$ then
18:           **return**
19:       open←q;

4. Motion Controller

4.1   Pure pursuit

Pure-pursuit algorithm is a popular trajectory tracking algorithm, widely used in mobile robotics and vehicular control for numerous reasons. The operation is simple and straightforward as it depends only on the kinematic model of the target mechanical system. The algorithm can be tuned by choosing look-ahead distance of points of the reference trajectory, see Figure1.

The widely used versions of the pure-pursuit algorithm may vary slightly, but generally, the process works as follows (assuming a vehicle with a wheelbase length l): The current location of the vehicle and its rear wheel in the global coordinate system (Xvehicle, Yvehicle) and (Xrear, Yrear) are determined; A goal point (Xla, Yla) with a constant lookahead distance is selected from the next waypoint array; The goal point (Xla, Yla) is transformed into rear wheel coordinates (Xrear, Yrear); The steering angle is calculated, and the curvature is derived from it, as per (Velagić, et al., 2014).
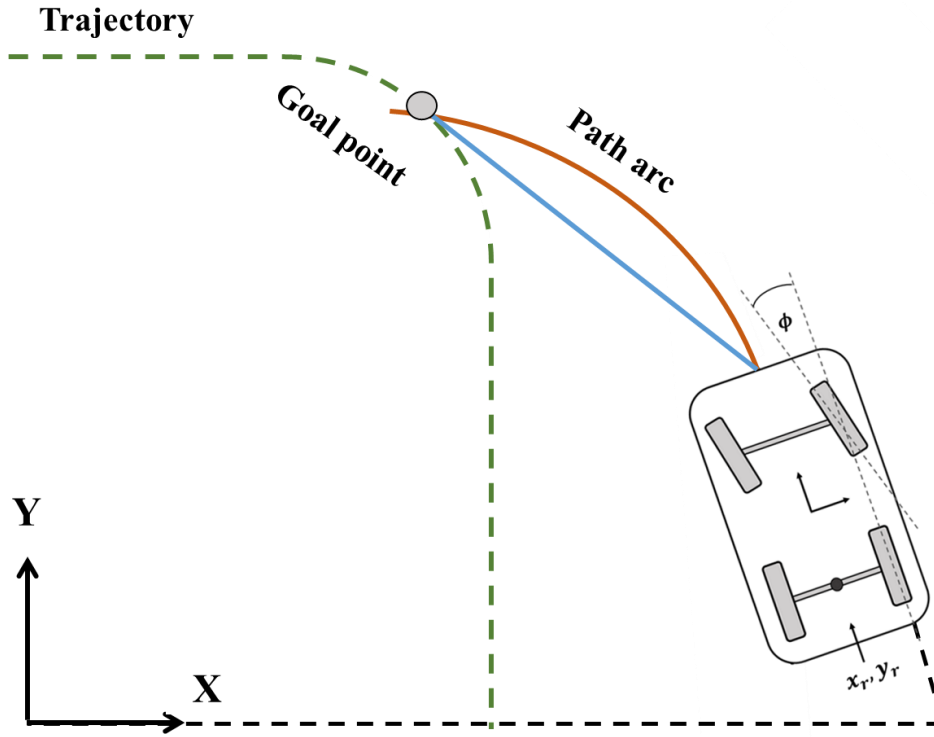
Fig.1. Mobile robot path.

5. Model of a Differential-Drive Mobile Robot

5.1   Kinematic Model of a Differential-Drive Mobile Robot

The proposed method in this paper is a car-like mobile robot using a MATLAB Simulink. The vehicle wheels commonly used in a mobile robot are two steered front wheels and two fixed-heading rear wheels which separated by a specified track width with a single fixed axle. the front wheels are steered using Ackermann steering (Lynch, Kevin M., and Frank C. Park, 2017), to avoid the slipping of these wheel (see Figure 2). The wheels can be driven independently, robot speed and heading are defined from the axle center. To identify the configuration of the car-like mobile robot, where (x, y) is the location of the midpoint between the rear wheels, the rolling angles of the four wheels are ignored, q = (φ, x, y, ψ). θ is the mobile robot's heading, Linear velocity of the point R is represented by v. φ is the mobile robot's heading direction, and l is the distance between the rear and the front wheels axes. Where is v the linear *velocity of mobile robot, while ω is the angular velocity. The right and the left wheel speed are represented by $\dot{\phi}$R, $\dot{\phi}$L, The Wheel radius is noted r, d is the track width, and ψ is the* steering angle of the mobile Robot, where l is the wheelbase between the front and rear wheels. The Wheel Speed Equation of the Mobile Robot:

$$\begin{bmatrix} \dot{x} \\ \dot{y} \\ \dot{\theta} \end{bmatrix} = \begin{bmatrix} \frac{r}{2}\cos(\theta) & \frac{r}{2}\cos(\theta) \\ \frac{r}{2}\sin(\theta) & \frac{v}{2}\sin(\theta) \\ -r/2d & r/2d \end{bmatrix} \begin{bmatrix} \dot{\phi}L \\ \dot{\phi}R \end{bmatrix} \tag{1}$$

The kinematic equation of the mobile robot is illustrated by:

$$\dot{q} = \begin{bmatrix} \dot{\theta} \\ \dot{x} \\ \dot{y} \\ \dot{\psi} \end{bmatrix} = \begin{bmatrix} (\tan\Psi)/l & 0 \\ \cos\theta & 0 \\ \sin\theta & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} \tag{2}$$

The control v is limited to a closed interval. These can be converted to the controls (v, ψ) by the relations:

$$v = v, \quad \psi = \tan^{-1}\left(\frac{l\omega}{v}\right) \tag{3}$$

The constraints on the controls (v; !) due to the constraints on (v;) take a somewhat complicated form, as we will see shortly.
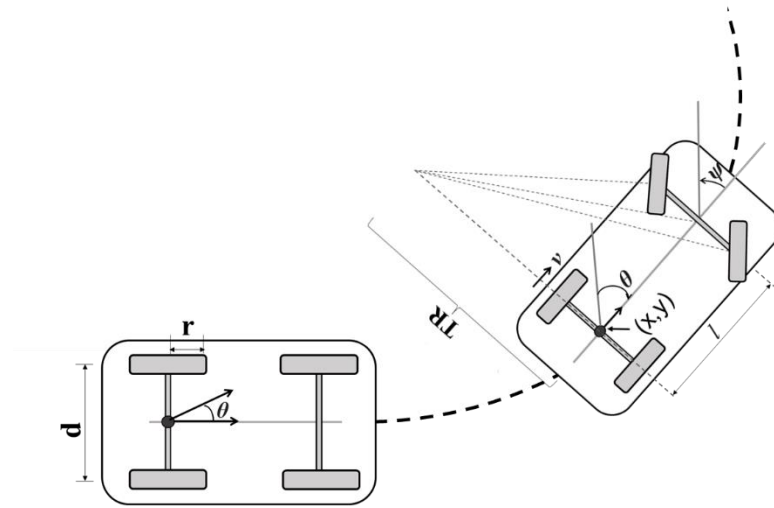
Fig.2. Model of the four-wheel car like mobile robot.

The simplified car kinematics can now be written:

$$\dot{q} = \begin{bmatrix} \dot{\theta} \\ \dot{x} \\ \dot{y} \end{bmatrix} = G(q)u = \begin{bmatrix} 0 & 1 \\ \cos\theta & 0 \\ \sin\theta & 0 \end{bmatrix} \begin{bmatrix} v \\ w \end{bmatrix} \tag{4}$$

The nonholonomic constraint implied by (4) and can be derived using one of the equations from

$$\dot{x} = v\cos\theta \tag{5}$$

$$\dot{y} = v\sin\theta$$

to solve for v, then substituting the result into the other equation to get

$$A(q)\dot{q} = [0\ \sin\theta\ -\cos\theta]\dot{q} = \dot{x}\sin\theta - \dot{y}\cos\theta = 0$$

5.2   *Motion capture*

Motion capture (MoCap) is the technique of digitally pursuing and recoding the movements of objects or living beings in space. The Algorithms for mobile robots of MoCap typically involve using a combination of sensors, such as cameras, lidar, and Inertial Measurement Unit (IMU), to track the movement and position of the robot. These algorithms often rely on visual odometry, which uses the robot's camera data to estimate its position and movement based on changes in the visual features of its environment. Another standard mobile robot motion capture method is lidar data, which uses laser range finding to create a 3D map of the environment and track the robot's movement within it. Some mobile robots also use a combination of visual and lidar data, along with data from an IMU, to improve the accuracy of their motion capture and localization. These algorithms can help mobile robots navigate and avoid obstacles in real-time and can be used in a variety of applications such as autonomous driving, delivery, and exploration. Various technologies and techniques have been progressed to capture motion. The depth based on the time delay from light emission to backscattered light detection can calculate the Camera-based systems with infrared (IR) cameras, projecting light towards an object, Depth sensitive cameras. Systems based on inertial sensors (DudzikORCID, 2020)electromagnetic fields and potentiometers that track the relative movements of articulated structures. The motion capture experimental research of the mobile robots carried by the Camera-based systems. These positions are transmitted to Matlab-Simulink via an Ethernet port and then processed by the control logic blocks within Simulink in real-time. The data are then transmitted to the robot with the help of QUARC -Real time. The ground control station is a setup that includes a computer with a powerful Intel Core i7 processor and a large amount of memory, specifically 16GB of DDR4 RAM. This setup includes several software programs, such as Matlab 2020a and QUARC Real-Time Control Software 2020, Additionally, the lab has three monitors, a USB flight controller joystick, and a two-band WiFi router. In the MoCap testing of control algorithms, the setup consists of 16 Cameras (see Figure 3). The camera that was used type of Vicon camera system. Vicon is a motion capture Camera related to the company that collects accurate, reliable data for movement analysis applications. The number of cameras that required at least four cameras to find the location and direction of any object. The software of Vicon cameras sets up the reference coordinate system for the mobile robots and all other objects, also maps the whole working space.

The robot's coordinates are represented in a 3-dimensional space, with positions on the X, Y, and Z axes, as well as Euler angles for roll, pitch, and yaw. However, since the mobile robot in question is a ground vehicle, it only moves in a 2-dimensional plane and thus the Z-directional data and angles for roll and pitch are not considered.

Once communication is established between the Vicon system and Simulink through Ethernet, the cameras are calibrated for synchronization and detection using a calibration wand.
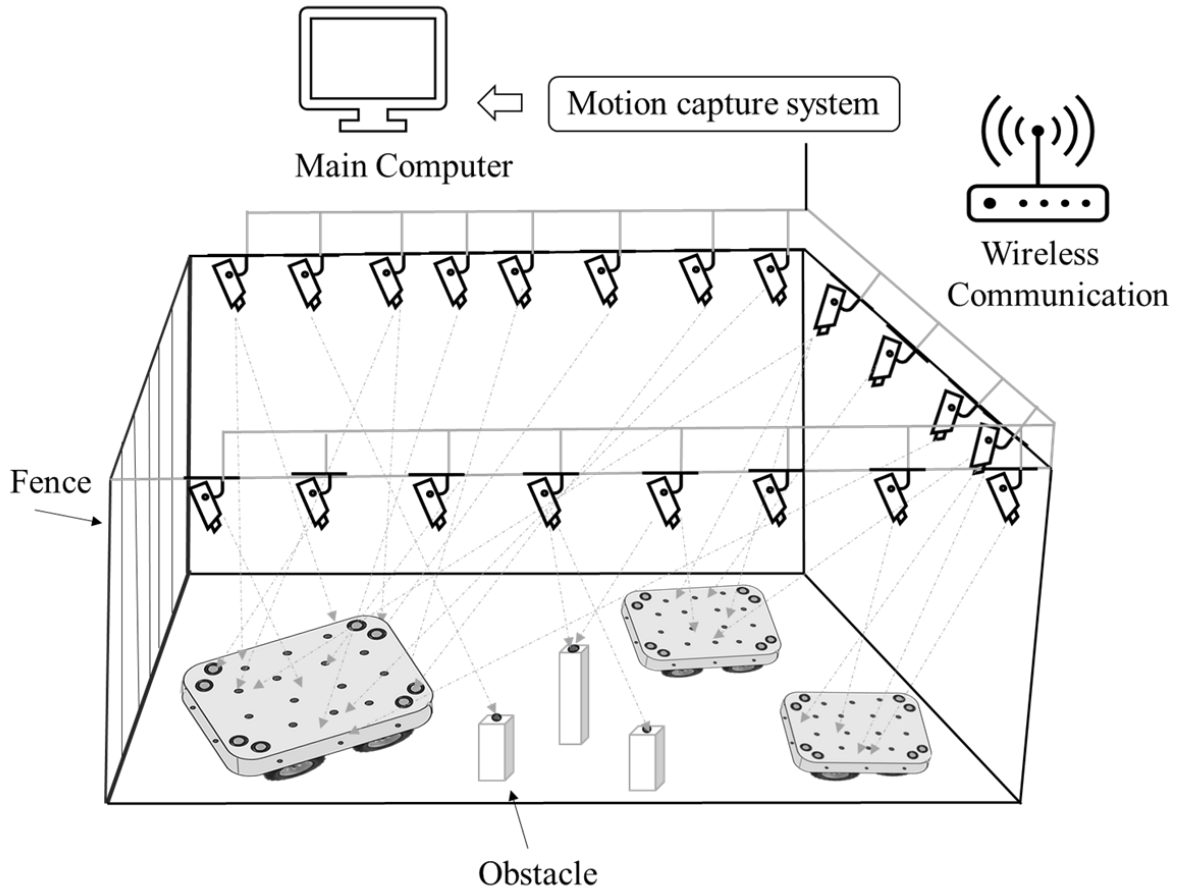
Fig.3. Mobile robot platform with motion capture system

6. Results and Discussion

The safety surround is the best solution for implementing a safe environment for safety-relevant objects and mobile robots. The safety border's certified and partially redundant sensors ensure that mobile robots do not harm any objects. Additionally, the safety modular concept allows for adaptability to any mobile robot in industry. The safety control system also prevents injuries for any safety-relevant objects. However, safe navigation methods, such as line following, are not advanced and limit new approaches in mobile robotics. Despite this, line following is a reliable method as it clearly always defines the robot's position and eliminates the need for multiple virtual agents or particles. With safer sensors and more reliable software, modern navigation methods, such as probabilistic methods, may become viable in the future. The cost of implementation is low as most mobile robots already have line-following sensors, LiDAR systems, or distance sensors.

This work introduces a control system that employs a subsequent path controller to produce control signals for the robot to move along the intended path. The radius of the goal, which signifies the desired proximity between the robot's final location and the goal location, is set. Once the robot reaches this distance threshold, it will cease movement. Additionally, the distance between the robot's current location and the goal location is continually computed. If this distance exceeds the goal radius, the robot will stop to prevent unexpected behavior near the goal. Our approach has been implemented and tested extensively with our mobile robot as well as in simulation runs. Throughout the experiments the robot was moving with speeds of

up to 60 rad/s for the left wheel and 50 rad/s for the right wheel to result in a right turn solver on the derivative function with a time span of 1 second and 0.03 second timesteps (see Figure 4). Which is that short time and more speed and safe. which make the robot to reach to the desire goal with short time, in addition, the robot could move quickly and effectively, avoiding obstacles and reaching its target destination. The derivative function used to control the robot's turns played an essential role in ensuring its smooth and accurate navigation. This function allowed the robot to make sharp turns while maintaining stability and control, even in challenging environments. The precise combination of high speeds and a well-calibrated derivative function was demonstrated by the robot's successful execution of a right turn and its ability to reach its desired goal safely and efficiently. This achievement highlights the potential for robots to be utilized in various settings, from industrial to domestic, where precise and rapid movements are critical to success. The successful demonstration of these capabilities paves the way for further development and integration of robots into various industries, where they can play a vital role in increasing efficiency and productivity.

The robot's path was monitored through simulations, and the variation in the path when the robot was positioned in different places was also tracked. The simulation assumed that the robot's wheels were rolling without slipping. The results of the experiments were then compared to the simulation results to evaluate the enhancement in the path traced.
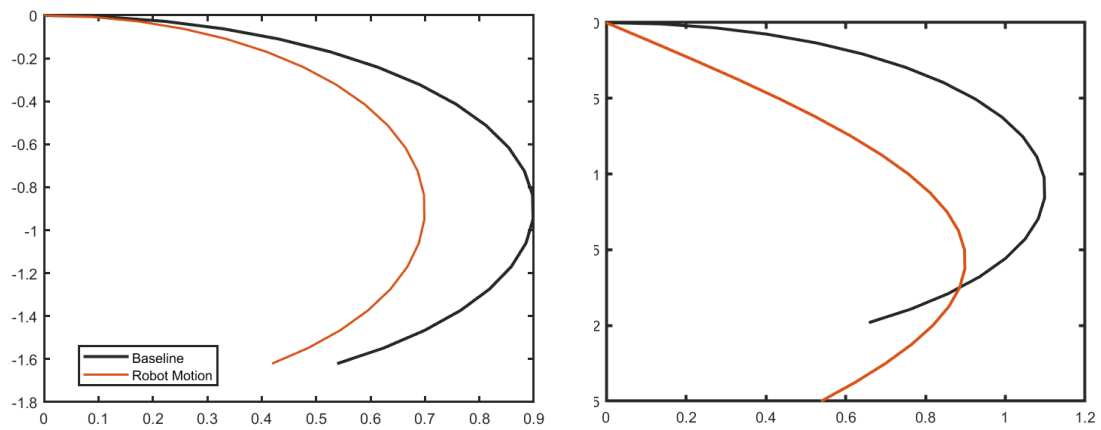
Figure 4: Simulation Result of the mobile robot motion that moving with different wheel speed

The experiment used a differential drive mobile robot and developed a control algorithm for its trajectory control. The algorithm was then implemented on the robot and evaluated through numerical simulations. The nonlinear model, which was implemented in Matlab/Simulink was tested on five different paths, including straight lines with varying angles based on the desired path and goal (see Figure 5). The model inputs left and right wheel speeds, also linear and angular velocities to determine the robot's heading.

The results of the experiments showed that the developed control algorithm could effectively control the trajectory of the differential drive mobile robot. The algorithm achieved accurate and stable trajectory control, even under challenging conditions such as dynamic obstacles and changing terrain. The numerical simulations provided valuable insights into the algorithm's performance and helped identify areas for improvement. The novel aspect of the approach lies in using a nonlinear model, which considers linear and angular velocities to determine the robot's heading. This approach accurately represents the robot's motion and

enables the algorithm to handle complex environments and scenarios. Additionally, the evaluation of the algorithm on five different paths, including straight lines with varying angles, demonstrates the versatility and robustness of the approach.

The experiment aimed to develop a control algorithm that would allow the differential drive mobile robot to navigate effectively in complex environments while ensuring stability and accuracy. The results showed that the algorithm could meet this goal, demonstrating its potential for practical applications in mobile robotics
.

Figure 5: Simulation Result of the mobile robot Path plan

7. Conclusions

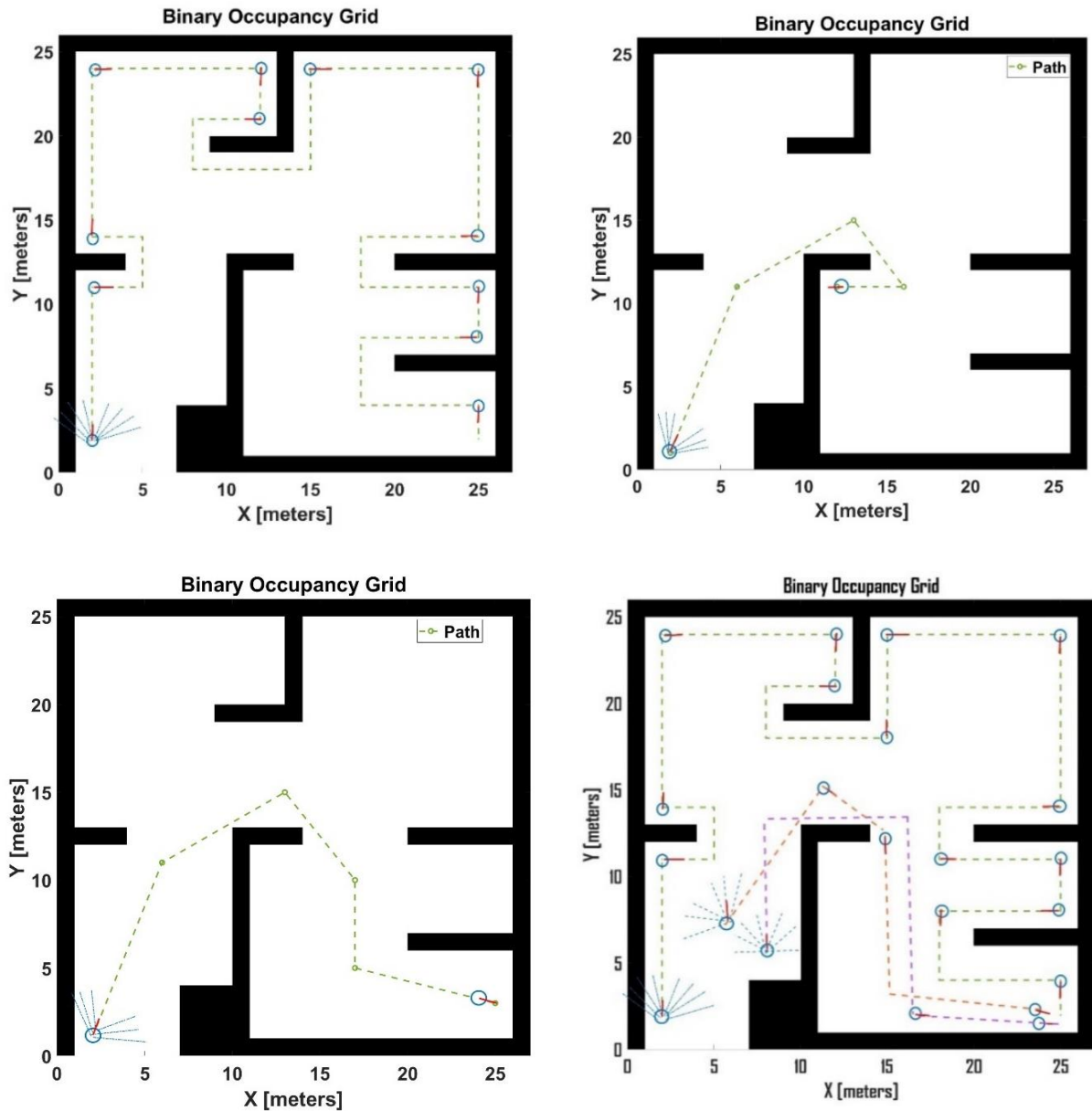This paper proposes a technique to improve the safety of mobile robots (MRs) by integrating probabilistic methods into the path planning and localization components, as well as incorporating robust obstacle avoidance and safety hazard features, as demonstrated in Matlab simulation results of the robot's motion. The drive train of the MRs will be enhanced by using various types of differentials, making the robots more efficient and safer. To achieve this, the robot must be programmed to navigate the map safely and reach the goal, which includes utilizing a camera system and sensors to detect obstacles and avoid collisions, as well as implementing safety protocols to prevent harm to humans or other objects in the environment. Furthermore, the robot's controllers must be designed to react appropriately to unexpected events or sensor readings to prevent deviation from the intended path or unintended harm. As future work, Improve the controller's robustness to external disturbances and environmental changes. This could be achieved by incorporating sensor feedback and using advanced control algorithms such as adaptive or robust control, additionally, incorporating the ability of the robot to handle dynamic changes in the path, such as changes in direction or speed or unexpected obstacles, which would make it more versatile and adaptable to different scenarios.

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IOT DEVICE FOR SLEEP APNEA DETECTION

Michal Bogár[1], Zhanar Moldabaeva[2]

Abstract

The main objective of this article is to design and construct a measuring device capable of detecting symptoms of sleep apnea. The first part of the paper introduces the current status of the topic and presents a general definition of the different types of sleep apnea and sleep apnea diagnostics. The next part focuses on the selection of suitable sensors based on different physiological parameters and development boards. Furthermore, a circuit diagram of the device is presented with an explanation of all the used components and the way they are connected. Also, the process of assembling the measuring device is discussed accompanied by a short description of all the necessary libraries needed for programming the microcontroller. The next part of the article presents the ThingsBoard platform used to collect, store and graphically display all the measured data. Finally, results of the simulated apnea episode reveal that the device is fully functioning and can be used in a home environment as a tool for screening to detect specific symptoms of sleep apnea.

Keywords

Sleep apnea, OSA, CSA, Internet of things, IoT, microcontroller

1. Healthcare and IoT

The concept of IoT continues to expand and penetrate sectors such as healthcare, where synergistic effects are becoming increasingly apparent. IoT-compatible devices not only simplify the daily lives of users but also provide invaluable information to doctors and professionals who can then apply it in practice.

One of the driving forces behind the adoption of IoT solutions in healthcare is the high demand for financial, time, and human resources resulting from the traditional approach rooted in healthcare. Indeed, even today, the vast majority of diagnostic and treatment procedures rely on regular patient encounters with medical staff, which can be at least partially replaced by automated methods. (Bisio et al., 2019) This is creating new opportunities for computer-aided medicine, referred to in the literature as eHealth, where traditional medicine is combined with information technology to better support diagnosis, prevention, and treatment. The linking of eHealth with IoT is usually done in the areas of patient monitoring, rehabilitation, drug dosing, and recently even personal health monitoring using wearable electronics known as Wearables. As a result, eHealth IoT technologies are not only being deployed in hospitals but also in homes and social facilities. (Scarpato, 2017) The rapid growth of IoT devices in the world is largely due to wearables. Even the share of people owning wearable electronics has increased from

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13% in 2015 to 43% in 2020 and more than half of the respondents using wearables, also use them to monitor some aspects of their health, where the most commonly monitored metrics are heart rate, blood pressure, sleep quality but also blood sugar. (Desilva et al., 2021)

2. Sleep apnea

One of the conditions where computer-aided medicine can help patients is sleep apnea. But even in this case, there is still room for improvement in the integration of IoT devices into the treatment and diagnostics of this disease. The term apnea refers to a stoppage of breathing that lasts for more than 10 seconds, which is accompanied by a drop in blood oxygen saturation (SpO2) of 4% or more. The mechanism of sleep apnea differentiates between obstructive sleep apnea (OSA), central sleep apnea (CSA), and mixed sleep apnea, which combines the symptoms of both OSA and CSA (El-Solh & Doherty, 2019). The distribution of each type is heavily skewed towards OSA, which accounts for approximately 80% of all cases of sleep apnea. The other 20% of cases are split approximately equally between CSA and mixed sleep apnea. (Dorkova, Tkáčová, 2007) In addition to apnea, hypopnea, defined as a decrease in the volume of inhaled air of more than 50%, is also often diagnosed. As hypopnea has similar health effects to apnea, the term apnea-hypopnea index (AHI) is currently used to reflect the number of breathing halts, or significant reductions in breathing per hour of sleep. (Mucska, 2016)

2.1   Obstructive sleep apnea

Obstructive apnea is the most common type of sleep apnea and occurs when the absence of breathing lasts for at least 10 seconds and more while breathing effort is still maintained. Respiratory effort is expressed by paradoxical chest movement, despite the absence of ventilation. OSA causes constriction of the upper respiratory tract, which is normally kept free by the upper respiratory tract muscles, such as the tongue and the muscles of the soft palate. Experts believe that if OSA lasts for several years, damage and hypertrophy of the upper respiratory tract muscles occur, resulting in further worsening of the OSA. (Tkáčová, 2006) In obstructive hypopnea, the airway does not close completely, but there is a significant narrowing. (Mucska, 2016) OSA is divided according to the frequency of occurrence of breathing halts into mild (AHI 5-15/h), moderate (AHI 15-30/h), and severe (AHI 30 and more/h). (Hobzová, 2010)

The risk factors for sleep apnea are mainly obesity, but the position of the temples, the size of the tongue, or the enlargement of the tonsils can also contribute to the risk of OSA. Sleep position also has a large influence on OSA, as OSA occurs the most in the position where the patient sleeps at the back, due to the pressure it puts on the upper respiratory tract. (Boudewyns & Verbraecken, 2019). The occurrence of OSA, however, is not limited to overweight patients and is estimated to be present in 9% of all women and 24% of all men. It should be noted that OSA is undiagnosed in up to 80-90% of patients. (Tkáčová, 2006) The gender of the patient also influences the development of OSA, with males being a high-risk group, having up to a 5-fold higher risk of developing OSA, which is due mainly to the different anatomy and physiology of the body. (Mucska, 2016)

The most common symptom of OSA is definitely snoring (Kuna, 2019). Although snoring is not necessary for the presence of OSA, most patients suffer from it and are usually warned by their family or partner. The interruption of breathing during sleep also results in a significantly reduced quality of sleep, as patients wake up very frequently during the night. This causes significantly increased irritability and fatigue throughout the day. In severe conditions

of chronic fatigue, patients may even fall asleep while performing active activities such as working, talking, and even driving, which can be very dangerous not only for the patient. (Tkáčová, 2006) In addition, OSA increases the risk of cardiovascular diseases such as hypertension, heart attacks, and heart failure. This is probably caused by hypoxia. Hypoxia is a state in which there is not a sufficient amount of oxygen in the body. (White, 2006)
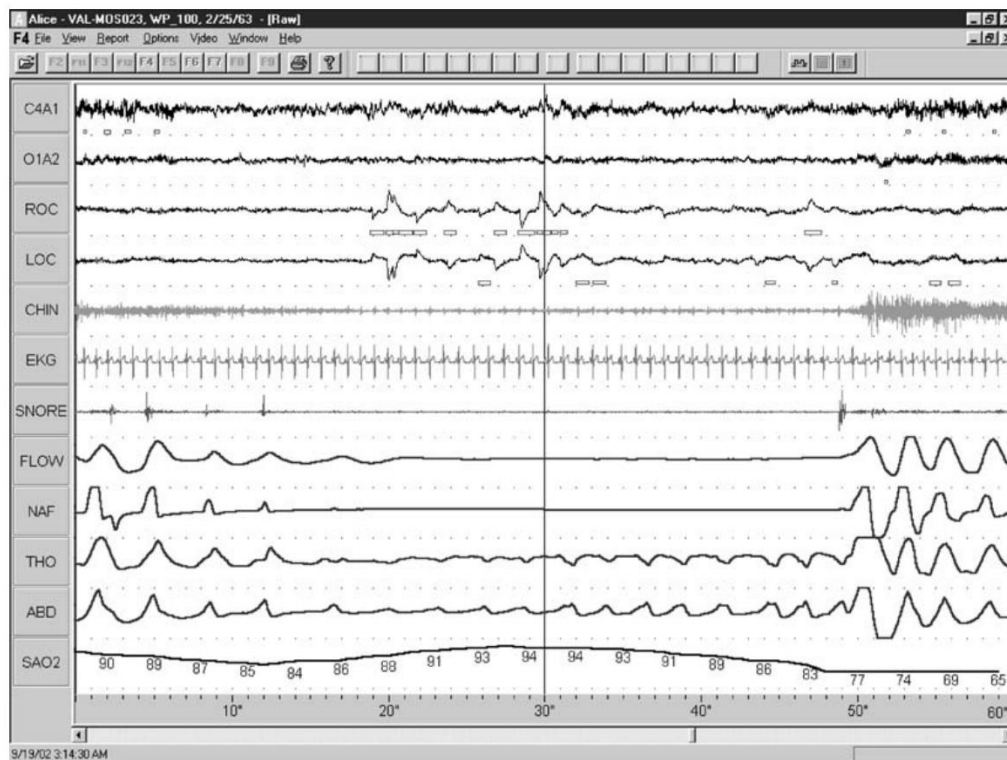
2.2   Central sleep apnea

When breathing stops for more than 10 seconds during sleep and the respiratory center is deactivated at the same time, it is called central sleep apnea. In contrast to OSA, there are no chest movements present at all during CSA. The mixed apnea type first starts as CSA and gradually transitions to OSA as the breathing activates. CSA occurs in relatives, so it is important to obtain the family history during the medical examination. A factor influencing CSA is the low stimulation of the respiratory center by CO_2, and this is also one of the reasons why there is a high incidence of CSA in patients with heart failure. When $PaCO_2$ drops below a certain threshold due to reduced heart function, CSA can occur in the patient. (Tkáčová, 2006).

The signs of CSA are similar to those of OSA, and most often include significant daytime fatigue due to reduced sleep quality. In addition, investigations show a higher incidence of heart rhythm disturbances, a more frequent need for heart transplantation, and an overall higher mortality rate in heart failure patients with CSA compared to those without CSA (Tkáčová, 2006).

2.3   Diagnosis of sleep apnea

All types of sleep apnea are diagnosed using the same procedure and only then is the diagnosis specified. When sleep apnea is suspected, an initial screening examination can be carried out in the home environment using a screening test that is similar to the sleep laboratory tests but is done in a simpler form. However, a polysomnographic (PSG) examination lasting the entire night is required to make an accurate diagnosis. Such an examination monitors the electro-potentials of different parts of the body, for example, the brain which is known as EEG, but also snoring, SaO2, chest movements and airflow through the respiratory tract, etc. (Mucska, 2016) The PSG examination should last at least 6 hours and is always performed in a specialized sleep laboratory and with expert staff present. The final diagnosis is made by the physician after manual analysis of the measured data with the possible assistance of a computer program. With multiple PSG examinations, the patient's overall OSA/CSA ratio may vary over time. (Tkáčová, 2006)

Figure 1: Example of a polysomnographic examination record with present OSA

(Source: White, 2006)

2.4 Treatment

There are several ways to treatment of sleep apnea, such as surgery to remove tonsils when they become enlarged, or pharmacological treatment for central sleep apnea (Brouillette & Gagnon, 2017). However, the most effective and common treatment is non-invasive ventilation using continuous positive airway pressure (CPAP) ventilation. The concept of how CPAP works is that the higher air pressure prevents the airways from collapsing. As a result, CPAP is very effective in the treatment of obstructive apnea and the results are apparent immediately on the very first night. During CPAP use, snoring is significantly reduced and sleep quality greatly is improved. Furthermore, CPAP is also effective in patients with central apnea, but the effects of treatment take several weeks to become apparent. Patients with heart failure have weakened breathing muscles and CPAP helps to reduce the strain that is put on them, which reduces the incidence of apnea during the night. (Tkáčová, 2006)

3 Goal of the article

The aim of the article is to create a functional measuring device that is able to monitor selected body parameters, which can help in the diagnosis of sleep apnea. The device is not intended to replace currently existing professional medical devices used in complete polysomnographic examinations, but rather to complement the range of available tools used in diagnostics. The device shall be suitable for screening purposes, which can also be carried out in the home of the patient.

The recorded data will be viewable through a mobile device or computer via a web browser, allowing for easier evaluation of the user's current status. For this purpose, the measured values will be sent wirelessly by the measuring device to a separate server. The

functionality of the device will also be tested to see if the measured data are indeed adequate to be used for sleep apnea detection.

The device is designed with an emphasis mainly on quality of construction and user comfort, as well. As the device is operated without the assistance of specialist personnel, the use of the assembled device should be sufficiently intuitive.

4   Parameters that can be reliably measured in a home environment

To determine the presence of sleep apnea, it is necessary to obtain accurate data on the processes that take place in the body. However, reliable monitoring of the body tends to be complicated because the physiological signs of a patient's vital functions are complicated. Based on the description of the signs of apnea given above, we know that the halt of breathing during apnea also affects a number of other indicators.

During the respiratory arrest, changes can be seen in not only in EEG readings, but also in blood oxygen saturation, pulse, respiratory muscle activity, or the volume of air flowing through the upper respiratory tract. Though, such diagnostics often require professional equipment that is only available in sleep laboratories. Nevertheless, breathing has other secondary manifestations that are easier to detect in the home environment. These include the temperature difference between inhaled and exhaled air or the visible movement of the rib cage and diaphragm when muscles are activated during breathing effort, which is weakened in sleep apnea. Snoring is a separate, well-known sign of OSA, characterized by distinctive acoustic vibrations that occur during the collapse of the upper respiratory tract.

Based on the analysis, we decided to use physiological signs that we can monitor accurately and easily. W, therefore, focused on the secondary signs of respiration and selected sensors that seemed promising for use in the home environment.

Therefore, these are namely acoustic indications in the case of upper respiratory tract collapse, and for reliable detection of OSA noises, it is advisable to use a sufficiently sensitive microphone, which must also be small so it does not distract the patient. An electret microphone with a built-in amplifier and an option to adjust the volume threshold proved to be a suitable choice, solving the problem of noise caused by normal human movement, as the microphone ignores it and only sends a signal when the volume exceeds a pre-set threshold.

Following, we chose chest movement during breathing in which we measure the movement using an elastic band attached to the chest. This belt is electrically conductive and changes its electrical resistance as it deforms during breathing, which can be accurately measured using a microcontroller.

And last but not least, we will measure subtle temperature changes in the exhaled air with a small thermistor that changes its electrical resistance depending on its temperature, which is also monitored by the microcontroller's analog input.

5   Assembled device

After we have chosen the variables which will be measured, and also selected the necessary components, we proceeded to the actual assembly of the measuring device. For the final assembly of the device, we prepared the schematic shown in the figure below, which shows how all the components are connected. The sensors are connected to a 32-bit ESP8266 microcontroller running at 80 MHz and powered by an attached battery. There is 4 MB of flash

memory and 64 KB of RAM available, which is adequate for the majority of projects. The microcontroller provides a reasonable number of pins for communication with the connected sensors, and also supports connection to Wi-Fi wireless networks in the 2.4 GHz frequency band using the integrated antenna. The chip itself operates at 3.3V, but thanks to the built-in voltage regulator it can also operate at 5V.

Figure 2: Wiring diagram
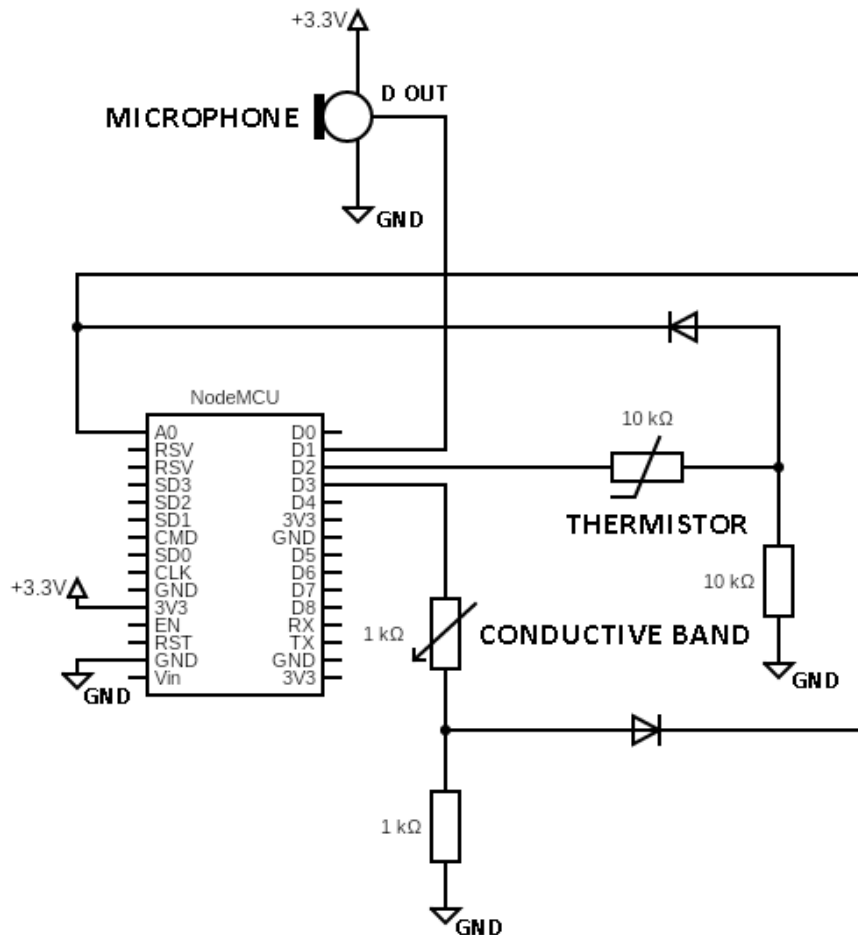
(Source: By author)

Wiring the thermistor and elastic band as sensors cannot be done by simply connecting them to the ESP8266 input, as this pin is not designed to detect the value of the sensor's electrical resistance (Grokhotkov, n.d.). Therefore, it's necessary to connect the sensors using a voltage divider, which is also shown in the schematic. This is because the microcontroller can only monitor the change of the voltage on the input pin, which is affected by the changing resistance of the sensor. To ensure even voltage division, the second resistor present in the circuit should have approximately the same value as the resistance of the sensor at room temperature. In our circuit, a thermistor with a resistance of 10 kΩ is used, so we will also use a resistor with the same value of 10 kΩ. The elastic band used is complemented by a 1 kΩ resistor.

When assembling the device, we used freely available materials so that the result could be easily replicated. The facemask is made from a conventional FFP2 respirator and the involved face sensor made from a thermistor is inserted into a modified exhalation valve of the respirator, which makes the airflow better around the sensor. The use of an off-the-shelf respirator is also advantageous from the standpoint of hygiene and low cost, as the respirator can be easily and quickly replaced at a cost of tens of cents or less. In addition to the thermistor, a microphone is attached to the respirator to be as close as possible to the source of the sound.

The chest sensor is wired similarly, but in this case, it is attached to a length-adjustable belt that also includes a buckle for fastening, so putting on the chest belt is effortless. The material of the additional belt is completely non-elastic, so only the belt sensor is deformed during breathing due to the expansion of the rib cage.

Figure 3: Assembled device

(Source: By author)

6   Programming the microcontroller

To program the microcontroller, we used an open-source development environment called Arduino IDE, which is freely available. In order to work with the ESP8266 microcontroller in the Arduino IDE, it is necessary to first add support for the ESP8266 chip from the project website.

Once the ESP8266 microcontroller is successfully added in the development environment, we can start working on the actual software part of the device. First, we need to

import all the necessary libraries for the program to work. The libraries need to be installed in the library manager directly in the Arduino IDE. Primarily, this is the developer library for the ThingsBoard platform that is required to connect the device to the platform. Next is the library that provides ESP8266 connectivity to wireless networks. Finally, the moving median library by Rob Tillaart was used to smooth the measured data.

7 Visualizing data and testing functionality

We used the ThingsBoard IoT platform to visualize the measured data, which proved useful for the frequent data collection that occurs several times per second, which is necessary for this solution. It is a cloud-based service that stores telemetry data. Users can view real-time data or access historical data.

A dashboard is a convenient way to visualize measured data, and ThingsBoard offers a rich menu of settings and graphical elements for dashboards that are capable of displaying data of various types. A simple drag-and-drop system is used to add different graphical widgets, and the selected widget just needs to be dragged with a mouse cursor to the desired location. The use of dashboards and a platform that stores all the measured data eliminates the need for another person to be responsible for the continuous monitoring of physiological parameters and measured data during the night.

7.1 Simulated sleep apnea episode

Once the device was linked with the ThingsBoard platform and was transmitting data reliably, we proceeded to test the device more thoroughly by simulating typical signs of sleep apnea. We repeatedly simulated both OSA and CSA for approximately fifteen minutes and monitored the current results on the previously constructed dashboard. Any change in breathing or in loudness was immediately mirrored on the graph and it was apparent when an apneic episode had occurred.

The figure below shows breathing on a nearly sinusoidal curve, and on the other hand, breathing arrests or slowing of breathing is indicated by a relatively flat segment of the graph. This change in breathing was detected by both the face sensor with the aid of a thermistor, which can be seen on the top left graph and the chest elastic band, which is shown on the top right graph. The lower graph then represents changes in loudness detected by the microphone. The increase in loudness due to brief snoring can be seen as increased values represented by the bars in the graph.

Figure 4: Dashboard that displays a simulated sleep apnea
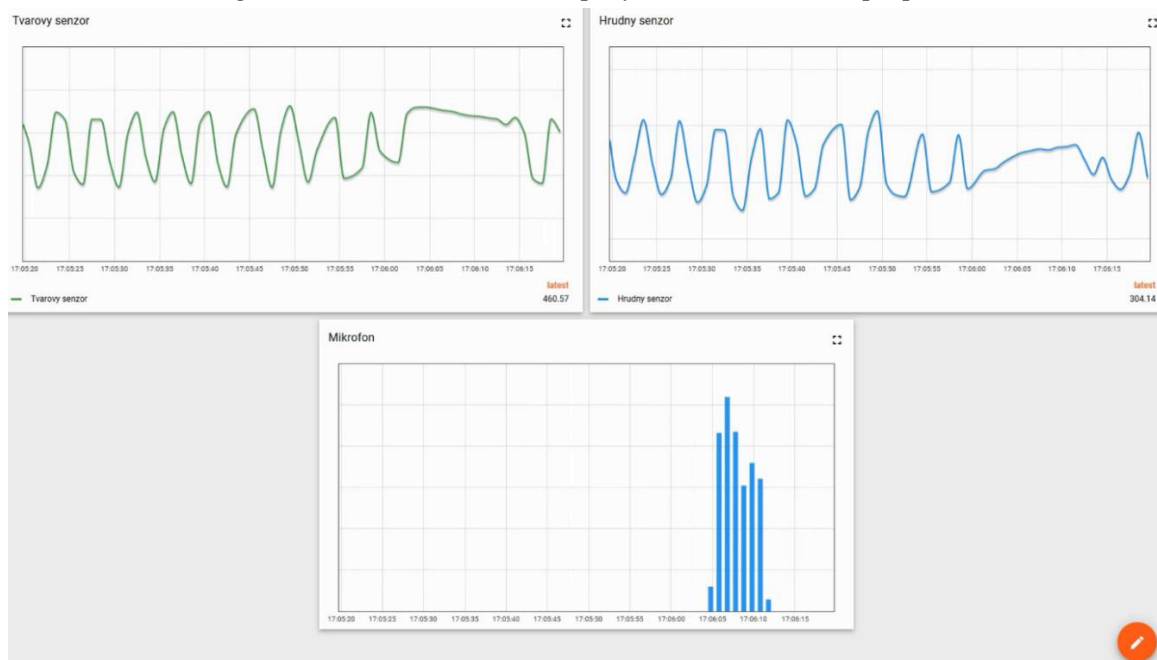
(Source: By author)

8   Conclusion

The integration of medicine with modern technologies such as the Internet of Things is becoming more noticeable every day. It's starting to be used in the diagnosis and treatment of many diseases and will form a large part of IoT devices. Our proposed sleep apnea detection device is one such device and based on the findings above, we may say that we have succeeded in creating a working measuring device that is affordable and user-friendly, making it usable by less technologically savvy patients. The device may be beneficial for people with suspected sleep apnea to perform screening examinations at home or for long-term monitoring of patients with sleep apnea. The constructed device is not intended to compete with professional medical devices and is intended to be used only for primary screening when sleep apnea is presumed in a patient before a thorough diagnostic evaluation in a sleep laboratory.

A further extension of the project could be the addition of functionality for automatic analysis of the measurement data. This would simplify the evaluation by providing a final report with possible recommendations, such as displaying a message to the patient that sleep apnea is suspected and a doctor should be contacted as soon as possible, or that no symptoms of sleep apnea were detected. A module to detect how the exhalation of air is ventilated could also be added, as this is one of the clearest direct indicators in a test conducted at home.

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POSSIBILITIES OF APPLICATION OF THE PARALLEL COMPUTATIONS IN SOLVING PROBLEMS OF THE NUMERICAL METHOD

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Abstract

This article discusses the possibilities of implementing differential equations by the Runge-Kutta method using the OpenMP parallel technology. In particular, using the Runge-Kutta method of differential equations, in traditional and parallel computing solutions of the problem, semantic differences in the implementation of the program code and the speed of its execution in time were determined. In the MS Visual C++ environment, parallel computing can be performed using threads, OpenMP, MPI, and CUDA methods. We chose the OpenMP method depending on the efficiency of use and frequency of use compared to other methods. As a result, of practical work, it is shown that with parallel computing, the program execution speed is 2-3 times higher, but if the flow rate increases, then the program execution speed slows down. The flow rate can be controlled by omp_num_threads variables, omp_set_num_threads procedures, and identification of the num_threads concept with the parallel directive. In addition, the speed of program execution directly depends on the computer core.

Keywords

A numerical method, Parallel computing, OpenMP, Runge-Kutta method, MS Visual C++, Thread.

1. Introduction

It is impossible not to correlate any section of the programming language with mathematical problems, especially when classical methods reveal conditions under which solutions to problems are not found. One of the branches of mathematics is numerical methods. *Numerical method* is a branch of computational mathematics that studies approximate approaches to solving typical mathematical problems that cannot be solved or are difficult to solve by specific analytical methods. Numerical methods are the main means of solving modern applied problems. Therefore, quantitative analysis of mathematical models-method, algorithm, program, computational experiment -is currently an actual and effective tool for constructive research of applied problems. It should also be noted the computer-oriented nature of digital methods, and, ultimately, their implementation depends on the application and application of computer technology and programming. Of course, progress in the field of computational mathematics largely depends on new opportunities in the development of computer resources. However, even the relatively high performance of modern computers is efficient and cost-effective in terms of computational costs, without solving the problem of developing solution methods specializing in certain classes of problems. The problem of optimization

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(transformation, modernization) of computational methods retains its independence and determines the prospects for further development of quantitative analysis [1].

In the last century in the field of mathematics there is a list of about 3 thousand problems that have not yet been solved. In 2000, the Clay Institute for Mathematical Research in the USA compiled a list of unsolved mathematical problems, comprising 7 problems. These reports are known as the "Millennium Reports". They:
- Yang–Mills and Mass Gap;
- Riemann Hypothesis;
- P vs NP Problem;
- Navier–Stokes Equation;
- Hodge Conjecture;
- Poincaré Conjecture;
- Birch and Swinnerton-Dyer Conjecture [2].

One of the effective ways to solve these problems is the use of multiprocessor computing systems. Therefore, in order to find a solution to such problems and build your own model, you can use parallel calculation - a way of organizing computer calculations.

The development of high-performance parallel computing is one of the modern requirements. Currently, there are many unsolved mathematical problems and problems of numerical methods that require a lot of time in calculations. When solving such problems, high-performance calculations are necessary.

Iterative methods allow us to determine the solution of the system as the limit of a continuous computational process, which, in turn, determines the next really approximate solution [3]. The advantage of such solutions is the situation of detection using computer methods. General numerical methods consist of sections such as differential equations, Gauss method, Seidel method. Well, in this article we have chosen the Runge-Kutta method for solving differential equations. Therefore, the purpose of the article is to determine the possibilities of implementing the differential equation by the Runge-Kutta method using the OpenMP method of parallel computing.

There are many ways and means of solving mathematical problems on a computer. In particular, Matlab, MathCAD, MS Visual C++, MS Visual C#, Python, Java, etc. This article discusses the solution of problems of numerical methods using the MS Visual C++ programming language. Well, one of the modern directions of its solution is parallel computing.

In general, the use of parallel computing systems and supercomputers is a strategic direction for the development of computer technologies. With parallel computing, you can use multiple processing elements simultaneously to solve any problem. Parallel computing has the following advantages over serial computing:
- It saves time and money because many resources that work together reduce time and reduce potential costs;
- in serial calculations, the solution of large-scale tasks may not be possible;
- When local resources are limited, it can use non-local resources.

There are the following types of concurrency:

Parallelism of the household level. This is a type of parallel computing based on increasing the size of the processor. This reduces the number of instructions that the system must execute to complete a task in large data. Example: Consider a scenario in which an 8-bit processor has to calculate the sum of two 16-bit integers. First it has to sum 8 lower-order bits and then add 8 higher-order bits, which requires two instructions to perform the operation. A 16-bit processor can perform an operation with only one instruction.

Instruction-level parallelism. The processor can address less than one instruction for each phase of the clock cycle. These instructions can be reordered and grouped. They are executed simultaneously without affecting the result of the program later. This is called instruction-level parallelism.

Parallelism of tasks. Task parallelism uses splitting a task into subtasks and then splitting to complete each subtask. Processors simultaneously perform subtasks.Concurrency at the data level. Instructions for a single thread work with multiple data at the same time, that is, they are limited by irregular data processing models and memory bandwidth.

The history of parallel computing in the XVIII century, at the initiative of the French scientist Gaspard de Prony, work was carried out to clarify the values of logarithmic and trigonometric tables. To perform it, several large-scale computational work was required at the same time. Based on this, the idea of parallel computing arose. And in the twentieth century, Arjen Lenstra and Mark Menes created a program for factorizing long-chain numbers. They ran on multiple machines to implement and speed up the process. Thus, parallel computing is evolving day by day and is currently being increasingly used in our use.

Parallel calculations are performed by S. Pomelov, V. V. Vasilyevich, O. Nepomnyashchy, N. Sirotinina, K. Korshun, Borzunov S. V., A. Malyavko, Fedotov I., Barsky A. B., Raven J. K., Kort J.In their works, such researchers as H., Novikova N.S., Karaseva E. are considered.

2. Methodology

To determine the possibilities of implementing the differential equation by the Runge-Kutta method using the OpenMP method of parallel calculations, comparison methods were used. In general, it was obtained with the help of results using classical and parallel programming to create reports, and methods of program implementation were used to achieve the purpose of the article.

3. Results

Before implementing the tasks of numerical methods using parallel calculations. Consider the Runge-Kutta method.

In general, the Runge-Kutta method is a large class of numerical methods for solving the Cauchy problem for ordinary differential equations and their systems. The Runge-Kutta method has the following advantages over the methods of other numerical methods [4]:

1.These methods are unambiguous, that is, we need to know the information about the previous point (xm, ym) in order to find the solution $ym+1$.

2. The runge-Kutta method is compared with the Taylor sequence before determining the hp order.;

3. The Runge-Kutta method requires solving the function itself, and not calculating the derivative f(x, y).

The Runge-Kutta method is widely used in solving differential equations. The 4th order method of the Runge-Kutta method is widely used in practice.

$$y_{i+1} = y_i + \sum_{k=1}^{p} c_k n_k^i$$

$$\eta_l^i = f(x_i, y_i)$$

$$\eta_k^i = f(x_i, +ah, y_i + hb, f(x_i, y_i))$$

where, i is a parameter defining the values of the function next to the point. The generally accepted representation of the 4th order method:

$$\eta_1^i = f(x_i, y_i)$$

$$\eta_2^i = f(x_i + \frac{h}{2}, y_i + \frac{h}{2} f(x_i, y_i))$$

$$\eta_3^i = f(x_i + \frac{h}{2}, y_i + \frac{h}{2} \eta_2^i)$$

$$\eta_4^i = f(x_i + h, y_i + h\eta_3^i))$$

$$y_{i+1} = y_i + \frac{h}{6}(\eta_1^i + 2\eta_2^i + 2\eta_3^i + \eta_4^i)$$

This method is more specific than Euler's method, but requires a lot of calculations. For example, to determine the value of points($x\_(i+1)$, $y\_(i+1)$) it is necessary to carry out calculations of the function f (x, y) of the 4th order. But with the help of a computer, these calculations can be determined quickly and without errors [5].

To perform parallel calculations in the MS Visual C++ environment [6]:
- System with shared memory: threads, OpenMP.
- Systems with assigned memory: MPI;
- Heterogeneous systems: CUDA can be used.

To implement the tasks of numerical methods, we use the OpenMP method.

OpenMP is a set of compiler directives and procedure libraries designed for programming multithreaded applications in a shared memory system [7]. The OpenMP standard was first developed in 1997 as an OS for implementing multithreaded applications. It was first based on Fortran, and then on C, C++. The OpenMP interface is one of the most popular parallel programming technologies. The OpenMP method uses a parallel execution "branching" model. In the OpenMP method, the number of threads executed in parallel can be controlled using the following methods [8]:
- using omp_num_threads variables;
- calling omp_set_num_threads procedures;
- by matching the num_threads concept with the parallel directive.

The Runge-Kutta method can be implemented using an online C++ compiler (Fig. 1) [9]:

```
int main() {
    double a=0;
    double b=1;
    double h=0.1;
    double n=(b-a)/h;
    double X[(int)n];
    double Y1[(int)n];
    double Y2[(int)n];
    double Y3[(int)n];
```

```
double Y4[(int)n];
double Y[(int)n];
// calculation
X[0]=a; Y[0]=2;
for(int i=1; i<=n; i++){
        X[i]=a+i*h;
        Y1[i]=h*F(X[i-1],Y[i-1]);
        Y2[i]=h*F(X[i-1]+h/2.0,Y[i-1]+Y1[i]/2.0);
        Y3[i]=h*F(X[i-1]+h/2,Y[i-1]+Y2[i]/2);
        Y4[i]=h*F(X[i-1]+h,Y[i-1]+Y3[i]);
        Y[i]=Y[i-1]+(Y1[i]+2*Y2[i]+2*Y3[i]+Y4[i])/6;        }
    return 0;}
```

Fig. 1: Execution of the Runge-Kutta method in C++

Source: Authors

Where the program execution time is t=3900 c (Fig.2).

Fig. 2: The result of the program

Source: Authors

Let's calculate the Runge-Kutta method using parallel programming methods. Here we will look at the program parts using functions. As usual, initialization of variables is performed first [8]:

```
double func(int m, double x, double y, double a, double b, double c, double d, double e, double f){
// m- to select a function; x, y are function variables. a, b, c, d, e, f – functions
//coefficients
double a=0; switch(m){
case 1: {s=a+b*(y*c*sin(d*x))-(e*y*f*y); break;}
case 2: {s=a*cos*(b*x+c*y)+d*(e*x-f*y); break;}
case 3:{s=((a*cos(b*x)/(x+c))-(d*y*e*y)*f)); break;}
case 4:{s=a*(b*x+c*y)/(e*f)*d; break;}
default: {s=0;}}}
```

Then we declare the variables used in the computational process [9]:

```
int as, size, kol, , *m= new int[100], buffer=1
int i=0, n=0,num;
double h,ot1, oy2, k1=0, k2=0, k3=0, k=0,
*a=new double[100],
*b=new double[100],
*c=new double[100],
*d=new double[100],
*e= new double[100],
* f=new double[100];
```

consider the openmp directive, which creates a parallel scope:

```
# pragma omp parallel for private (k,i,x,y,j,k1,k2,k3,k4) shared (a,b,c,d,e,f,h,y2) num_threads(num)
for (k=0; k<kol; k++){
y[0]=y2[k]; x[0]=0;
for (i=1;i<n; i++){
x[i]=0; y[i]=0;}
```

The program for implementing the Runge-Kutta method of the 4th order with the call of the functions described above is as follows [10]:

```
for(i=0; i<=0; i++){
k1=func(m[k],x[i],y[i], a[k],b[k],c[k],d[k],e[k], f[k])*h;
k2=func(m[k],x[i]+h/2,y[i]+(k1/2),a[k],b[k],c[k], d[k],e[k], f[k])*h;
k3=func(m[k],x[i]+h/2,y[i]+(k2/2),a[k], b[k],c[k], d[k],e[k], f[k])*h;
k4=func(m[k],x[i]+h,y[i]+k3, a[k], b[k],c[k], d[k],e[k], f[k])*h;)
y[i+1]=y[i]+((1/6)*(k1+k2+k3+k4));
x[i+1]=x[i]+h;}
```

Fig. 3: Implementation of the Runge-Kutta method through parallel programming

```cpp
/************************************************************************


                |   |   |       Online C++ Compiler.
            Code, Compile, Run and Debug C++ program online.
Write your code in this editor and press "Run" button to compile and execute it.


*************************************************************************/

#include <iostream>
#include <cmath>
using namespace std;
double func(int m, double x, double y, double a, double b, double c, double d, double e, double f)
{
double a=0; switch(m) {
case 1: {s=a+b*(y*c*sin(d*x))-(e*y*f*y); break;}
case 2: {s=a*cos*(b*x+c*y)+d*(e*x-f*y); break;}
case 3:{s=((a*cos*(b*x)/(x+c))-(d*y*e*y)*f)); break;}
case 4:{s=a*(b*x+c*y)/(e*f)*d; break;}
default: {s=0;}}}


int main() {
    int as, size, kol, , *m= new int[100], buffer=1
int i=0, n=0,num;
double h,ot1, oy2, k1=0, k2=0, k3=0, k=0, *a=new double[100], *b=new double[100], *c=new double[100], *d=new double[100], *e= new double[100], *

for(i=0; i<=0; i++){
k1=func(m[k],x[i],y[i], a[k],b[k],c[k],d[k],e[k], f[k])*h;
k2=func(m[k],x[i]+h/2,y[i]+(k1/2),a[k],b[k],c[k], d[k],e[k], f[k])*h;
k3=func(m[k],x[i]+h/2,y[i]+(k2/2),a[k], b[k],c[k], d[k],e[k], f[k])*h;
k4=func(m[k],x[i]+h,y[i]+k3, a[k], b[k],c[k], d[k],e[k], f[k])*h;)
y[i+1]=y[i]+((1/6)*(k1+k2+k3+k4));
```

Source: Authors

Where the program execution time is t=0.0892 seconds.

In the process of implementing the program, first of all, we are asked about the number of functions. A list of equations to choose from is published. If we do not select the appropriate number, a message like "invalid parameter not entered" will be published. After we have selected the size of the function, we need to enter the coefficients of the function, the initial and final value of the interval, the step, the number of threads, gradually according to the specified variable. After the value of all variables is entered correctly, the result and time of the task execution are determined in the corresponding one.

Consider the result of executing the program in each data set in Table 1. We have marked the maximum size of 100. Therefore, consider the intervals 0; 50; 100.

Table 1: Program execution time

Measurement	Accuracy	Execution time (1 thread)
5	0,01	0,00304
	0,001	0,01556
	0,00001	1,67988
50	0,01	0,01672
	0,001	0,13029
	0,00001	12,3426
100	0,01	0,02944
	0,001	0,22674
	0,00001	25,3355

Source: Authors

4. Discussion

You can also specify data related to 2 threads and 4 threads in general. If in the course of practical work we increase the number of threads during the execution of the program, then the execution time will increase. In the course of the work, the possibilities and effectiveness of the OpenMP method, which can work in a c++ environment, were considered.

5. Conclusion

During the writing of the article, programmatically homogeneous differential equations were performed by the Runge-Kutta method using the OpenMP method and its effectiveness was determined. In addition, during the experiment, it was found that with the classical method of differential equation and parallel implementation, the execution time is performed approximately 2-3 times faster, and the time for software solution of the problem increases as the number of threads increases. Using the examples discussed in the article, it can be determined that when solving problems using a parallel program, the simplest tasks themselves are not trivial. Summing up the results of the considered work, we come to the conclusion that the speed of execution of tasks produced using MPI technology increases, but it, in turn, also depends on the number of cores.

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THE NATIONWIDE SURVEY OF PROJECT MANAGEMENT EDUCATION AT UNIVERSITIES IN SLOVAKIA

Veronika Horniakova[1]

Abstract

Project management is considered a key skill abroad, but in Slovakia, the importance of this skill is still growing. There are many examples of unsuccessfully completed projects, so there is a reason to start training high-quality project managers already at universities, who can help with successful projects. During 2021, we conducted a unique nationwide survey of universities and colleges to bring an up-to-date picture of the situation in the given area. As a result, we also proposed action steps that we will implement in the coming period in cooperation with the professional associations of project management. This article presents the most interesting findings and steps for improving project management education at universities, as well as better cooperation between academic and commercial environments.

Keywords

Project management, Education, Survey, Universities, Slovakia

1 Introduction

This national wide survey follows the topic of education in the field of project management which we have been working on for several years. In Horniakova (2021), we focused on research in the field of certifications in project management in the commercial sector. One of the findings that we investigated was the form in which employers today ensure the education of their employees, as it is necessary to increase their level of knowledge. From the responses of the respondents in Figure 1, we can see that the preferred forms of education are external and internal training, followed by self-education and webinars and conferences. (IPMA Slovakia, KPMG, Next Level Consulting, PMI Slovakia, 2020) Almost 50% of the employees need to take qualified training to improve their skills. The authors Caganova and Hromada (2019, 2020) also pointed out some of these shortcomings and the need for deeper education even after graduation in their work dealing with quality assurance and comparative analysis in higher education in Slovakia.

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Fig. 1: Preferred forms of project management education
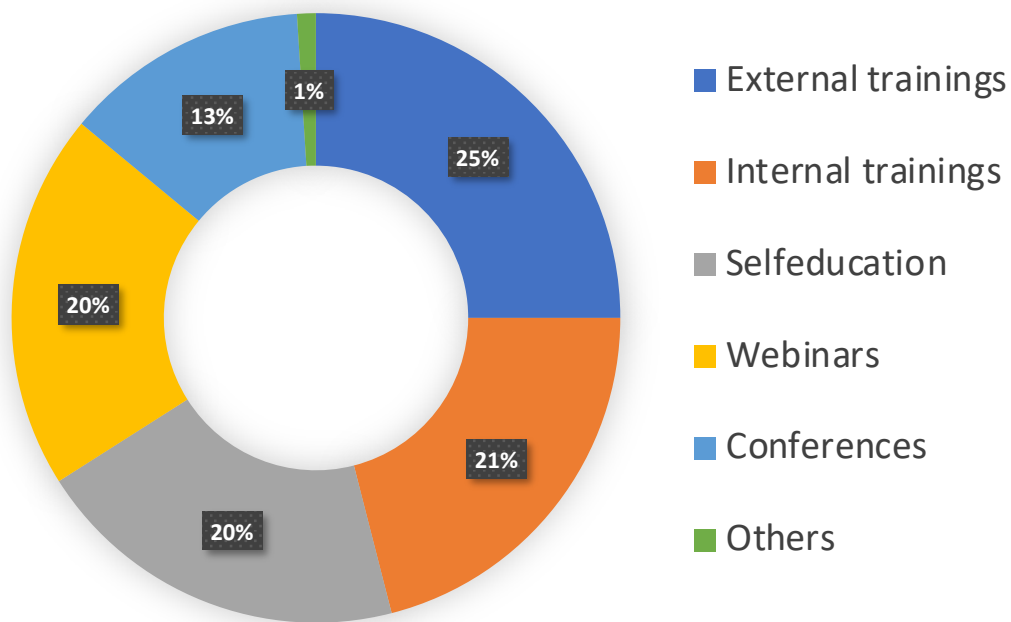
Source: Own work

The final output of the survey was the identification of areas in which the respondents see room for improving the level of project management in Slovakia. The indicated areas are:

- Introduction and support of project management education at high schools and universities and greater connection with the academic community;
- Expanding the possibility of project management education outside the IT sector and project-oriented companies;
- Increasing awareness of the importance of experienced experts in the field of project management by emphasizing the clear definition of this position and related competencies and responsibilities;
- Creating a platform, or community space for project managers and project training graduates to share practical experience and support the connection of theory with practice in the field.

After we explored the commercial sector, we began to focus on the other side, the academic field. We, therefore, decided to survey all universities in Slovakia to get a picture of how education in the field of project management is carried out at individual faculties.

1.1 Higher education in Slovakia

The faculties of higher education institutions in Slovakia can be classified into individual levels according to the following criteria (Centre for Scientific and Technical Information SR, 2021):

- Focus - division at the level of their focus (Architecture and construction, Economics, Electrical engineering, informatics and information technology,

Philosophical and humanities, Medical, healthcare, pharmaceutical and veterinary, Other technical disciplines, Pedagogical teaching, Agriculture, Forestry, Legal, Natural sciences, Mechanical engineering, Theology and theology, Artistic and visual, Military and police);

- Founder – division at the level of their inclusion according to the founder (faculties of public, state, and private universities);
- Level of education provided – breakdown by level of education provided (I. level, II. level, III. level).

Data on the number of universities and their faculties according to the mentioned criteria are regularly updated by the Centre for Scientific and Technical Information SR in the section Overview of universities. According to data for the 2020/2021 academic year, there are 20 public universities with 106 faculties, 3 state universities with 6 faculties, and 10 private universities with 16 faculties in Slovakia. The number of students is shown in Figure 2.

Fig. 2: Number of students at types of universities in the academic year 2020/2021
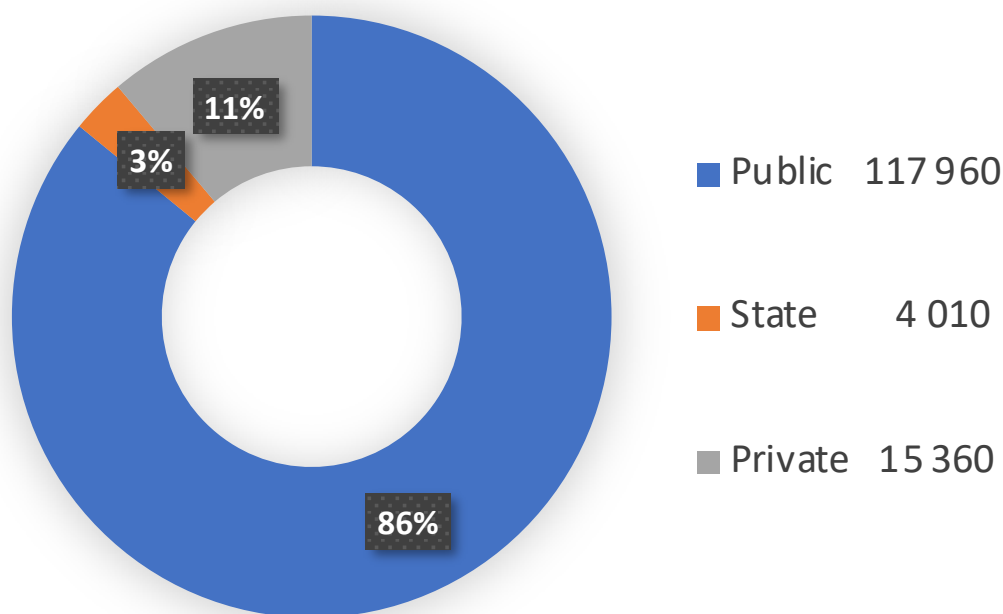
Source: Own work

From Figure 2, we can see that up to 86% of university students are in public schools, the rests are state (3%) and private university students (11%). Figure 3 shows the percentage of faculty students according to their specialization.

Fig. 3: Types of universities students in percentage in the academic year 2020/2021
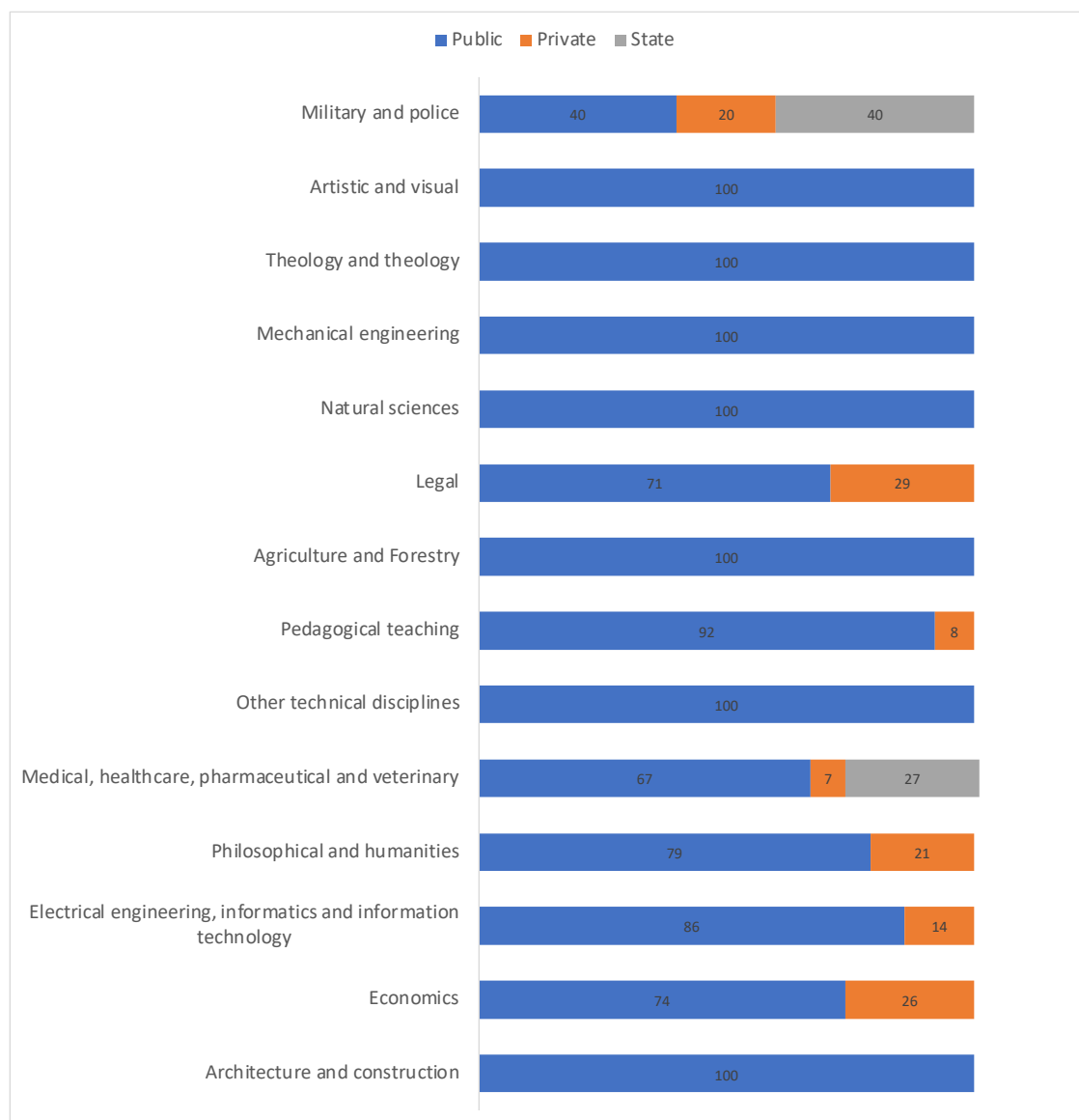
Source: Own work

Based on the examination of the content of individual fields of study, the scope of acquired knowledge, skills, and competencies, which profile the graduates of study programs by the relevant levels of the national qualification framework, 38 fields of study (79%) provide space for education in the field of project management.

According to the content, the remaining 10 fields of study (21%) do not expect the acquisition of skills, knowledge, and competencies related to the field of project management.

1.2 Methodology of the survey

An important step in the implementation of the survey was the project creation, the formation of the project team in cooperation with members of IPMA Slovakia, and the identification of the interested parties of the project. With the project team, it was necessary to define the scope of the project with a division into individual phases (see Figure 4) and sub-

tasks, identify risks, and draw up a communication plan and a project timetable. The main contribution of the project was defined in the form of improving the quality of the education process in the field of project management at universities.

Fig. 4: Project timeline

Source: Own work

After the preparation of the project, we analyzed how it is possible to get contacts to the higher schools that we want to address, and we also chose the method and form of addressing them. To contact universities, we decided to use the contacts for deans published on the websites of individual university faculties, representatives of the Council of Universities of the Slovak Republic (Council of Universities of the Slovak Republic, 2021), and contacts published on the PortalVS.sk page (2021).

To conduct the survey, we used a questionnaire sent in electronic form via e-mail. The questionnaire is one of the most frequently used methods in research for quickly ascertaining facts, attitudes, preferences, etc. (Serrano-García & García-Valcárcel, 2019).

We chose the e-mail form due to the availability of contacts in this form and to reach as many schools as possible. In research works, the questionnaire can serve as the main, but also as a supplementary research method. (Bell &Young, 2018) In our case, this is the main research method, since the activity of mapping education in the field of project management across Slovakia has not yet been implemented, or we are not aware of any outputs of similar activities from publicly available sources.

We used the MS Forms tool from Microsoft to create the questionnaire. When choosing a tool, we considered various paid (Qualtrics, SurveyMonkey, Click4Survey) and free (Google Forms, MS Forms) alternatives.

After careful consideration, we decided to use a free alternative - MS Forms, which better met our questionnaire creation and design requirements than the other free tool, Google Forms.

To distribute the questionnaire, we used the Mailchimp tool, which is a complex marketing platform designed especially for smaller businesses (Mailchimp, 2021).

The questionnaire contained 27 questions. The individual questions of the questionnaire followed each other, while the questionnaire contained several decision blocks in which, based on the previous answer, the relevant group of the following questions was displayed to the respondent, as we can see in Figure 5.

Fig. 5: Order of questions with branching
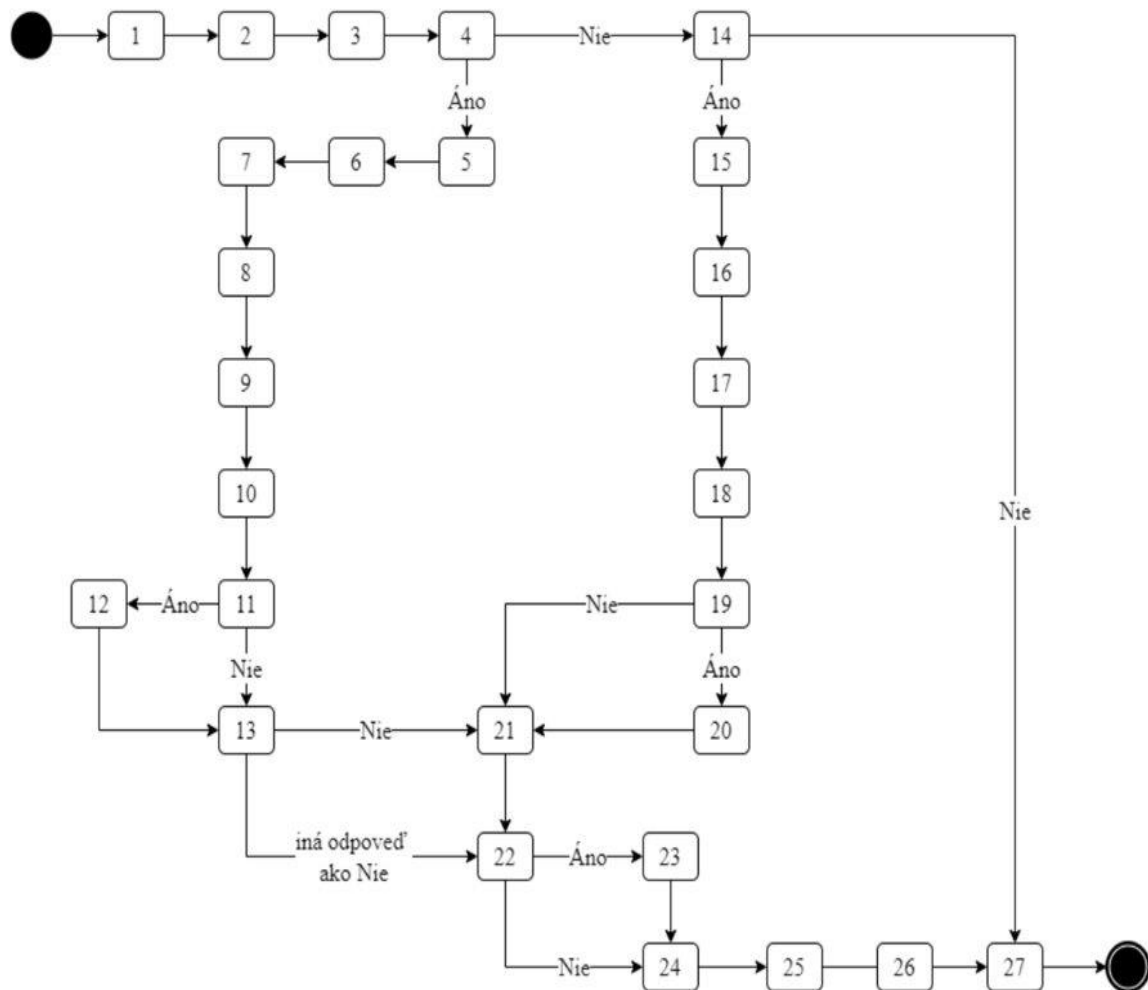
Source: Juricek, M., 2022. Mapping the state of education in the field of project management in schools in Slovakia

1.3   Results to be mentioned

Number of participating faculties

In total, 49 out of 128 university faculties participated in the survey, which, given our assumptions, exceeded expectations. We were perceiving the problems and various limitations that schools had to face during the survey period in connection with the COVID-19 pandemic.

Table 1: Types of universities participated

	Number of faculties	Percentage
Architecture and construction	2	4%
Economics	9	18%
Electrical engineering, informatics, and information technology	2	4%
Philosophical and humanities	4	8%
Medical, healthcare, pharmaceutical, and veterinary	9	18%
Other technical disciplines	3	6%
Pedagogical teaching	3	6%
Agriculture and Forestry	1	2%
Legal	2	4%
Natural sciences	2	4%
Mechanical engineering	3	6%
Theology	2	4%
Artistic and visual	3	6%
Military and police	3	4%
Others	2	4%
Total	49	100%

Source: Juricek, M., 2022. Mapping the state of education in the field of project management in schools in Slovakia

Project management teaching

From the answers of representatives of individual faculties, it emerged that project management is taught at 23 faculties, which represents 47%, while at 26 faculties, i.e. 53%, it is not taught yet.

Based on this question, we obtained the basic information necessary from the point of view of fulfilling our goal, i.e. what is the share of schools where the project management subject is currently taught?

Subsequently, we were interested in, if the subject was taught, and whether the subject was classified as compulsory, compulsory optional, or optional. Here, the compulsory option was highly prevalent, which represented up to 78%, followed by the compulsory optional at 17% and the optional 4%.

The range of teaching length of the subject is represented in 90% of the length of 1 semester.

These findings are proof that project management as a subject can be found at universities in Slovakia. However, it will be necessary to continue expanding awareness, as project management education is given much more space abroad. (Al-Harthy & Al-Harthy, 2018)

Possibilities of improving the teaching of the subject
In this optional question, most faculties representatives did not name the possibilities of improving the teaching of the given subject. However, even from the smaller number of answers, faculties representatives see the possibility of improvement by connecting teaching with practice, in cooperation with experts and representatives of relevant project management associations, in the inclusion of current innovations in the curriculum, and in greater IT support of project management.

We also see an area for improvement in the case of software tools to support the teaching of project management. We asked the respondents whether working with software tools used in practice is part of the teaching of the subject in the field of project management. Only 26% use some type of tool.

Following the answers, the most of universities where the project management subject is currently being taught do not include supporting software tools as part of the teaching.

The most preferred tool among schools that use such tools as part of teaching is MS Project.

2   Conclusion

After a thorough examination of the results of the survey, we found that there are many similarities in the taught, or the desired type, scope, and form of the subject as well as in the included knowledge areas in the curriculum and the form of cooperation with practice. Here it is possible to see that education in Slovakia in the field of project management is approaching abroad, which is also proven by comparison with the work of Wang and Chen (2019).

In our opinion, all students should be given at least basic knowledge in the field of project management, regardless of their focus. Acquiring these principles can help them already in the organization of their study duties, especially later during their professional career. Of course, it is important to choose the right scope of teaching depending on the level of education and the very focus of the school, faculty, or specific department. In trade unions, respectively specializations, where it is assumed that students will encounter a project approach in their professional career rather occasionally, there is no need for a separate subject that deals with the issue in-depth, but it is sufficient to incorporate these principles into existing compulsory or supplementary subjects. On the contrary, in trade unions, or specializations where active contact of students with projects and project management in their professional career is expected, whether, in the role of project managers or other roles, we highly recommend introducing a subject directly devoted to this area.

We are going to support our idea in the next period in the form of action steps that we want to implement as a discussion between the academic community, professional organizations, the private sector, and representatives of governing bodies.
These steps will be divided as follows:
- preparation of a sample curriculum;
- ongoing cooperation with a professional organization IPMA Slovakia;

- presentation of results for discussion with governing bodies in Slovakia;
- cooperation with the private sector to improve practical teaching.

We believe that these activities will help in the goal we have set and bring higher education in the field of project management closer to higher and qualified standards.

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DEVELOPMENT AND PROSPECTS OF FINANCIAL TECHNOLOGIES IN UZBEKISTAN

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Abstract

The article analyzes the working mechanism of modern innovations, the features of the current stage of development of financial technologies, Fintech organizations in the Uzbek market, their specific aspects, financial indicators, and development trends on the example of Fintech.

1. Introduction

Currently, the fastest growing segment of the financial services market is considered to be "Financial Technologies", which is defined as technological innovation (from a technological point of view), however, the use of innovative technologies is often considered to be organizational and product innovations. The subject of research is the activity of Fintech organizations operating in the Republic of Uzbekistan in the context of digitalization of the economy.

These technologies are being actively implemented not only by traditional players of the financial market (banks, innovative, insurance organizations, etc.), but also by newly created organizations that aim to operate in this direction. In addition, organizations from other sectors of the economy are actively entering this market. The launch of the Samsung Pay payment system by the Korean electronics manufacturer Samsung and the Google Pay payment system created by the American Internet company Google are a clear example of the trend, and in Uzbekistan the Zood Pay payment system of the ZoodMall organization which comes first before our eyes.

2. State of the Art

The relevance of the topic: Fintech operators have begun to introduce certain traditional technologies into their activities, and traditional financial institutions have gradually started using fintech elements (Makhmudova, 2020). Patrick Schuffel, a professor at the Friborg School of Management, reviewed more than 200 scientific papers published over the past four decades and defined the term Fintech as follows: "Fintech is an industry which is an emerging financial sector that uses technology to improve financial performance."(Schueffel, 2017). Irene Aldridge and Steve Kravtsiv point to several areas where fintech is spreading, such as insurance automation (often referred to as InsurTech)(Samiev, 2019), trading and risk management.

The purpose of the study is to determine the reasons for such a rapid development of fintech in modern conditions: Analysis of the status and statistical indicators of organizations providing

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financial technologies in the Republic of Uzbekistan. The article argues that the development of fintech requires a radical change in the competencies of finance, banking and business professionals.

The object of the research work is Fintech organizations operating in the Republic of Uzbekistan.

The subject of research is the activity of Fintech organizations operating in the Republic of Uzbekistan in the context of digitalization of the economy.

3. Research methods

Comparative analysis, classification, logical method, systematic analysis, scientific abstraction, generalization methods were used in the research process.

In terms of processes, the term "FinTech" refers to new applications, processes, products or business models in the financial services industry consisting of one or more value-added financial services delivered entirely or largely over the Internet. Services may be provided simultaneously by different independent service providers, usually through at least one licensed bank or insurance company. There are completely different models and classifications of fintech.
However, the key differentiator is the ability of fintech companies to innovate.

The following are the main factors of the emergence and rapid spread of fintech:

- qualitative and quantitative growth of information technologies

- the need to improve the performance of financial and non-financial companies

- change in consumer habits.

The development of financial technologies to a large extent modernizes traditional financial services and products in several directions:

- payments and transfers: online payment services, online transfer services, P2P currency exchange (transfers between individuals), B2B payment and transfer services (transfers between legal entities), cloud cash registers and smart terminals, public payment services;
- financing: P2P consumer loan, P2P business loan, crowdfunding;
- money management: robo-advice, financial planning software and applications, social trading, algorithmic stock trading, mutual fund services.
- insurance (InsurTech): subscription insurance, microinsurance, automatic calculation of losses (insurance payments without the participation of the insured)(Grishina, 2019).

According to the Decree of the President of the Republic of Uzbekistan No. PF-4947 of February 7, 2017, in Chapter 3, Section 1 of the "Strategy of Actions on Five Priority Areas of Development of the Republic of Uzbekistan in 2017-2021", Financial The provision of increasing the types and volume of services was a big step for the development of the Fintech direction. In order to continue the development in this field, according to the Decree of the President of the Republic of Uzbekistan No. PF-60 of January 28, 2022, the 25th goal of the "New Development Strategy of Uzbekistan for 2022-2026" is "increase the volume of the software industry 5 times", and increasing their export by 10 times to 500 million US dollars", it is envisaged that all organizations operating in the field of Fintech will be supported by the government. As a result of these opportunities, according to the Global Innovation Index

published in 2015 by the World Intellectual Property Organization, Uzbekistan ranked 122 out of 140 countries. In 2020, in the Global Innovation Index consisting of 80 indicators, Uzbekistan took 93rd place among 131 countries and achieved positive results in the following areas:

Institutions, Human capital and research, Infrastructure, knowledge economic and technological results (Knowledge & technology outputs) and creative productivity (Creative outputs) (Maksad, 2020). Today, according to the 2022 report of the Global Innovation Index, Uzbekistan's rank has increased by 11 places and has taken the 82nd place, and the 3rd place in the Central and South Asian region (Anonymus. n.d.).

A high percentage of cashless payments is a direct indicator of the prospects of fintech startups in the country. It is ripe for innovative fintech solutions if consumers refuse to accept cash en masse.

A sharp increase in cashless payments was recorded in 2020 during the pandemic. This was caused by the reluctance of customers to appear in crowded places and the fear of paper banknotes, which carry the virus. But even before the pandemic, the share of cashless payments was growing gradually.

Fig. 1

Source: https://cbu.uz/uz/payment-systems/interbank-calculations/
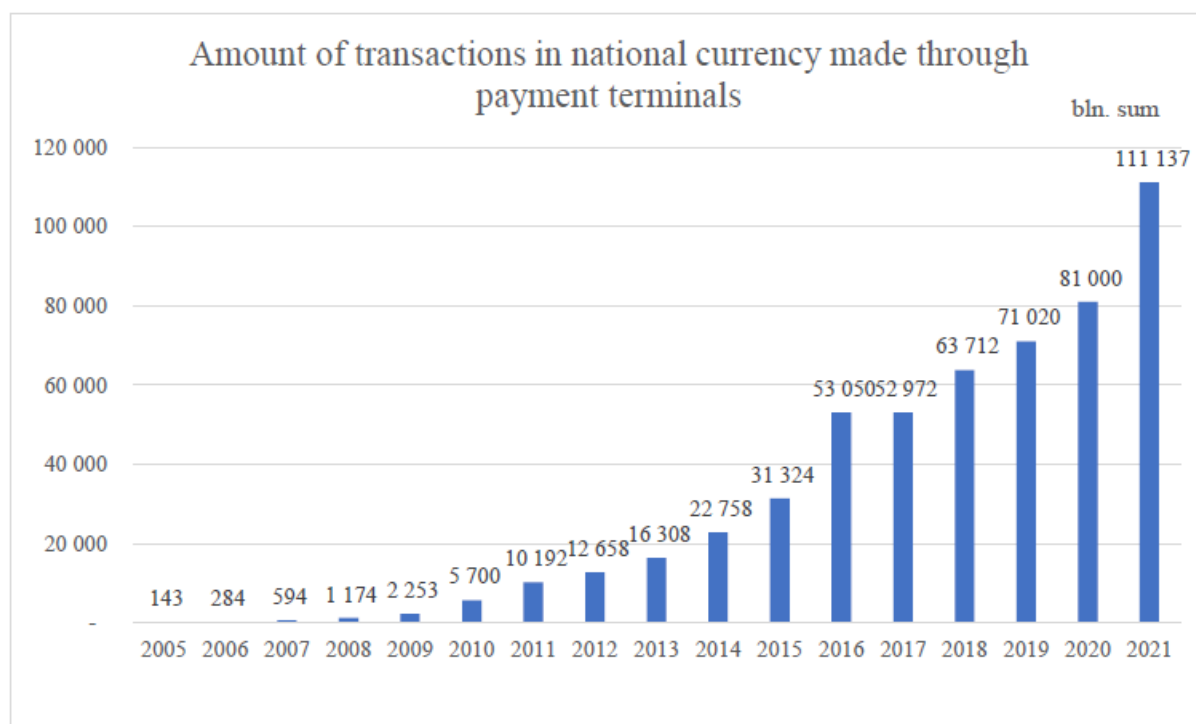
One of the main reasons for this is the commitment of young people to new technologies. Young people are attracted to the digital world and in this world it is not possible to pay cash for many goods. Even with a strong desire, it is unlikely that you will subscribe to an online course or music streaming.

Following the youth, other layers of consumers are switching to cashless money. Many companies encourage customers to pay for goods online, for example, discounts for cashless payments. This payment format is useful for business - money goes into circulation faster. According to forecasts of IMF economists, its share may approach zero in the next 5-17 years in the least popular countries.

The increase in the percentage of cashless payments means that consumers are used to paying online and are willing to use other fintech tools.

Uzbekistan is an actively developing fintech market. Remote banking services are used by 22 million people, which is 65% of the country's population. The leading means of payment in the country are Payme and «Click» e-wallets owned by TBC Bank of Georgia. By 2022, the number of active consumers has reached 1.3 million people. The Payme app has been downloaded by 6 million consumers over the six years the service has been available. As of June 2022, «Click» service is used by 8 million people and more than 25 thousand sales points in Uzbekistan.

Fig. 2
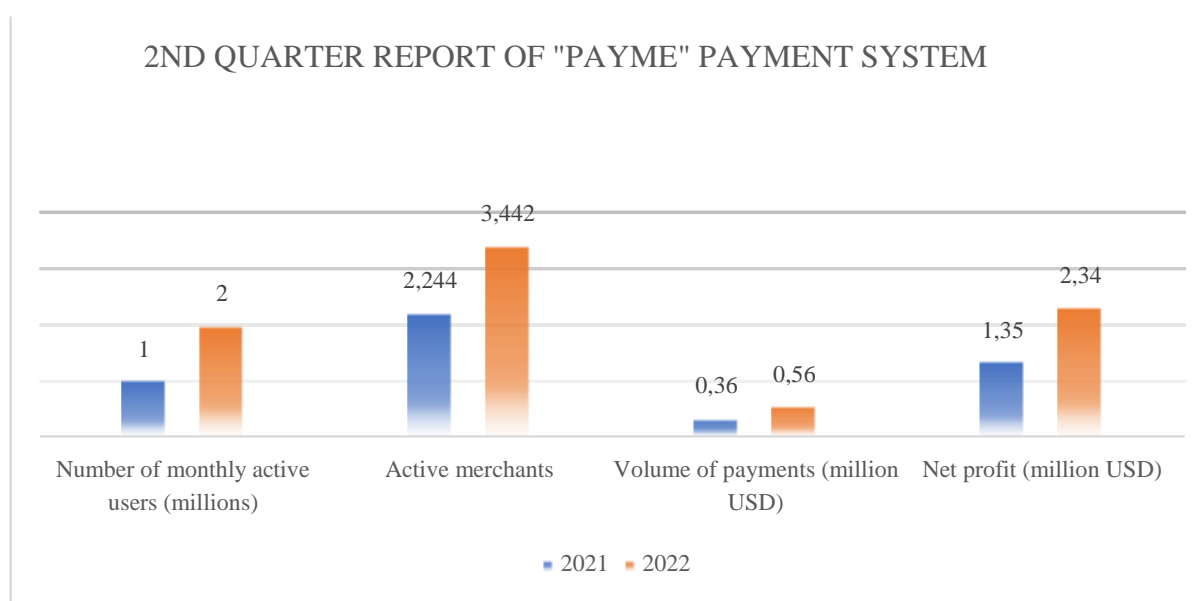
Source: Based on unaudited consolidated data of TBC Bank Group PLC for Q2 2022

The changes in all aspects of the Payme payment system in the corresponding period compared to the previous year were as follows:

- the number of monthly active consumers has doubled;
- the number of active merchants increased by 53%;
- payment volume 56% (P2P money transfers: 75% for 2021; 74% for 2022;
- payments for services: 19% for 2021; 20% for 2022; others: 6% for 2021-2022; is
- net profit increased by 73%.

Another famous fintech company that provides payment systems, bank cards, money transfers and mobile communication services is "Humans" (Humans Companies) JSC. This organization acquired the UPay payment system in May 2022 and became the full and sole owner. Also, according to the reports of the 2nd quarter of 2022, it ended with a net profit of 88,936.50 thousand soums (Xmaxmudjonov, n.d.).

All of the fintech companies mentioned above are competing in the same direction. The organization that provides services based on investment, term payment, Islamic finance is "IMAN Group Ltd" (it provides its services through applications such as "IMAN Invest", "IMAN PAY" and "IMAN Merchant"). These mobile applications are interconnected and include services such as Islamic finance-based investment, term payment and commodity

trading for businesses, financial literacy, and honest income. If we look at the financial statements of this fintech organization for the period of January-July 2022, we can see the following changes (Udevs, n.d.):

Fig. 3
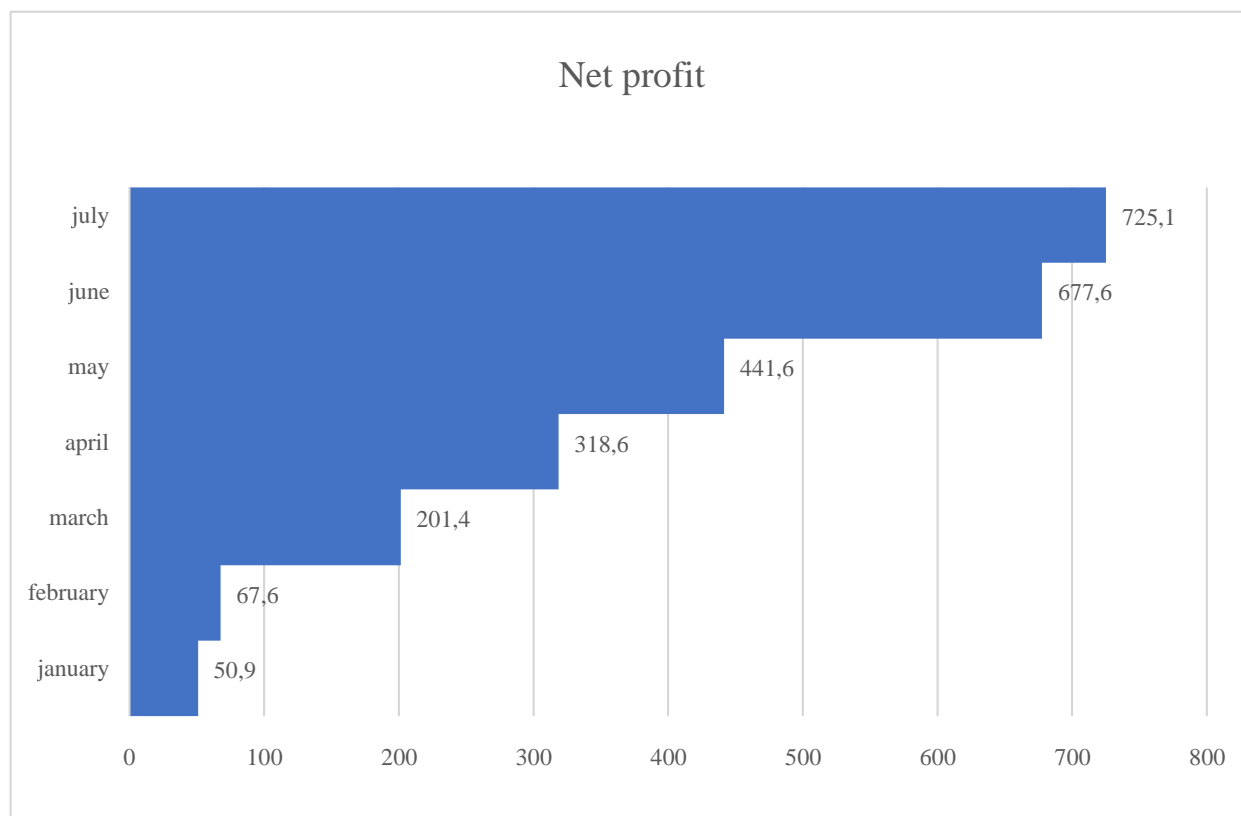
In November 2021, «Click» celebrated its 10th anniversary. Today, the company has about 8 million customers and annual growth is about 25-30%. "«Click»" is expanding significantly, and this can be seen not only in a sharp increase in the number of employees (from 70 at the beginning of 2020 to 308 in June 2022), but also in the number of projects launched by the payment service. These are the children's application "«Click» Start", the logistics aggregator

"«Click» BOX" and the marketplace "«Click» Market".

According to the summary of 2021, "«Click»" occupied 65% of the market of payment organizations. The fintech market is just taking shape and it cannot be said that it is yet divided among the players. All this was influenced by the introduction of the cashback system in 2019 and there was a noticeable increase in p2p transfers. They have two types of cashback: regular - up to 1% of the payment amount from a regular card and 2% of the payment amount from a «CLICK» card is paid by the «CLICK» company itself; and large - up to 50% of the payment amount is paid by supplier companies. Big cashback, launched in 2021, it is more often chosen by new establishments: swimming pools, restaurants, beauty salons and others in order to quickly unwind and gain a customer base. According to this indicator, the annual turnover growth is 20%.

Fig. 4

Source: https://docs.Click.uz/en/
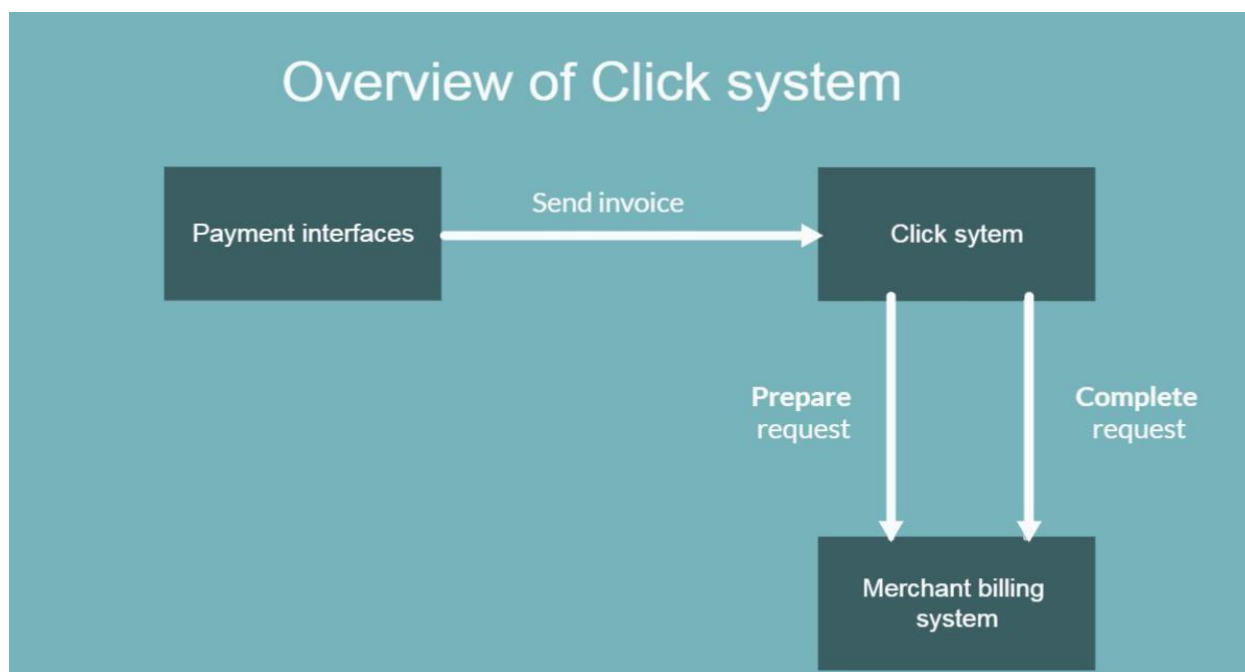
At the beginning of the company's work, only payment for mobile communication accounted for 90-95% of the total turnover. Consumers spend an average of 50,000 sum UZS, per month on mobile communications, and it turns out that consumers spent only 5% of their money on mobile communications and Internet providers. In other cases (payment for utilities, food, transport, etc.), consumers have been making payments mostly offline. As key features of «CLICK» we can say payment directly from a plastic card, even in cases where it is not with you, transfer of funds from card to card by card number or phone number, «CLICK» terminal service payment in stores/restaurants by scanning a QR code or USSD, manage invoices through any system interface, the AutoPay service automates recurring payments: for a mobile phone, internet, etc., view payment history by days, cards and transactions, online check of bank account balances details for each card, service Help a friend for payments in case of insufficient funds on your card, repayment of a loan received from a bank or credit organizations, SMS notifications for all transactions in the «CLICK» system.

Great attention is paid to the issue of security system. Ensuring the security mechanisms of the «CLICK» system (encryption, authentication in the Web interface, EDS for requests) is based on the use of symmetric/asymmetric encryption algorithms, as well as irreversible (oneway) hashing algorithms. To encrypt and sign EDS requests between subsystems (DC and BCS), the OpenSSL cryptographic package is used. It also uses the O`z DSt 1105:2009 encryption standard to sign payments. A secure encrypted channel is established between the user's browser and the DC over the HTTPS protocol based on the SSL or TLS transport layer protocol (depending on the version of the user's browser). All data on this channel is transmitted in encrypted form. The transmitted data is encrypted with a key from 256 to 2048 bits long (depending on the browser version). Encryption keys are one-time for each session. All modern browsers support 256-bit key encryption, which is currently strong cryptographic protection (Click, n.d.).

Fig. 5

Source: https://docs.Click.uz/en/merchant/

Fig 6

Source: https://docs.Click.uz/en/Click-api/
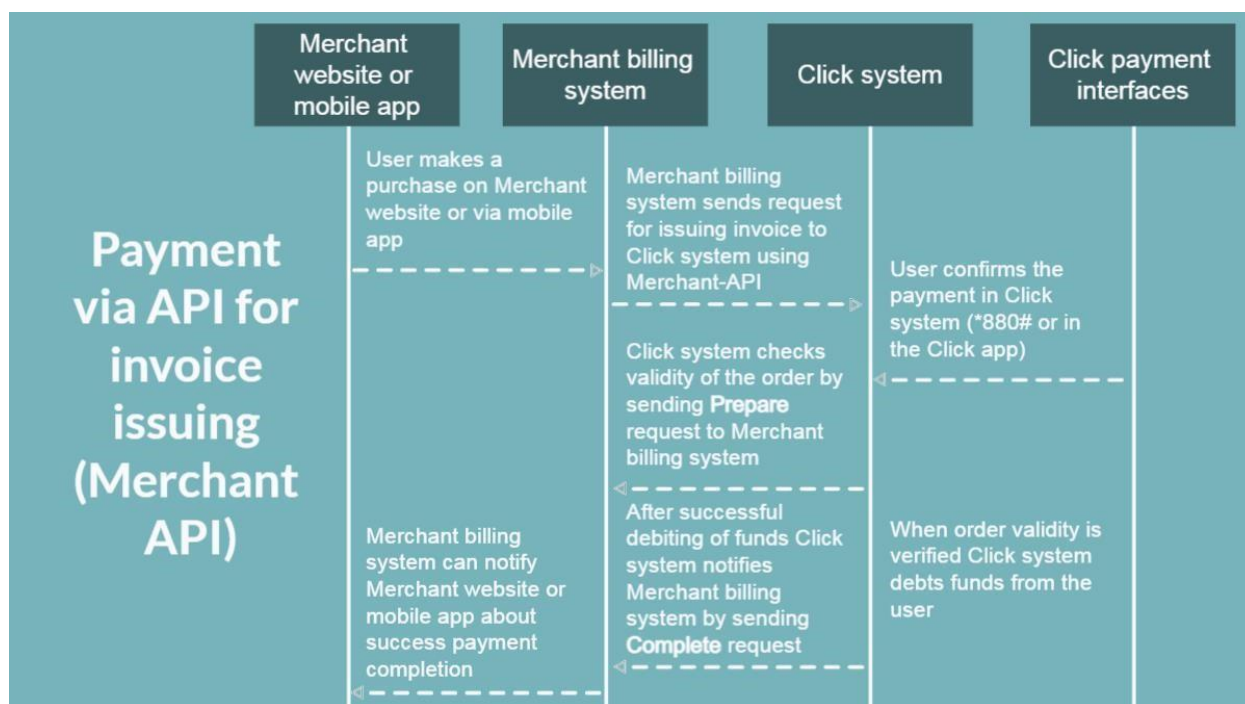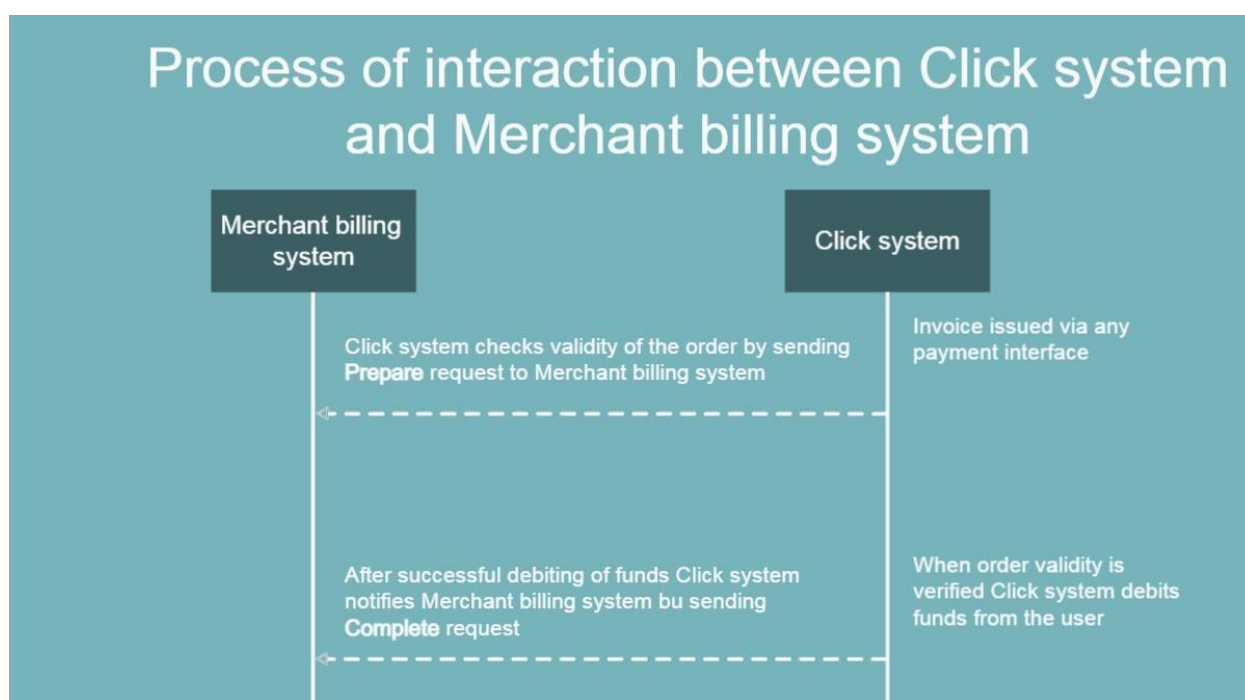
Nowadays, «Click» offers more services, and now the payment for mobile communication is only 35% of the total turnover. The remaining 65 percent are utilities, various purchases, payment for transportation, gasoline, and others (Fayzulloevna, n.d.).

4. Conclusion

The Fintech organizations mentioned above are one of the most famous, popular and main players of the market of Uzbekistan. Banks are also offering similar services through their mobile applications. Nevertheless, the number of competing organizations in the market is small. Companies combining traditional and innovative models and tools of providing financial services in one way or another can dominate the financial services market.

The fact that the ««Click»» payment system has reached a new stage in its activity, entering new types of activities, offering special services to the user segment, can be included among the promising Fintech organizations of the Uzbek market. Now, «Click» is pushing the envelope even further by introducing a Buy now Pay later payment system similar to Visa and Mastercard. This, in turn, allows for an increase in the number of partners, consumers, merchants and transactions, commission, income and net profit.

They can't do this on their own. So, they need to work with banks around the world to provision that capital, and then all of a sudden, that business can now engage in a payment that otherwise they wouldn't be able to do. And that enables more consumer transactions which get the flywheel turning in the economy.

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According to the Decree of the President of the Republic of Uzbekistan No. PF-4947 dated February 7, 2017 "Strategy of Actions on the five priority areas of development of the Republic of Uzbekistan in 2017-2021"

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APPLIED INFORMATICS IN BUSINESS AND THE DIGITAL ECONOMY

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Abstract

The article describes the role and importance of applied informatics in business and business management in the digital economy. Features, tasks and business analysis of business informatics are covered.

Keywords: digital economy, applied informatics, business informatics, information systems, operational information and communication systems, global operating environment, business analyst, business management

The article is under review

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AN EXECUTION EFFICIENCY OF A SEQUENTIAL SEARCH, MULTI-THREADED, AND A PARALLEL SEARCH FOR A DATA IN A SYMBOL TABLE IMPLEMENTED IN AN ARRAY, AND IN A LINKED LIST

Igor Košťál[1]

Abstract

A symbol table is an abstract mechanism used in many kinds of applications, including search applications, to store key-value pairs (information), where we can later search for and retrieve the value by specifying a key. For an effective symbol table implementation, it is important to choose an appropriate data structure. We have created a C# application with search methods that use symbol tables implemented in an array and in a linked list. We were interested in which of these data structures is more suitable for a sequential search, multi-threaded search, and parallel search for the data set in the symbol table by the C# application search methods. Our C# application allows to search for values according to given keys in a symbol table implemented in an array and in a linked list sequentially, on multiple threads and in parallel using its instance methods, while the application measures the execution times of particular searches. By comparing these execution times, we were finding which a data structure, an array, or a linked list, allows more efficient searching in a sequential search, multi-threaded, or in a parallel search. The results and an evaluation of this experiment are presented in the paper.

Keywords

execution efficiency, sequential search, multi-threaded search, parallel search, symbol table, linked list

1 Introduction

Many applications allow us to search for data in large data sets. With the increasing size of the volume of searched data, increases the importance of a choice of an abstract mechanism for storing data in search applications, and its appropriate implementation in the selected data structure. If the volume of searched data is really large, the choice of search technique is also important, i.e., whether the application will search sequentially, on multiple threads or in parallel. An effective combination of these selections is important. For our searched data, URL - IP address pairs, it is appropriate to use a symbol table, by which we have chosen an abstract mechanism used for storing data in the search application. Next, we need to choose a suitable implementation of the symbol table, we choose either an array or a linked-list implementation, and we also need to choose an efficient search technique, a sequential search, multi-threaded, or a parallel search. To carry out an efficient combination of the mentioned selections enables our C# application with search methods that search for data in a symbol table implemented in an array and in a linked list, while the application allows us to perform a sequential search, multi-threaded, and a parallel search for a set of values according to given keys in both implementations of a symbol table by these its search methods. The application measures the execution time of each search and writes it along with its results to a log disk file. By comparing these execution times, we were finding in the experiment which data structure, an array, or a

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linked list, allows to search more efficiently in a sequential search, in a multi-threaded search or in a parallel search. We assume that this could be an implementation of a symbol table in an unordered linked list. The experiment and its results, which are described in the chapter of the same name, will confirm, or refute our hypothesis. In the chapter *A Symbol Table, its Use in Applications*, we briefly discuss the symbol table and its wide use in various kinds of applications. A dynamic array and a linked list with an implemented symbol table are discussed in the chapter of the same name. The Task Parallel Library, kinds of a parallelism and a task parallelism are discussed in the next chapter. In the chapter *A C# Application, its Methods*, we briefly describe the class architecture of our C# application, its key search methods, and their use in sequential, multi-threaded and a parallel search for multiple values according to a set of given keys in two different implementations of a symbol table, in an array and in a linked list. In the *Conclusion*, we summarize the results of the performed experiment.

2   A Symbol Table, its Use in Applications

As we mentioned above, a symbol table is an abstract mechanism used to store key-value pairs (information) that we can later search for and retrieve (a *value*) by specifying a key (Sedgewick, 2011, Sedgewick & Wayne, 2022, 1, Sedgewick & Wayne, 2022, 2). In other words, a symbol table is a data structure of items with keys that supports two basic operations: insert a new item, a key-value pair, and return an item (a *value*) with a given key (Sedgewick, 1998). That the symbol table is often used in different applications is confirmed by the many kinds of applications in which it is implemented. These are e.g., applications that work with (Sedgewick & Wayne, 2022, 3):

- a phone book (the key is the name; the value is the phone number)
- a dictionary (the key is the word; the value is the meaning of the word, its pronunciation and other information about it)
- accounts (the key is the account number; the value is the account data)
- a Java compiler (the key is the identifier of the variable; the value is its memory location)
- an e-book (the key is the term; the value is the page numbers of the book where it is located)
- DNS records (the key is the domain (DNS) address of the web application; the value is its IP address)
- etc.

From the given overview of the use of the abstract mechanism, the symbol table, its wide use in various kinds of applications is evident, therefore it makes sense to consider its use in the development of such or similar kinds of applications.

As we mentioned above, in order to the implementation of the symbol table in any application was execution- and memory-efficient, it is very important to choose an appropriate data structure for its implementation. A symbol table can be implemented in an ordered or unordered array, an ordered or unordered linked list, a balanced or unbalanced binary search tree, and in other data structures. We were interested in which of two elementary implementations of the symbol table, in an unordered array and in an unordered linked list, is more suitable for a sequential search, multi-threaded, and for a parallel search for the same data set in the symbol table by the search methods of a C# application. We assume that this could be implementation in an unordered linked list, despite its more complex construction compared to the dynamic array construction in the application source code itself. To confirm or refute this hypothesis, we have created the C# application with search methods that can be executed sequentially, on multiple threads, and in parallel. This C# application implements a symbol table in an unordered array of objects and in an unordered linked list of objects. The application

stores the same key-value pairs, in its case these are domain address (URL) - IP address pairs, into both these implementations. The application allows to search IP addresses according to domain address keys, or domain addresses according to IP address keys in an array and in a linked list sequentially, on multiple threads, and in parallel, while the application measures the execution time of each search in each implementation of the symbol table. By comparing these execution times, we were finding which implementation of the symbol table is more suitable for sequential, multi-threaded, and for a parallel search for the data set in it using the same search methods of the application. The results of comparing these execution times also allowed us to confirm or refute our hypothesis that the implementation of the symbol table in an unordered linked list of objects is more suitable for sequential, multi-threaded, and for parallel search for the data set in it using the same search methods of the application as its implementation in an unordered array of objects.

An array and a linked list are discussed briefly in the next chapter. Their use in our C# application, its key search methods, and the evaluation of the comparison of execution times of a sequential search, on multiple threads and a parallel search in each implementation of the symbol table are discussed in the next chapters of the paper.

3   A Dynamic Array and a Linked List with Implemented a Symbol Table

To create an unordered dynamic array of objects with an implemented symbol table (Fig. 2) is not very complicated. It is possible to access the particular elements of the array and move on in this array using indexes in the array of references to particular objects (elements). (Košťál, 2022)

To create an unordered linked list with an implemented symbol table (Fig. 4) is more complex than to create a dynamic array with implemented the same symbol table. However, a linked list is a true dynamic data structure that is maximal memory efficient. We can even create an empty list that contains no data elements (nodes), only informational data, in our case the *head*, and *tail* references and the *Count* instance variable. We can add new data elements (nodes) to the linked list at its beginning, end, or any place in it during the execution of the application. We can also delete any data element (a node) from the list, it can be the first, last or any of its element (a node). That is, the list can dynamically grow or shrink during the application execution, still maintaining maximum memory efficiency. A dynamic array cannot work like that. However, there are also disadvantages of working with a list, e.g., we cannot access its data element (a node) as easily as using an index to a dynamic array element. In the list, we have to get to the given data element (a node) by going through all previous data elements (nodes) (Drozdek, 2013). Therefore, we must always consider whether it is appropriate to use a linked list, depending on the circumstances of the specific implementation in a specific application. We used a linked list in our C# application, moreover, we assume that the implementation of the symbol table in it will be more execution efficient and more suitable for sequential, multi-threaded, and for a parallel search for the same set of data in the symbol table by the search methods of this application than its implementation in a dynamic array. (Košťál, 2022)

4   The Task Parallel Library, Kinds of a Parallelism, the *Parallel.Invoke* Method

We have created a C# application, which uses in its parallelized source code the *System.Threading.Tasks.Parallel* library class, from the Task Parallel Library.

This Task Parallel Library (TPL) is a set of public types and APIs (Application Programming Interfaces) in the *System.Threading* and *System.Threading.Tasks* namespaces in the NET Framework. The purpose of the TPL is to make developers more productive by simplifying the process of adding parallelism and concurrency to applications. (Microsoft, 2022)

In parallel programming in the .NET Framework, we know two kinds of a parallelism - data and task parallelism.

Data parallelism refers to scenarios in which the same operation is performed concurrently (that is, in parallel) on elements in a source collection or array. Data parallelism with imperative syntax is supported by several overloads of the *For* and *ForEach* methods in the *System.Threading.Tasks.Parallel* class through which TPL supports this parallelism. In data parallel operations, the source collection is partitioned so that multiple threads can operate on different segments concurrently. We do not have to create threads or queue work items. The TPL handles all the low-level work for us. When a parallel loop runs, the TPL partitions the data source so that the loop can operate on multiple parts concurrently. Behind the scenes, the *Task Scheduler* partitions the task based on system resources and workload. When it is possible, the scheduler redistributes work among multiple threads and processors if the workload becomes unbalanced. However, we can also supply our own custom partitioner or scheduler. (Microsoft, 2022) We did not use a data parallelism in a parallelized code of our C# application.

The Task Parallel Library (TPL), as its name implies, is based on the concept of a task, which represents an asynchronous operation. The term **task parallelism** refers to one or more independent tasks running concurrently. Tasks provide two primary benefits (Microsoft, 2022):

- More efficient and more scalable use of system resources. Behind the scenes, tasks are queued to the *ThreadPool*, which has been enhanced with algorithms that determine and adjust to the number of threads and that provide load balancing to maximize throughput. This makes tasks relatively lightweight, and we can create many of them to enable fine-grained parallelism.
- More programmatic control than is possible with a thread or work item. Tasks and the framework built around them provide a rich set of APIs that support waiting, cancellation, continuations, robust exception handling, detailed status, custom scheduling, and more.

For both these reasons, TPL is the preferred API for writing multi-threaded, asynchronous, and parallel code in .NET. (Microsoft, 2022)

Task parallelism with the *Parallel.Invoke* method is used in a parallelized code of our C# application.

The ***Parallel.Invoke*** method provides a convenient way to run any number of arbitrary statements concurrently. Just pass in an *Action* delegate for each item of work. The easiest way to create these delegates is to use lambda expressions. The lambda expression can either call a named method or provide the code inline. (Microsoft, 2022)

Parallel.Invoke is a static method with two overloaded versions. Here is the signature and brief description of the version of *Parallel.Invoke* from (Microsoft, 2022) that is used in a parallelized code of methods of our C# application. This description explains how this method operates in this code.

Syntax (in C#)

*public static void **Invoke** (params Action[] actions);*

Parameters

actions - an array of *Action* delegates to execute.

5   A C# application, Its Methods

Our C# application, which implements a symbol table in an unordered array of objects and in an unordered linked list of objects, and which allows to search IP addresses according to domain address keys, or domain addresses according to IP address keys in this array and in this linked list sequentially, on multiple threads, and in parallel, while this application measures the execution time of each search in each implementation of the symbol table, was created in the C# language and built in the Microsoft Visual Studio 2019 development environment. The source code of this application contains the following four classes:

- **SeqSearchSTarr** - objects of this class are elements of a dynamic array of objects, containing key-value pairs, domain address (URL) - IP address, in the *key* and *value* instance variables and the number of these pairs of the implemented symbol table in the *n* instance variable. The *refSeqSearchSTarr* reference points to the array of objects (Fig. 2). The *SeqSearchSTarr* class has the following member methods:
  - *SetKey*, *GetKey*, *SetValue*, *GetValue*, *Get_n* - these methods serve to get and set the values of the *key*, *value* and *n* instance variables of the *SeqSearchSTarr* class object.
  - *Put_KeyValue* - the helper member method inserts the values of the key-value pair, URL - IP address, into the *key* and *value* instance variables of the *SeqSearchSTarr* class object.
  - *LoadDataOfInputFile* - the static member method reads key-value pairs line by line from the data stream associated with the *fileNameX* disk file, creates objects of the *SeqSearchSTarr* class, inserts them into the array of such objects, and inserts the read key-value pairs into the *key* and *value* instance variables of these objects by calling the *Put_KeyValue* helper instance method.
  - *StreamContainsKey* - helper static member method used by the *Put_KeyValue_AtEnd* member method to find whether the *keyX* key is in the data stream associated with the *fileNameX* disk file or is not. Based on this finding, the *Put_KeyValue_AtEnd* method will write or will not write the key-value pair, *keyX-valueX*, into this data stream and into the *fileNameX* disk file associated with this data stream.
  - *Put_KeyValue_AtEnd* - static member method creates a new object of the *SeqSearchSTarr* class, inserts it at the end of the array of these objects, and initializes the *key*, *value*, and *n* instance variables of the inserted object by calling the *Put_KeyValue* helper instance method. Then the *Put_KeyValue_AtEnd* method finds whether the *keyX* key is in the data stream associated with the *fileNameX* disk file or is not, using a call the *StreamContainsKey* member method, and based on this finding, will write, or will not write the key-value pair, *keyX-valueX*, into this data stream and into the *fileNameX* disk file associated with this data stream.
  - *RemoveNodeKeyValue_str* - the static member method removes the *SeqSearchSTarr* class object with the given *keyX* key from the array of these objects and by calling the *RemoveLineWithNodeKeyValueFromStream* helper static member method deletes the line with this *keyX* key from the data stream and then from the *fileNameX* disk file associated with this data stream, thus synchronizing the contents of this file with the array objects.
  - *SearchValueArr* - the static member search method uses the *GetKey* instance method to search for the *value* associated with the given *keyX* key in the instance variables of the objects of the array of the *SeqSearchSTarr* class objects. If it finds it, then this method will return this *value*, otherwise it returns an empty string.

- **NodeLLUn** - objects of this class that contain key-value pairs, domain address (URL) - IP address in the *key* and *value* instance variables, and a reference to the next data element (a

node) in the *Next* instance variable (Fig. 4), create the data elements (nodes) of a linked list with an implemented symbol table. The *Set_keyValuePair* member method serves to initialize the *key* and *value* instance variables of the *NodeLLUn* class object, and the *Get_key* and *Get_value* member methods serve to get the values of the *key* and *value* instance variables of such object.

- **LinkedListSTUn** - an object of this class, containing references to the first and the last data element (a node) of the linked list in the *head* and *tail* instance variables and their number in the *Count* instance variable, represents a link list (Fig. 4), in which data elements (nodes) a symbol table is implemented. The data elements (nodes) of a linked list are objects of the *NodeLLUn* class. The *LinkedListSTUn* class has the following member methods:
  o *LinkedListSTUn* - constructor, initializes the *head*, *tail* and *Count* instance variables of the object created by it.
  o *Get_Count* - static member method gets the value of the *Count* static instance variable of the *LinkedListSTUn* class object.
  o *AddAtEndOfLLUnsort_LoadData* - the helper member method adds one new data element, an object of the *NodeLLun* class, to the end of the linked list, inserts one key-value pair, URL - IP address, into the *key* and *value* instance variables of this object, by calling the *Set_keyValuePair* instance method of this object. This member method can also work with an empty linked list, it is called only by the *LoadDataOfInputFile_LL* instance method.
  o *LoadDataOfInputFile_LL* - the member method reads key-value pairs line by line from the data stream associated with the *fileNameX* disk file, inserts them into the *key* and *value* instance variables of objects of the *NodeLLUn* class using the called *AddAtEndOfLLUnsort_LoadData* member method. This called method inserts these objects at the end of the linked list, so that it creates a linked list from all the data stored in this data stream.
  o *StreamContainsKeyLL* - helper static member method used by the *AddAtEndOfLLUn* member method to find whether the *keyX* key is in the data stream associated with the *fileNameX* disk file or is not. Based on this finding, the *AddAtEndOfLLUn* method will write or will not write a key-value pair, *keyX-valueX*, into this data stream and into the *fileNameX* disk file associated with this data stream.
  o *AddAtEndOfLLUn* - the member method adds to the end of the existing linked list one new data element (a node), an object of the *NodeLLun* class, inserts one pair of key-value, URL - IP address, into the *key* and *value* instance variables of this object by calling the *Set_keyValuePair* instance method of this the *NodeLLun* class object. Then the *AddAtEndOfLLUn* method finds whether the *keyX* key is in the data stream associated with the *fileNameX* disk file or is not, using a call the *StreamContainsKeyLL* member method, and based on this finding, will write, or will not write a key-value pair, *keyX-valueX*, into this data stream and into the *fileNameX* disk file associated with this data stream.
  o *RemoveNodeKeyValueLL* - member method removes a data element (a node), the *NodeLLun* class object, with the given *keyX* key, from a linked list of these objects, and deletes a line with this the *keyX* key from the data stream and subsequently from the *fileNameX* disk file associated with this data stream by calling the helper member method *RemoveLineWithNodeKeyValueFromStreamLL*. By this is the content of this file synchronized with a linked list.
  o *SearchValueLL* - the member search method searches for a data element (a node) of a linked list, the *NodeLLun* class object, with the given *keyX* key using the *Get_key*

instance method. If it finds it, then this method will return the *value* associated with this key, otherwise it returns an empty string.

- *Work* - class contains the *Main* static member method that contains source code that calls sequentially, on multiple threads, and in parallel the *SeqSearchSTarr.SearchValueArr* static method of the *SeqSearchSTarr* class and the *linkedLSTUn.SearchValueLL* instance method of the *linkedLSTUn* object of the *LinkedListSTUn* class. At the same time, the *Main* method measures the execution times of all calls to both these search methods and writes them together with the search results to the *LogFile.txt* disk log file.

The **SearchValueArr** key static member search method (Fig. 1) of the *SeqSearchSTarr* class searches for the *value* associated with the given *keyX* key in the symbol table implemented in the unordered dynamic array, on which the *refSeqSearchSTarrX* reference points to (Fig. 2). The elements of this array are objects of the *SeqSearchSTarr* class, which contain key-value pairs, domain address (URL) - IP address, in the *key* and *value* instance variables and the number of these pairs in the entire symbol table in the *n* instance variable. These objects can call the *GetKey* and *GetValue* instance methods, which get the values of the *key* and *value* instance variables. If the *SearchValueArr* method finds an object with the given *keyX* key in this array of objects, then it returns the *value* associated with the given *keyX* key and stored in the found object using a call the *GetValue* instance method, otherwise it returns an empty string. (Košťál, 2022)

Fig. 1: The source code of the 'SearchValueArr' static member method

```
public static string SearchValueArr(SeqSearchSTarr[] refSeqSearchSTarrX, string keyX,
                                                             int lines_countX) {

    for (int i = 0; i < lines_countX; i++)
      if (refSeqSearchSTarrX[i].GetKey() == keyX)
        return refSeqSearchSTarrX[i].GetValue();  // search hit: return associated value

    return "";  // search miss  }
```

Source: (Košťál 2022)

Fig. 2: The unordered array of the objects of the 'SeqSearchSTarr' class with implemented symbol table with the key-value pairs, domain address (URL) - IP address, in the 'key' and 'value' instance variables of these objects
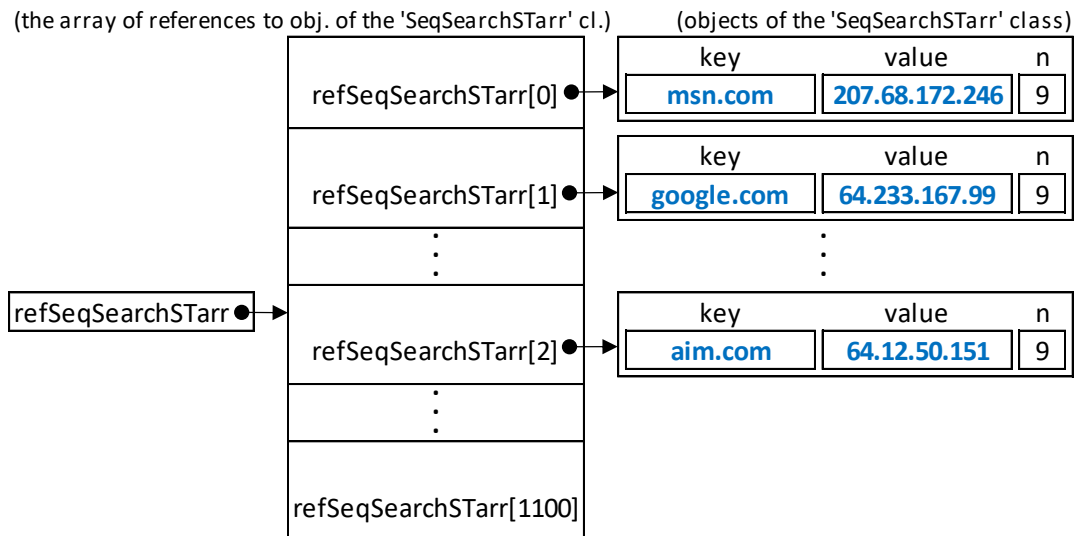
Source: (Košťál 2022)

The **SearchValueLL** key member search method (Fig. 3) of the *LinkedListSTun* class searches for the *value* associated with the given *keyX* key in the symbol table implemented in

the unordered linked list represented by the *linkedLSTun* object (Fig. 4). The data elements (nodes) of the list are objects of the *NodeLLun* class, which contain key-value pairs, domain address (URL) - IP address, of a symbol table in the *key* and *value* instance variables, and a reference to the next data element (a node) in the *Next* instance variable (Fig. 4). The *Get_key* and *Get_value* instance methods of the current *curr* object of the *NodeLLun* class can get the values of the *key* and *value* instance variables of this object, which the *SearchValueLL* search method uses when searches for the *NodeLLun* class object with the given *keyX* key. The *linkedLSTun* object of the *LinkedLSTun* class contains references to the first and last data element (a node) of the linked list in the *head* and *tail* instance variables, and the number of data elements (nodes) in the list in the *Count* instance variable. If the *SearchValueLL* search method finds a data element (a node) of a linked list, an object of the *NodeLLun* class with the given *keyX* key, then it returns the *value* associated with this key using a call the *Get_value* instance method, otherwise it returns an empty string. The operation of the *SearchValueLL* method is also evident from its source code (Fig. 3). (Košťál, 2022)

Fig. 3: The source code of the 'SearchValueLL' member method

```
public string SearchValueLL(string keyX) {
    NodeLLun curr = head;  // Traverse from a head

    while (curr.Next != null)
    {
        if (curr.Get_key() == keyX)
        {
            return curr.Get_value();  // search hit: return associated value
        }
        else
            curr = curr.Next;  // Move ahead in the linked list.
    }
    if (curr.Get_key() == keyX)
        return curr.Get_value();  // search hit: return associated value

    return ""; }
```

Source: (Košťál 2022)

Fig. 4: The unordered linked list of the objects of the 'NodeLLUn' class with implemented symbol table with the key-value pairs, domain address (URL) - IP address, in the 'key' and 'value' instance variables of these objects that create the data elements of this linked list
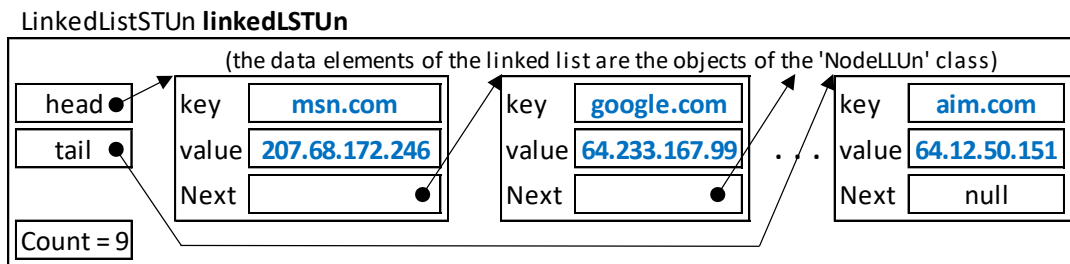
Source: (Košťál 2022)

The following sections of the source code of the *Main* static member method of the *Work* class contain the source code by which the C# application can search for 5 values associated with the user-specified 5 keys in the *SeqSearchSTarr* class objects of the array of these objects, on which the *refSeqSearchSTarr* reference points to, and in the *NodeLLUn* class objects of the linked list represented by the *linkedLSTUn* object. These source code sections call sequentially, on multiple threads, and in parallel the *SeqSearchSTarr.SearchValueArr* static method of the

SeqSearchSTarr class and the *linkedLSTUn.SearchValueLL* instance method of the *linkedLSTUn* object of the *LinkedListSTUn* class.

The **asynchronous execution** of these methods on multiple threads is realized using the *BeginInvoke* and *EndInvoke* instance methods of the objects of the delegate types that we had to declare, and which signature must match the signature of the method to which the delegate, the object of the delegate type, will point to.

The common language runtime automatically defines *BeginInvoke* and *EndInvoke* methods for these delegate types, with the appropriate signatures. The *BeginInvoke* method initiates the asynchronous call to a target method on a secondary thread. It has the same parameters as the method that we want to execute asynchronously, plus two additional optional parameters. *BeginInvoke* returns immediately and does not wait for the asynchronous call to complete. *BeginInvoke* returns an *IAsyncResult*, which can be used to monitor the progress of the asynchronous call. The *EndInvoke* method retrieves the results of the asynchronous call. It can be called any time after *BeginInvoke*. If the asynchronous call has not completed, *EndInvoke* blocks the calling thread until it completes. The parameters of *EndInvoke* can include the *out* and *ref* parameters of the method that we want to execute asynchronously, plus the *IAsyncResult* returned by *BeginInvoke*. (Microsoft, 2022)

The **parallel execution** of 5 the *SeqSearchSTarr.SearchValueArr* static methods and 5 the *linkedLSTUn.SearchValueLL* instance methods is realized using the *Parallel.Invoke* static method that uses lambda expressions.

The C# application measures the execution time each of these methods and saves it along with the search results to the *LogFile.txt* disk log file.

Fig. 5: The sections of the source code of the Main method, in which the C# application searches for 5 values associated with 5 given keys by the user sequentially, on multiple threads, and in parallel

```
// Declares a delegate type for a method that takes in a reference to a 'refSeqSearchSTarrXx'
// array, a string, and an int, and returns a string.
public delegate string AnyM_DelegSeqSearchSTarr(SeqSearchSTarr[] refSeqSearchSTarrXx,
                                                 string keyXx, int lines_countXx);


// Declares a delegate type for a method that takes in a string and returns a string.
public delegate string AnyM_DelegSearchValueLL(string keyXx);


class Work
{
  // Define the lock object.
  private static Object obj = new Object();

  static void Main(string[] args)
  {
    // Declare the 'refSeqSearchSTarr' reference to the array of references to objects of
    // the 'SeqSearchSTarr' class.
    SeqSearchSTarr[] refSeqSearchSTarr;

    // Create the 'refSeqSearchSTarr' reference to the 1100-element array of references to
    // objects of the 'SeqSearchSTarr' class.
    refSeqSearchSTarr = new SeqSearchSTarr[1100];

    // Create the object of the 'LinkedListSTUn' class.
    LinkedListSTUn linkedLSTun = new LinkedListSTUn();
                                . . .
```

Source: (author)

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Fig. 5: (continued)

```
// ******** SEQUENTIAL search for IP addresses or URLs for given keys in a symbol table

  // 'n' ... the number of keys given by the user
  if (n == 1)  { . . .}                              . . .
  else if (n == 5)  {
    string[] results = new string[10];
    stopWatch.Reset(); // Stops time interval measurement and resets the elapsed time to zero.
    stopWatch.Start(); // Starts, or resumes, measuring elapsed time for an interval.
    // *** sequential search for 5 IP addresses or 5 URLs for 5 given keys in a symbol table
    // *** implemented in an array of objects of the 'SeqSearchSTarr' class
    results[0] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr, split_inputs[0], lines_count);
    results[1] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr, split_inputs[1], lines_count);
    results[2] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr, split_inputs[2], lines_count);
    results[3] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr, split_inputs[3], lines_count);
    results[4] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr, split_inputs[4], lines_count);
    stopWatch.Stop(); // Stops measuring elapsed time for an interval.
    // Get the elapsed time as a 'TimeSpan' value.
    TimeSpan ts = stopWatch.Elapsed;
    string strIntervalStopWatch = ts.ToString();
    double msIntervalStopWatch = ts.TotalMilliseconds;

    stopWatch.Reset();        stopWatch.Start();
    // *** sequential search for 5 IP addresses or 5 URLs for 5 given keys in a symbol table
    // *** implemented in a linked list (the 'linkedLSTUn' object) of objects of the 'NodeLLUn' class
    results[5] = linkedLSTun.SearchValueLL(split_inputs[0]);
    results[6] = linkedLSTun.SearchValueLL(split_inputs[1]);
    results[7] = linkedLSTun.SearchValueLL(split_inputs[2]);
    results[8] = linkedLSTun.SearchValueLL(split_inputs[3]);
    results[9] = linkedLSTun.SearchValueLL(split_inputs[4]);
    TimeSpan ts1 = stopWatch.Elapsed;
    string strIntervalStopWatch1 = ts1.ToString();
    double msIntervalStopWatch1 = ts1.TotalMilliseconds;
                                        . . .
// ******** Search for IP addresses or URLs for given keys in a symbol table implemented in an array
// ******** of objects of the 'SeqSearchSTarr' class with the 'refSeqSearchSTarr' reference
// ******** on MULTIPLE threads

  // Declare the 'refAnyM_DelegSeqSearchSTarr' reference to the array of references to objects of
  // the 'AnyM_DelegSeqSearchSTarr' delegate type.
  AnyM_DelegSeqSearchSTarr[] refAnyM_DelegSeqSearchSTarr;

  // Create the 'refAnyM_DelegSeqSearchSTarr' reference to the n-element array of references to
  // objects of the 'AnyM_DelegSeqSearchSTarr' delegate type.
  refAnyM_DelegSeqSearchSTarr = new AnyM_DelegSeqSearchSTarr[n];
  for (int l = 0; l < n; l++)
    // Create the delegate object and bind to the 'SeqSearchSTarr.SearchValueArr' target method
    refAnyM_DelegSeqSearchSTarr[l] =
                        new AnyM_DelegSeqSearchSTarr(SeqSearchSTarr.SearchValueArr);

// Declare the 'refAsyncResults' reference to the array of references to instances of the
  // 'IAsyncResult' interface.
  IAsyncResult[] refAsyncResults;

  // Create the 'refAsyncResults' reference to the array of references to instances of the
  // 'IAsyncResult' interface.
  refAsyncResults = new IAsyncResult[n];

  stopWatch.Reset();          stopWatch.Start();
```

Fig. 5: (continued)

```
for (int z = 0; z < n; z++)
   // Initiate the asychronous call. Start the 'BeginInvoke' method call. The execution on the
   // secondary thread continues immediately without waiting for the return of the 'BeginInvoke'
   // method call.
   refAsyncResults[z] = refAnyM_DelegSeqSearchSTarr[z].BeginInvoke(refSeqSearchSTarr,
                                                split_inputs[z], lines_count, null, null);

string[] returned_values = new string[n];

for (int c = 0; c < n; c++)
{ // Lock the 'obj' object, and block until it is obtained. We need to synchronize access to the
   // 'returned_values' array.
   Monitor.Enter(obj);
   try {
      // When the lock is obtained, write to the 'returned_values' array.
      // Call the 'EndInvoke' method to wait for the asychronous call to complete, and to retrieve
      // the results that will be stored into the 'returned_values' array.
      returned_values[c] = refAnyM_DelegSeqSearchSTarr[c].EndInvoke(refAsyncResults[c]);
   }
   finally
   {   Monitor.Exit(obj);  // Ensure that the lock is released.  }
}
stopWatch.Stop();
TimeSpan ts2 = stopWatch.Elapsed;
string strIntervalStopWatch2 = ts2.ToString();
double msIntervalStopWatch2 = ts2.TotalMilliseconds;
                                            . . .
// ******** Search for IP addresses or URLs for given keys in a symbol table implemented in a linked
// ******** list (the 'linkedLSTUn' object) of objects of the 'NodeLLUn' class on MULTIPLE threads

   // Declare the 'refAnyM_DelegSearchValueLL' reference to the array of references to
   // objects of the 'AnyM_DelegSearchValueLL' delegate type.
   AnyM_DelegSearchValueLL[] refAnyM_DelegSearchValueLL;

   // Create the 'refAnyM_DelegSearchValueLL' reference to the n-element array of
   // references to objects of the 'AnyM_DelegSearchValueLL' delegate type.
   refAnyM_DelegSearchValueLL = new AnyM_DelegSearchValueLL[n];

for (int l = 0; l < n; l++)
   // Create the delegate object and bind to the 'linkedLSTun.SearchValueLL' target method
   refAnyM_DelegSearchValueLL[l] =
                          new AnyM_DelegSearchValueLL(linkedLSTun.SearchValueLL);

IAsyncResult[] refAsyncResultsLL;        refAsyncResultsLL = new IAsyncResult[n];
stopWatch.Reset();        stopWatch.Start();

for (int z = 0; z < n; z++)
   refAsyncResultsLL[z] = refAnyM_DelegSearchValueLL[z].BeginInvoke(split_inputs[z], null, null);

string[] returned_valuesLL = new string[n];

for (int c = 0; c < n; c++)  {
   Monitor.Enter(obj);
   try
   {   returned_valuesLL[c] = refAnyM_DelegSearchValueLL[c].EndInvoke(refAsyncResultsLL[c]); }
   finally
   {   Monitor.Exit(obj);  }
}
```

Fig. 5: (continued)

```
   stopWatch.Stop();
   TimeSpan ts2LL = stopWatch.Elapsed;
   string strIntervalStopWatch2LL = ts2LL.ToString();
   double msIntervalStopWatch2LL = ts2LL.TotalMilliseconds;
                                        . . .
// ******** Search for IP addresses or URLs for given keys in a symbol table in PARALLEL

   string[] returned_valuesP = new string[n];
   string[] returned_valuesLLP = new string[n];

   if (n == 3)  { . . .}                        . . .
   else if (n == 5)  {
// ******** Search for IP addresses or URLs for given keys in a symbol table implemented in an
// ******** array of objects of the 'SeqSearchSTarr' class with the 'refSeqSearchSTarr'
// ******** reference in PARALLEL
   stopWatch.Reset();        stopWatch.Start();

   // Perform five tasks in parallel on the source array
   Parallel.Invoke(
       () =>     // Param #1 - lambda expression
       {    returned_valuesP[0] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr,
                                                   split_inputs[0], lines_count);  }, // close 1st Action
       () =>     // Param #2 - lambda expression
       {    returned_valuesP[1] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr,
                                                   split_inputs[1], lines_count);  }, // close 2nd Action
       () =>     // Param #3 - lambda expression
       {    returned_valuesP[2] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr,
                                                   split_inputs[2], lines_count);  }, // close 3rd Action
       () =>     // Param #4 - lambda expression
       {    returned_valuesP[3] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr,
                                                   split_inputs[3], lines_count);  }, // close 4th Action
       () =>     // Param #5 - lambda expression
       {    returned_valuesP[4] = SeqSearchSTarr.SearchValueArr(refSeqSearchSTarr,
                                                   split_inputs[4], lines_count);  } // close 5th Action
   ); // close Parallel.Invoke

   stopWatch.Stop();        TimeSpan ts2P = stopWatch.Elapsed;
   string strIntervalStopWatch2P = ts2P.ToString();
   double msIntervalStopWatch2P = ts2P.TotalMilliseconds;
                                        . . .
// ******** Search for IP addresses or URLs for given keys in a symbol table implemented in a
// ******** linked list (the 'linkedLSTUn' object) of objects of the 'NodeLLUn' class in PARALLEL
   stopWatch.Reset();        stopWatch.Start();

   // Perform five tasks in parallel on the source array
   Parallel.Invoke(
       () => {    returned_valuesLLP[0] = linkedLSTun.SearchValueLL(split_inputs[0]);  },
       () => {    returned_valuesLLP[1] = linkedLSTun.SearchValueLL(split_inputs[1]);  },
       () => {    returned_valuesLLP[2] = linkedLSTun.SearchValueLL(split_inputs[2]);  },
       () => {    returned_valuesLLP[3] = linkedLSTun.SearchValueLL(split_inputs[3]);  },
       () => {    returned_valuesLLP[4] = linkedLSTun.SearchValueLL(split_inputs[4]);  }
   ); // close Parallel.Invoke

   stopWatch.Stop();        TimeSpan ts2LLP = stopWatch.Elapsed;
   string strIntervalStopWatch2LLP = ts2LLP.ToString();
   double msIntervalStopWatch2LLP = ts2LLP.TotalMilliseconds;
                                        . . .
  }
```

6   Experiment and Its Results

We assume that an implementation of a symbol table in an unordered linked list is more appropriate for sequential, multi-threaded, and for a parallel search for the set of data in a symbol table by the same search methods of a C# application than its implementation in an unordered array of objects.

To verify this hypothesis, we performed an experiment using our C# application that has searched for the same set of values associated with given keys inserted by a user in two implementations of a symbol table, in an unordered array of objects, and in an unordered linked list of objects, sequentially, on multiple threads, and in parallel. This application has also measured the execution times of all sequential, all multi-threaded, and all parallel searches that were executed by its search methods. The C# application has written all execution times together with results of all searches into the *LogFile.txt* disc log file. Using these execution times, we want to confirm or refuse our hypothesis.

During this experiment, our C# application has searched for the same set of 5 IP addresses according to 5 given URLs, *amazon.com*, *microsoft.com*, *sun.com*, *epinions.com*, *aim.com*, and the same set of 5 URLs according to 5 given IP addresses, *72.21.203.1*, *207.46.197.32*, *72.5.124.61*, *64.74.210.45*, *64.12.50.151*, in unordered arrays of objects, and in unordered linked lists of objects using its search methods sequentially, on multiple threads, and in parallel. These unordered arrays of objects, and unordered linked lists of objects contained 50, 100, 150, 200, 250, 300, 350, 400, and 460 the same DNS records.

Search methods of the C# application have the following *identifiers in graphs*:
- for a sequential search:
  SeqSearchSTarr.SearchValueArr -> *SeqSearchSTarr.SearchVal_Seq*
  linkedLSTun.SearchValueLL -> *linkedLSTun.SearchVal_Seq*
- for a search on multiple threads:
  SeqSearchSTarr.SearchValueArr -> *SeqSearchSTarr.SearchVal_MT*
  linkedLSTun.SearchValueLL -> *linkedLSTun.SearchVal_MT*
- for a parallel search:
  SeqSearchSTarr.SearchValueArr -> *SeqSearchSTarr.SearchVal_Par*
  linkedLSTun.SearchValueLL -> *linkedLSTun.SearchVal_Par*

The C# application was running on the computer with the following basic hardware configuration: Intel Core i5-8250U Processor (6MB Cache, 1.60 GHz (Processor Base Frequency), 3.40 GHz (Max Turbo Frequency), 4 GT/s (Bus Speed), 4 Cores, 8 Threads), RAM: 8 GB. The Microsoft Windows 10 Home, 64-bit operating system and the Microsoft .NET Framework 4 were installed on this computer.

One of the outputs of our C# application displayed in the system console after sequential, multi-threaded, and a parallel search for the set of 5 IP addresses according to 5 given URLs, *amazon.com*, *microsoft.com*, *sun.com*, *epinions.com*, *aim.com*, in an unordered array of objects with 460 elements, and in an unordered linked list with 460 nodes, by the same search methods of this application is shown in Fig. 6. The C# application writes the same output into the *LogFile.txt* disc file. The C# application writes the results of other searches into the same *LogFile.txt* file, too.

Fig. 6: The output of our C# application (inputs of the user are written in bold type)

```
Choose input file: dns_modif5.csv (insert: '1'), dns_modif.csv (insert: '2') :  2
Do you want to search for DNS items according to URLs (insert: '1') OR IP addresses (insert: '2')?  1


Insert more URLs separated by ',' that will be used for searching for IP addresses
(e.g. 'espn.com, google.com, yahoo.co.jp, ebay.com, euba.sk, fhi.euba.sk, of.euba.sk, nhf.euba.sk'):
amazon.com, microsoft.com, sun.com, epinions.com, aim.com
                ********** Sequential search **********
      (the number of ALL key-value pairs in an array: 460)
      IP addresses for given URLs found (5) by 'SeqSearchSTarr.SearchValueArr':
            amazon.com, 72.21.203.1
            microsoft.com, 207.46.197.32
            sun.com, 72.5.124.61
            epinions.com, 64.74.210.45
            aim.com, 64.12.50.151
      [Execution time:  00:00:00.0008581, 0,8581 ms]


      IP addresses for given URLs found (5) by 'linkedLSTun.SearchValueLL':
            amazon.com, 72.21.203.1
            microsoft.com, 207.46.197.32
            sun.com, 72.5.124.61
            epinions.com, 64.74.210.45
            aim.com, 64.12.50.151
      [Execution time:  00:00:00.0002989, 0,2989 ms]


            ********** Searching on multiple threads **********
   IP addresses for given URLs found (5) by 'SeqSearchSTarr.SearchValueArr' on multiple threads:
            amazon.com, 72.21.203.1
            microsoft.com, 207.46.197.32
            sun.com, 72.5.124.61
            epinions.com, 64.74.210.45
            aim.com, 64.12.50.151
    [Execution time:  00:00:00.0060288, 6,0288 ms]


   IP addresses for given URLs found (5) by 'linkedLSTun.SearchValueLL' on multiple threads:
            amazon.com, 72.21.203.1
            microsoft.com, 207.46.197.32
            sun.com, 72.5.124.61
            epinions.com, 64.74.210.45
            aim.com, 64.12.50.151
    [Execution time:  00:00:00.0002774, 0,2774 ms]


            ********** Searching in PARALLEL **********
   IP addresses for given URLs found (5) by 'SeqSearchSTarr.SearchValueArr' in PARALLEL:
            amazon.com, 72.21.203.1
            microsoft.com, 207.46.197.32
            sun.com, 72.5.124.61
            epinions.com, 64.74.210.45
            aim.com, 64.12.50.151
    [Execution time:  00:00:00.0088869, 8,8869 ms]


   IP addresses for given URLs found (5) by 'linkedLSTun.SearchValueLL' in PARALLEL:
            amazon.com, 72.21.203.1
            microsoft.com, 207.46.197.32
            sun.com, 72.5.124.61
            epinions.com, 64.74.210.45
            aim.com, 64.12.50.151
    [Execution time:  00:00:00.0004153, 0,4153 ms]
```

Source: (author)

We also computed the speedup of every parallel search, and every multi-threaded search by static, and instance methods of the C# application using *p* computing elements (CPUs) by the following formula

Speedup(p) = Tsequential / T(p)

The term *Tsequential* refers to the execution time of the sequential search by static, and instance methods of the C# application.

The execution times of all sequential, all multi-threaded, and all parallel searches, and speedups of all multi-threaded searches, and all parallel searches that were executed by the C# application search methods are shown in the following graphs.

Fig. 7: The execution times of all sequential, all multi-threaded, and all parallel searches, and speedups of all multi-threaded searches, and all parallel searches that were executed by the C# application search methods
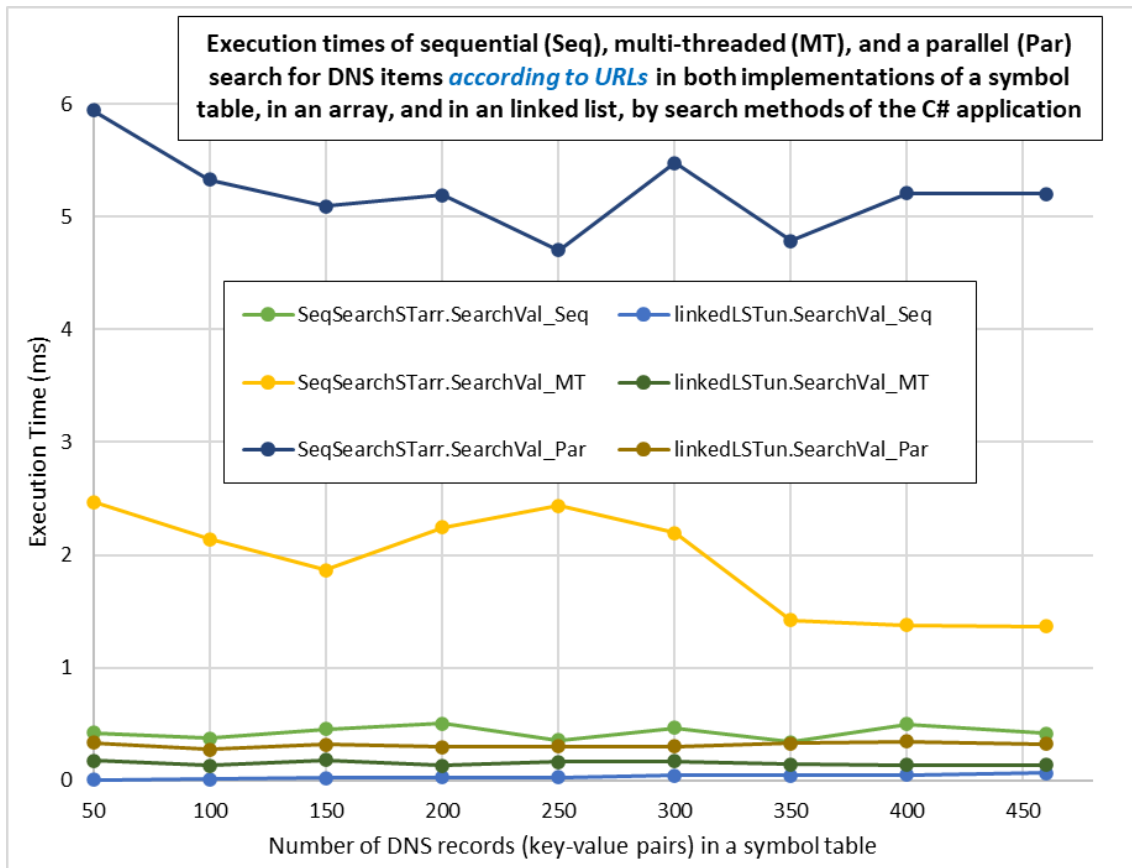
Source: (author)

Fig. 7: (continued)

Fig. 7: (continued)

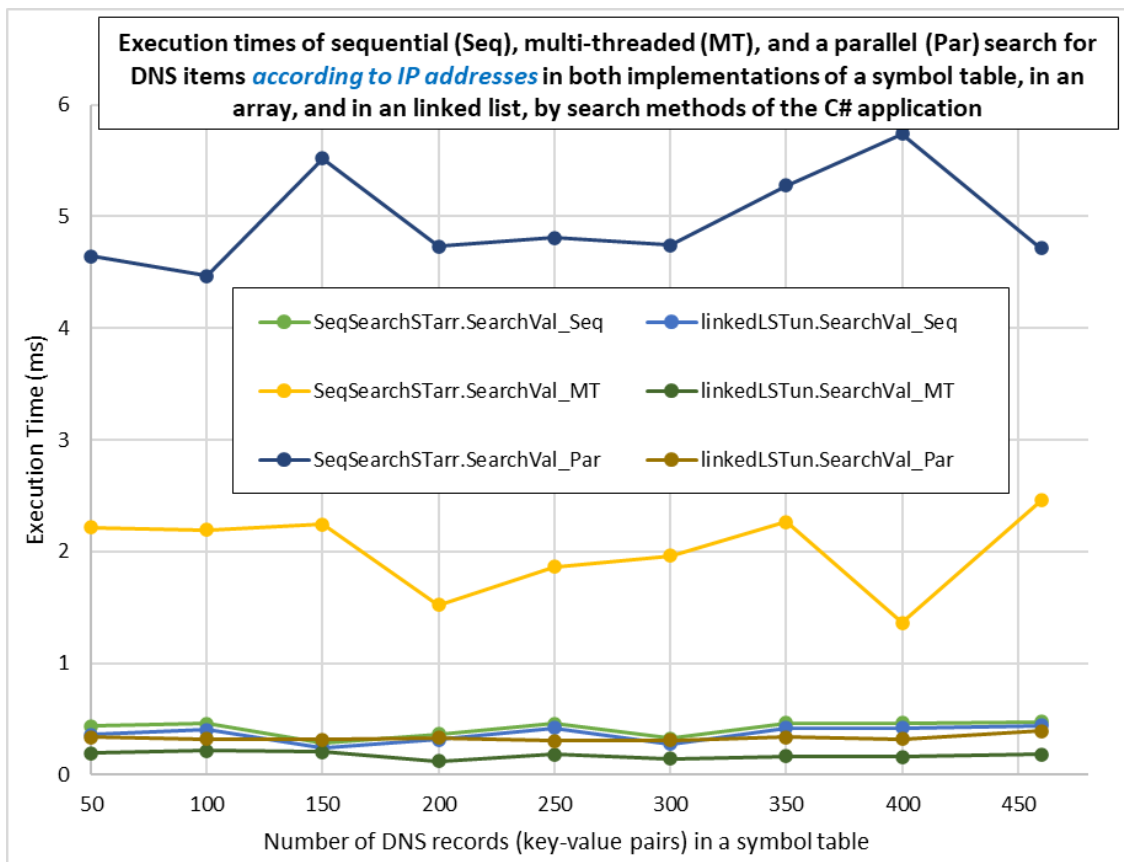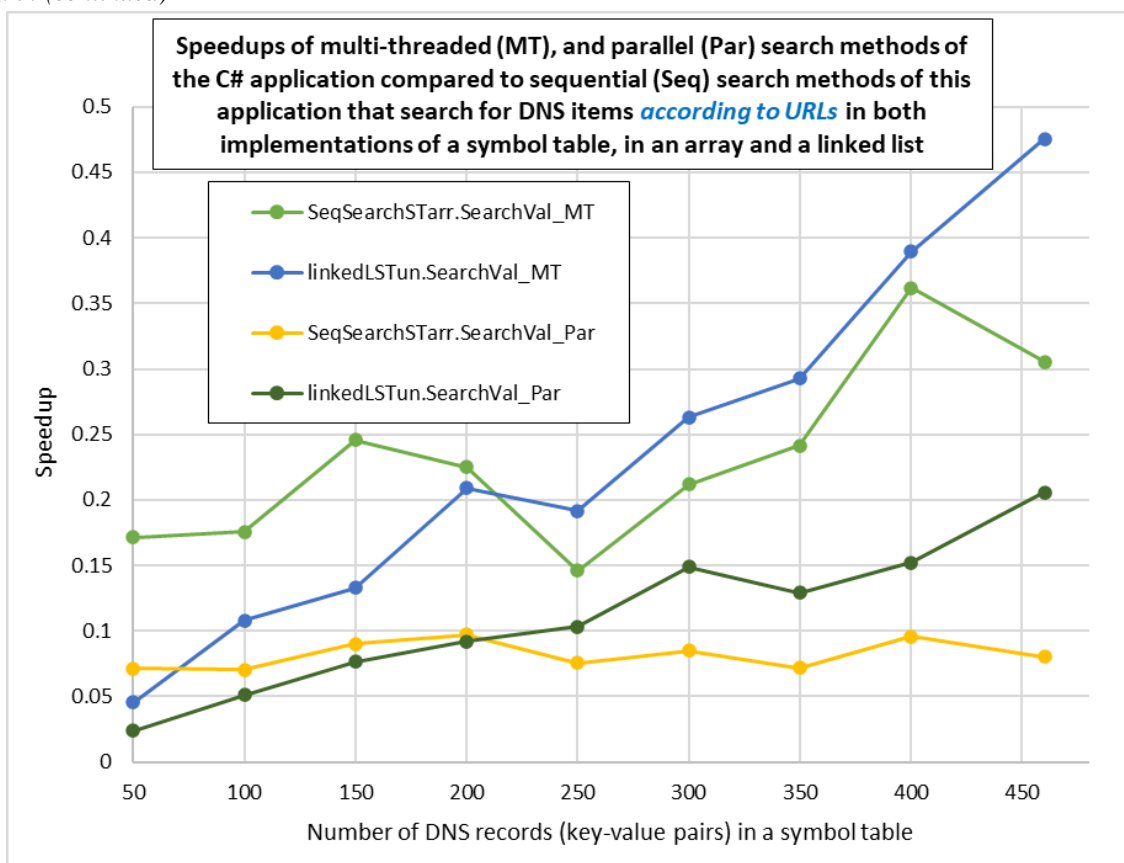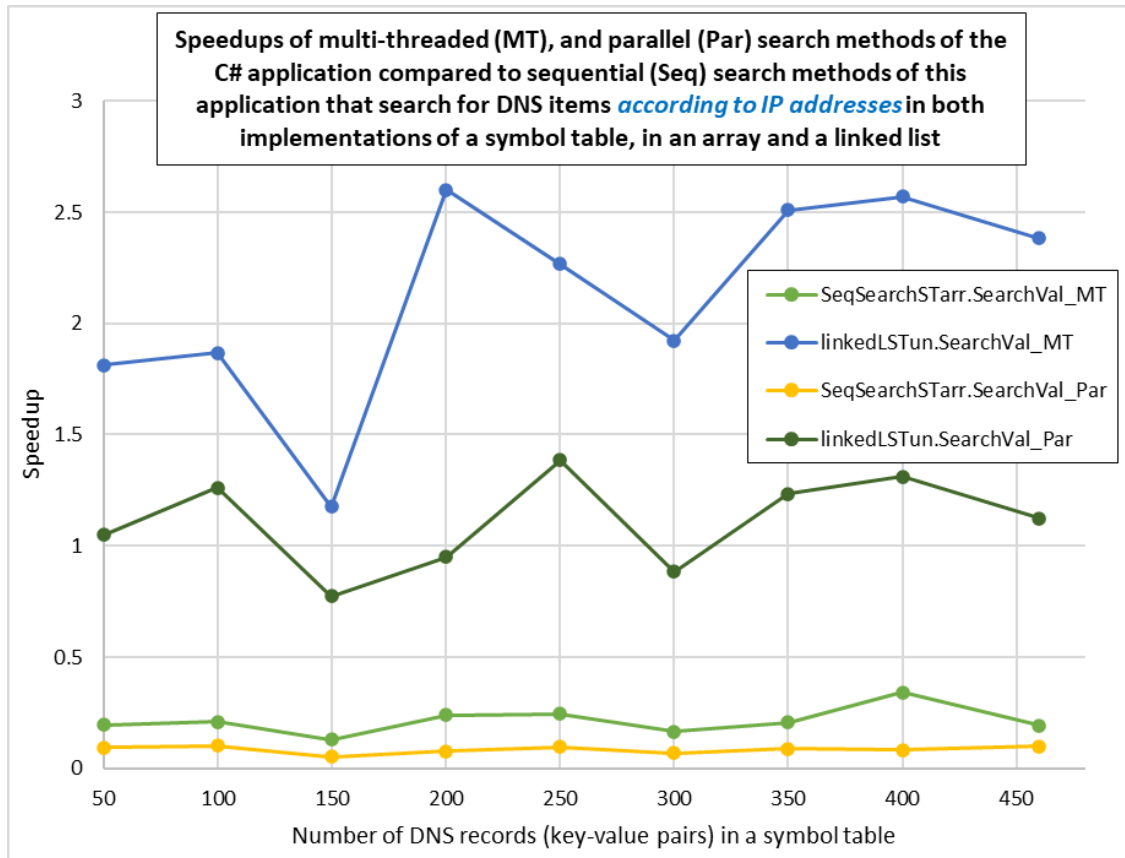*Brief results analysis*. From the graphs showing execution times of all sequential, all multi-threaded, and all parallel searches by the C# application search methods that have searched for the same set of 5 IP addresses according to 5 given URLs, and the same set of 5 URLs according to 5 given IP addresses, in unordered arrays of objects, and in unordered linked lists of objects, it is obvious that searches that were executed in unordered linked lists of objects have significantly shorter execution times than searches that were executed in unordered arrays of objects. Only a sequential search the same set of 5 IP addresses according to 5 given URLs, and the same set of 5 URLs according to 5 given IP addresses in unordered arrays of objects has similar execution times as all sequential, all multi-threaded, and parallel searches in unordered linked lists of objects.

Only speedups of multi-threaded searches, and parallel searches for the same set of 5 URLs according to 5 given IP addresses in unordered linked lists of objects have values greater than 1, parallel searches achieve the highest speedups, up to 2.6. Speedups of multi-threaded searches, and parallel searches for the same set of 5 IP addresses according to 5 given URLs in unordered arrays of objects, and in unordered linked lists of objects have values less than 1, it is even deceleration.

From all results of the experiment, it is clear that the implementation of a symbol table in an unordered linked list of objects is a better choice for sequential, multi-threaded, and a parallel search by the C# application search methods than its implementation in an unordered array of objects.

7 Conclusion

From the results of the comparison of the execution times of all sequential, all multi-threaded, and all parallel searches by the C# application search methods that have searched for the same set of 5 IP addresses according to 5 given URLs, and the same set of 5 URLs according to 5 given IP addresses, in unordered arrays of objects, and in unordered linked lists of objects, it is obvious that searches that were executed in unordered linked lists of objects have significantly shorter execution times than searches that were executed in unordered arrays of objects. Also, speedups of multi-threaded searches, and parallel searches for the same set of 5 URLs according to 5 given IP addresses in unordered linked lists of objects have values greater than 1, parallel searches achieve the highest speedups, up to **2.6**.

From all results of the experiment, it is clear that the implementation of a symbol table in an unordered linked list of objects is a better choice for sequential, multi-threaded, and a parallel search by the C# application search methods than its implementation in an unordered array of objects. It confirms our hypothesis.

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A PARALLELIZATION OF THE CALCULATION OF PARTIAL SUMS OF CONVERGENT INFINITE NUMBER SERIES IN A C# APPLICATION

Igor Košťál[1], Peter Schmidt [2]

Abstract

Mathematicians often study convergent infinite series. They need to know the partial sum of a huge number of terms of a series, e.g., a partial sum of 500 million or 1 billion terms. Or they need to examine the speed of convergence to the target number of a given number series, etc. It is difficult to calculate these parameters of convergent infinite number series by ordinary computing means and with the help of office software. We have created a C# application that can calculate such parameters of the Leibniz, Euler and Bailey-Borwein-Plouffe number series. The methods of our C# application calculate the partial sums of the required number of terms of these series sequentially, in parallel, and in parallel with the partitioner, which should be the most efficient way of a calculation from these listed. To confirm or refute this assumption, we have performed an experiment in which we have examined the execution efficiency of sequential, parallel, and parallel instance methods working with the partitioner of our C# application calculating the partial sums of the required numbers of terms of the specified series. The results of this experiment, as well as a brief description of these instance methods are presented in the paper.

Keywords (Space Before: 12 p, Space After: 6 p, Times New Roman 13p, Bold)

convergent infinite series, the Leibniz, Euler and Bailey-Borwein-Plouffe number series, data parallelism

1   Introduction

As we mentioned above, mathematicians often need to examine the parameters of convergent infinite number series, e.g., the sum of a huge number of their terms or the speed of convergence to a target number of such series. It is difficult to calculate e.g., a partial sum of 500 million or 1 billion terms of a given series by ordinary computing means and with the help of office software. We have created a C# application that can calculate partial sums of such huge numbers of terms of the Leibniz, Euler and Bailey-Borwein-Plouffe (BBP) series. Our C# application tries to calculate these partial sums efficiently with the maximum use of the target computer computing resources, because it also includes parallel methods. We assume that C# application parallel methods should be more efficient in execution than its sequential methods. To confirm or refute this assumption, we have performed an experiment in which we have examined the execution efficiency of sequential, parallel, and parallel instance methods working with the partitioner of our C# application calculating the partial sums of the required numbers of terms of the specified series. A short description and results of this experiment are presented in the *Experiment and Its Results* chapter. In the *Series, Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) number series* chapter, we briefly deal with these series. *The Task Parallel Library, Kinds of a Parallelism, the Parallel.For and Parallel.ForEach methods*

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chapter contains a brief description of the Task Parallel Library, a brief overview of the kinds of parallelism supported by the .NET Framework class libraries, and a description of the *Parallel.For* and *Parallel.ForEach* static parallel methods. In the *C# application and its methods* chapter, we describe the sequential, parallel, and parallel methods with the partitioner of our application. In the *Conclusion*, we summarize the results of the performed experiment.

2   A Series, the Leibniz, Euler, and Bailey-Borwein-Plouffe Number Series

A *series* is an infinite ordered set of terms combined together by the addition or subtraction operator. The fact that a series is *infinite* means that a series contains an infinite number of terms. A series may converge to a definite value, it is a convergent series, or may not, in which case it is called divergent. For a given series it means, if the sequence of partial sums of its terms converges to a definite value, the series is said to converge. On the other hand, if the sequence of partial sums of series terms does not converge to a limit (e.g., it oscillates or approaches $\pm \infty$), the series is said to be divergent. (Wolfram MathWorld, 2022, 2, 3, 5)

The series for the inverse tangent, also denoted *arctan* (Bartsch, 1983)

$$arctan\, x = x - \frac{x^3}{3} + \frac{x^5}{5} - \frac{x^7}{7} + \cdots \tag{1}$$

Plugging in $x = 1$ gives the formula (Bartsch, 1983)

$$\frac{\pi}{4} = arctan\, 1 = 1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + \cdots \tag{2}$$

It is a convergent infinite alternating series called the **Leibniz series** (Wolfram MathWorld, 2022, 4). This series converges very slowly to the $\pi/4$ target number.

The **Euler series** is also a convergent infinite alternating series (Bartsch, 1983)

$$\frac{\pi}{4} = arctan\, \frac{1}{2} + arctan\, \frac{1}{3} = \left(\frac{1}{2} + \frac{1}{3}\right) - \frac{1}{3}\left(\frac{1}{2^3} + \frac{1}{3^3}\right) + \frac{1}{5}\left(\frac{1}{2^5} + \frac{1}{3^5}\right) - \cdots \tag{3}$$

The **Bailey-Borwein-Plouffe series** is a convergent infinite series (Bailey, 1997) (Wolfram MathWorld, 2022, 1)

$$\pi = \sum_{i=0}^{\infty} \frac{1}{16^i}\left(\frac{4}{8i+1} - \frac{2}{8i+4} - \frac{1}{8i+5} - \frac{1}{8i+6}\right) \tag{4}$$

All these series can be used for calculating the value of π. We have implemented the formulas 2, 3, and 4 into member methods of the C# application.

3   The Task Parallel Library, Kinds of a Parallelism, the *Parallel.For* and *Parallel.ForEach* Methods

We have created a C# application with methods that implement the Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) series. This application has three methods - sequential, parallel, and parallel with a partitioner for each from these series. Parallel methods use class library types from the Task Parallel Library.

This Task Parallel Library (TPL) is a set of public types and APIs (Application Programming Interfaces) in the *System.Threading* and *System.Threading.Tasks* namespaces in

the NET Framework. The purpose of the TPL is to make developers more productive by simplifying the process of adding parallelism and concurrency to applications. (Microsoft, 2022)

In parallel programming in the .NET Framework we know two kinds of a parallelism - task and data parallelism.

The Task Parallel Library, as its name implies, is based on the concept of the task. The term **task parallelism** refers to one or more tasks running concurrently. A task represents an asynchronous operation, and in some ways it resembles the creation of a new thread or *ThreadPool* work item, but at a higher level of abstraction. (Microsoft, 2022) We did not use task parallelism in a parallelized code of our C# application.

Data parallelism refers to scenarios in which the same operation is performed concurrently (that is, in parallel) on elements in a source collection or array. Data parallelism with imperative syntax is supported by several overloads of the *For* and *ForEach* methods in the *System.Threading.Tasks.Parallel* class through which TPL supports this parallelism. In data parallel operations, the source collection is partitioned so that multiple threads can operate on different segments concurrently. We do not have to create threads or queue work items. The TPL handles all the low-level work for us. When a parallel loop runs, the TPL partitions the data source so that the loop can operate on multiple parts concurrently. Behind the scenes, the *Task Scheduler* partitions the task based on system resources and workload. When it is possible, the scheduler redistributes work among multiple threads and processors if the workload becomes unbalanced. However, we can also supply our own custom partitioner or scheduler. (Microsoft, 2022) Data parallelism with the *Parallel.For* and *Parallel.ForEach* methods is used in a parallelized code of our C# application.

Parallel.For is a static method with several overloaded versions. Here is the signature and brief description of the version of *Parallel.For* from (Microsoft, 2022) that is used in a parallelized code of methods of our C# application. This description explains how this method operates in this code.

```
For<TLocal>(Int32, Int32, Func<TLocal>, Func<Int32, ParallelLoopState,
TLocal, TLocal>, Action<TLocal>)
```

The method executes a *for* loop with thread-local data in which iterations may run in parallel, and the state of the loop can be monitored and manipulated.

Syntax (in C#)

```
public static System.Threading.Tasks.ParallelLoopResult For<TLocal> (
int fromInclusive, int toExclusive, Func<TLocal> localInit,
Func<int, System.Threading.Tasks.ParallelLoopState, TLocal, TLocal> body,
Action<TLocal> localFinally);
```

Parameters

fromInclusive - the start index, inclusive.
toExclusive - the end index, exclusive.
localInit - the function delegate that returns the initial state of the local data for each thread.
body - the delegate that is invoked once per iteration.
localFinally - the delegate that performs a final action on the local state of each thread.
Returns

A *ParallelLoopResult* structure that contains information about which portion of the loop completed.

Remarks

The *body* delegate is invoked once for each value in the iteration range: <*fromInclusive*, *toExclusive*). It is provided with the following parameters: the iteration count (*Int32*), a *ParallelLoopState* instance that may be used to break out of the loop prematurely, and some local state that may be shared amongst iterations that execute on the same thread.

The *localInit* delegate is invoked once for each thread that participates in the loop's execution and returns the initial local state for each of those threads. These initial states are passed to the first *body* invocations on each thread. Then, every subsequent *body* invocation returns a possibly modified state value that is passed to the next *body* invocation. Finally, the last *body* invocation on each thread returns a state value that is passed to the *localFinally* delegate. The *localFinally* delegate is invoked once per thread to perform a final action on each thread's local state. This delegate might be invoked concurrently on multiple threads; therefore, we must synchronize access to any shared variables (the *pi* variable in the source codes of the *ParallelPi_Leibniz*, *ParallelPi_Euler*, and *ParallelPi_BBP* our parallelized methods).

Parallel.ForEach is also a static method with several overloaded versions. Here is the signature and brief description of the version of *Parallel.ForEach* from (Microsoft, 2022) that is used in a parallelized code of methods of our C# application. This description explains how this method operates in this code.

```
ForEach<TSource, TLocal>(Partitioner<TSource>, Func<TLocal>, Func<TSource,
ParallelLoopState, TLocal, TLocal>, Action<TLocal>)
```

Syntax (in C#)

```
public static System.Threading.Tasks.ParallelLoopResult ForEach<TSource,
TLocal> (System.Collections.Concurrent.Partitioner<TSource> source,
Func<TLocal> localInit,
Func<TSource,System.Threading.Tasks.ParallelLoopState,TLocal,TLocal> body,
Action<TLocal> localFinally);
```

Parameters

source - the partitioner that contains the original data source.
localInit - the function delegate that returns the initial state of the local data for each
        thread.
body - the delegate that is invoked once per iteration.
localFinally - the delegate that performs a final action on the local state of each thread.

Returns

A *ParallelLoopResult* structure that contains information about which portion of the loop completed.

Remarks

This overload is provided for scenarios where you want to override the default partitioning scheme. For example, small loop bodies might benefit from partitioning the range.

The description of the *localInit*, *body*, and *localFinally* delegates is the same as the description of the same delegates in the Remarks of the *Parallel.For* method above.

4   A C# application, Its Methods

Our C# application with methods that implement the Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) series, was created in the C# language, and was built in the Microsoft Visual Studio 2019 development environment. This application has three methods - sequential, parallel, and parallel with a partitioner for each from these series. The source code of this application contains the *Program* class that has the following member methods:

- *SequentialPi_Leibniz*, *SequentialPi_Euler*, *SequentialPi_BBP* (Fig. 1) - the static member methods that implement the Leibniz, Euler, and BBP series using the formulas 2, 3 and 4. These methods compute the partial sums of given numbers of terms of these series by a *for* loop sequentially.
- *ParallelPi_Leibniz*, *ParallelPi_Euler*, *ParallelPi_BBP* (Fig. 2) - the static member methods that also implement the Leibniz, Euler, and BBP series using the formulas 2, 3 and 4. However, these methods compute the partial sums of given numbers of terms of these series by the *Parallel.For* method in parallel.
- *ParallelPartitPi_Leibniz*, *ParallelPartitPi_Euler*, *ParallelPartitPi_ BBP* (Fig. 3) - the static member methods that also implements the Leibniz, Euler, and BBP series using the formulas 2, 3 and 4. These methods compute the partial sums of given numbers of terms of these series by the *Parallel.ForEach* method in parallel with the partitioner.

Fig. 2: The source code of the 'SequentialPi_BBP' static member method

```
static double SequentialPi_BBP(int nx) {
  double pi = 0.0;
  for (int i = 0; i < nx; i++)
          // the BBP series is implemented in this statement using the formula 4
      pi += 1 / (Math.Pow(16, i)) * (4.0 / (8 * i + 1) - 2.0 / (8 * i + 4) - 1.0 / (8 * i + 5) - 1.0 / (8 * i + 6));

  return pi;  }
```

Source: (author)

Fig. 2: The source code of the 'ParallelPi_BBP' static member method that uses the 'Parallel.For' method

```
static double ParallelPi_BBP(int nx)  {
  double pi = 0.0;
  object monitor = new object();
                    // thread local initializer
  Parallel.For(0, nx, () => 0.0, (i, state, local) =>        // body
  {
              // the BBP series is implemented in this statement using the formula 4
    return local + 1 / (Math.Pow(16, i)) * (4.0 / (8 * i + 1) - 2.0 / (8 * i + 4) - 1.0 / (8 * i + 5) - 1.0 /
                                                                            (8 * i + 6));

  }, local => { lock (monitor) pi += local; });

  return pi;  // The result of all thread-local computations.  }
```

Source: (author)

Fig. 3: The source code of the 'ParallelPartitPi_BBP' static member method that uses the 'Parallel.ForEach' method

```
static double ParallelPartitPi_BBP(int nx)
{
  double pi = 0.0;

  object monitor = new object();
                        // a range partitioner        // thread local initializer
  Parallel.ForEach(Partitioner.Create(0, nx), () => 0.0, (range, state, local) =>      // body
  {
    for (int i = range.Item1; i < range.Item2; i++)
            // the BBP series is implemented in this statement using the formula 4
     local += 1 / (Math.Pow(16, i)) * (4.0 / (8 * i + 1) - 2.0 / (8 * i + 4) - 1.0 / (8 * i + 5) - 1.0 / (8 * i + 6));
    return local;
  }, local => { lock (monitor) pi += local; });
  return pi;  // The result of all thread-local computations.
}
```

Source: (author)

The C# application measures execution times of all sequential, parallel, and parallel static methods working with the partitioner in its *Main* method and saves them into the *LogFile.txt* log file on the hard disc and displays them into the console.

5   Experiment and Its Results

We performed the experiment to measure the execution efficiency of parallelized methods of the C# application compared to sequential methods of the same application. Execution times of particular sequential and parallel methods provides us C# application itself. It measures these times in its *Main* method, saves them into the *LogFile.txt* log file on the hard disc and displays them into the console. We used the measured execution times for calculations of speedups of parallel methods, and parallel methods using the partitioner of our C# application in opposite to sequential methods of the same C# application calculating the partial sums of the required numbers of terms of the specified series.

The C# application was running on the computer with the following basic hardware configuration: Intel Core i5-8250U Processor (6MB Cache, 1.60 GHz (Processor Base Frequency), 3.40 GHz (Max Turbo Frequency), 4 GT/s (Bus Speed), 4 Cores, 8 Threads), RAM: 8 GB. The Microsoft Windows 10 Home, 64-bit operating system and the Microsoft .NET Framework 4 were installed on this computer.

During the experiment, the parallel methods, the parallel methods using the partitioner, and the sequential methods of the C# application were calculating the partial sums of 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 million terms of the Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) series. The C# application have measured the execution time of each of these calculations. By comparing the execution times of both types of parallel methods with the execution times of sequential methods, we have examined the execution efficiency and the speedup of both types of parallel methods compared to sequential methods.

We also computed the speedup of every parallel method using *p* computing elements (CPUs) by the following formula

Speedup(p) = Tsequential / T(p)

The term *Tsequential* refers to the execution time of the sequential version of the given method.

Using values of partial sums of 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, and 1000 million terms of the Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) series, that was computed by parallel methods with partitioner of the C# application, we have examined the speed of convergence to the target number of the given series.

One of the outputs of our C# application displayed in the system console after sequential and parallel computations of partial sums of 1000 million terms of the Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) series is shown in Fig. 4. The C# application writes the same output into the *LogFile.txt* disc file. The C# application writes the results of other computations into the same *LogFile.txt* file, too.

Fig. 4: The output of our C# application (inputs of the user are written in bold type)

```
Insert the number of steps of particular computations: 1000000000

The numerical computation of PI by methods with implemented the Leibniz, Euler and Bailey-Borwein-
Plouffe (BBP) series with the 1000000000 (1 billion) number of steps


                                Pi exactly: 3,14159265358979...

00:00:02.6909067, 2690,9067 (ms):        3,14159265258805 computed by the 'SequentialPi_Leibniz' m.
00:00:04.2322018, 4232,2018 (ms):        3,14159265258959 computed by the 'ParallelPi_Leibniz' m.
00:00:01.1526774, 1152,6774 (ms):        3,14159265259055 computed by the 'ParallelPartitPi_Leibniz' m.


----


00:02:50.0007275, 170000,7275 (ms):      3,14159265358979 computed by the 'SequentialPi_Euler' m.
00:00:51.8974371, 51897,4371 (ms):       3,14159265358979 computed by the 'ParallelPi_Euler' m.
00:00:50.0961482, 50096,1482 (ms):       3,14159265358979 computed by the 'ParallelPartitPi_Euler' m.


----


00:01:32.9961930, 92996,193 (ms):        3,14159265358979 computed by the 'SequentialPi_BBP' m.
00:00:29.3435419, 29343,5419 (ms):       3,14159265358979 computed by the 'ParallelPi_BBP' m.
00:00:24.5335860, 24533,586 (ms):        3,14159265358979 computed by the 'ParallelPartitPi_BBP' m.
```

Source: (author)

Execution times of all methods and speedups of all parallel and parallel methods using a partitioner of our C# application calculating the partial sums of the required numbers of terms of specified series, and values of the partial sums of the required numbers of terms of specified series calculated by parallel methods with a partitioner are shown in the following graphs.

Fig. 5: Execution times of all methods and speedups of all parallel and parallel methods using a partitioner of our C# application calculating the partial sums of the required numbers of terms of specified series
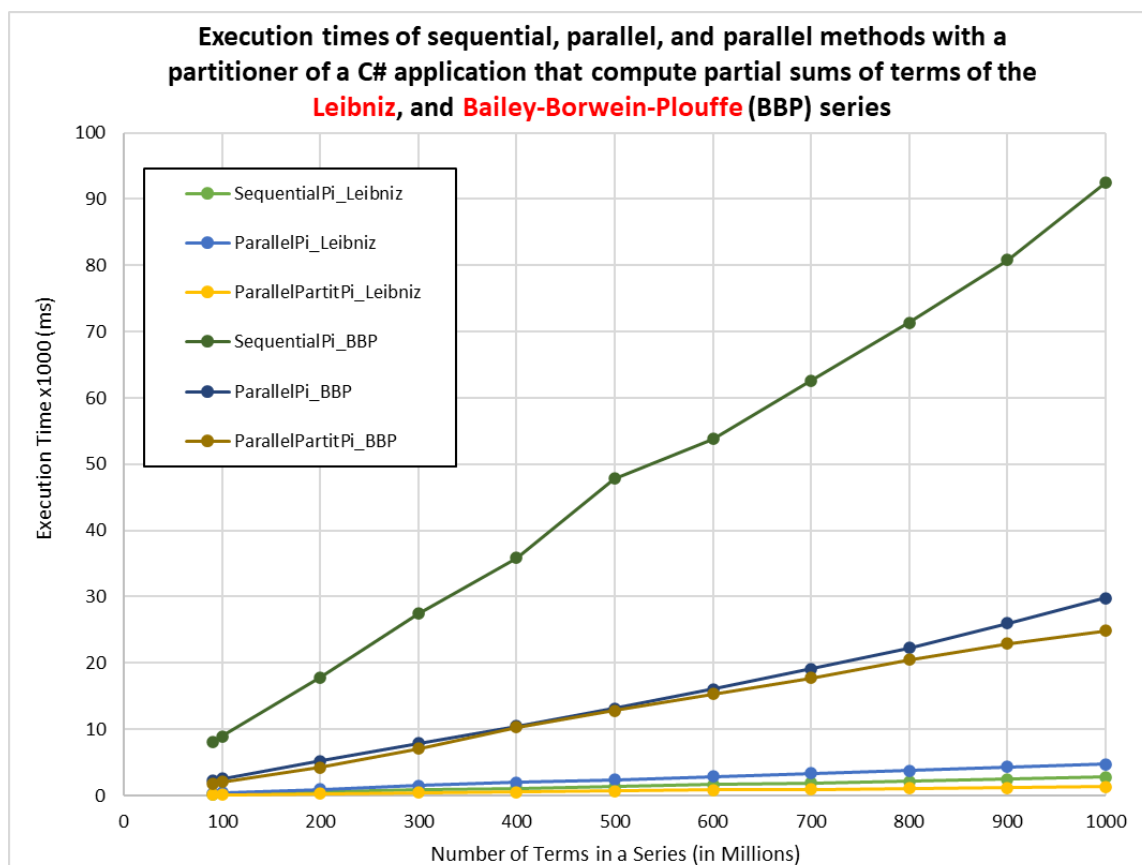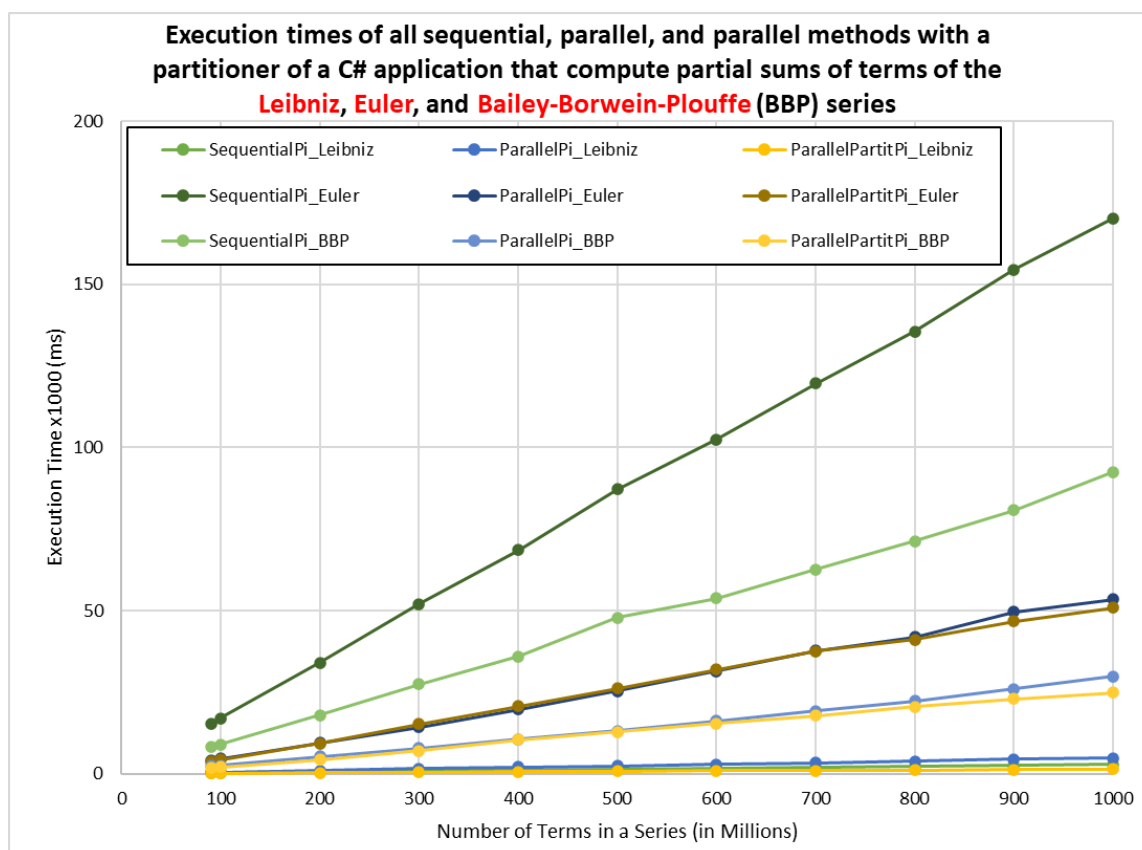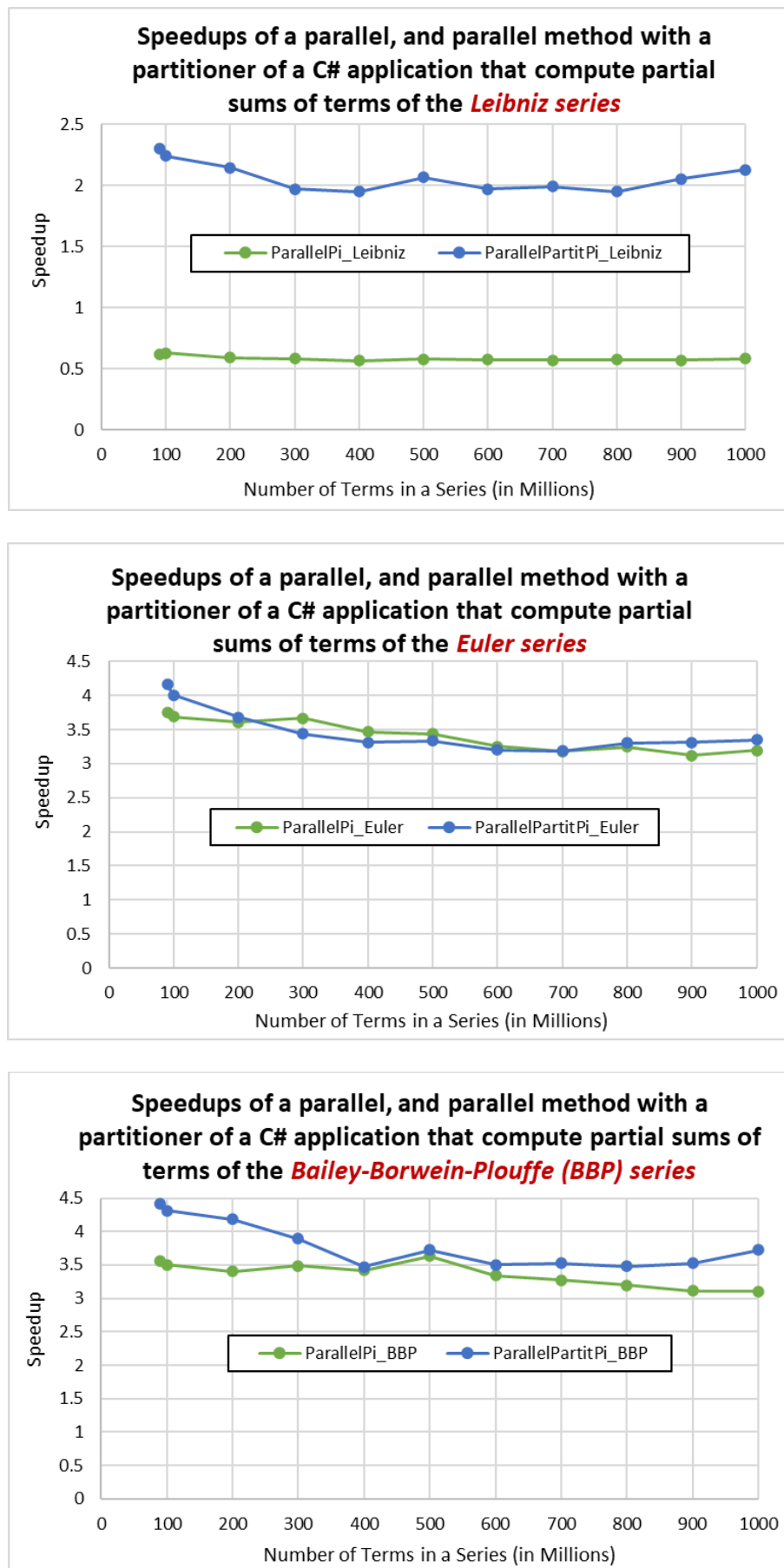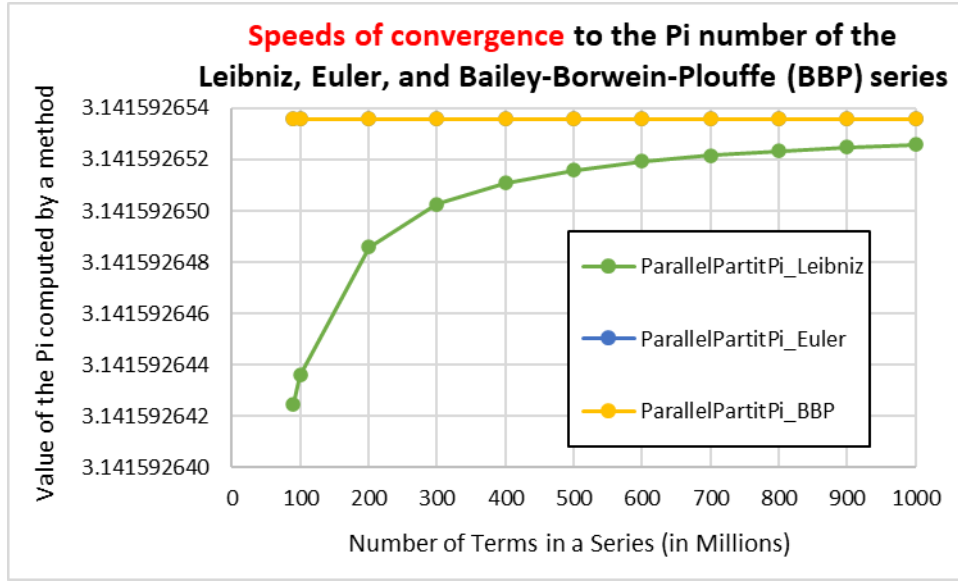

Source: (author)

Fig. 5: (continued)

Fig. 6: Speeds of convergence to the Pi number of the Leibniz, Euler, and Bailey-Borwein-Plouffe (BBP) series (the graph of the 'ParallelPartitPi_Euler' method is overlapped by the graph of the 'ParallelPartitPi_BBP' method)

Source: (author)

Brief results analysis. From the presented graphs showing execution times of all sequential, parallel, and parallel methods using a partitioner of a C# application that compute partial sums of terms of the Leibniz, Euler, and Bailey-Borwein-Plouffe series in dependency on the numbers of terms in series it is obvious that parallel methods have significantly shorter execution times compared to sequential methods. Parallel methods, and parallel methods using a partitioner of a C# application have relatively large speedups, up to 4.3 when computing partial sums of terms of the Bailey-Borwein-Plouffe series by a parallel method using a partitioner, compared to sequential methods of the same C# application.

From the graph (Fig. 6) showing speeds of convergence to the Pi number of the Leibniz, Euler, and Bailey-Borwein-Plouffe series it is obvious that the Leibniz series converges to the Pi number the slowest.

6   Conclusion

Parallel methods, and parallel methods using a partitioner of our C# application presented in this paper are able to calculate partial sums of relatively a large number of terms (up to 1 billion) of the Leibniz, Euler, and Bailey-Borwein-Plouffe series with significantly shorter execution times than sequential methods of the same C# application.

Parallel methods using a partitioner of this C# application have relatively large speedups, up to **4.3** when computing partial sums of terms of the Bailey-Borwein-Plouffe series, compared to sequential methods of the same C# application. This enables our C# application to achieve very interesting execution efficiency in the calculations of partial sums of terms of the Leibniz, Euler, and Bailey-Borwein-Plouffe series by these parallel methods. Therefore, our C# application can be used by mathematicians when they examine the Leibniz, Euler, and Bailey-Borwein-Plouffe series and they need to know the partial sum of a huge number of terms of these series, for example, the partial sum of **1 billion** terms, or they need to examine the speed of convergence to the target number of these series.

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COMPARISON OF EXECUTION EFFICIENCY OF AN INDEX SORT AND REFERENCE SORT OF STRUCTURED DATA IN THE QUICKSORT ALGORITHM

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Abstract

Unsorted structured data can be sorted by different ways: by a direct sort, when the entire items to be sorted are moved, if they are large, it can be an inefficient way, or by an indirect sort: we rearrange not the items themselves, but rather an array of references (or indices) such that the first reference (or index) refers to the greatest item, the second reference (or index) refers to the next greatest item, and so forth. In this case, we only move references or indices, not large items. These two ways of an indirect sort, a reference and index sort, interest us, because they appear to be more execution efficient than a direct sort, in which the entire items to be sorted are moved. We wanted to know which of these two ways of an indirect sort, a reference or index sort, is more execution efficient if we use them in the Quicksort algorithm. To research their execution efficiency, we created a C# application that contains three sorting methods with an implemented Quicksort algorithm that sort structured data. The first method uses a moving sort, the second a reference sort and the third method uses an index sort. The C# application measures the execution time of sorting each structured data set by these sorting methods and records it along with the sorting results into a disk log file. By evaluating the comparison of these execution times, we determined in the experiment which way of sorting structured data, a reference or index sort, is more execution efficient in the Quicksort algorithm. The results and evaluation of the experiment are presented in the paper.

Keywords

direct sort, indirect sort, reference sort, index sort, the Quicksort algorithm, C# application

1 Introduction

As we mentioned above, we are interested in the execution efficiency of an index sort and a reference sort of structured data, because such ways of indirect data sort can be more execution efficient, especially when sorting huge sets of structured data, than a direct moving sort. The higher execution efficiency of an index and reference sort of structured data when sorting huge sets of structured data should be caused by the fact that in such sorts only indices or references are moved, not entire, often large, structured items to be sorted are moved. In the paper, we research the execution efficiency of an index and a reference sort of structured data using our C# application that sorts the same sets of structured data using its three instance methods. The first method uses a moving sort, the second uses a reference sort, and the third method uses an index sort. The C# application measures the execution time of sorting each structured data set by these sorting methods and records it along with the sorting results into a disk log file. In the chapter *Experiment, its Results and their Brief Analysis*, we determined using the evaluation of

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the comparison of these execution times, which method of sorting structured data, reference or index, is more execution efficient in the Quicksort algorithm. In the chapter *A Direct and Indirect Sort, Index and Reference Sorting*, we briefly deal with the principles of such sorting and briefly with a direct moving sort. In the chapter *C# Application, its Methods*, we briefly describe the class architecture of our C# application, its key sorting methods in more detail and their use in sorting a structured data set. In the *Conclusion*, we summarize the results of the performed experiment.

2   A Direct and Indirect Sort, Index and Reference Sorting

Sorting programs normally access items to be sorted in one of two ways: either keys are accessed for comparison, or entire items are accessed to be moved (Sedgewick, 1998). It is a *direct sort*. If these items are large, their moving is not execution effective. A better way of their sorting in this case is to use an *indirect sort*: we rearrange not the items themselves, but rather an array of references (or indices) such that the first reference (or index) refers to the greatest item, the second reference (or index) refers to the next greatest item, and so forth (Sedgewick, 1998). In this case we only move references or indices not large items.

A reference and index sort are two kinds of an indirect sort that sorting items without moves of them. An *index sort* maintains an index array with keys in the items accessed only for comparisons. Suppose that the items to be sorted are in an array *ref2dArrSts[0][0], …, ref2dArrSts[N-1][0]*, and that we do not wish to move them around, for some reason (perhaps they are large). To get the effect of sorting, we use a second array a of item indices. We begin by initializing *I[i]* to *i* for *i = 0, …, N-1*. That is, we begin with *I[0]* having the index of the first data item, *I[1]* having the index of the second data item, and so on. The goal of the sort is to rearrange the index array a such that *I[0]* gives the index of the data item with the greatest key, *I[1]* gives the index of the data item with the second greatest key, and so on. Then we can achieve the effect of sorting by accessing the keys through the indices. (Sedgewick, 1998)

But a *reference sort* is much more general, because the references could point anywhere, and the items being sorted do not need to be fixed in size. As is true in index sorting, if *ref2dArrSts* is an array of references to keys, then a call to sort will result in the references being rearranged such that accessing them sequentially will access the keys in order. We implement comparisons by following references; we implement exchanges by exchanging the references. (Sedgewick, 1998)

3   The Quicksort Algorithm

The Quicksort algorithm (Khreisat, 2007) works by partitioning an array into two parts (Abhyankar & Ingle, 2011), then sorting the parts independently (Drozdek, 2013). The crux of the method is the partitioning process, which rearranges the array to make the following three conditions hold:
- The element *a[i]* is in its final place in the array for some *i*.
- None of the elements in *a[l], …, a [i-1]* is greater than *a[i]*.
- None of the elements in *a[i+1], …, a[r]* is less than *a[i]*.

We achieve a complete sort by partitioning, then recursively applying the method to the subfiles.

We use the following general strategy to implement partitioning. First, we arbitrarily choose *a[r]* to be the partitioning element (Fredman, 2014, El-Aker, 2005) - the one that will go into its final position. Next, we scan from the left end of the array until we find an element greater than the partitioning element, and we scan from the right end of the array until we find

an element less than the partitioning element. (Durand, 2003) The two elements that stopped the scans are obviously out of place in the final partitioned array, so we exchange them. Continuing in this way, we ensure that no array elements to the left of the left pointer are greater than the partitioning element, and no array elements to the right of the right pointer are less than the partitioning element, as depicted in the following Fig. 1:

Fig. 3: The array to be sorted by the Quicksort algorithm
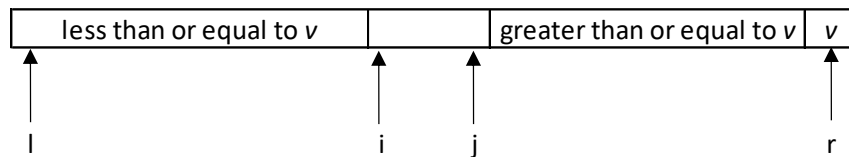
Source: (Sedgewick, 1998)

Here, v refers to the value of the partitioning element, i to the left pointer, and j to the right pointer. As indicated in Fig. 1, it is best to stop the left scan for elements greater than *or equal to* the partitioning element and the right scan for elements less than *or equal to* the partitioning element. (Sedgewick, 1998)

4   C# Application, its Methods

Our C# application that contains three sorting methods with an implemented Quicksort algorithm that sort structured data was created and built in the Microsoft Visual Studio 2019 development environment for the Microsoft .NET Framework version 4 and for the Microsoft operating systems Windows 10 and Windows 11. The first sorting method uses a moving sort, the second a reference sort and the third sorting method uses an index sort. A C# application also measures the execution time of sorting each structured data set by these sorting methods. The source code of this application contains the following three classes:

- **Date** - an object of this class contains a date of birth of a student. This object is the *birthday* instance variable of an object of the *Student* class. The *Date* class has the *d*, *m* and *y* member variables that serve to store the day, month, and year of birth of a student.
- **Student** - an object of this class contains a data of a student. These objects are elements of the *ref2dArrSts* dynamic array of objects of the *Student* class that contain data of students. The *Student* class has the *firstname*, *surname*, *residence*, *birthday* (the object of the *Date* class), *points_acc*, *income*, *distance_resid*, *aver_grade* and *isic* member variables that serve to store the data of a student.
- **IndexS_QuickS** - an object of this class contains the *ref2dArrSts* dynamic array of objects of the *Student* class that contain data of students. The *IndexS_QuickS* class has the following member methods:
  - *CreateStudentsArray* - the method reads data of students line by line from the *srx* data stream associated with a given disk file, creates the *ref2dArrSts* two-dimensional dynamic array of objects of the *Student* class, creates objects of the *Student* class, inserts them into the *ref2dArrSts* array of such objects, and inserts the read data of students into instance variables of these objects.
  - *Compare_sts* - the private member method compares the *a* and *b* students according to the *criterX* criterion. The method can compare these two students according to points for accommodation (*criterX* == 1), the distance from their residences to the university (*criterX* == 2), their incomes (*criterX* == 3), their average grades (*criterX* == 4), their birth dates, their surnames, their first names, and according to numbers of ISICs. The

Compare_sts method is called by the *QuickS_movingSort2d*, *QuickS_indexSort2d*, and *QuickS_referSort2d* methods.

o *Exch2d_moving* - the private member method that exchanges two elements (objects) of the *dataX* two-dimensional dynamic array of objects of the *Student* class with indices *ix* and *jx*. The method moves elements of the *dataX* array during their exchange. The *Exch2d_moving* method is called by the *QuickS_movingSort2d* method.

Fig. 2: The source code of the 'Exch2d_moving' private member method

```
private void Exch2d_moving(ref Student[][] dataX, int ix, int jx)
{
    Student[][] t;
    t = new Student[1][];
    t[0] = new Student[1];
    t[0][0] = new Student();
    t[0][0] = dataX[ix][0];

    dataX[ix][0] = dataX[jx][0];
    dataX[jx][0] = t[0][0];
}
```

Source: (authors)

o *Exch* - the private member method that exchanges two elements (indices) of an index array. The method exchanges only indices (integers), it does not move structured elements of the *ref2dArrSts* array of objects. The *Exch* method is called by the *QuickS_indexSort2d* method.

Fig. 3: The source code of the 'Exch' private member method

```
private void Exch(ref int[] Ix, int ix, int jx)
{
    int t = Ix[ix];
    Ix[ix] = Ix[jx];
    Ix[jx] = t;
}
```

Source: (authors)

o *Exch2d* - the private member method that exchanges two elements (references) of an array of references. The method exchanges only references, it does not move structured elements of the *ref2dArrSts* array of objects. The *Exch2d* method is called by the *QuickS_referSort2d* method.

Fig. 4: The source code of the 'Exch2d' private member method

```
private void Exch2d(ref Student[][] dataX, int ix, int jx)
{
    Student[] t;
    t = new Student[1];
    t[0] = new Student();
    t = dataX[ix];
    dataX[ix] = dataX[jx];
    dataX[jx] = t;
}
```

Source: (authors)

- o *QuickS_movingSort2d, QuickS_indexSort2d, QuickS_referSort2d* - sorting methods that implement the Quicksort algorithm and that sort structured data. The *QuickS_ movingSort2d* method (Fig. 5) uses a moving sort, the *QuickS_indexSort2d* method (Fig. 6) uses an index sort, and the *QuickS_referSort2d* method (Fig. 7) uses a reference sort.
- o *Display_ref2dArrSts* - the method displays the current content of the *ref2dArrSts* two-dimensional dynamic array of objects of the *Student* class. The *Main* method uses the *Display_ref2dArrSts* method for displaying the current content of the *ref2dArrSts* array after sorting of this array by the *QuickS_movingSort2d* and *QuickS_referSort2d* methods.
- o *DisplaySortedSts_indexSort2d* - the method also displays the current content of the *ref2dArrSts* two-dimensional dynamic array of objects of the *Student* class, however, the *Main* method uses the *DisplaySortedSts_indexSort2d* method for displaying the current content of the *ref2dArrSts* array after sorting of this array by the *QuickS_ indexSort2d* method.

The **QuickS_movingSort2d** key sorting method (Fig. 5) that implements the Quicksort algorithm, sorts structured data of students that are stored in the *ref2dArrSts* two-dimensional dynamic array of objects of the *Student* class. This method uses a moving sort, that is, it moves elements of the *ref2dArrSts* array by calling the *Exch2d_moving* method (Fig. 2) during their sorting if it is necessary.

Fig. 5: The source code of the 'QuickS_movingSort2d' member method

```
public void QuickS_movingSort2d(Student[][] data, int left, int right, int criterx)
{
    if (left < right)
    {
        int i = left, j = right;
        p2d[0][0] = data[(left + right) / 2][0];

        do
        {
            while (Compare_sts(data[i][0], p2d[0][0], criterx) > 0) i++;
            while (Compare_sts(p2d[0][0], data[j][0], criterx) > 0) j--;

            if (i >= j)
                break;

            Exch2d_moving(ref data, i, j);
        } while (true);
        QuickS_movingSort2d(data, left, j, criterx);
        QuickS_movingSort2d(data, j + 1, right, criterx);
    }
}
```

Source: (authors)

The **QuickS_indexSort2d** key sorting method (Fig. 6) that also implements the Quicksort algorithm, sorts structured data of students that are stored in the *ref2dArrSts* two-dimensional dynamic array of objects of the *Student* class. This method uses an index sort, that is, it exchanges only indices (integers) of an index array by calling the *Exch* method (Fig. 3) if it is necessary, it does not move structured elements of the *ref2dArrSts* array of objects.

Fig. 6: The source code of the 'QuickS_indexSort2d' member method

```
public void QuickS_indexSort2d(Student[][] data, ref int[] I, int left, int right, int criterx)
{
    if (left < right)
    {
        int i = left, j = right;
        p2d[0][0] = data[I[(left + right) / 2]][0];

        do
        {
            while (Compare_sts(data[I[i]][0], p2d[0][0], criterx) > 0) i++;
            while (Compare_sts(p2d[0][0], data[I[j]][0], criterx) > 0) j--;

            if (i >= j)
                break;

            Exch(ref I, i, j);
        } while (true);
        QuickS_indexSort2d(data, ref I, left, j, criterx);
        QuickS_indexSort2d(data, ref I, j + 1, right, criterx);
    }
}
```

Source: (authors)

The ***QuickS_referSort2d*** key sorting method (Fig. 7) that also implements the Quicksort algorithm, sorts structured data of students that are stored in the *ref2dArrSts* two-dimensional dynamic array of objects of the *Student* class. This method uses a reference sort, that is, it exchanges only references of an array of references by calling the *Exch2d* method (Fig. 4) if it is necessary, it does not move structured elements of the *ref2dArrSts* array of objects.

Fig. 7: The source code of the 'QuickS_referSort2d' member method

```
public void QuickS_referSort2d(Student[][] data, int left, int right, int criterx)
{
    if (left < right)
    {
        int i = left, j = right;
        p2d[0][0] = data[(left + right) / 2][0];

        do
        {
            while (Compare_sts(data[i][0], p2d[0][0], criterx) > 0) i++;
            while (Compare_sts(p2d[0][0], data[j][0], criterx) > 0) j--;

            if (i >= j)
                break;

            Exch2d(ref data, i, j);
        } while (true);
        QuickS_referSort2d(data, left, j, criterx);
        QuickS_referSort2d(data, j + 1, right, criterx);
    }
}
```

Source: (authors)

All these three key sorting methods, *QuickS_movingSort2d*, *QuickS_indexSort2d*, and *QuickS_referSort2d* call the *Compare_sts* method (Fig. 8) that compares the *a* and *b* students

according to the *criterX* criterion. The *Compare_sts* method compares the *a* and *b* students as follows:

- If *criterX* == 1, then the method compares these two students according to points for accommodation. If these students have achieved the same points for accommodation, then they will be compared according to their average grades. If these students have achieved the same average grades, then they will be compared according to their incomes. If these students have the same incomes, then they will be compared according to distance from their residences to the university.

- If *criterX* == 2, then the method compares these two students according to distance from their residences to the university. If these students have the same distances from their residences to the university, then they will be compared according to their average grades. If these students have achieved the same average grades, then they will be compared according to their incomes.

- If *criterX* == 3, then the method compares these two students according to their incomes. If these students have the same incomes, then they will be compared according to points for accommodation. If these students have achieved the same points for accommodation, then they will be compared according to their average grades. If these students have achieved the same average grades, then they will be compared according to distance from their residences to the university.

- If *criterX* == 4, then the method compares these two students according to their average grades. If these students have achieved the same average grades, then they will be compared according to points for accommodation. If these students have achieved the same points for accommodation, then they will be compared according to their incomes. If these students have the same incomes, then they will be compared according to distance from their residences to the university.

- If these two students have the same values of all keys in each from mentioned comparisons above, then they will be compared according to their dates of birth. If these students have the same dates of birth, then they will be compared according to their surnames. If these students have the same surnames, then they will be compared according to their first names. If these students have the same first names, then they will be compared according to numbers of their ISICs.

Fig. 8: The source code of the 'Compare_sts' private member method

```
private int Compare_sts(Student a, Student b, int criterX) {
    int porovnanie;

    if (criterX == 1) {
        if (a.points_acc > b.points_acc) return 1;
        if (a.points_acc < b.points_acc) return -1;

        if (a.aver_grade < b.aver_grade) return 1;
        if (a.aver_grade > b.aver_grade) return -1;

        if (a.income < b.income) return 1;
        if (a.income > b.income) return -1;

        if (a.distance_resid > b.distance_resid) return 1;
        if (a.distance_resid < b.distance_resid) return -1;  }

    if (criterX == 2) {
        if (a.distance_resid > b.distance_resid) return 1;
        if (a.distance_resid < b.distance_resid) return -1;
```

Source: (authors)

Fig. 8: (continued)

```
    if (a.points_acc > b.points_acc) return 1;
    if (a.points_acc < b.points_acc) return -1;

    if (a.aver_grade < b.aver_grade) return 1;
    if (a.aver_grade > b.aver_grade) return -1;

    if (a.income < b.income) return 1;
    if (a.income > b.income) return -1;
}

if (criterX == 3) {
    if (a.income < b.income) return 1;
    if (a.income > b.income) return -1;

    if (a.points_acc > b.points_acc) return 1;
    if (a.points_acc < b.points_acc) return -1;

    if (a.aver_grade < b.aver_grade) return 1;
    if (a.aver_grade > b.aver_grade) return -1;

    if (a.distance_resid > b.distance_resid) return 1;
    if (a.distance_resid < b.distance_resid) return -1;
}

if (criterX == 4) {
    if (a.aver_grade < b.aver_grade) return 1;
    if (a.aver_grade > b.aver_grade) return -1;

    if (a.points_acc > b.points_acc) return 1;
    if (a.points_acc < b.points_acc) return -1;

    if (a.income < b.income) return 1;
    if (a.income > b.income) return -1;

    if (a.distance_resid > b.distance_resid) return 1;
    if (a.distance_resid < b.distance_resid) return -1;
}

long da, db;
da = a.birthday.d + a.birthday.m * 100 + a.birthday.y * 10000;
db = b.birthday.d + b.birthday.m * 100 + b.birthday.y * 10000;

if (da < db) return -1;
if (da > db) return 1;

porovnanie = String.Compare(a.surname.ToLower(), b.surname.ToLower());
if (porovnanie < 0)  return 1;
else if (porovnanie > 0)  return -1;

porovnanie = String.Compare(a.firstname.ToLower(), b.firstname.ToLower());
if (porovnanie < 0)  return 1;
else if (porovnanie > 0)  return -1;

if (a.isic < b.isic) return 1;
else if (a.isic > b.isic) return -1;

return 0;
}
```

The *Main* method calls the *QuickS_movingSort2d*, *QuickS_indexSort2d*, and *QuickS_referSort2d* key sorting methods as instance methods of the *sort_obj* object. This is object of the *IndexS_QuickS* class. The internal structure of the *sort_obj* object is shown in Fig. 9 and Fig. 10.

Fig. 9: The internal structure of the 'sort_obj' object of the C# application. Blue arrows depict a reference sort, and the red arrow depicts a moving sort.

Source: (authors)

Fig. 10: The internal state of the 'sort_obj' object of the C# application during an index sorting of students according to points for accommodation. Blue color depicts indices of the the 'ref2dArrSts' array of objects used in an index sorting.

Source: (authors)

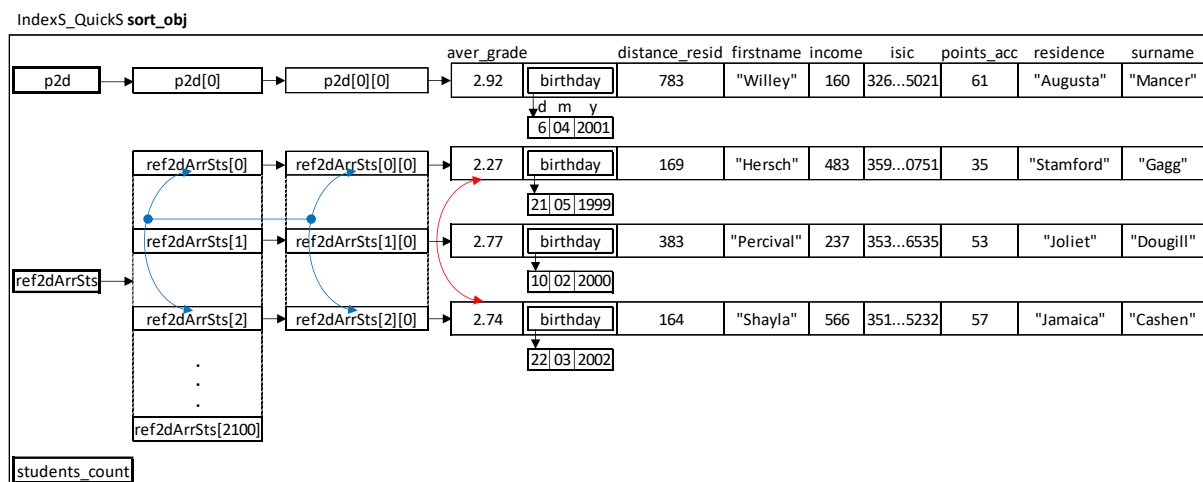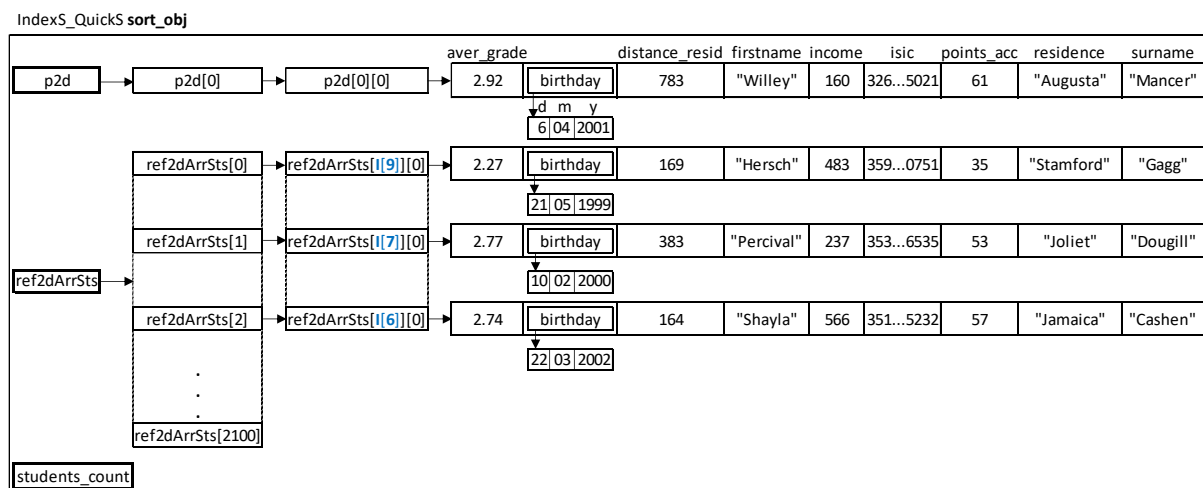*Fig. 11: The internal state of the 'I' array of the C# application after an index sorting of ten students according to points for accommodation. The output of the C# application after this index sorting is displayed in Fig. 12.*

Source: (authors)

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5 Experiment, its Results and their Brief Analysis

We assume that in the Quicksort algorithm indirect sorts, a reference, and index sort, are more execution efficient than a direct sort, in which the entire items to be sorted are moved. We also assume that a reference and index sort have the same execution efficiency approximately.

To verify these hypotheses, we performed an experiment using our C# application, which sorted each of the 20 structured data sets using its three sorting instance methods that implement the Quicksort algorithm and that use a moving sort, a reference sort, and an index sort.

The C# application have measured the execution time of sorting each structured data set by these sorting methods and records it along with the sorting results into the *LogFile.txt* disk log file. Using these execution times, we want to confirm or refuse our hypotheses.

During this experiment, the *QuickS_movingSort2d*, *QuickS_indexSort2d*, and *QuickS_referSort2d* sorting instance methods of our C# application have sorted each of 20 structured data sets that contained structured data of 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, and 2000 students. A structured data of each student was stored in the *firstname*, *surname*, *residence*, *birthday* (the object of the *Date* class), *points_acc*, *income*, *distance_resid*, *aver_grade* and *isic* instance variables of the object of the *Student* class. These objects were stored in the *ref2dArrSts* array of the objects of the *Student* class. Each of three sorting instance methods of a C# application have sorted structured data of students stored in the *ref2dArrSts* array of the objects of the *Student* class.

The C# application was running on the computer with the following basic hardware configuration: Intel Core i5-8250U Processor (6MB Cache, 1.60 GHz (Processor Base Frequency), 3.40 GHz (Max Turbo Frequency), 4 GT/s (Bus Speed), 4 Cores, 8 Threads), RAM: 8 GB. The Microsoft Windows 10 Home, 64-bit operating system and the Microsoft .NET Framework 4 were installed on this computer.

One of the outputs of our C# application displayed in the system console after sorting a structured data set that contained structured data of 10 students according to points for accommodation (numbers in parentheses in the first numerical column) is displayed in Fig. 12.

Fig. 12: The output of our C# application (inputs of the user are written in bold type)

```
Choose input file:
students11c2sk.txt (insert: 1), students10c2en.txt (2), students100c2en.txt (3), students200c2en.txt
(4), students300c2en.txt (5), students400c2en.txt (6), students500c2en.txt (7), students600c2en.txt
(8), students700c2en.txt (9), students800c2en.txt (10), students900c2en.txt (11),
students1000c2en.txt (12), students1100c2en.txt (13), students1200c2en.txt (14),
students1300c2en.txt (15), students1400c2en.txt (16), students1500c2en.txt (17),
students1600c2en.txt (18), students1700c2en.txt (19), students1800c2en.txt (20),
students1900c2en.txt (21), students2000c2en.txt (22)
2
The student's data loaded from the 'students10c2en.txt' file.

Choose sorting criterion of students:
sorting according to:
-points for accommodation (insert: 1),
-distance of their residence from the university (insert: 2),
-income of students (insert: 3),
-average grade (insert: 4)
1
The students will be sorted according to 'points for accommodation'.

    *** students are stored in the 'Student[][] ref2dArrSts' array ***
```
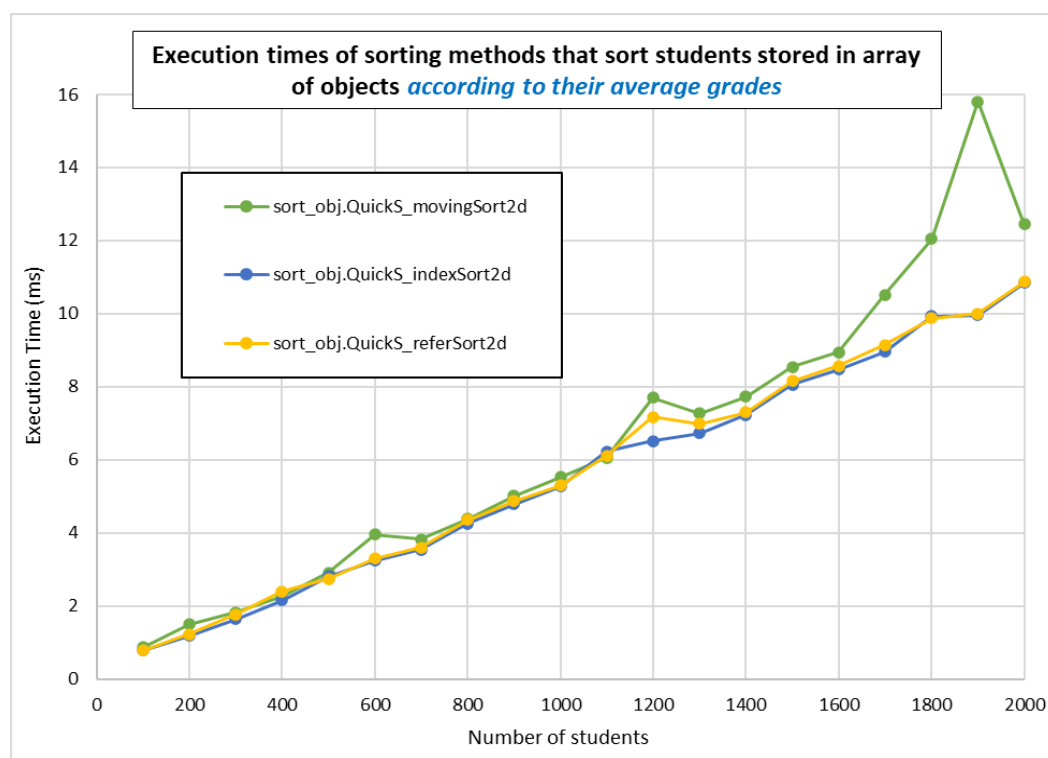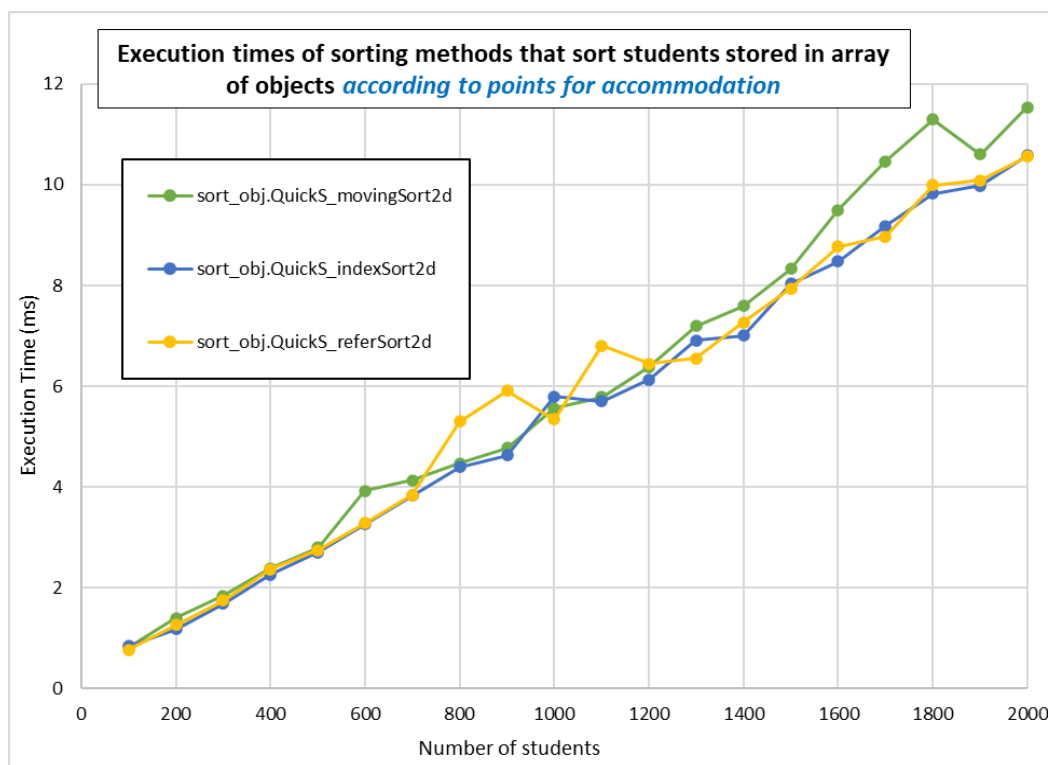
Source: (authors)

Fig. 12: (continued)

```
    students sorted by the 'sort_obj.QuickS_indexSort2d' instance method
    (INDEX sort in the Quicksort, Execution time: 00:00:00.0003429, 0.3429 ms)

 1  33928014847747866  Gabbidon Guilbert    (73) 381  2.05   1999-07-23  Bloomington (572)
 2  35350197848168233  Danilovitch Roxine   (72) 627  4.66   2003-03-01  Chicago (326)
 3  35978397704389789  Mannin Cchaddie      (66) 340  2.05   2001-04-17  Jacksonville (32)
 4  35201185262631838  Coopper Roslyn       (62) 570  4.68   2003-11-24  Grand-Rapids (177)
 5  32630895575785021  Mancer Willey        (61) 160  2.92   2001-04-06  Augusta (783)
 6  32322011686544786  Gerardot Edithe      (57) 383  1.2    2001-01-22  Topeka (703)
 7  35150528961405232  Cashen Shayla        (57) 566  2.74   2002-03-22  Jamaica (164)
 8  35352737044886535  Dougill Percival     (53) 237  2.77   2000-02-10  Joliet (383)
 9  33931482295090410  L'Anglois Jeana      (51) 421  2.8    2000-08-06  Boynton-Beach (289)
10  35988187656170751  Gagg Hersch          (35) 483  2.27   1999-05-21  Stamford (169)


    The 'Student[][] ref2dArrSts' array after the 'sort_obj.QuickS_indexSort2d' instance method call
    (UNSORTED STUDENTS, only TEST of an array)
 1  35988187656170751  Gagg Hersch          (35) 483  2.27   1999-05-21  Stamford (169)
 2  35352737044886535  Dougill Percival     (53) 237  2.77   2000-02-10  Joliet (383)
 3  35150528961405232  Cashen Shayla        (57) 566  2.74   2002-03-22  Jamaica (164)
 4  35978397704389789  Mannin Cchaddie      (66) 340  2.05   2001-04-17  Jacksonville (32)
 5  32630895575785021  Mancer Willey        (61) 160  2.92   2001-04-06  Augusta (783)
 6  32322011686544786  Gerardot Edithe      (57) 383  1.2    2001-01-22  Topeka (703)
 7  33931482295090410  L'Anglois Jeana      (51) 421  2.8    2000-08-06  Boynton-Beach (289)
 8  35350197848168233  Danilovitch Roxine   (72) 627  4.66   2003-03-01  Chicago (326)
 9  33928014847747866  Gabbidon Guilbert    (73) 381  2.05   1999-07-23  Bloomington (572)
10  35201185262631838  Coopper Roslyn       (62) 570  4.68   2003-11-24  Grand-Rapids (177)


    students sorted by the 'sort_obj.QuickS_referSort2d' instance method
    (reference sort in the Quicksort, Execution time: 00:00:00.0004781, 0.4781 ms)

 1  33928014847747866  Gabbidon Guilbert    (73) 381  2.05   1999-07-23  Bloomington (572)
 2  35350197848168233  Danilovitch Roxine   (72) 627  4.66   2003-03-01  Chicago (326)
 3  35978397704389789  Mannin Cchaddie      (66) 340  2.05   2001-04-17  Jacksonville (32)
 4  35201185262631838  Coopper Roslyn       (62) 570  4.68   2003-11-24  Grand-Rapids (177)
 5  32630895575785021  Mancer Willey        (61) 160  2.92   2001-04-06  Augusta (783)
 6  32322011686544786  Gerardot Edithe      (57) 383  1.2    2001-01-22  Topeka (703)
 7  35150528961405232  Cashen Shayla        (57) 566  2.74   2002-03-22  Jamaica (164)
 8  35352737044886535  Dougill Percival     (53) 237  2.77   2000-02-10  Joliet (383)
 9  33931482295090410  L'Anglois Jeana      (51) 421  2.8    2000-08-06  Boynton-Beach (289)
10  35988187656170751  Gagg Hersch          (35) 483  2.27   1999-05-21  Stamford (169)


    students sorted by the 'sort_obj.QuickS_movingSort2d' instance method
    (moving sort in the Quicksort, Execution time: 00:00:00.0004828, 0.4828 ms)

 1  33928014847747866  Gabbidon Guilbert    (73) 381  2.05   1999-07-23  Bloomington (572)
 2  35350197848168233  Danilovitch Roxine   (72) 627  4.66   2003-03-01  Chicago (326)
 3  35978397704389789  Mannin Cchaddie      (66) 340  2.05   2001-04-17  Jacksonville (32)
 4  35201185262631838  Coopper Roslyn       (62) 570  4.68   2003-11-24  Grand-Rapids (177)
 5  32630895575785021  Mancer Willey        (61) 160  2.92   2001-04-06  Augusta (783)
 6  32322011686544786  Gerardot Edithe      (57) 383  1.2    2001-01-22  Topeka (703)
 7  35150528961405232  Cashen Shayla        (57) 566  2.74   2002-03-22  Jamaica (164)
 8  35352737044886535  Dougill Percival     (53) 237  2.77   2000-02-10  Joliet (383)
 9  33931482295090410  L'Anglois Jeana      (51) 421  2.8    2000-08-06  Boynton-Beach (289)
10  35988187656170751  Gagg Hersch          (35) 483  2.27   1999-05-21  Stamford (169)
```

The execution times of sorts of students according to points for accommodation, their average grades, and their incomes that were executed by all three sorting instance methods of our C# application are shown in the following graphs.
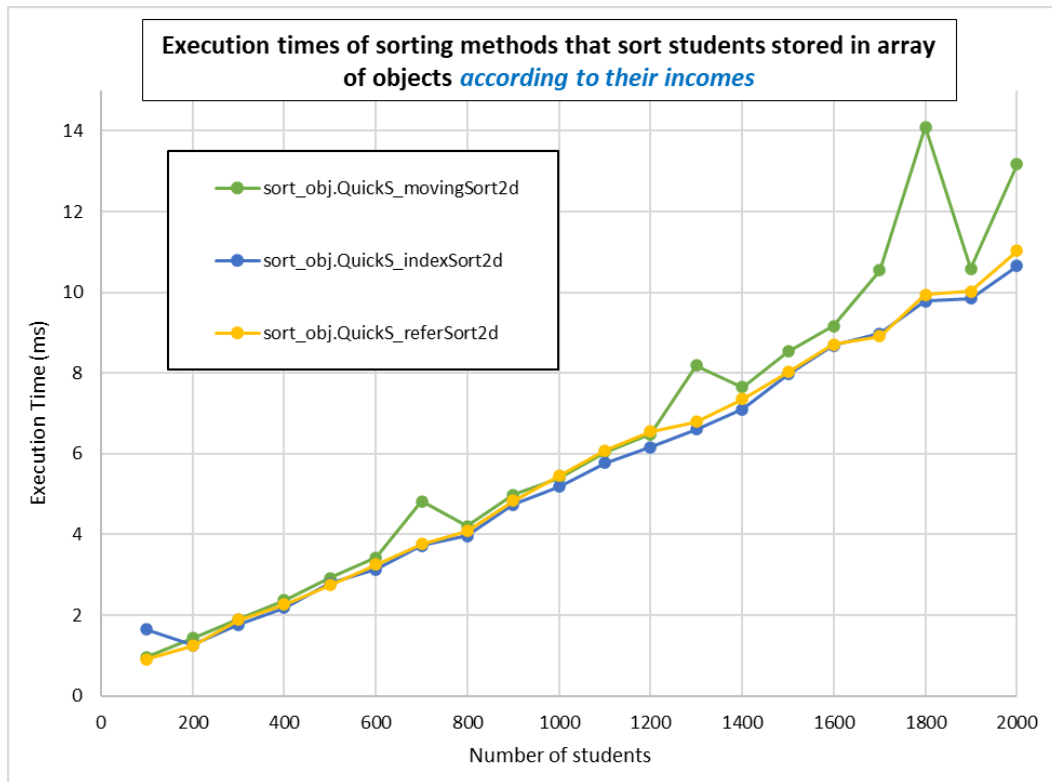
Fig. 13. The execution times of sorts of students according to points for accommodation, their average grades, and their incomes that were executed by all three sorting instance methods of our C# application.

Source: (authors)

Fig. 13: (continued)

Brief results analysis. From the graphs showing execution times of all three sorting instance methods of our C# application that implement the Quicksort algorithm, and that have sorted the same 20 structured data sets containing structured data of students, it is obvious that indirect sorts, a reference, and index sort, are more execution efficient than a direct sort, in which the entire items to be sorted are moved. A significant difference between these execution times can be seen at the number of students 1600. This difference increases with the increasing number of students. Based on this, it is obvious that the use of indirect sorts, a reference, and index sort, in a C# application with implemented the Quicksort algorithm for more than 1600 students is more execution efficient than the use of a direct sort, in which the entire items to be sorted are moved.

From these graphs showing execution times of all three sorting instance methods of our C# application that have sorted the same 20 structured data sets that contained structured data of students, it is also obvious that a reference sort and index sort have the same execution efficiency approximately.

The results of the experiment confirmed both our hypotheses: we have assumed that in the Quicksort algorithm indirect sorts, a reference, and index sort, are more execution efficient than a direct sort, in which the entire items to be sorted are moved, and we have also assumed that a reference and index sort have the same execution efficiency approximately.

6   Conclusion

From the results of the comparison of the execution times of the *QuickS_movingSort2d*, *QuickS_indexSort2d*, and *QuickS_referSort2d* sorting instance methods of our C# application that implement the Quicksort algorithm and that use a moving sort, a reference sort and an index sort, it is obvious that indirect sorts, a reference, and index sort, are more execution efficient than a direct sort, a moving sort, in which the entire items to be sorted are moved. From the

results of this comparison, it is also obvious that a significant difference between these execution times can be seen at the number of students 1600 and higher and that a reference sort and index sort have the same execution efficiency approximately.

From all results of the experiment, it is clear that we can recommend to use a reference sort and an index sort in a C# application instance methods that implement the Quicksort algorithm, and which sort structured data set with the number of students 1600 and higher, because these sorts are more execution efficient than a direct sort, a moving sort, in which the entire items to be sorted are moved.

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THE CONCEPT OF A MATHEMATICAL MODEL FOR DETERMINING THE PROBABILITY OF DETECTING AN INTERNAL ATTACKER OF AN ORGANIZATION (INSIDER) ON THE BASIS OF METADATA ABOUT HIM

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Abstract

The article presents the concepts of a mathematical model for determining the probability of a resonant high psycho-emotional state in order to become an attacker and ready to leak the trade secrets of the company. An employee who processes information and has full access to it becomes the target of an attacker, as well as he himself may be an intruder and become a source of leakage of confidential information. The analysis of data about the employee allows us to make assumptions about his emotional state, and willingness to honestly do the job. The collected data requires analysis according to their type, and this is what the work is dedicated to. Data from video surveillance cameras is analyzed to identify the time of the employee's appearance and his location during working hours. The metadata obtained is intended to create a model of an internal violator, followed by an assessment of the threat level emanating from the employee.)

Keywords

1 Introduction

The purpose of this article is to investigate how to extract metadata about an employee from his environment in order to then mathematically calculate the probability of the main causes and consequences of employee fraud, focusing on the dynamic changes in the face when he performs his functional tasks at work, at the company and is involved in the stages and stages of the business process. The authors note the fact that metadata collected from the external environment somehow affects the behavior of an employee of the company and introduces him to an imbalance in the performance of work functions (he more often conflicts with colleagues, more often skips or performs less productively the amount of work and reduces its quality) (Omar et al., 2016).

The compliance of the company (considering the employment relationship) with the employees, is clearly the most appreciated characteristic by the employees, and our participants.

After this characteristic, the objectives of the company seem to be the most valued by the employees, which reveal concern to comply with their obligations to the company, along with their belief in the fulfillment of the employment relationship by the organization. This leads us to admit that there is a greater belief of the employees in the fulfillment of the physical contract than in the fulfillment of the psychological contract. On the opposite, the most negative aspect highlighted in the company is the concern with its employees, that is, the employees think that the company does not care as much about them as they would like, or how they think that the company should be concerned, what causes a low satisfaction among employees.

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Findings also indicate that both the company's interest in knowing the life of the employee and the fulfillment of the financial obligations of the company, have a low impact on the employees, not causing a considerable impression. The company's weak concern with its human resources proves the weak internal branding of the organization (Omar et al., 2016).

Many Prior studies of science have found that a company with high employee integrity (absent Internal intruders) and cultivating integrity culture within an organization impacted on business efficiency and information security company, it also positively impacted the financial performance over the years. Besides, Rosli, Abd Aziz, Mohd, and Said, (2015) claimed that an organization with high integrity might have the potential to contribute toward competitive advantage and improve public trust and transparency in all its activities. The result of many studies show that the practices of the integrity system is affected by leadership quality, but the result of the internal control system of employer showed a mixed relationship with the practices of accountability. Their study reveals that an integrity system can help an organization to enhance its accountability to the various group of stakeholders. The focus has now turned to the competency, integrity, and attractiveness of a company in protecting the public trust. Thus, various benefits will be gained by the organization if integrity becomes the focal point of the organization. The evidence of a psychological contract breach may be a first indicator of a possible future turnover, very common in IT corporations. The psychological contract may play the role of formal governance particularly in the case of IT outsourcing (Alam et al., 2019). Thus, the literature acknowledges the particular relevance of the psychological contract to IT consultancy corporations while at the same time the additional challenges of internal branding due to the typical outsourcing role of employees. They always feel that they do have not the longest contract with a company (Engelbrecht et al., 2017).

Having studied the circumstances of conscientiousness of behavior and performance of their functions by an employee, the authors of this article came to the conclusion that in order to help the company's management, it is necessary to create a mechanism for collecting metadata about an employee from the perspective of the external environment of his life (family, relatives and their impact on him) as well as within the company's team (its conflict-free or vice versa, a change in tolerance in business-in the process of the company).

The improvement of information processing technologies entails a reduction in the possibilities for unauthorized receipt of confidential information by an external attacker, while an employee with access to confidential information may become a source of leakage of valuable information, through malicious intent or careless handling of the information processing system. Both in the case of unintentional mistakes in handling the company's information resources, which is the result of emotional fluctuations: apathy, fatigue, bad mood, and in the case of deliberate transfer of information to third parties, hostile actions against the welfare of the company are affected by the emotional state of a person. That is, different degrees of negative actions of an employee of the company are affected by various emotional deviations caused by a reaction to external factors of the same nature. Knowing the set of these factors and the degree of their impact, it is possible to conduct a presumptive analysis of the emotional state and, as a consequence, the possible behavior of the subject, for this purpose, a model of the internal violator is compiled, reflecting the spectrum of negative emotional states of a person.

2   Materials and Methods

Metadata is information about other information or data related to additional information about the content or object. Metadata reveals information about the features and properties that characterize any entities, allowing you to automatically search for and manage them in large information flows (Jaakson et al., 2013).

Next, in Figure 1, we present the concept of collecting metadata about an employee from open and open sources of the information space. Accordingly, we get the maximum amount of damage from the types of threats that may arise from an employee and the amount of the costs of information protection measures for the developed measures to face both external and internal threats. At the same time, the main focus of the information security specialist will be a new model for building a personnel management system at the stages of the business process and, accordingly, the amounts of possible damage to these stages (Stephenson, 2019).

For a more detailed analysis of the risks to a participant in the business process of becoming an insider of a competitor company, the authors developed a concept for studying the internal threats of business information leakage from insider personnel, based on its metadata related to the external environment, as shown (Vissak et al., 2013). As can be seen from Figure 1, the concept describes three types of collected information about a participant in a business process:

− information about the work of an employee within the company; − information from *closed sources (CSINT)*; − information from *open sources (OSINT)*.

Each type of information collection combines a group of search aspects that should be emphasized when identifying the threat of internal leakage of information from personnel. Thus, the authors distinguish between two types of risks - ($\sum R\ (CSINT)$ and $\sum R\ (OSINT)$ that are subject to a scientifically based measurement method, for the purpose of early detection of risks from an internal insider (Balla Moussa et al., 2015).

There is a set of tools for programs to interact with each other, called the API (Application Programming Interface), with which it is possible to get information about the participants of the business process using the data of an application. As mentioned above, business information can be information about the business process of the company, as well as data about the participants in this business process, especially customers who bring income (benefit).

If such information is publicly available on the Internet, for example, in social networks, it is possible to find, structure, and analyze such information through the use of API technology (whether an employee has problems).

Metadata creation can take place both manually and automatically. From various sources of both open and "leaks" of information from closed sources (debtors' databases, databases on offenses on the roads, etc.), flows of data about a person, his material support, and possible problems with the law are formed. From social networks, there is a stream of data on the worldview, political and social views of a person. You can also use internal data of the firm and video surveillance, indicating the movements of a person inside the object.
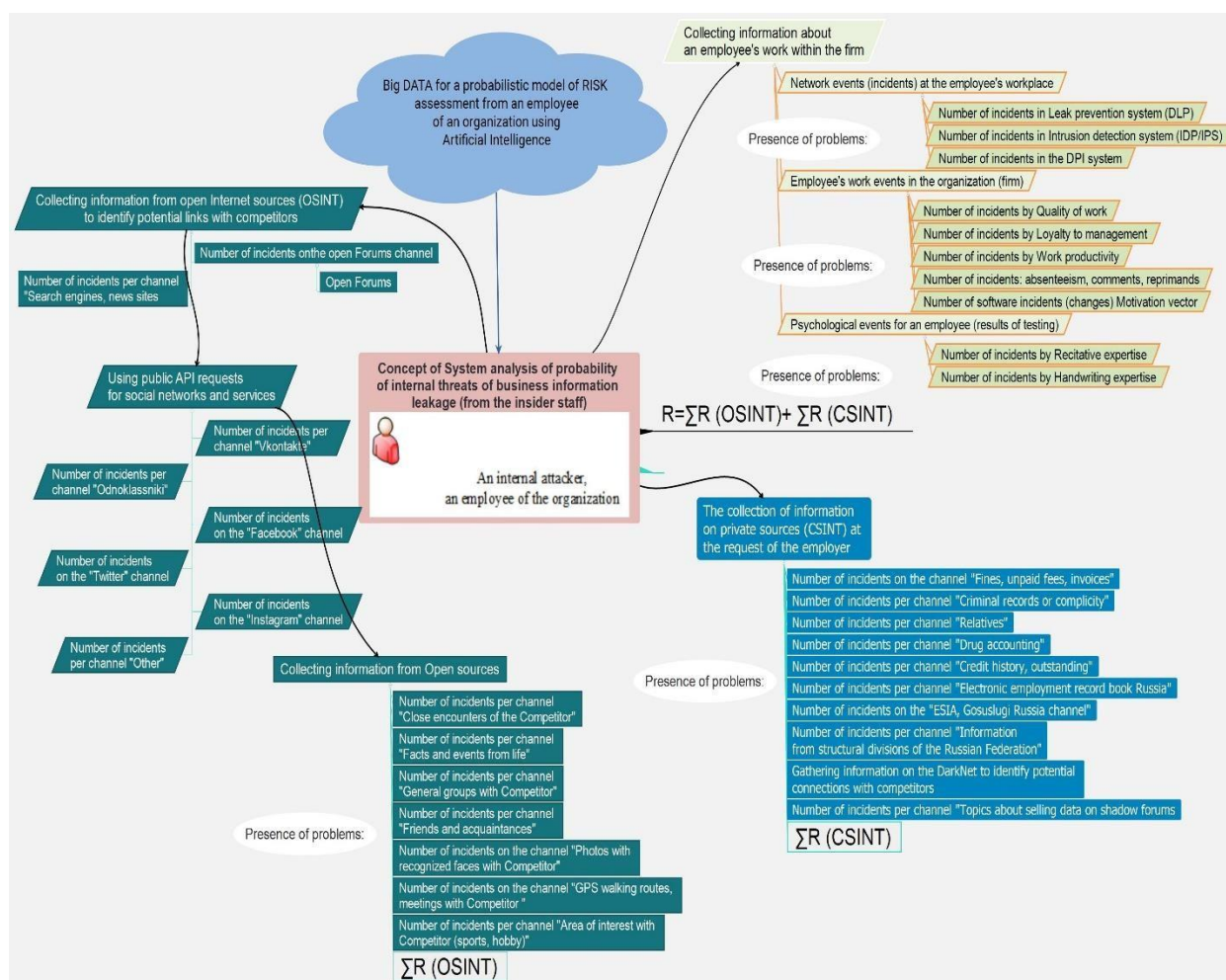
Figure 1 - Concept of collecting metadata about the worker for the mathematical model of probability of internal threats (risks of leaks of business information

The simplest and most accessible method for collecting metadata about a worker is the APIs requests, that are a technology, an architectural style focused on using the HTTP protocol as a transport protocol when generating requests to the server and responses returned by this server. If the information about the participants of the business process is located, for example, in a social network, then it can be likely obtained from the servers used by this social network via its API - leakage (from the insider staff).

An example is shown in Figure 2. The authors also believe that threats to a commercial organization can, in principle, be divided into two main types: external and internal).

The task of any criminal (as an attacker inside the company or a cyber fraudster from the external environment of the company) will be to «complicate» or «reset» the business information of the company between its stages of production and sale of products or services by introducing chaos, disorienting the employees of the company, violating the integrity of the aggregate information that discusses the entire business process. In turn, the amount of damages will depend on the recovery time or slow motion «information flow» between employees, and also the time of the financial flows between the client and the departments of the executors of the order, from the perspective of possible cyber-attacks aiming at «losing», «bankrupting», «resetting» the transaction itself and creating a «direct financial» damage from subsequent alterations, or claims (return receipts) on the client side in the form of deviations from the approved parameters of the business process.

```
1     import requests
2
3     token = '1f036ad11f036ad11f036ad1461f7521c911f031f036ad17f1ed244d3bbc59f2880e49c'
4     version = 5.89
5     user_ids = '290490593'
6     fields = 'photo_50,verified'
7     name_case = 'nom'
8
9
10    response = requests.get('https://api.vk.com/method/users.get',
11                            params={
12                                'access.token': token,
13                                'v': version,
14                                'user_ids': user_ids,
15                                'fields': fields,
16                                'name_case': name_case
17                            }
18                            )
19    data = response.json()
20  ● print(1)
```

Figure 2 – Program source code using the API requests for collecting metadata of employer

Common factors that are considered when making threat prediction models are sociodemographic factors such as age, gender, education, migration background and ethnicity, religious affiliation, marital status, household, employment, and income. For more accurate predictions we propose taking psychological factors like social learning into account as well.

Figure 3 goes on to present the concept of a mathematical model for processing collected metadata about worker Xi for the purpose of calculating the probabilities of his behavior in two types: the firm's "*Own* (employee)" and "*Alien*" employee of the firm.

The model includes the collection of metadata about the worker in two types. Two types of "Alien" and "Own" coexist in one employee at once but in the mode of triggering an external internal emotional state from external factors. The composition of the desired indicators and model factors.

- $X_1^n = \{1, 2, \dots n\}$ – an employee of the company from the staffing table who gained access to the company's trade secrets;
- $S_j(X_i)^{ext_m}$ – probabilistic stable state of external motivation of the employee S_i (after exposure from the outside to someone else's threat, when the employee has moved to an unstable state S_j- and ready for "malicious intent", t. a. to "Winnings"»), through observable conditionally measurable indicators (incidents) per employee$=\sum QX_i(ERIF)+\sum QX_i(IEFI)$.

As a result, we will get conditionally constant values of natural values of facts (0-no, 1-yes) for two streams of information (next table 1).

Let us stipulate that simultaneously with this flow of *ERIF*, the " *External resonance flow of information»* threat fixation information for the employee will be monitored, namely the observed facts and events from his private life: conflicts and quarrels in the family, illnesses, alimony, his outstanding loans, mortgage debts, fines, interest on microloans, car accidents, etc. the facts of influencing the motivation of the employee through subsequent changes in his state "Employee" - "Internal violator".

Abbreviated *IEFI* (*Insider the Emotional Flow* of Information fixing the threat).
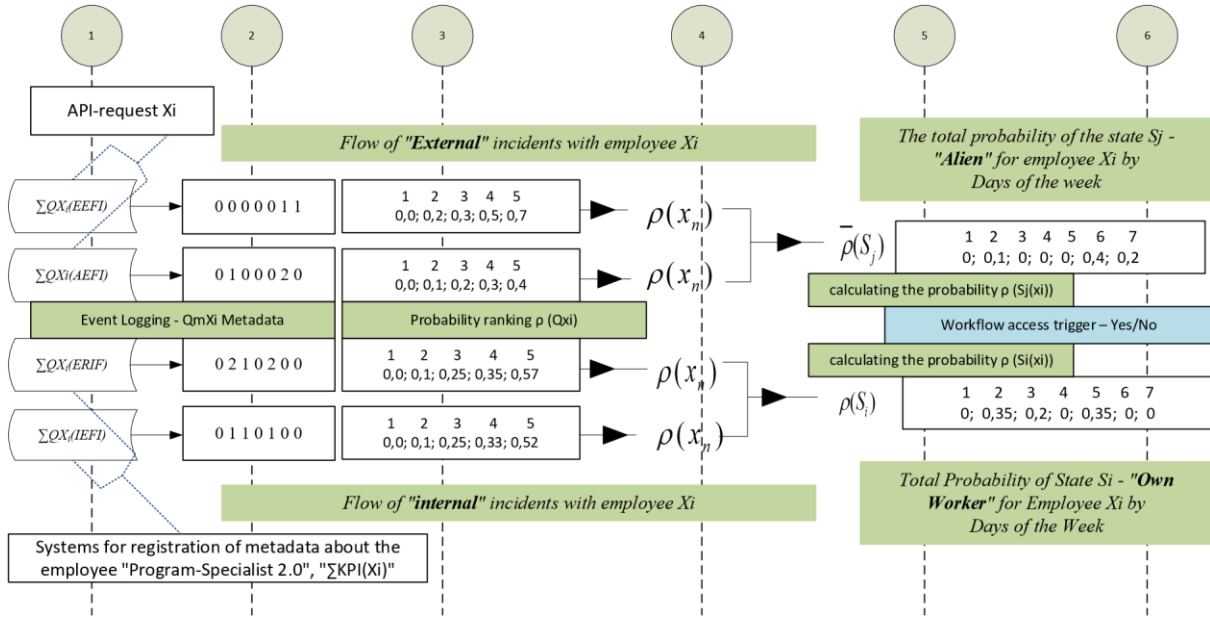
Figure 3 – The concept of a mathematical model of collection metadata of employer

Social learning theory is a theory of learning process and social behavior which proposes that new behaviors can be acquired by observing and imitating others. According to social learning theory, people engage in crime because of their association with others who engage in crime. Their criminal behavior is reinforced and they learn beliefs that are favorable to crime (Suhartana et al., 2014). They essentially have criminal models that they associate with. As a consequence, these individuals come to view crime as something that is desirable, or at least justifiable in certain situations. Learning criminal or deviant behavior is the same as learning to engage in conforming behavior: it is done through association with or exposure to others.

At this stage of work, we propose the following concept of two scientific hypotheses – who is such an employee for the purposes of controlling access to the company's trade secrets (Toapanta et al., 2020). The first hypothesis (assumption) states that our object-worker is defined as an employee with a "public face" (in society, in a collective), as a predetermined "unstable deterministic system" of a set of indicators (factors) describing his current psycho-emotional (the first flow of metadata) and physical-economic (the second flow of metadata) states, and accordingly is interpreted by us as a "stable" or "unstable" state of his motivation to "become or not to become" an internal violator of the firm (Martyanov, 2017).

The second hypothesis (assumption), predetermines which of the two independent streams of metadata proposed according to the first hypothesis, about the confirmed (or unconfirmed) facts of its developing "crisis" in the ethics of behavior (conflicts, empathy, selfishness, etc.) and in labor indicators (productivity, quality, simple, etc.), should have a different philosophy of comprehension that is converted into different levels of ranking the probabilistic state of stability and instability of the object. The fact is that the internal environment of functioning in the enterprise "requires" from our object of research the fulfillment of a set of indicators of functioning in the company, but which reflect its "some" current in development "intermediate" state of motivation and satisfaction, which for the research model is a certain "rank" of the state.

3   Results and Discussion

Further, table 1 shows the method of collecting and processing information flows about the employee - metadata such as "*External resonance flow of information*" - ERIF and "*Intra-emotional flow of information*" - IEFI for the employee Xi.

Table 1 – Metadata processing on an example "External resonance flow of information" - ERIF and "Intra-emotional flow of information" - IEFI

№ pp	for each Xi employee with access to commercial information	One week metadate of life of employee Xi (frequency of observations 2 times a day)						
	TIME OF DATA COLLECTION	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	5	6	7	8	9
1	TOTAL Machine information gathering API-enquiries - Daily= [AMOUNTS(ERIF)+AMOUNTS(IEFI)] (string 2+ string 10)	0	1	0	0	0	3	1
2	External resonance flow of information AMOUNTS(ERIF) (string 3: string 9)	0	0	0	0	0	1	1
3	Other people's fines	0	0	0	0	0	0	0
4	Other people's debts	0	0	0	0	0	0	0
5	Other people's loans	0	0	0	0	0	0	0
6	Other people's diseases	0	0	0	0	0	1	1
7	Other people's threats	0	0	0	0	0	0	0
8	Other people's accidents and damages	0	0	0	0	0	0	0
9	Other people's problems from connections	0	0	0	0	0	0	0
10	Intra-emotional flow of information AMOUNTS(IEFI) (string 11: string 17)	0	1	0	0	0	2	0
11	Own fines	0	0	0	0	0	0	0
12	Your debts	0	0	0	0	0	0	0
13	Your credits	0	0	0	0	0	0	0
14	His illnesses	0	0	0	0	0	0	0
15	Your quarrels in the family	0	1	0	0	0	1	0
16	Own accidents and damages	0	0	0	0	0	0	0
17	Your Depression	0	0	0	0	0	1	0

With the use API from multiple web services and social media applications, we can determine whether an employee could become a threat or not. Looking at what kind of people they follow or if any of their close friends and family members have committed any criminal offenses for instance can tell us if the employee is more inclined to deviant behavior.

Information compiled from this factor as well as others will be analyzed and put into a mathematical model which will calculate the probability of the employee being a threat. Should

the probability be higher than a certain threshold which is determined by the head of information security then the employee is locked out of the organization's system.

One confirmed event returns a value of 0 in 1(Table 1), which is important for calculating the probability, which means that there is a fact of a certain proportion (weight) of the information and the psychological impact of this flow of information on Xi- of the employee until the subsequent confirmation of the fact. After all the steps of collecting metadata for the mathematical model, at the end of the algorithm it will be necessary to calculate the probabilistic final states "Own" - or "Alien" - for employee Sij(Xi) from the number of Q(Xi) incidents affecting him "from the outside"(Jean Dezert et al., 2018).

The previously presented hypothesis for calculating the full probability of the observed impact of incidents on the employee's condition is "Alien" according to the generalized Bayes formula $\rho_j S_j(X_i)^{ext}{}_m X_i$ (Oliveira et al., 2019) (1).

$$P\left(\frac{D_{Xi}}{K^{Sj}}\right) = P(D_{Xi}) * P(\frac{K^{Sj}}{D_{Xi}})/P(K^{Sj}) \qquad (1)$$

Where is:

$P\left(\frac{D_{Xi}}{K^{Sj}}\right)$ – obtained full probability by state Sj – « Alien»;

$P(D_{Xi})$ – preliminary marginal probability (threshold hypothesis) of employee dissatisfaction Xi.

By converting the probabilities from the incidents observed from closed and open sources confirming the impact of the i-threat on the Xi-employee from the first ERIF data stream and the second IEFI data stream into their cumulative probability – that there is a current value – "Alien", we will compare it with the full Bayesian probability according to the formula.

Observations are carried out 1 time per day in 1 week $\vec{\rho}(x^{ERIF}{}_i)\ \vec{\rho}(x^{IEFI}{}_i) \bigcup \bar{\rho}(S_j)$

$$\bar{p} = \frac{1}{7} * \sum_1^7(0,0 + 0,0 + 0,0 + 0,0 + 0,0 + 0,2 + 0,2) + \frac{1}{7} * \sum_1^7(0,0 + 0,1 + 0,0 + 0,0 + 0,0 + 0,2 + 0,0) = 0,057 + 0,042 = 0,1 \qquad (2)$$

Comparing, we get two responses from the employee's access trigger to the firm's business process for this employee Xi: "Access is open" or "Access is denied".

The authors on a conditional example of the company and taking as the studied object of the employee - the "office manager" for which the hypothetical threshold of the dissatisfaction coefficient was set D = (0.6), and the resulting probability from two streams = 0.1, we get the next complete Bayes probability (formula 3 and 4), which will confirm or refute the reliability of the values obtained. $\bigcup \bar{\rho}(S_j)$

$$P_A(H_1) = \frac{0,5*0,6}{0,5*0,56+0,55*0,1} = \frac{0,3}{0,45} = 0,77 \qquad (3)$$
$$P_A(H_2) = \frac{0,5*0,1}{0,5*0,56+0,55*0,1} = \frac{0,05}{0,35} = 0,18 \qquad (4)$$

That is, the state of "Alien" for employee Xi is reliable by 77%. Therefore, the trigger of the company's information security system will be confidently defined for the employee as "Access is allowed".

Next, we will repeat the same procedure and calculations for the third and fourth data streams for the Xi employee to calculate the probability that he is "His" and is in the state Si (table 2).

$S_i(X_i)^i{}_m{}^{nt}$ – stable state of internal motivation of the employee (positive state of the motive for work "Own") - conditionally measured multifactorial indicators (registered events, incidents) as a registered fact of the state of the object (5)

QXi =∑QXi(ERIF) +∑QXi(AEFI)   (5).

Table 2 – Information flows of data by type "External-emotional flow of information" EEFI and "Intra-emotional flow of information" of AEFI by employee Xi

№ss	for each Xi employee with access to commercial information	One week of life of employee Xi (frequency of observations 1 time per week)						
	TIME OF DATA COLLECTION	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	2	3	4	5	6	7	8	9
1	**SUMMARY Manual collection of** information EXPERT requests – once a week= [AMOUNTS(ERIF)+AMOUNTS(EEFI)] (string 2+ string 10)	**0**	**3**	**2**	**0**	**3**	**0**	**0**
2	External-emotional flow of information AMOUNTS(EEFI) (string 3: string 8)	**0**	**2**	**1**	**0**	**2**	**0**	**0**
3	Facts of conflicts with colleagues	0	1	1	0	0	0	0
4	Facts of quarrels and aggression	0	0	0	0	0	0	0
5	Facts of burnout and weak motivation	0	0	0	0	1	0	0
6	Facts of swearing at the management	0	1	0	0	0	0	0
7	Facts of excessive curiosity, boredom	0	0	0	0	0	0	0
8	Facts of empathy and hatred	0	0	0	0	1	0	0
9	Intra-emotional flow of information AMOUNTS(AEFI) (string 10: string 14)	**0**	**1**	**1**	**0**	**1**	**0**	**0**
10	Facts of truancy and laziness	0	0	0	0	0	0	0
11	Facts of a decrease in the quality of work	0	0	1	0	1	0	0
12	Facts of negligence and mistakes and lies	0	0	0	0	0	0	0
13	Facts of a decline in labor productivity	0	0	0	0	0	0	0
14	Facts of theft and damage	0	1	0	0	0	0	0

When trying to assess the probability, experts note that the only way to obtain objective values of the parameter "Probability of threat realization" is to accumulate statistics on incidents, which will determine the number of implementations of threats of a certain type on an information asset of a certain type (Shcheglov et al., 2015).

However, in the domestic practice of activities for the accumulation of statistical data, insufficient attention is paid and it is currently absent in the flows of information indicated by us.

At next table 3 then summarizes the probability of the Office Manager employee's state probability calculation across four metadata streams, and Figure 4 and 5 shows the probabilities of the employee's states by day.

Table 3 – rank approach to assessing the degree of probability of transition from the state – "Own" to the state – "Alien" (on the example of an employee – "Office Manager" of the enterprise) $S_i S_j$

Probabilities for Employee Data Stream X_i - *Office Manager*	constant probability Sj				
number of incidents	0	1	2	3	4
External resonance flow of information AMOUNTS(ERIF)	**0,0**	**0,2**	**0,3**	**0,5**	**0,7**
levels are set on the assumption that external threats (incidents) affect strongly and constantly, and vice versa					
Intra-emotional flow of information AMOUNTS(IEFI)	**0,0**	**0,1**	**0,2**	**0,3**	**0,4**
levels are established on the assumption that the inner personality by the age of 40 is satisfied to be resistant to threats (incidents) and their impact is not prolonged.					
	variable probability Si				
number of incidents	0	1	2	3	4
External-emotional flow of information AMOUNTS(EEFI)	**0,00**	**0,1**	**0,25**	**0,35**	**0,57**
levels are established on the assumption that the external manifestation of personality emotions by the age of 40 is satisfied with the rapid but also retreating to threats (incidents) and the impact depends on the duration of external contacts					
Activity-economic flow of information AMOUNTS(AEFI)	**0,00**	**0,1**	**0,25**	**0,33**	**0,52**
levels are set on the assumption that the business activity of an individual by the age of 40 is satisfied with the unstable to threats (incidents) and the impact is dangerous					

As can be seen from the figure 4, the maximum impact on the probabilistic states of the employee is exerted by the "Active-emotional flow of information" and "External-emotional flow of information".
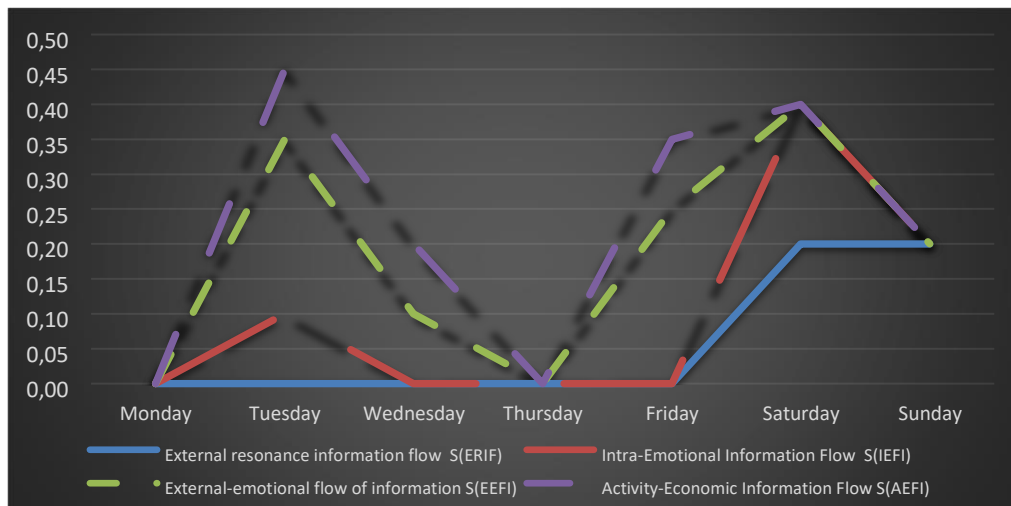
Figure 4 – the result of the effects of information flows on the Office Manager employee for 7 days of observations of the automated model

The data is in four streams of metadata and forms the two States of Alien and Own, in the following Figure 5. The most "dangerous" from the point of view of the company's security information system - "External resonance" flow did not affect the object of research.
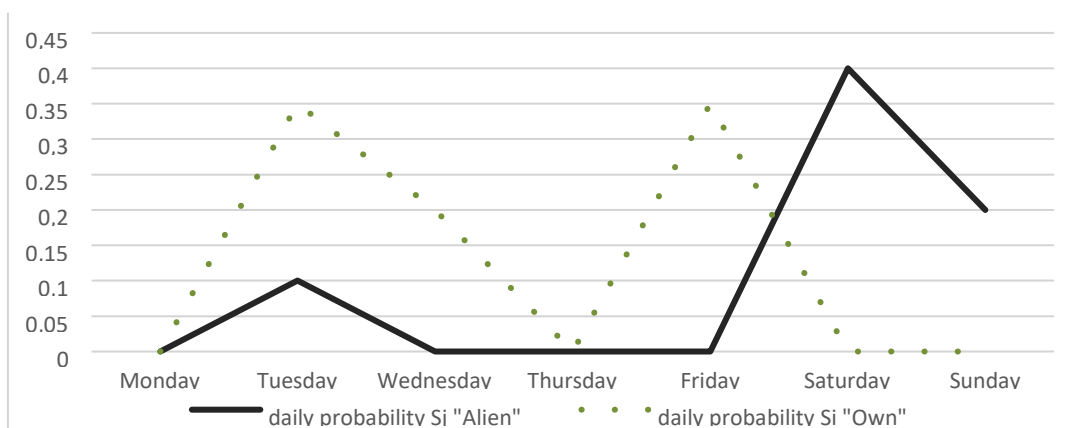

Figure 5 – probabilities of the states "Own" and "Alien" for the office-manager employee for

7 days of observations of the semi-automated mathematical model

As can be seen from Figure 5, the state of "Alien" is observed in an employee on weekends and has a stronger impact on the state of his motivation as an employee, which is confirmed by the state of "Own". That is, at work in a team, he has the "restraining" forces of the stability of the psycho-emotional state of being a conscientious worker. All values of probabilities did not exceed the established maximum probabilistic threshold of "malicious intent" - 0.77.

Therefore, based on the results of the collection and processing of metadata for the employee "Office Manager", we have an employee to whom the management of the enterprise and the information security department can "trust" a trade secret for a period - a week ahead. The next measurement of information flows will either refute or confirm the status of this employee - you can verify the trade secret and be admitted to the business process of the company. After mathematical processing of the aggregate probability, the information security system of the company through the mechanism of the automated system of the company (DLP)

will either provide access to the employee (in our example, this is the office manager of the company) or restrict access to the workplace (figure 6).

The employee, in the event that he is denied access to the workplace by the security system, is obliged to contact the security department of the company to clarify the reasons and circumstances of the refusal.
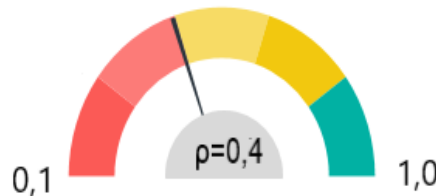

Figure 6 – trigger of the information security system (DLP) of the employee's access
to the trade secrets of the company scan

4 Conclusion

The article discusses the scale of metadata that can be offered to the information security department to collect about each employee, and also presents the concept of metadata processing using the Bayes formula and presents the results of calculating the probability of one of the employees - an office manager, how the final probability of his weekly state is calculated - either as a type of "Own", or transitional and the dangerous condition of a "Stranger" who, as having access to a trade secret, is already capable of criminal actions (leakage, theft of information or negligence).

The main factors of metadata that need to be collected and taken into account from open and closed sources of information about each employee at the enterprise, for all employees with access to trade secrets and the business process of the company, are presented and deciphered, which allowed us to propose the concept of a multifactorial mathematical model for identifying an internal violator based on measuring the probability of risks of a transitional state for each employee of the company. from the "Own" type to the "Alien" type as an internal threat to trade secrets from the personnel of the enterprise, as well as the algorithm of employee admission inside the access system to the company's trade secrets. The appearance of an internal violator is multifactorial, in fact, a dynamic process that has its own typology and a set of corresponding threats that lead to such a phenomenon as an Internal Violator (often referred to as an insider), who, being under the influence of resonant factors, becomes a threat of leakage of the company's trade secrets.

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FEATURES OF TRAINING FUTURE COMPUTER SCIENCE TEACHERS FOR STEM EDUCATION

Maratova Tolganay[1], Bostanov Bektas[2], Kultan Jaroslav[3]

Abstract

In recent years, STEM technologies have been actively developed and applied in various spheres of human life. In the article, the authors emphasize the importance of STEM technologies in education for modern society and provide statistical data demonstrating the tools needed to develop areas of application of STEM technologies for future teachers of computer science. STEM sets itself the task of introducing education, training specialists with project and research competencies and opportunities for interdisciplinary communication in universities. This article will show the features of using the STEM education approach for future computer science teachers.

STEM technologies are actively developed and used in various spheres of human life. The introduction of STEM education sets the task of training a specialist with interdisciplinary communication capabilities. In this article: a design method is used that develops the thinking and important qualities of students; escribes the relevance of the topic; the features and possibilities of using STEM-technologies by future teachers of informatics are considered; ➢ stressed the importance of STEM technologies in education for modern society. The authors also provide statistics on technology applications for future teachers.

Keywords*: STEM-education, STEM-technologies, informatics, teacher training, education

1. Introduction

One of the main problems of students is the training of students in an integrated approach to solving the tasks set on the basis of the knowledge gained throughout the training. Very often, students do not understand the relationship between individual subjects and there are questions why they need them (Schmidt & Sadvakašova, 2017). In recent years, there have been demands in science, technology, engineering and mathematics that should be based solely on the creation of interdisciplinary connections (Schmidt, 2018), conducting deeper research outside the subject – STEM has become a potentially useful tool in solving this problem STEM.org. (n.d.).

STEM education is based on the creation of a mixed environment in which students not only learn scientific methods at a theoretical level, but also begin to understand how to apply them in practice. In addition to mathematics, computer science, physics, etc., students of the chosen technical program study robotics, on the basis of which they will have the opportunity

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to expand their research competencies, awaken interest in the subject and develop leadership qualities.

STEM is a methodology for teaching students based on comprehensive research into science, technology, engineering, and mathematics as the most sought-after disciplines. STEM technologies in education imply not only the theoretical study of the material, but also practical application (Chen & Liu, 2021).

The implementation of the stem education concept in Kazakhstan sets the task of training future teachers of informatics with interdisciplinary and design-research competencies to higher education (ENU, 2021). This means that in addition to the ability to solve standard professional tasks in the field of training, education and development of the younger generation, a graduate of a pedagogical university should be ready to generate new ideas, implement them in projects, conduct research, implement their results and have managerial qualities. This is due to the fact that, in accordance with the requirements of the new time, specialists are required who have a more developed meta-subject connection than specialists working in one direction.

STEM is used to develop a new line of study. Educators can use STEM as a set of multiple activities and tasks, rather than as a holistic teaching method. STEM education consists of a system of complex teaching methods based on problem-based, project or educational requests that require the teacher to move from a traditional form of learning to the activities of an observer or supporter of research with the help of students Land, M. (2013).
The main features of the application of the STEM method are as follows:

Impacton creativity: STEM and innovation can lead to new ideas and innovations. If we look at the results of recent research, without innovation, it is impossible to achieve results in the field of artificial intelligence and digital education.

Resilience: Students can try to succeed in the development process in a safe environment by correcting mistakes using the STEM method as a tool.

Supporting Innovation: It's impossible to achieve results without some risk in the process of creating any technological scientific research. In the course of the study: "How do you implement this result?" or "Are you sure that this study will have a result?", etc., asking such questions can make students take risks, achieve results.

Group work: by combining students of different skill levels or interests into a group, it becomes possible to achieve different results.

Application of knowledge related to different subjects: different practical possibilities are needed to solve the problem. Based on this, students strive for further improvement of their knowledge.

Improving the use of technology: Technology and innovation are managed through STEM education.

Problem-solving opportunities: Through STEM education, students learn to analyze, think critically, and find answers to solve any problem (Steambuilders ,2022)*.*

From this it follows that in addition to the ability to solve standard professional tasks in the field of training, education and development of the younger generation, graduates of pedagogical universities should be competent in generating new ideas, implementing them in projects, conducting scientific research and implementing their results.

The terms "STEM", "science", etc. Science, technology, engineering, and mathematics (STEM) is a curriculum that combines classes in science, engineering, engineering, and mathematics. STEM education is based on the application of an interdisciplinary and applied approach, as well as the integration of all four disciplines into a single learning scheme. The purpose of this study, which aims to address this issue, is to identify the current state of STEM research, research trends, and emerging trends in STEM education.

Education is developing in many countries, in particular in Australia, Great Britain, Finland, Israel, Canada, China, Singapore and the United States. Its creation was a continuation of the concept of STEM education

2. Purpose

The purpose of this study is to analyze the existing directions in the development of the STEM system, to develop the possibilities of using STEM in Kazakhstan, to adapt it to the conditions in Kazakhstan, as well as to clarify the positive and negative aspects of using STEM. To achieve this goal, it is necessary to solve the following tasks:

- to study the state of application of integrated education in Kazakhstan
- determine the methods and possibilities of obtaining data
- select tools for conducting questionnaires
- to analyze the relationship between researchers in this field - the study of: the relationship between the individual elements of this methodology; the relationship between the individual subjects of the school; the attitude of the teacher to mixed learning.

By solving these issues, it is possible to create a team of scientific and pedagogical workers who will not only develop theoretical issues of this method , but also practical application in Kazakhstan.

3. Methodology

In thispart, some of the main methods of studying this question are considered, as well as the methods used in the STEM system. Based on the provisions on this technique, it is necessary to conduct a more detailed analysis of the state of application of this technology, the relationship between the works of scientists in this field and some tools aimed at creating surveys.

4. Implementation Tools - Define a survey tool

According to research in recent years, one can see a desire to answer some questions, for example, how to properly apply the STEM method in the education system of Kazakhstan, which makes it difficult to introduce it into the educational process and the formation of an understanding of interdisciplinary relations.

The main idea of the STEM method is to eliminate all the differences between disciplines and present everything as a whole. Modern didactic methodology is an integral system of teaching subjects, built on the basis of mastering the disciplines of logical mathematics, physics, computer science and creative thinking, etc.

In this section, you have chosen a methodology that includes surveys, testing, and other methods. Tools such as Google Forms and MS Teams, which were selected to survey students in order to gradually introduce this methodology into the educational process, were also considered.

In the process of modern education, we have separate approaches to various tasks. For example, in one problem we study the solution of differential equations - in mathematics, and in physics - an electric field, and in the courses of electric machines we study the electric motor. Applying this approach, we should draw the relationship between these topics in all three courses. These problems must be addressed as a whole.

To study this approach at the present stage , we suggest using survey tools: Google forms, MS Teams, etc. The data will be presented in two different ways:

- By distributing handouts with questionnaire questions;
- By sending a link to Google forms with survey questions;

For a more detailed analysis of the relationship of individual publications, you can use vos viewer programs. Given the capabilities of this tool, you can not only determine the relationship of the available

5. Experimental stages.

It would be useful to create tests with questions from each area to determine the readiness of future computer science teachers to form interdisciplinary connections between subjects. To create these tests, we will use the Google Forms tool. Here, teachers from different fields can formulate interrelated tasks between several subjects.

Assembling questions on Google's forms platform allows you to do this in a simple way. Thus, it is very easy to choose different types of questions, change the sequence of answers, make different videos or graphs of questions, choose the time and date, etc. Because of this, in addition to the fact that the questionnaire designer can change any temporary changes and additions, he can also make test results, graphs, etc. In addition to his thoughts from the respondents.

In the course of the analysis, several areas of the survey were identified, which make it possible to find out the level of subjects taught, their relationship and the possibility of combining the selected subjects in the learning process. It is also necessary to find out which topics of hotel items are related to each other.

Therefore, the first group of questions is aimed at creating a relationship between individual subjects. The following are examples of questions for a survey:

1. Which subject belongs to the subject of mathematics "Solving linear equations"?
2. Is it possible to find a connection between the solution of quadratic equations in the field of physics?"
3. What types of equations from the field of mathematics can be used in chemistry?

These questionnaires will be distributed and the results will be analysed and included in future publications. Based on the data obtained, it is possible to study the measure of integrated training at the present stage, to find ways to improve the existing situation, to find tools for the effective implementation of this methodology in the educational process.

6. Outcomes

The analysis of the state of use of the STEM system can be analyzedfrom several angles. First, we will consider publications from the point of view of their authors and subsequently consider their relationship in terms of their content, terminology and definition (Lin & Hwang, 2022)

7. Analysis of the current state of STEM in foreign literature.

This part provides some of the main tasks of STEM application, such as: solved tasks aimed at a basic overview of the current state of STEM; what is STEM; when the STEM name begins to apply. which authors began to use this concept and what are the main works and results of scientists of world and Kazakhstani authors.

It is difficult to find a precise definition of the concept, there are many opinions on how to apply STEM knowledge. For example, according to Sanders (2009, p. 21), "STEM education

includes approaches that explore teaching and learning between any two or more STEM subject areas, or between a STEM subject and one or more other school subjects." Gonzalez and Cuenzi (2012, p. 1), on the other hand, argue that the term "STEM education" refers to education in science, technology, engineering, and mathematics and usually includes educational activities at all postdoctoral levels from preschool education. in a formal and informal setting.

Bybee (2010) looked at the origins of STEM research and what the acronym actually is. He said that in biology, the term is usually associated with "stem cells", but in education it is used only in a general sense. He noted that educators typically use it in science and mathematics education, while technology and engineering are generally ignored, and suggested that instead of using the term STEM education as a simple motto, it should be a core part of the curriculum (National Science Board, 2021). With regard to disciplinary integration, Henriksen (Lin, & Hwang, 2022) confirmed that the interdisciplinary nature of STEM (science, technology, engineering and mathematics), based on the integration of four disciplinary areas, helps students apply their knowledge from different perspectives to solve a complex problem.

An acronym for Science, Technology, Engineering and Math (Herschbach, 2011), STEM education is an approach to teaching and learning that integrates the content and skills of science, technology, engineering, and mathematics (National Research Council, 1996). There is no exact definition of STEM, and so there are many opinions on how STEM education should be applied.

In addition, the universality of STEM education should be noted as a determinant of meta-subject connections between different disciplines (Vasquez et al., 2013). Research involving STEM teaching methods can be critical to understanding and meeting the needs of all future computer science teachers to expand science learning opportunities (Provasnik et al., 2012). In recent years, in connection with the development of new technologies, a lot of work has been done to improve education in the field of natural sciences in connection with the state of development and restoration of science. Evidence of this is the development and implementation of an interdisciplinary approach that studies the standards of the new wave of time (NGSS), i.e. s - scientific education, T - technology, E - engineering, M - mathematical science (Ritz & Fan, 2015). In the early 1990s, the acronym STEM was used by various faculty members supporting SMET, including Charles E. Vela, founder and director of the Center for Hispanic Development (CAHSEE) in Science and Engineering Education (Hughes, B. S. et al.,2022).

8. Analysis of mutual relations of publications about STEM

In this research paper, in accordance with the topic selected from the global Scopus database, a study of articles for the period from 2018 to 2022 was conducted, and the articles were selected from titles and summaries, which should contain the keywords "STEM", "education" and "project". The selection of articles was carried out in the following areas:
- published in 2018-2022,
- in English,
- nopen access.

After analyzing the topic, summary and keywords, 189 articles from 1311 articles were selected and analyzed.

As a result, a total of 373 articles in the field of "social sciences" and "computer science" were identified using keywords. The first of the articles selected as a result of the study dates back to 2018 (m=45), with a key number (n=16) Number of articles in 2019 (m=63), number of key articles (n=113) Number of articles in 2020 (m=85), number of key articles (n=344)

Number of articles in 2021 (m=90), number of key articles (n=654) In 2022, number of articles (m=90), number of key articles (n=820) (Figure 1).

Fig. 1 Annual trend of publications on the use of the STEM method
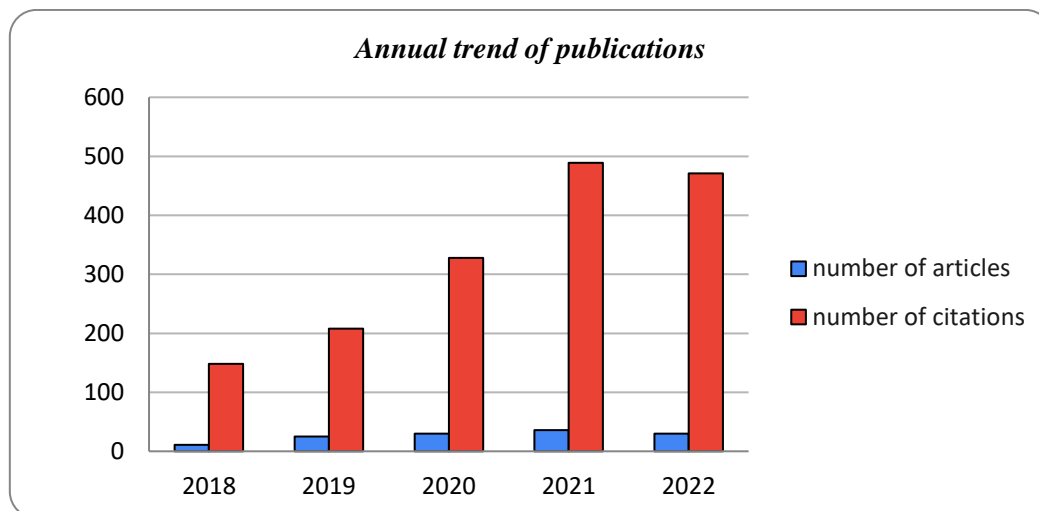
Based on data analyzed from a systematic review using vos viewer, we determined the number of "STEM", "education", and "project" keywords used for articles published over the past 5 years. In the course of the study, we showed in the program the use of keywords, using those that are most often found in headings and resumes.

In VOS Viewer, in order for related items to appear on the map, a word must occur at least 5 times, and out of 5300 terms, 260 elements of this condition satisfy the condition. As a result of the selected theme, 2 main clusters of 8 elements were identified and 2 colors were shown (Figure 2):

Fig. 2 Resume analysis
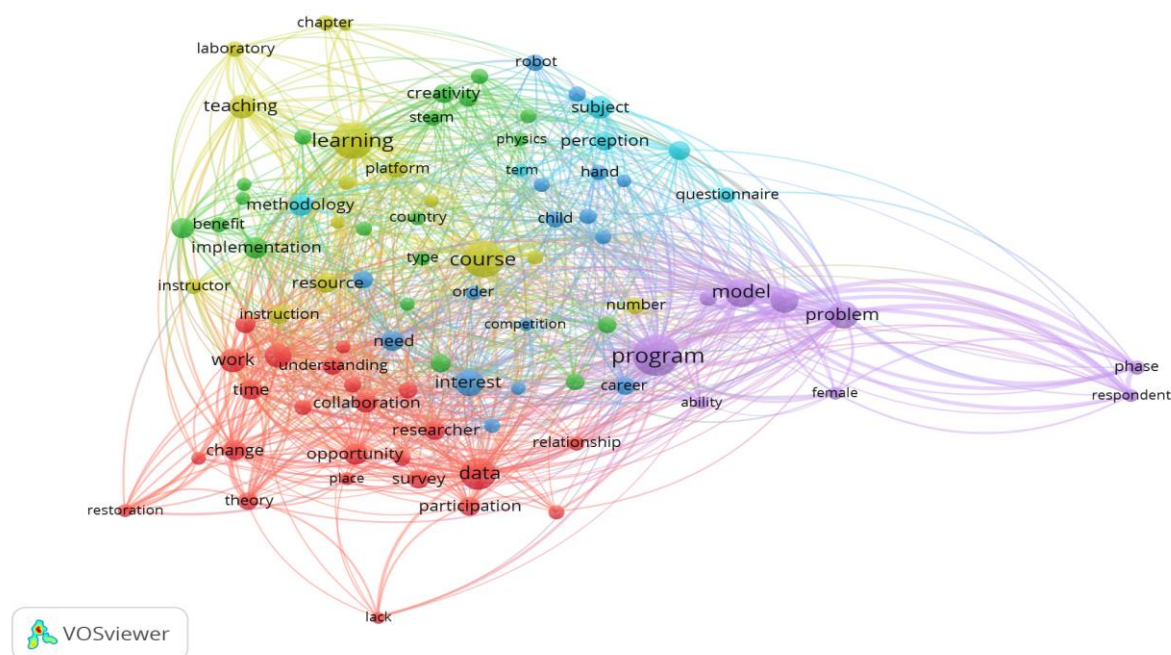
The next step was to analyze the resume. As a result of the selected abstracts, 6 main clusters of 89 elements were identified and shown in 6 colors. Here, each element is connected to each other, the total number of connections is 2686 (Figure-2):

The first red cluster has 24 elements, the second color cluster has 19 elements, the third dark blue cluster has 16 elements, the fourth yellow cluster has 16 elements, the fifth violet cluster has 9 elements, the sixth bright blue cluster has 6 elements.

The most common and most studied topics in the resume are: "Program" N = 86, "Training" n = 83, "Work" n = 83, "Interest" n = 80, "Implementation" n = 76, "Methodology" N = 71.

9. Solution-Developing a New Approach-STEM

Proponents of the STEM method can only speak in simple terms about the state of the method in the classroom, but only teachers who know how to properly compose or use the method in accordance with the curriculum.

STEM-based programs require a holistic education and training system that incorporates some connection between curricula, standards, and assessment systems.

STEM-interdisciplinary communication. Usually, in interdisciplinary communication between teachers involved in the methodology, there should be a group connection. This is because if, in the course of explaining topics relevant to their disciplines, conditions are created in which they consult with other disciplines and even explain the same subjects, linking them to the topics they teach, then this will be a real interdisciplinary connection. Of course, each subject has its own scope and content, but if teachers of computer science and mathematics introduce interdisciplinary connections, then both new methods of computer science and new methods of mathematics will be characterized by a complex conclusion. This overarching statement is seen as a bidirectional point of communication. For example, if the concept was based on some data, a math teacher could teach them how to collect data and draw it on some graph, a computer science teacher could organize data collection in a fund and visualize a graph using various application programs.

Using a STEM method in a class has the following features:

- Students participating in STEM programs should ask a variety of thought-provoking questions, seek answers to such questions, apply what they have learned in practice, and try to be creative in the process. For example: in the course of conducting research in the discipline of robotics, learn from students a lot of questions about how to create a robot that will move depending on the direction of color, the principles of operation of the robot, the various methods of its work, the actions necessary to perform it in other directions with a change of color; think creatively about your project and how to develop further.

- When working on the STEM method, teamwork and an exchange of views between project participants are necessary. Because thanks to this, you can discuss issues related to the project, discuss ways to solve the inconveniences that arise and find a solution (Doran & Treagust, 2020). In accordance with this, students seek to divide their responsibilities among themselves, listen to each other, praise and resolve differences.

- By dividing students into different groups for different strategic reasons , you can create very strong groups that learn how to help each other how to effectively develop their strengths and methods. For example, if a group is given the task of creating a 3D model of

a differential equation, then one of the groups is very good at solving equations, while the other may be interested in optical illusions or 3D glasses.

10. Conclusion

STEM education should be based on targeted development programs, which, in turn, should include the active involvement of educational recipients.

In this article, when preparing future teachers for professional activities, first of all, it is necessary to ensure the formation of their cognitive skills, as well as intrapersonal and interpersonal-emotional intelligence. It is important to conduct active explanatory work aimed at familiarizing students with world trends in education, among which STEM comes out on top (Karsenti & Collin, 2020).

In conclusion, education should be student-centered. The STEM method allows students not only to teach high technologies, but also to apply the skills of critical thinking, problem analysis, solve complex problems, achieve goals, implement projects at a crossroads in practice. The use of the STEM method allows you to solve complex problems and apply them in practice, creating interdisciplinary connections with various other disciplines. Thanks to this, we will be able to establish interpersonal connections and increase the interest of students.

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THE STATE OF THE INITIAL MATHEMATICAL KNOWLEDGE OF ENGINEERING STUDENTS IN THE POST-PANDEMIC PERIOD AS A STARTING POINT FOR THE DEVELOPMENT OF E-COURSES

Mária Mišútová[1], Martin Mišút [2], Hana Stúpalová[3]

Abstract

The paper describes the research focused on creating e-learning material based on the identification of the status of the results of mathematical education from the previous teaching level in students in the 1st year of bachelor's studies at MTF STU in Trnava. The aim is to improve students' knowledge of secondary school mathematics so that they complete not only mathematical subjects but also subjects of a university base and, consequently, professional subjects of technical study.

Keywords

teaching model, digital technologies, mathematics, e-learning

1. Introduction

The research described is part of large-scale research whose primary goal is to increase the quality of learning outcomes by focusing on the learner. And thereby, in line with the needs of the circular economy and current trends in the world (Faridhan, Loch, & Walker, 2013; Reisel, Jablonski, Hosseini, & Munson, 2012), increase the number of graduates of technical universities by implementing innovative online teaching models using digital technologies and an emphasis on developing transversal competencies. (Martin Mišút & Mišútová, 2013; Mišútová & Mišút, 2012) Also contribute to the enrichment of the theory of pedagogy in the field of methodology of mathematical and informatics subjects.

One sub-goal was creating an e-project with the highest possible didactic efficiency. Therefore, we first surveyed students for their state of knowledge in high school mathematics. Students who made up the set of respondents completed part of their secondary studies during the pandemic.

We identified the status of the results of mathematical education from high school in three ways:

1. Analysis of student written works from the previous two academic years 2021/2022 and 2020/2021.

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2. Using a questionnaire filled in by Mathematics I students in the academic year
   2021/2022.
3. By evaluating the entrance test from the academic year 2022/2023.

Based on the results, we developed an e-project, „Prerequisite of a technical student", –
interactive teaching materials suitable for self-study. In addition to the theoretical part, they
also contain self-tests designed for individual feedback. They are designed according to the
principles of creating e-learning materials for knowledge testing. (Andrade-Aréchiga, López,
& López-Morteo, 2012; Daly, Pachler, Mor, & Mellar, 2010; Divjak, Zugec, & Anicic, 2022;
Hostovecky, Misut, & Pribilova, 2015; Kortesi, Simonka, Szabo, Guncaga, & Neag, 2022;
McCallum & Milner, 2021; Rowlett, 2022; Swan & Burkhardt, 2012; Webb, Gibson, &
Forkosh-Baruch, 2013)

The current situation requires education to be made more effective. (Orszaghova, 2017)
As a result, it is necessary to innovate the educational process in terms of content, methods, and
forms. (Baneres, Baró, Guerrero-Roldán, & Rodríguez, 2016; Diefes-Dux, Zawojewski,
Hjalmarson, & Cardella, 2012; Fuentes, Garcia, Ramirez-Gomez, & Ayuga, 2014; Kortesi et
al., 2022; Timotheou et al., 2022; Valverde-Berrocoso, Acevedo-Borrega, & Cerezo-Pizarro,
2022; Wesiak, Al-Smadi, Höfler, & Gütl, 2013)

The e-project is part of an innovative model of online teaching. This contains e-learning
materials from the subjects Mathematics I, Intelligent Management Methods, Modeling and
Simulation of Systems available for students MTF STU in the students information system. It
also includes e-courses in Software Engineering, Business Process Modeling, and Database
Systems created in the Moodle environment and available to students at FHI EU. Verification
of the didactic effectiveness of the online model is carried out at the moment through
pedagogical experiments. The results will be processed and used to update online teaching
models. Recommendations for pedagogical practice will also be developed with a view to
implementation in teaching.

2. Methodology

We identified the status of the results of mathematical education from high school as
follows:
1. By analyzing student written works from the previous two academic years 2021/2022 and
   2020/2021.
   We analyzed 218 written works of students – calculations for the final test in the subject
   Mathematics I in the exam period of the academic year 2021/2022, and 154 written works
   in the exam period of the academic year 2020/2021. In each exam period, we selected the
   two most numerous dates. An analysis of these 372 papers gave us a sufficient picture of
   the most common mistakes made by students. Table 1 shows the dates of the most
   numerous exams dates and the number of student tests.

Table 1 The number of student tests

Exam	Number of tests
4.1.2022	146
11.1.2022	72
12.1.2021	103
19.1.2021	51
Total	372

Source: Own work

2. By questionnaire

   The questionnaire was created using Google Forms. The return on the questionnaire was almost 40%. It was completed by 76 students out of 192 students in the 1st year of bachelor's full-time study at MTF STU in the academic year 2021/2022. Of these, 58 are men (76.3%), and 18 are women (23.7%). Among the respondents, there were 14 gymnasium graduates (18.4%), 37 graduates of an industrial secondary school (48.7%), 24 graduates of a secondary vocational school (31.6%) and one respondent has already attended at least one-semester bachelor's degree university (1.3%). Respondents replied to 6 items of the anonymous e-questionnaire.

3. By entry test from the secondary school curriculum in the academic year 2022/2023.

   The respondents consisted of 99 students in the 1st year of full-time bachelor's studies studying study programs in Industrial Management, Personal Policy in Industrial Plant, Production Devices and Systems, Manufacturing Technologies, Production Technologies and Production Management. Of these, 71 were men, and 28 were women. The test took the form of a quasi-standardized test. It contained five closed tasks with a choice of answer. The student could get max. 5 points. The solution time was 20 minutes. Along with the test, students were also required to submit auxiliary calculations.

   All students wrote the test at the same time in one room. The Sancho app was used for evaluation. (Misut & Misutova, 2017)

   The results of the previous part of the research showed that students have a positive attitude towards online teaching. (Martin Mišút & Mišútová, 2021; Mišútová & Mišút, 2021) The results of this part of the research also predict the impact of gender on students' attitudes towards online teaching. Women rated online teaching less positively than men.

   We wanted to know whether there would be a statistically significant difference in the success rate of the entry test by men and women. And also, among students of different study programs. We established the following working hypotheses:

   Hypothesis 1: There is no statistically significant difference between the success rate of women and men in solving the entrance test.
   Hypothesis 2: There is no statistically significant difference between students' success from different study programmes.

   To verify the established hypotheses, we used Independent Sample Test using SPSS.
   The data was formed from the results of the entry test of 99 students. The following tables provide descriptive data statistics by gender (Table 2) and study programme (Table 3).

Table 2 Descriptive data statistics by gender

	N	Minimum	Maximum	Mean	Std. Deviation
M	71	0	5	2,00	1,183
W	28	0	5	2,32	1,517
Total	99	0	5	2,09	1,286

Source: Own work

Table 3 Descriptive data statistics by the study programme

Study program	N	Minimum	Maximum	Mean	Std. Deviation
PMA	32	0	5	1,91	1,553
PPP	12	1	4	2,08	,996
PPT	44	0	4	2,11	1,104
VTE	5	1	5	2,80	1,483
VZS	6	1	4	2,33	1,506

Source: Own work

3. Results and discussion

3.1 Analysis of student tests

Table 4 presents the areas of the most common student errors obtained as a result of the analysis of tests. Areas are sorted in descending order, based on the relative number of tests that have resulted in errors from that topic area.

Table 4 The areas of the most common student errors

Thematic area of mathematics	Number of tests in which errors from the area occurred					The relative number of errors %	Relative number of tests %
	4.1.2022	11.1.2022	12.1.2021	19.1.2021	Total		
Algebraic expression	63	30	41	21	155	22,22	41,65
Elementary functions	54	27	36	18	136	19,48	36,50
Inequalities	37	19	27	13	95	13,69	25,66
Quadratic equations	32	17	22	11	82	11,70	21,92
Fraction operations	32	14	22	12	79	11,36	21,28
Operations with powers	31	16	23	9	78	11,24	21,06
Linear equations	28	14	20	10	72	10,32	19,33

Source: Own work

The table shows that students make the most mistakes in the field of editing algebraic expressions, which we assumed. However, we were surprised that as many as 21.28% of students made mistakes in the area of operations with fractions.

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3.1   Questionnaire

Table 5 shows the number of student responses to the questionnaire entry: Which of the areas of high school mathematics most often caused you difficulties in solving tasks in the subjects Mathematics 1 and Mathematics 2? In the last column, there is also a relative number of respondents out of a total of 76 who indicated a given area of mathematics.

Table 5 Problem areas based on the questionnaire

Thematic area of mathematics	Number of respondents	The relative number of respondents %
Fraction operations	16	21,05
Operations with powers	15	19,74
Algebraic expression	30	39,47
Linear equations	15	19,74
Quadratic equations	17	22,37
Inequalities	20	26,32
Elementary functions	28	36,84
Straight line, circle, parabole, hyperbole	41	53,95
Vectors	38	50,00
2D, 3D cartesian coordinate system	31	40,79
No area	8	10,53

Source: Own work

From Table 5, it can be seen that students most often indicated geometric areas. Almost 54% of students are problems with geometric figures, 50% with vectors and almost 41% with 2D and 3D Cartesian coordinate systems. The areas of mathematics that students marked in other places coincide with the areas we identified by analysing the students' tests. (see Fig. 1) Algebraic expressions cause problems for 39.47% of students, and elementary functions for 36.84%. Inequalities were identified by 26.32% of students, quadratic equations by 22.37% and operations with fractions by 19.74% of students. Although 97.4% of respondents stated that they had attended an entry course in high school mathematics, only 10.53% indicated the possibility that no area of high school mathematics was causing them problems.
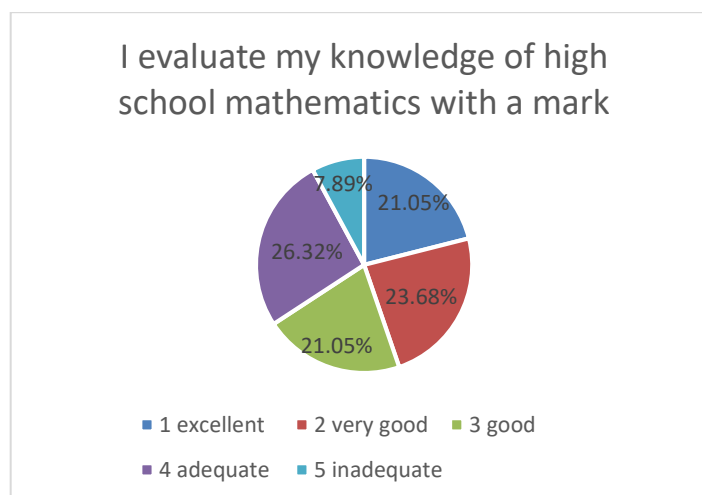
Fig. 4: Comparison of problem areas based on questionnaire and test analysis
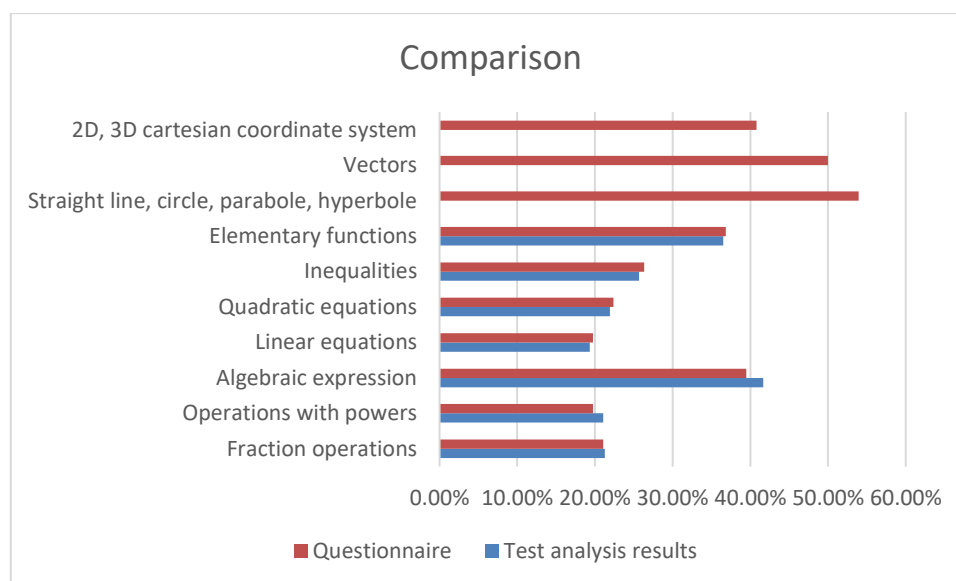
Source: Own work

The high school mathematics course students could attend before the start of the academic year was described by 44.6% of respondents as useful, 35.1% chose the "partially useful" option, 9.5% of respondents described the course as "rather unhelpful". 8.1% of respondents chose the "I don't express myself" option, and only 2.7% (2 students) called the course unhelpfully.

We were positively surprised by the response to the questionnaire item: If there were regular consultations from selected areas of high school mathematics during the 1st or 2nd semester, would you be interested in them? More than half of the respondents declared an interest in such consultations. 25% of respondents answered "yes", and 30.3% "rather yes"

Figure 2 provides a graph of responses to one of the questionnaire items. Interestingly, students rate their knowledge of high school mathematics mainly with a grade of 1 to 4. Only 7.89% of respondents (6 students) identified their knowledge as insufficient.

Fig. 2: The graph of responses to one of the questionnaire items

Source: Own work

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3.2   Entry test from the high school curriculum

Fig.3 shows a graph of the relative success rate of solving the tasks of the entry test. It can be concluded that students achieved the lowest success rate of only 28.07% in solving a task from the Vectors area. This thematic area was identified as problematic by the students in the questionnaire.

Fig. 3: Relative success rate of solving the tasks of the entry test
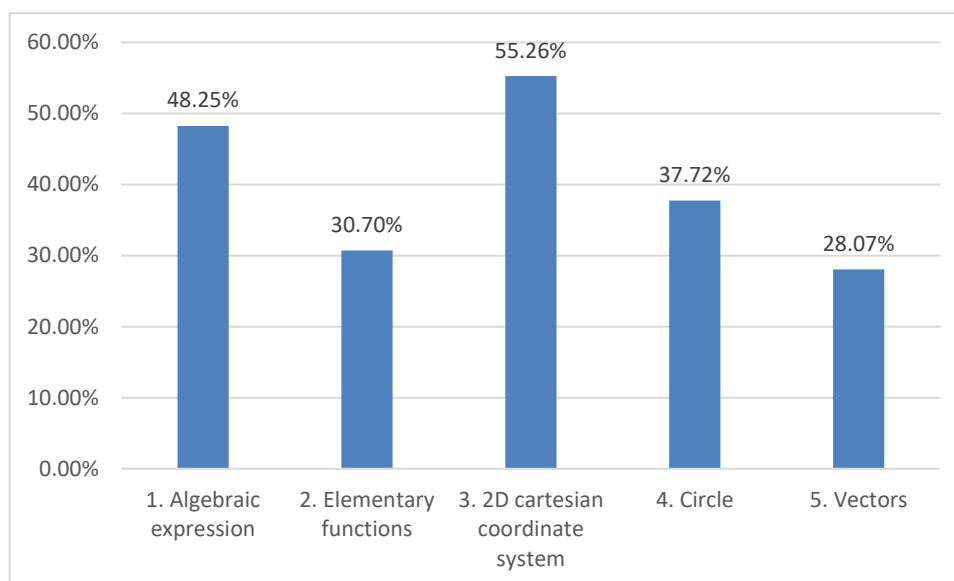
Source: Own work

Up to 50% of students did so. On the other hand, although as many as 40.79% of students identified 2D, and 3D Cartesian coordinate systems as a problem area, in the entry test, this task had the highest pass rate, up to 55.26%. The success rate of solving the other tasks was low. The results of the entry test confirmed that solving tasks from thematic areas of mathematics, as we identified them by analyzing written works and using a questionnaire, causes significant problems for students in the 1st year of bachelor's studies. That is why we have developed the e-project "Prerequisite of the technical student ", designed for self-study and self-control. It contains a theoretical part and tests from selected thematic areas. Based on the experience of many years of pedagogical practice, it can be assumed that with the help of this tool, it is possible to improve students' knowledge from the secondary school curriculum. The aim is for them to successfully complete mathematical and higher education subjects, followed by professional subjects of technical study. The didactic effectiveness of the teaching model using the above-mentioned e-project will be verified by a pedagogical experiment. Fig.4 shows the entry screen of the e-project "Prerequisite of the technical student" and a demonstration of an incorrectly and correctly solved task from the selected self-test.

Fig. 4: The entry screen of the e-project

Figure 5 The entry screen of the e-project

Source: Own work

Hypothesis 1, in which we assumed that there is no statistically significant difference between the success rate of women and men in solving the entry test, **has been confirmed**.

The Independent Sample T-Test using SPSS confirmed that there is no statistically significant difference between female and male results. (p=0.265). Table 6 shows Group Statistics for the T-Test.

Table 6 Group Statistics of the Test score

Sex	N	Mean	Std. Deviation	Std. Error Mean
M	71	2,00	1,183	,140
W	28	2,32	1,517	,287

Source: Own work

Hypothesis 2, in which we assumed that there is no significant difference between the success of students of different study programs in solving the entry test, **was also confirmed**. None of the p-values was less than 0,05.

4. Conclusion

In conclusion, it can be concluded that solving tasks from thematic areas of mathematics, as we have identified them by analyzing written theses and using a questionnaire, causes significant problems for students in the 1st year of bachelor's studies. Our conclusions are in line with the results of the research work of Országhová et al. (Orszaghova, Farkasova, Drabekova, & Bulgakov, 2019; Orszaghova, Greganova, & Horvathova, 2019), where the authors surveyed the mathematical knowledge of students in economic study programs. The

results of our research confirmed the assumption (Hypothesis 1) that there is no statistically significant difference between men and women in the quality of secondary school entry. Although men performed worse than women, the difference in success rates was not statistically significant. The results of the described research will be used in the process of creating a model of online teaching of mathematical and informatics subjects using digital technologies and an emphasis on the development of transversal competencies so as to increase its didactic efficiency.

5. Acknowledgements

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THE USE OF MODERN DIGITAL TECHNOLOGIES IN EDUCATION

Nurgul Uderbayeva Kalievna[1], Peter Schmidt[2]

Abstract

Currently, the creation of an information system using the technology of interactive visualization of three-dimensional objects by means of augmented reality in real-time on a real scale for mobile devices is of great interest in education. The article provides a brief overview of augmented reality (English augmented reality, AR) using the Vuforia Engine in combination with the well-known game engine Unity. It also considers a practical example of a project for iOS, and Android, in which, when you hover your phone (in our case, android) on a label, where the user will see buttons and links on the smartphone screen, where the video will be played. When you click the label (icon), a link to YouTube appears, where there will be complete information about the components of a personal computer. The label, that is, the picture in the article, is a picture from the Primary School Digital Literacy textbook.

The article shows an example of using AR technology to develop practical material used in conducting classes in elementary grades of educational institutions.

Keywords

AR, augmented reality, Unity 3D, Android, Xcode, Vuforia Engine, digitalization, information and communication technologies.

1. Introduction

Digitalization has rapidly become a global trend. Especially now, when the world has survived the pandemic associated with the Covid-19 coronavirus infection when children were forced to study remotely (online), new technologies should be applied in education and be ready for the transition to a different learning format.

"In the modern world, one of the main factors of competitiveness is deep digitalization. For Kazakhstan, the transfer of modern digital technologies and the introduction of elements of industry 4.0 are extremely important. We must actively work with our strategic partners abroad. At the same time, it is important to nurture and strengthen the modern IT sector. The country needs young, educated, and motivated personnel. As part of the national digitalization project, it is necessary to train at least 100 thousand high-class IT specialists. Exports of services and goods of the digital industry should reach at least $500 million by 2025. These and other tasks will require a complete digital reboot of the public sector". (Eljubaeva, 2021).

In connection with this message, the Tech Orda program was developed as part of the task to train 100,000 IT specialists. The government allocates grants for those who want to master IT knowledge for 600,000 tenges (about 1200€) for each student, that is, by 2025 it is

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planned to train 20,000 IT specialists. With the help of this program, young people have the opportunity to deepen their knowledge or retrain.

All this demonstrates the global involvement in the processes of digitalization and, above all, it concerns young people.

The purpose of the study is to the effectiveness of the use of augmented reality (Chen et al., 2019) in the textbooks of Digital Literacy of the elementary grade in secondary schools in Kazakhstan.

2. Technologies used

Augmented reality is one of the many technologies for human-computer interaction (Sánchez-Alonso et al., 2019). Its specificity lies in the fact that it programmatically visually combines two initially independent spaces: the world of real objects around us and the virtual world recreated on a computer. A new virtual environment is formed by superimposing programmed virtual objects on top of the video signal from the camera and becomes interactive by using special markers. Augmented reality has been used for many years in medicine, the advertising industry, military technology, games, monitoring objects, and in mobile devices (Moreno et al., 2019).. The basis of augmented reality technology is an optical tracking system. This means that the camera becomes the "eyes" of the system, and the markers become the "hands". The camera recognizes markers in the real world, "transfers" them to a virtual environment, superimposes one layer of reality on another, and thus creates an augmented reality world (Vuforia, n.d.).

Augmented reality, or AR (augmented reality), is undoubtedly a huge breakthrough both in the way educational material is presented and in the assimilation of information by schoolchildren and students (Swensen, 2016). The effectiveness of its use is confirmed by various tests and experiments, which show excellent results. For example, several experiments were conducted in which one group of children was shown visual material with AR during the lessons, and the second group was shown ordinary posters and diagrams. It was found that in the group where augmented reality was used, the percentage of assimilation of information by children approached 90%, the level of discipline increased, and it was possible to keep the attention of about 95% of the audience. At the same time, in the group with two-dimensional benefits, all indicators were half and three times less. It was also found that a three-dimensional image stimulates thinking, develops motor skills, facial expressions, and attention, and increases the degree of assimilation, memorization, and, most importantly, understanding of information (Kannan et al., 2017).

Augmented reality has swept the world over the past decade, but so far it has failed to reach the general public. Student engagement has always been one of the main concerns for schools and teachers. Learning management systems based on AR and VR help teachers by increasing student engagement by attracting attention and immersion in the material being studied (Saad & Ismail, 2015).

Therefore, to attract the attention of students, immersive learning, that is, AR and VR technologies, has recently begun to be often used.

Such programs include the use of modern information technology in the learning process, which takes place inside various virtual worlds and simulations, often in a playful way. This type of training helps to increase involvement, communication between students, and interest in the subject.

Using 3D objects and views, different imaginative media, and simulations with different types of interactions is the easiest way to connect two isolated worlds. Through the use of augmented reality on the pages of printed books, textbooks will become dynamic sources of

information. Thus, people without computer education can still get a rich interactive experience (Kim & Kim, 2019).

3. Creation process step by step

Vuforia Engine (formerly Vuforia SDK) is a software package that includes an augmented reality platform and an augmented reality software developer toolkit (SDK - Software Development Kit). Vuforia Engine is integrated with the "game engine" Unity, which greatly facilitates the development of AR applications (Vuforia, n.d.).

This article discusses the Vuforia Engine on the Unity platform for the implementation of augmented reality, which will improve the assimilation of the material of students in general education schools in Kazakhstan. For example, the article shows a label (picture) from the 2nd-grade textbook "Digital Literacy", but we can also use any label in the textbook to implement augmented reality.

The article uses the Vuforia Engine software to implement augmented reality. An augmented reality application is created by linking the Vuforia Engine software with the Unity platform.

Consider an AR example where you can play a video using buttons and links that come out on a smartphone screen (Vuforia, 2020).

To create a new project, open UnityHub and in the Projects section, click on the NEW PROJECT button (Figure 1).

Fig. 1. Create New project in UnityHub
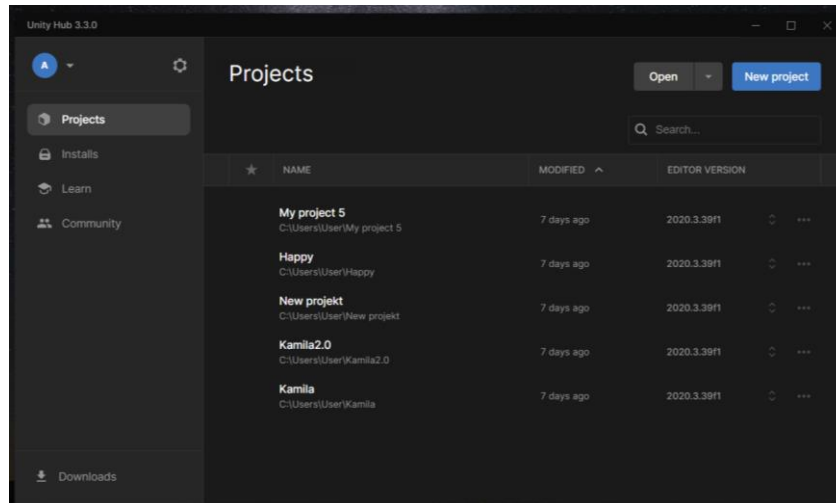
Source: Own elaboration

In the next window, choose *Templates → 3D* and give the name of the project, and then click Create. To turn on the camera, run the following command *GameObject → Vuforia Engine → AR Camera* (Vuforia, 2020).

For more work, we will need to get the license key from the Vuforia producers' portal (https://developer.vuforia.com/vui/develop/licenses). This procedure is free. After downloading the license key, go to *AR Camera* and enter the key in the *App License key* field in the *Vuforia Configuration* settings.

The next command is to create markers. To do this, go to developer.vuforia.com and create a new database under *Target Manager → Add Database*. In the window that appears in

the *Database Name* field, enter the name of the database, type Device, and click on *Create*. After you have created a database, you need to add markers, using the *Add Target* button.

    In the window that appears, select:
Type-Single Image
- *File-select* an image from our computer
- *Width*-1
- *Name*.

    When you add markers be sure to pay attention to the *Rating*, it should not be less than four or five stars, so that the camera is well recognized the picture. Now in *Download Database* load the created database. Next using *drag-and-drop* we import it into Unity. To select a picture in our project, choose *Image Target*. Next, go to Image Target and select our database there as in Figure 2.
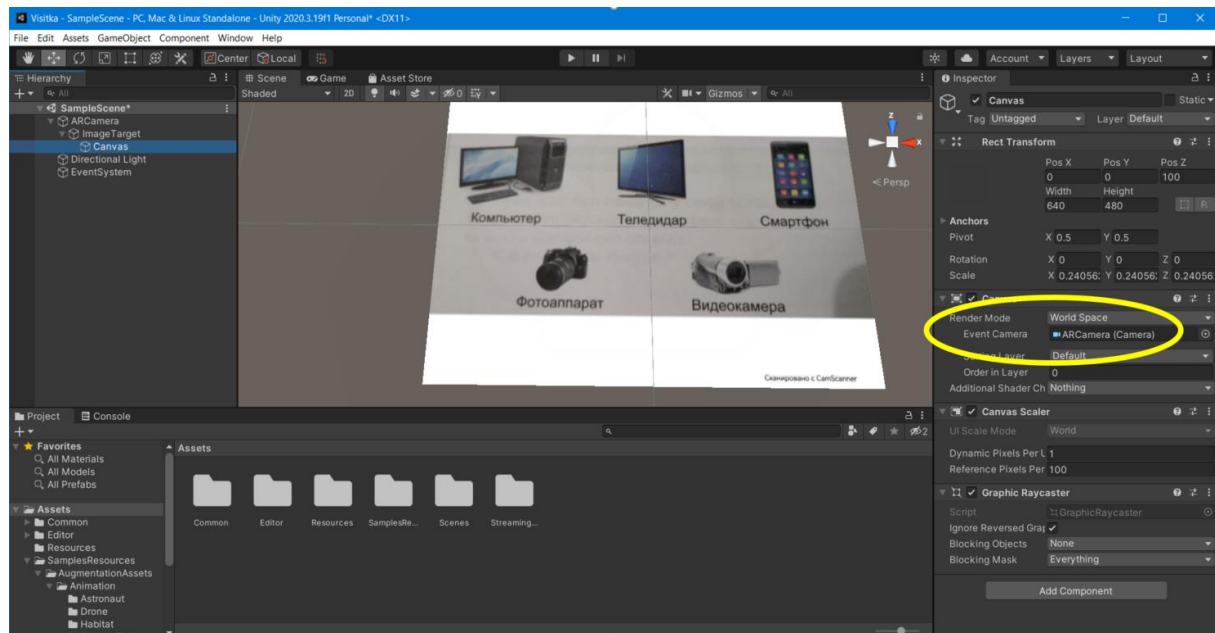
Fig. 2. Database selection
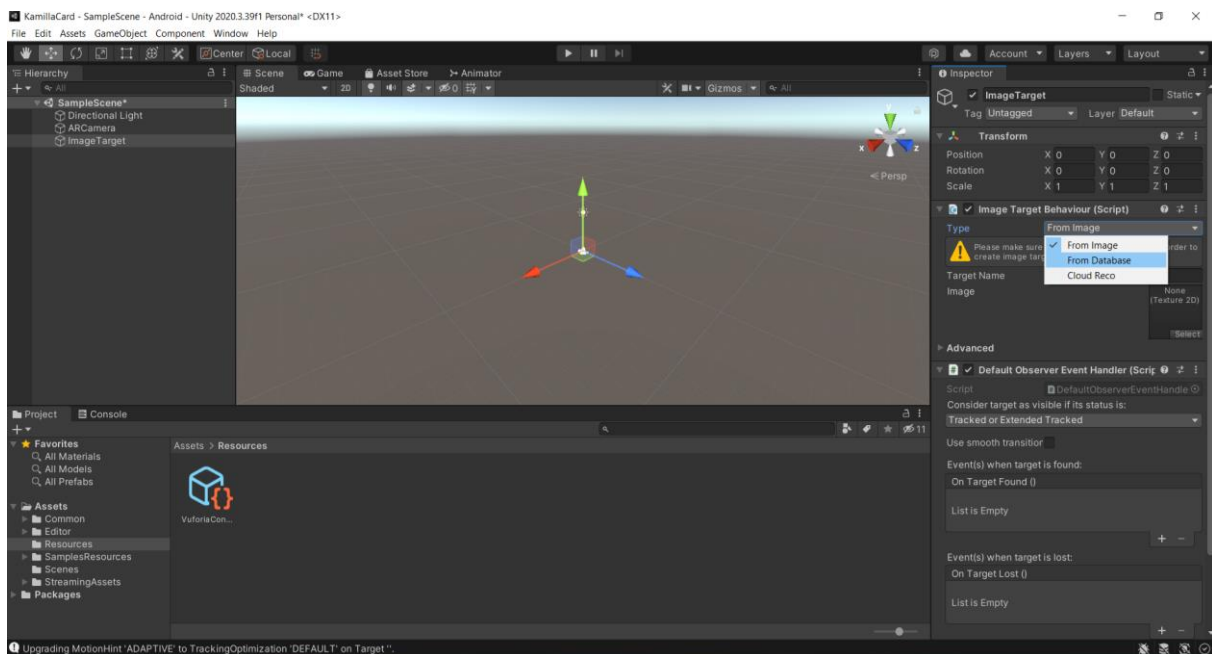
Source: Own elaboration

    We connect the canvas as a parent object to the Image Target, and in the parameters, we select: Render mode-*World Space*,
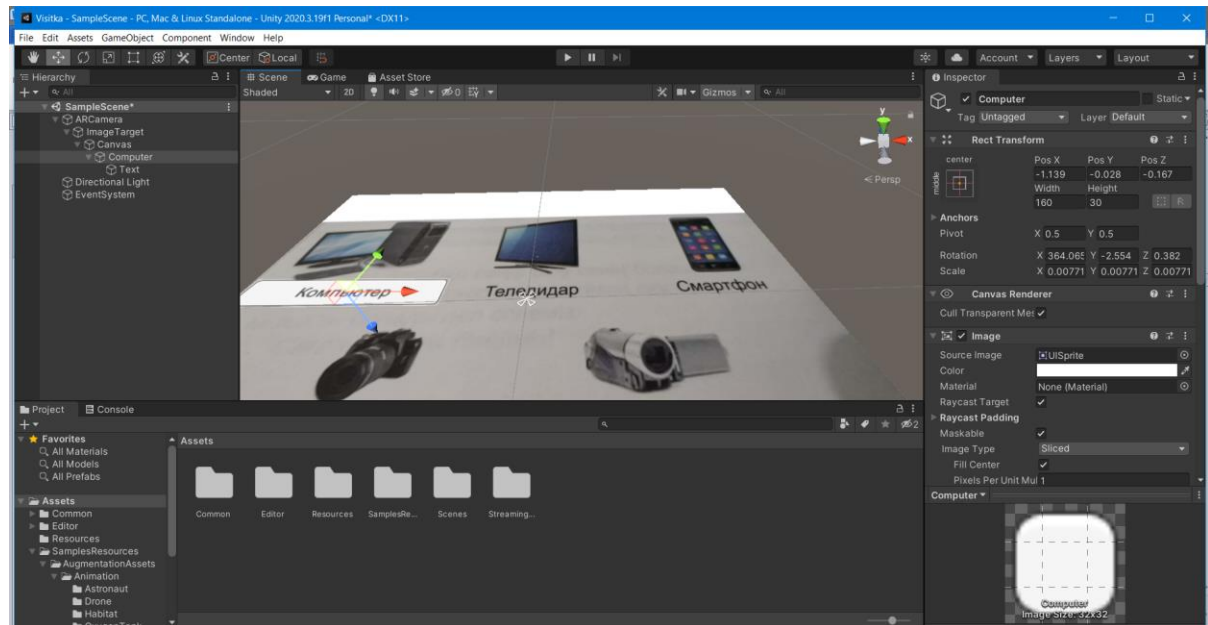   Event camera - *AR camera*.

Figure 3. Adding canvas

Source: Own elaboration

Next, we add buttons and align them, and overlay them on top of the existing signs. (Figure 4)
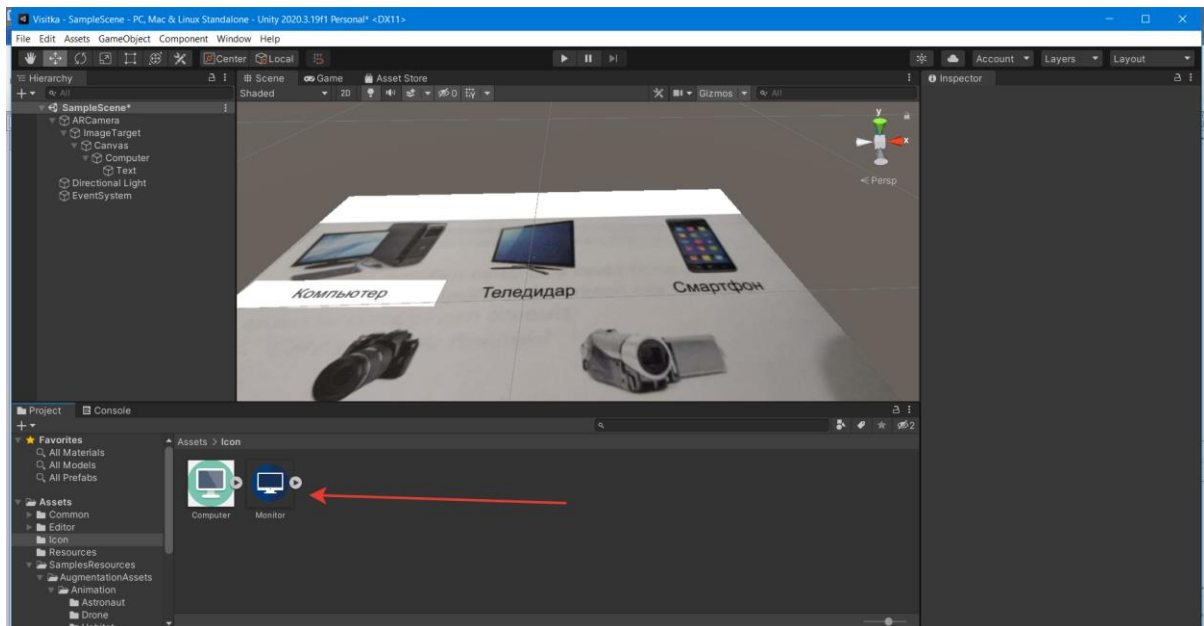
Figure 4. Adding buttons

Source: Own elaboration

Next, create a folder to store the icons. And there we add our icons without a background (Figure 5).
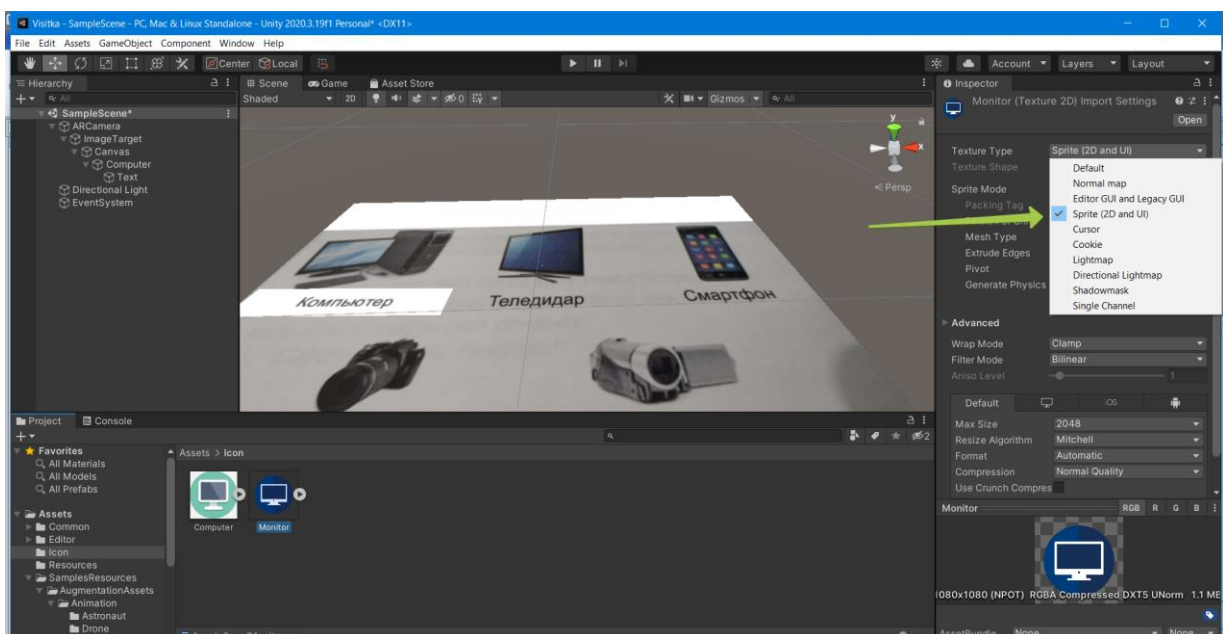
Figure 5. Adding icons

Source: Own elaboration

All images must be converted to Sprite (2D and UI) format.

Figure 6 Image Options

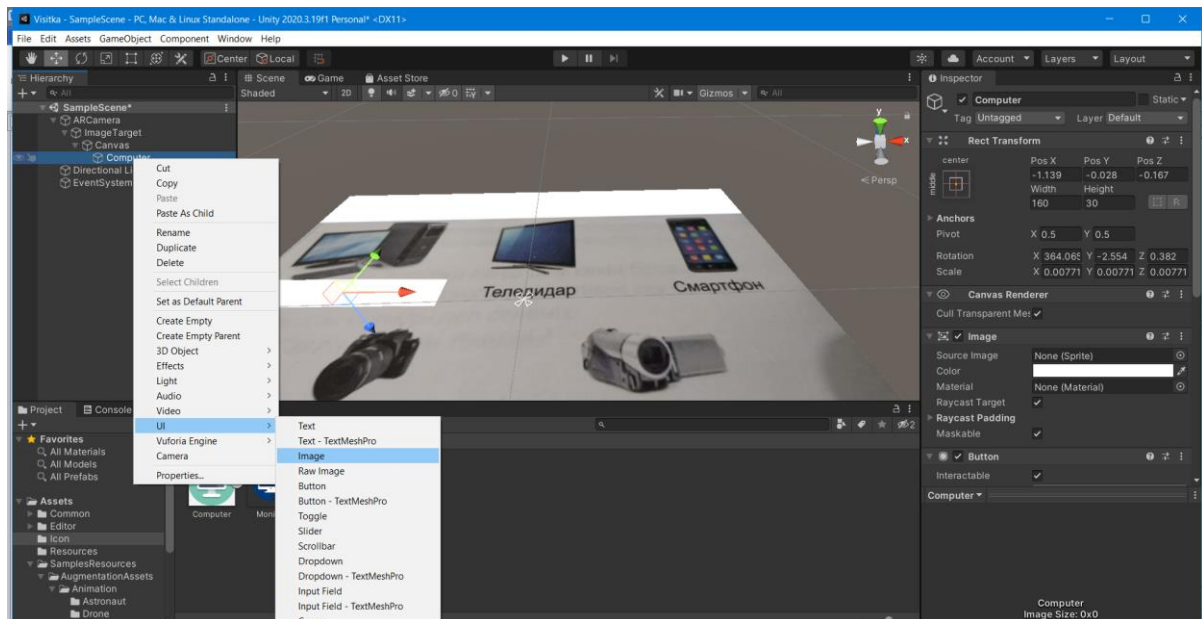*Source: Own elaboration*
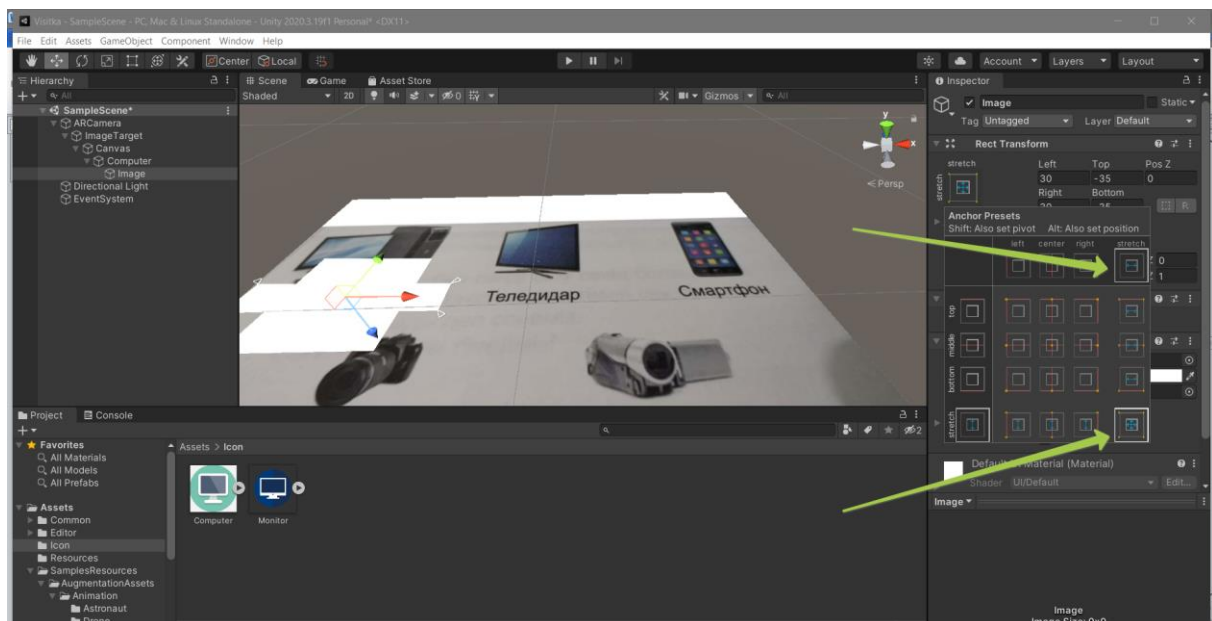
Delete the text and create an image instead.

Figure 7. Adding an Image

Source: Own elaboration

Let's replace stretch as shown in the image.

Figure 8 Replacing stretch

Source: Own elaboration

Let's edit the location and set the icon (Figure 9). Duplicate the existing button and adjust the location. Let's replace the image with the necessary icons.

Figure 9. Setting icons.
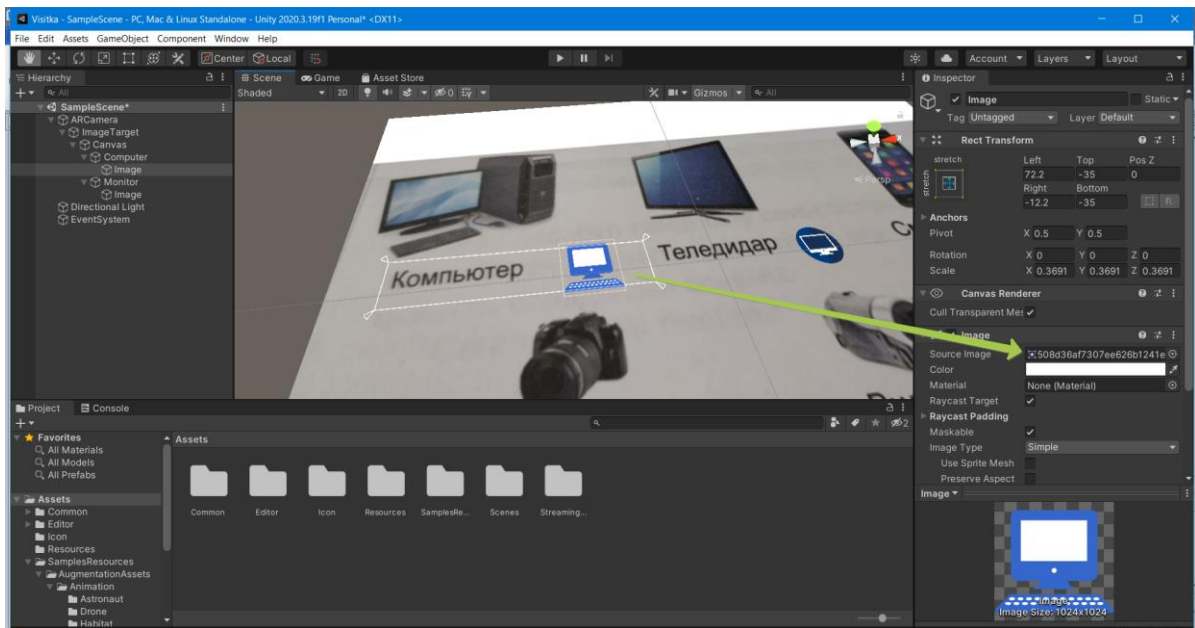
Source: Own elaboration

We create a script and add it to the project.

```
using UnityEngine;
using System.Collections;
using System.Collections.Generic;

public class button3d : MonoBehavior
{
     public void buttonFunction(string btnLink)
     {
          Application.OpenURL(btnLink);
     }
}
```

We create an object and transfer the code there (Fig. 10).

Figure 10. Creating an object
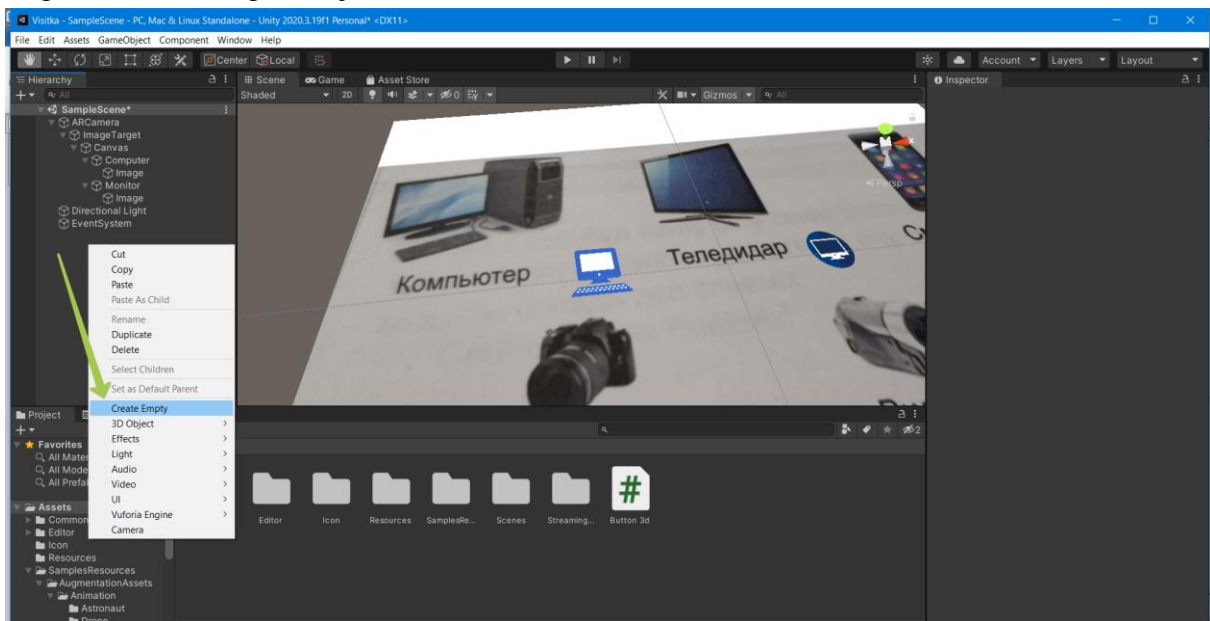
Source: Own elaboration

Select all buttons and create an action. Move the code to None, then create a function for them (Figure 11). Let's write a link in the field.

Figure 11. Creating a function for buttons.

1. step
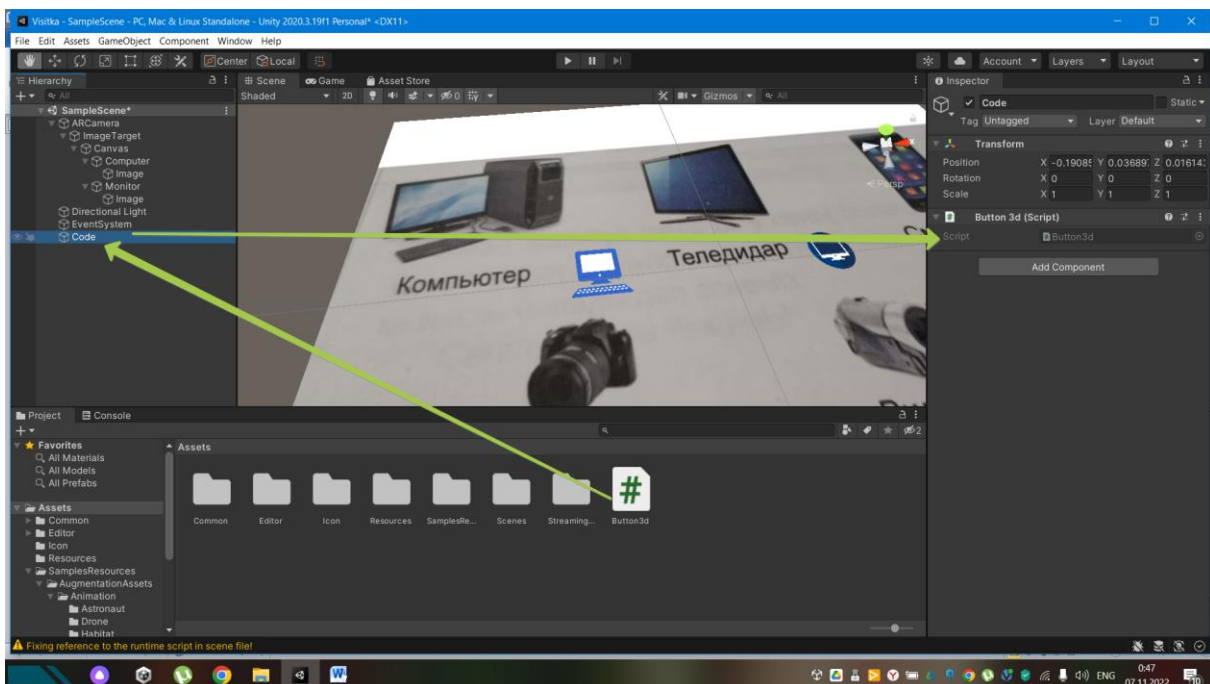
2. step
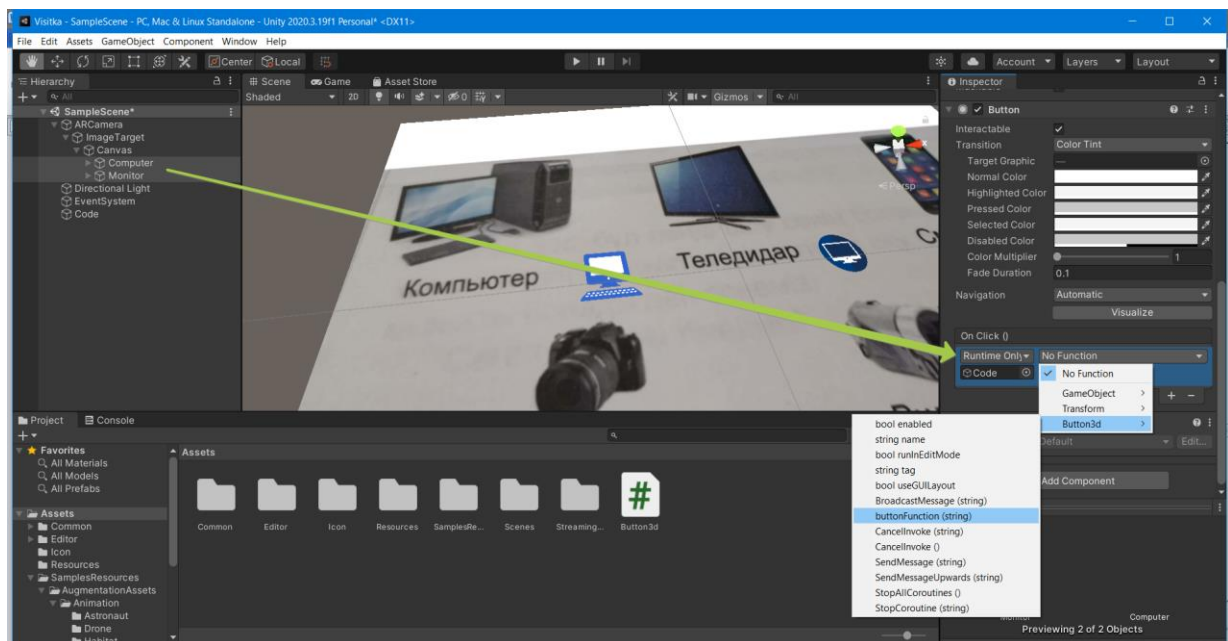
Source: Own elaboration

We save our project and test it. If everything is fine, we create an application for Android.

Figure 12. Creating an Android application.
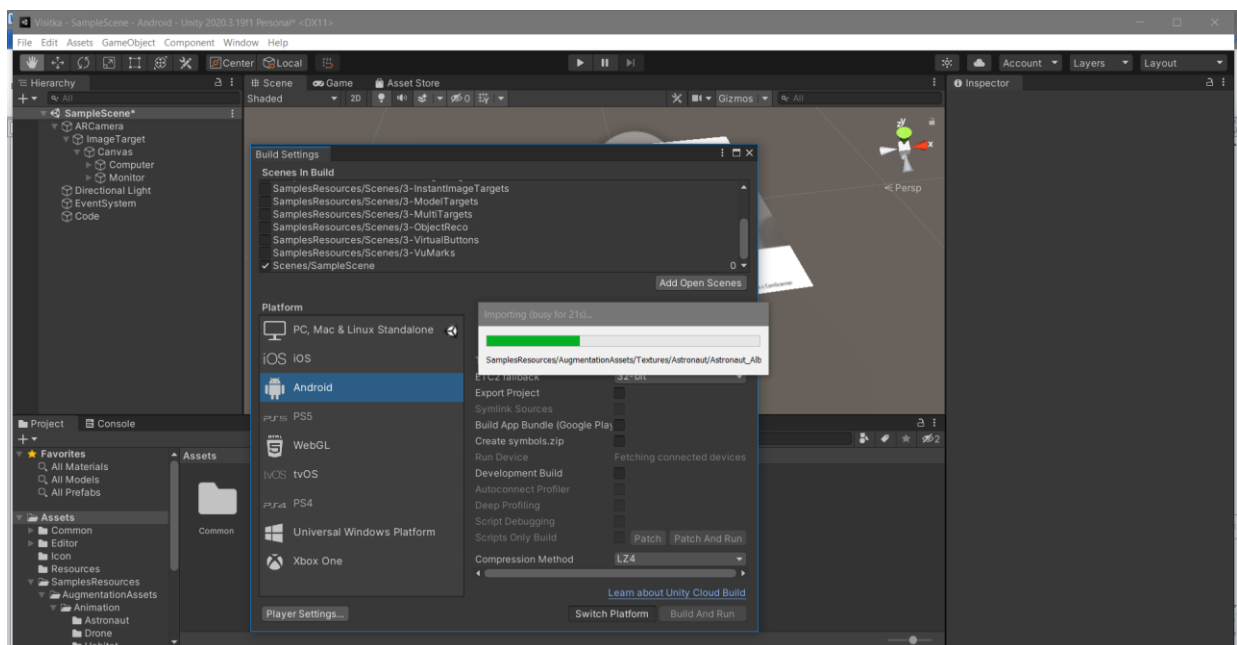
Source: Own elaboration

Now we have to check the correctness of our project, if the project is done correctly, then when we bring the smartphone screen closer to the picture, active icons will appear on the phone screen, when clicked, the video will be played (Figure 13).

Figure 13. Checking if icons and links are active.

Source: Own elaboration

4. Conclusion

In conclusion, it should be noted that the use of augmented reality technology significantly increases students' interest in the subject, as it allows them to clearly see processes that are sometimes difficult to imagine (Lavery & Burden, 2015). When preparing these digital aids, great attention must be paid to the correct choice of material, the quality of work, and all details from methodological to technical. The correct alignment of the methodology with the technical support is crucial for the student to get a correct idea of the researched issue. Using AR in teaching is very welcome by pupils and students, as most of them are addicted to their smartphones and enjoy every opportunity when they can use their smartphones. This way, they don't even realize that their curiosity is being used as a motivational tool, as they don't know what video will start when they point their smartphone at the "starting" image. This technology contributes to a better and faster understanding of the curriculum, precisely because pupils and students want to look at additional content (Guo & Chen, 2018). We know from didactics and practice that events, activities, and facts are easier to remember if they are perceived in a dynamic integrated context. Last but not least, AR is very useful for self-study, which is especially important today in connection with pandemic measures and the widespread introduction of distance education.

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DATA PREPARATION TOOL AND BRIEF GRAPHICAL ANALYSIS FOR FURTHER ANALYSIS OF DATASETS

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Abstract

In modern days there are plenty of data sources which can bring additional information to their owners. But not many of them are capable of evaluate these sources because the lack of knowledge in scientific domains such as statistics, mathematics and so. Our paper aims to this kind of problem and we created and implemented tool, that implements first steps to ease this process. This task consists of two steps, the first to create interface for uploading data in given format, then processing data in process called „cleansing" and making basic first time automatic analysis, the second step is to make interface to manually treating data to get other complex information hidden in given dataset. In this paper we implement the first step and in future we are going to implement the second. In first chapter we describe the problem at overall level, in second chapter we introduce technologies used in the project, third chapter describes project on its own, fourth chapter is about obtained data and last ones involves discussion and conclusion.

Key words

python, data science, data cleansing, streamlit, dataset

1. Introduction

In recent years, we have witnessed the rapid take-up of new technologies and the upgrading of existing ones and thus huge amount of data generated by them. There are plenty of solutions available on the market, some of them for free and some of them are paid. We are not going to describe these applications in this paper because of wide range and this is not the aim of our paper. More about free and paid solutions can be found for example at Mueller et al. 2019, Baumer et al. 2017 or Gearheart 2020. Those authors cover two upmost used languages in data science (R and Python) and the last one covers paid software solution called SAS. These three are very well known and used, but there exist a lot of others like SPSS from IBM company and much more. Furhter in the text we will introduce some of most used technologies, but our main goal is to use Python with specialized libraries to create our application. Our goal was to create and implement such an application, where user with standard capabilities can upload his/her dataset and make first steps operations on them like data cleansing and first overall analysis the dataset consequently saving dataset with processed modifications. First of all, in whole process of data science is to provide consistent data, but in real world scenario this is not possible, because of possibility of duplicity, erroneous data, abnormal or inconsistent data (Qinglei et al., 2017).

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1.1 First steps in data science

As aforementioned above, Qinglei et al. describe the whole process of preparing data for another evaluation. Without these important steps the final result could be distorted and therefore taken decision could be wrong and the whole process would be loss of time. First steps taken on provided dataset should cover data deduplication, deleting erroneous ones, finding missing data and correcting them by numbers with either neutral or averaging ones. There could be also other methods but, in our paper, we use three forms of replacing missing data, first is providing zero values, second average ones and the third is deleting whole rows of data, because no other methods are suitable. User can try all the methods on its own to evaluate which method is suitable for his/her needs. Later we will describe this whole process in detail. Now we briefly discuss about available environments and describe why we chose particular one.

1.2 R Language

R is a programming language and environment designed for statistical data analysis and their graphical display. It is an implementation of the S programming language under a free license. Because it is free, R has already overtaken the commercial S in terms of users and has become the de facto standard in many areas of statistics. The functions of the R environment can be extended using libraries called packages. For version 3.6.2, there were 15,325 available in the CRAN central repository as of January 2020. An example of a frequently used package is ggplot2 for data visualization. R is used from the command line, but there are several GUI frontends such as RKWard, RStudio, and R Commander. R is also linked or used in commercial software, e.g. in the SPSS environment, users can directly write and run programs in the R language over open data.

R provides a wide range of statistical and graphical techniques including linear and nonlinear modeling, classical statistical tests, time series analysis, clustering, and more. R is easily extensible with features and packages, and the R community is known for its active updates (Kaplan et al., 2017). Many standard R functions are written in the R language itself, making it easy for users to track algorithmic changes made. For computationally intensive tasks, the code can be linked to C, C++, and Fortran and called at runtime. Advanced users can use C, C++, Java, .NET, or Python to manipulate R objects directly. Another strength of R is static graphics, which can generate graphs suitable for scientific publications including, for example, mathematical symbols. Dynamic and interactive graphics are available through additional packages (Lewin-Koh, 2015).

1.3 SAS application

SAS (formerly Statistical Analysis System) is an integrated system of software products produced by SAS Institute. It serves both as a database system in companies and as a tool for analysis and business use of data, and on the other hand it is also used for statistical data analysis in science and technology. It is a modular software, so the customer can use only the parts that suit him. SAS includes its own programming language, also referred to as SAS. SAS software implements whole lifecycle of analytics. It comprises data administration which involves data cleansing and preparation. Second step is analytic platform which consists of various software tools and artificial intelligence and the last step is data quality management (Blokdyk, 2019). This platform is paid and is chosen by individuals not often, but in commercial area it is widely spread.

1.4   Python language

Python is a dynamic interpreted language. It is sometimes classified among the so-called scripting languages. But his possibilities are greater. Python was designed to allow the creation of large, full-fledged applications (including a graphical user interface - see, for example, wxPython, which uses wxWidgets, or PySide and PyQT for Qt, or PyGTK for GTK+).

Python is a hybrid (or multi-paradigmatic) language, that is, it allows you to use not only an object-oriented paradigm when writing programs, but also a procedural and, to a limited extent, a functional one, depending on what suits you or is best for the given task. Because of this, Python has excellent expressive capabilities. The program code is short and easy to read compared to other languages.

A distinctive feature of the Python language is productivity in terms of the speed of writing programs. This applies to both the simplest programs and very extensive applications. In the case of simple programs, this property is manifested mainly by the brevity of the notation. For large applications, productivity is supported by features that are used in large-scale programming, such as native support for namespaces, use of exceptions, standard tools for writing tests (unit testing), and more. High productivity is associated with the availability and ease of use of a wide range of library modules, enabling easy solutions to tasks from a number of areas (Jaworski et al., 2021).

Considering all the conditions that have to be met, we decided to use *Python* language with all the packages provided, also wide support of community of developers and the last fact was, that this language is also widely spread in commercial sphere.

1.5   Streamlit package

Streamlit is a free, open-source, all-python framework that enables data scientists to quickly build interactive dashboards and machine learning web apps with no front-end web development experience required. If you know python, then you are all equipped to use Streamlit (Li, 2022). It is cost free product and it consists of all that is needed to build interactive web pages with charts, maps, sliders and other useful tools. With few lines of code, you can create dashboards and other interactive content. It employs own web server, so application is then ready to go.

1.6   Pandas and matplotlib packages

In our application we used, amongst others, package called *Pandas* and *Matplotlib*. *Pandas* is an open source Python package that provides a number of data analysis tools. The package comes with several data structures that can be used for many different data manipulation tasks. It also has a variety of methods that can be used to analyze data, which is useful when working on data science and machine learning problems in Python. This package is widely used in data analysis and also to work with external data like excel worksheet, JSON (JavaScript Object Notation) files, CSV (comma separated values) files etc. Package contains extended capabilities for working with rows and columns altogether without having to use loops, functions are used instead, so we can call this type of programming paradigm as functional programming. In python it is a mix of procedural, object-oriented and functional access as already been aforementioned.

Matplotlib is a plotting library available for the Python programming language as part of NumPy, a numerical data processing resource. Matplotlib uses an object-oriented API to insert plots into Python applications (Nelli, 2018). In our application it is used to display a histogram plot.

2. Methodology

Based on literature review we have chosen some framework already mentioned in the text before. According to Richards "Streamlit shortens the development time for the creation of data-focused web applications, allowing data scientists to create web app prototypes using Python in hours instead of days." (Richards, 2021). According to Nokeri "Secure web apps and deploy them to cloud platforms" (Nokeri, 2021) we also decided to deploy our application into the cloud infrastructure in Oracle cloud. Now let us describe steps to fulfill our goal.

1. We decided to develop application which allows users to upload their datafiles and perform basic tasks on cleaning them up. This approach is called „data cleansing" and according to Nauman „Data cleansing is a complex set of tasks that takes as input one or more datasets and produces as output a single, clean data set" (Nauman et al., 2022). This process takes obviously a vast amount of time, so we decided to lessen this amount of time by reducing some tasks involved in data cleansing. Other tasks like removing duplicate values and alike will be involved in later versions of application
2. After doing some research we decided to use web technology due to its spread and easy usage with web browser.
3. Consequently, we decided to use web framework *Streamlit* based on *Python* language technology.
4. Developing basic source code to implement application.
5. Testing and deploying on local server.
6. Final deploy on Oracle cloud infrastructure on Linux virtual machine.

3. Environment preparation

3.1   Prerequisites

We needed to take mandatory steps to achieve the final goal. First of all, we have to download *Streamlit* libraries from the home website of the project. On the website there are installers suitable for various operating systems and architectures. After choosing the propriate one it is recommended to follow instructions to completely finishing installation process. To achieve this implementors should be aware of administering operating systems either *Windows*, *Linux* or *MacOS*. When installation is successfully done, we can start *streamlit* framework. If everything works fine, we get link and internal port which web server listens on. User is then redirected to web browser, where application will reside when completed. Steps described above are necessary to do, otherwise implementation will not be possible.

3.2   Choosing appropriate dataset

Our application is now fully suitable for all datasets. We aimed usage of this application on datasets, that mostly contain numerical values organized in rows and columns. So we prefer standard form of dataset known widely as for example Excel sheet or LibreOffice sheet but exported to CSV format. Other types od datasets that mostly contain string values are not

suitable. Later versions of such datasets could implement new functionalities which will employ algorithms that convert categorial values to groups of numbers allowing them to function properly.

Our dataset was taken from Statistical office of the Slovak Republic describing municipalities in Slovakia in a way e.g. year of founding municipality, altitude, the size of the areas a alike. These data showed up for us as very useful to test our application, for example a brief view on data with histogram plot we could see distribution of municipalities according their size across the districts in Slovakia. Another propriate datasets were also tested after finishing application developing. Data source also used was keggle.com website.

3.3   Chosen data cleansing techniques

Our project is divided into two parts, first is data cleansing and simple brief graphical analysis based on histogram plots and second part (which is not covered in this paper) will have broader possibilities of further data analysis like placing various conditions on attributes (columns) and alike.

We decided to accommodate three basic techniques, first is to replace *NA* values with dots (.) if text data is missing, and *zeroes* if numerical data is missing in particular column. Second possibility is to delete rows with *NA* values and the third one is to replace *NA* values with average value of the whole column. After choosing one of the supplied possibilities, application shows an insight on the table in small window and user can then click on two-arrow icon to expand to full-size view to quick check newly replaced values. User can also download modified file in CSV format to their computers and make further computations and analysis (Fig. 1).

Fig. 1: Data cleansing with provided possibilities
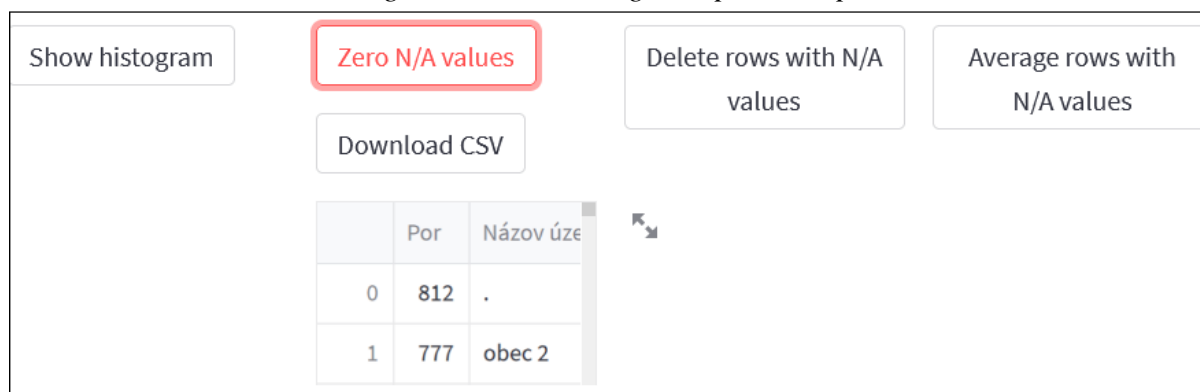
Source: own elaboration

There exist disputes which one of chosen techniques is the best one. The answer is – it depends on your data and you have to check the most possibilities depending on your further usage, e.g. in model testing. As Thanaki says: "You can select any of these techniques, but you need to train the model and measure the result." (Thanaki, 2018).

Besides techniques of data cleansing used in our application there also exist another ones, e.g. KNN method, using most frequent value, median and so on (Thanaki, 2018).

3.4   A brief look at the data

When user upload his/her data into the application, the first step is quick analysis, which tells user two findings: first is to detect only numerical data and second step is to calculate basic statistical information about provided dataset. Textual data are not considered, in case of

categorial data they need to be converted to the numerical ones beforehand. Following picture depicts such a situation (Fig. 2).

Figure 2: Statistical information about given dataset

	Por	Kód	kraj	Prvá_písom	Nadmorská_výška_obce	Celková_výmera_územia_obce
count	2,926.0000	2,926.0000	2,925.0000	2,922.0000	2,926.0000	2,926.0000
mean	1,514.0417	521,213.6617	5.4168	1,356.7687	308.0759	16,664,256.4156
std	867.6214	17,889.0598	2.0208	175.5973	176.9319	17,398,600.5991
min	4.0000	500,011.0000	1.0000	0.0000	97.0000	357,863.0000
25%	762.2500	508,995.0000	4.0000	1,263.0000	170.0000	7,206,699.5000
50%	1,516.5000	518,208.0000	6.0000	1,330.0000	251.0000	11,652,020.0000
75%	2,264.7500	526,140.0000	7.0000	1,414.0000	421.0000	19,764,453.7500
max	3,012.0000	599,972.0000	8.0000	1,993.0000	1,109.0000	359,787,046.0000

Source: own elaboration

As mentioned before textual columns were filtered out, and table on the figure 2 shows statistical information, so we can see count, mean, maximum and alike. Columns in dataset is written in Slovak and their translation is: serial number, code, region number, first written mention, altitude, overall area of the municipality. This translation is not crucial for our paper, only for better understanding for non-Slovak speakers. Every data analyst has to find out which data is meaningful to further analysis and which not. For example, from the picture above we can recognize lowest, highest and mean value from column *altitude*. Now we have a basic understanding of given dataset and after choosing appropriate column we can visualize it for another amount of additional information (Figure 3). Both – the original dataset and table with computed statistical data has clickable column headers, which means the user can sort data in ascending or descending order.

*Figure 3: Municipalities' distribution based on altitude across Slovakia*
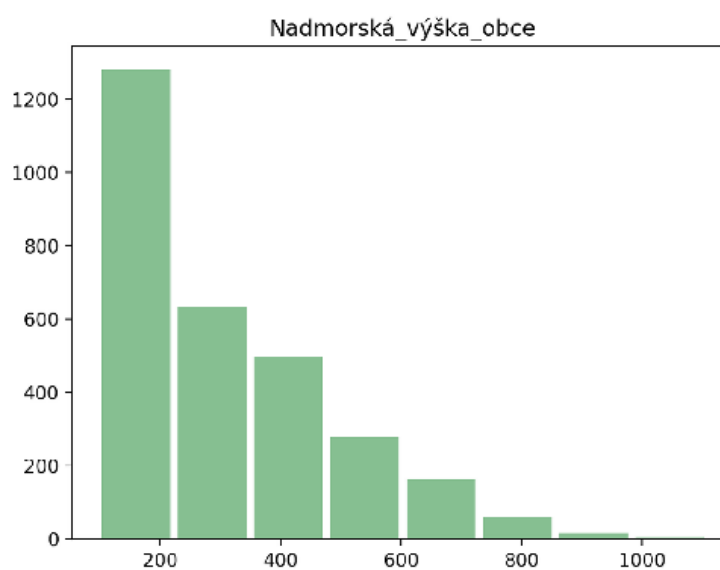
Source: own elaboration

User can instantly see, that most of municipalities in Slovakia can be found in lower altitudes (*X* axis). For example, if foreign company wants to build some kind of factory, this should be the first *must know* information. Histogram plot depicted on the figure 3 has granularity level set on 8 bins, user can change this value to test, if newly generated histogram would better describe data provided in CSV file.

3.5   *Saving and retrieving data set*

After finishing quick data analysis, user can choose further actions like deleting rows with *NA* values, averaging or zeroing them. Modified dataset can be then downloaded as CSV file to the user's computer. This analysis can be done over and over again on already modified and downloaded CSV files. Figure 4 shows quick view on the modified data and download button. User can briefly compare newly cleansed dataset with the original one which can be found right under the dynamically computed statistical data.

Figure 4: Download modified file and brief look on cleansed dataset
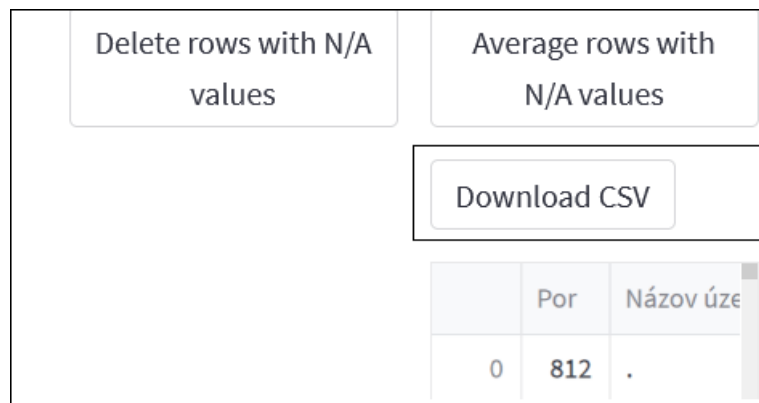
Source: own elaboration

4.   Conclusion

Aim of our paper was to allow people with less statistical knowledge to ease the process of the data preparation. Our secondary goal was also to make application which would be dataset independent (meaning no special names for columns and rows), so anyone with any dataset saved in CSV format would be able to upload it to our server. These goals were fulfilled and there remains the second – much more difficult part to further process prepared (cleansed) data. In brief these steps would comprise feature selection, various model testing and finally implementing winning model on our dataset. We've already implemented these steps in Python language using Pycaret package which is specifically designed to these data science tasks, but we have finally decided not to make it part of our application because of its high computational complexity. Our test case scenario we have prepared was run on Ubuntu server on Oracle cloud infrastructure took most than two hours to complete. These long-run tasks certainly depend on hardware configuration, so the more processors and more memory lead to better performance – shorten time of computations. Because of long time computations it would be for common user useless to wait for that long. Experts in the field of data science can ask for further possibilities mentioned before (e.g. propriate features/model selection). So our effort to the future will be to enhance efficiency by deploying our application on computers with higher

CPU performance. We took measurements while running Pycaret and we noticed, that all the running time virtual machine on Oracle cloud infrastructure, Pycaret took almost 100% of processor's power. We will test our infrastructure on Google cloud infrastructure with credit provided by Google for academic purposes for free with ability to manage numbers of CPUs (processors) used in virtual machines. Google cloud services also offers specialized virtual machine intended just to be used as data mining servers.

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PROJECT-ORIENTED COMPUTER SCIENCE TEACHING IN INCLUSIVE EDUCATION

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Abstract

Digital learning is closely linked to the use of all the possibilities of using inclusive methods and the level of training of teachers. With this in mind, it becomes important to present concepts and the results of national and foreign studies as additional material.

The article is devoted to the use of information and communication technologies by teachers and students of secondary schools, the formation of conditions for inclusive education and their training. The authors substantiate the need for equal education of normal children and children in need of special education.

The main methods of inclusive education implemented as a result of international practice are considered. In addition, based on the theoretical analysis of the data, the importance of using information and communication technologies in the conditions of inclusive education of primary school students is determined. Using digital educational resources of robotics in an inclusive group.

Keywords

Project-oriented learning, inclusive education, information and communication technologies, special needs

1. Introduction

One of the main objectives of the strategic development plan of the Republic of Kazakhstan until 2025 is the development of inclusive education in the country. In this regard, in the Address, the Head of State noted that „our education system should be accessible and inclusive".

The issues of organizing the educational process for children with disabilities in foreign countries were first considered in the 1970s, and inclusive educational programs were fully implemented in educational policy in the United States and European countries.

The success of a nation in the future is determined not by its natural resources, but by the competitiveness of people. Such programs as "Digital Kazakhstan", "trilingual education", "cultural and interfaith harmony" - concern for the preparation of the nation, all Kazakhstanis to the requirements of the XXI century.

2. Methodology

Inclusive education is one that aims to include all children in the general educational process, regardless of their health status, ethnic or social origin, language and individual characteristics, ensures equal access and has eight basic principles. Shown in Figure 1 below.

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Fig. 5: Principles of Inclusive Education

Principles of Inclusive education

A person's value does not depend on his abilities and achievements;

Everyone has the right to speak and be heard;

Everyone is capable of feeling and thinking;

Everyone needs each other;

Versatility expands the scope of human life.

For every student, success is something he or she can do;

Education should be realized only within the framework of real relationships;

Everyone needs the support and friendship of their peers;

Source: authors

In the country, daily school classes of students with special educational needs are conducted in accordance with state educational standards. Let us consider in more detail the components of the methodological system for teaching special children on an equal footing with Normal Children, project-oriented computer science in an inclusive classroom, while observing the values and principles of inclusive education.

The development of modern information and communication technologies and software and hardware support of general education institutions provide great opportunities for integrating students who need special knowledge into the educational process. The organization of the educational process that ensures education should be taken into account when preparing educational materials, conducting classes, monitoring knowledge, as well as organizing psychological and pedagogical support, depending on the specifics of the contingent of students. Undoubtedly, information technology, digital literacy play an important role in this.

Students with special educational needs should be trained according to an adapted and partially modified curriculum that provides for various teaching methods. The integration of any technology is preceded by the process of modeling the educational environment, which is the basis for the formation of a pedagogically developed personality. Ensuring the availability of an information educational environment for students in need of special knowledge in inclusive education is the creation of favorable conditions for interaction between the student and the teacher with the help of information and communication technologies. In turn, such interrelated elements of the educational process as a targeted training program and methods, mentors and information tools are characteristic.

It is important that digital resources demonstrate their accessibility functions in order to promote inclusive educational practices and for teachers to be aware of the difficulties and challenges associated with ICT accessibility .

In robotics development learning environment, students enhance positive attitudes to scientific researching (Hursen, C., & Uzunboylu, H. 2009). it is noted that project-oriented robotics training provides students with in-depth learning of creative topics and effectively uses conceptual knowledge for memorization. Adaptation of the content of teaching computer science is not only ensuring the availability of the educational text presented in electronic format, but also providing other options that will help a particular student, taking into account his individual educational characteristics.

In order to carry out high-quality education for students with special needs, in addition to general cultural and professional competencies, it is necessary to propose the formation of compensatory and compensatory-adaptive competencies in the context of the formation of a student's own workplace: to familiarize the student with various approaches to Computer Management, teach him to use standard special parameters of a personal computer, and install specialized software for compensatory purposes.

Means of teaching students with special educational needs:

- the teacher must ensure the availability of appropriate visual and technical means of teaching computer science with the help of digital technologies in order to realize equal opportunities for mastering and mastering educational material;
- offer an alternative to the requirements for the speed of completing tasks;
- suggest alternatives to answer or choose the execution of commands (for example, keyboard control alternatives);
- provide alternatives for physical interaction with the hand, voice, switch, joystick, keyboard or adapted keyboard.

Providing students with digital resources and teaching aids is often insufficient. To use this tool effectively, it is necessary to provide support. Many students need guidance assistance in the learning environment (both in terms of physical space and curriculum), and all students should be provided with the ability to use tools that help them achieve their goal of full attendance.

Theoretical material can be prepared as follows: text documents, presentations, structural-logical, web pages or sites, videos, animated stories, etc. When preparing text documents for students with visual impairments, it is advisable to prepare detailed texts with examples written in a living literary language close to the verbal capabilities of human communication, and in the process of self-preparation, they have the opportunity to listen to this text using special audio recordings, electronic learning tools.

Research experiments have shown that in order to increase the effectiveness of studying electronic text documents of children in need of special knowledge, it is recommended to add additional links to electronic Internet resources, as they usually contain a broad outlook, non-standard thinking, the need to obtain special information and detachment from the main topic through intellectual exercises.

The using ICT in inclusive education to develop of all aspects of child's speech and thinking, help to solve tasks which children have not learned or have not understand enough, to realize their potential capabilities that can not be occur in traditional conditions, to implement the self-control principle, allowing children feel free, to actively and independently control the game, it strengthens faith in their own strength unlike other games and activities, developing a verbal activity in three ways: as a communication tool; a computer as an user partner; three-way communication of the classroom: students, a teacher and a computer. As many authors note using computer games allows to optimize the pedagogical process, individualize the teaching of children with developmental disorders and increase the efficiency of any activity.

When preparing electronic text documents for special children with hearing problems, all basic requirements for the text must be observed, for example, short texts, symbols, the choice of color and size, the use of different fonts for different parts of the text. For this category of students, you can add to electronic documents: hyperlinks to explanatory dictionaries for explaining the most complex terms, hyperlinks to videos with gestures corresponding to the term, links to internet resources for a detailed study of the main sections of the topic, built-in

objects-pictures, graphs, tables, as well as in the process of using presentations, you can enter a сөзд dictionary with videos with sign language translation of key terms and key phrases.

Language is important for communication and socialization, especially in children. Language and communication skills can be phonological and pragmatic.

The focus in the development of language and communicative skills can be taken to phonological and pragmatic problems. The language is important for society and socialization, especially in children.

The delay in the development of language and communication skills can lead to phonological and pragmatic problems. Language is important for communication and socialization, especially in children.

As part of mastering the use of computer programs, when using various tables, flowcharts, graphs, diagrams, the following patterns are observed:

- for special children with hearing impairments, the schemes should be as "flat" as possible, located on one surface;
- for special children with visual impairments, an oral description of the scheme should be provided.

When preparing laboratory tasks for an inclusive class, it is mandatory to develop appropriate educational materials, taking into account psychophysiological features. For example, for special children with hearing impairments, a clear description of algorithms for solving problems on a computer with a dynamic illustration of the process of their implementation is required (using various demonstration rollers). In the description of algorithms, it is desirable to indicate the methodology of individual fragments of the use of various tools, the order of execution.

For special children with visual impairments, a verbal description of the process is necessary at a sufficient level to be understood through a text recognition program. Instructions for the implementation of a practical task should contain only a competent setting of the task and a requirement for the form of presentation of the final result. They like to create algorithms on their own. It is advisable to present information in the form of integrated complex blocks with the addition of graphic elements.

And theoretically, the standard option for conducting a lesson in the process of explaining a new topic is completely unsuitable for an inclusive audience. The hearing impaired student must first listen and understand the meaning of the message (sign language translation, visual and effective means of displaying basic concepts, etc.), and then carefully write from a blackboard or screen in a notebook. A visually impaired student can perceive information only by hearing, so it must be very clear, with the right emotional coloring. He can write information only under dictation in a special notebook or type it into a computer. The movement of some students who need special knowledge is very slow, so the pace of writing information is lagging behind that of others. As for one node, it implies the need for a special teaching method for each of the students who need special knowledge in the inclusive class.

3. Results

One of the tasks of project learning technology involves the formation of services for independent assimilation of knowledge and the ability to solve professional tasks, as well as integration knowledge and research, developing the competence of project thinking, cognitive skills of children in need of special knowledge. Learning outcomes arise as a result of a problem-solving process, the ultimate basis of learning proposed at the very beginning when implementing this methodology with the aim of responding to students as the final product in the acquisition of knowledge and skills through an interdisciplinary and collaborative approach.

Learning outcomes arise as a result of a problem-solving process, the ultimate learning goal proposed at the very beginning when implementing this methodology. Through an interdisciplinary and collaborative approach, students acquire knowledge and skills through research tasks in order to provide an answer to the problem or challenge facing them in the form of a final product.

The formation of creative work skills, independent decision-making is carried out in individual, group and project research work of students. Students master the information and Communication Technology of project cognitive learning through Group division, and develop projects on the topics of digital literacy. Carried out in the design of laboratory work, homework, individual and group Project Research tasks.

Thus, support for students with special needs in mastering the discipline "digital literacy" is carried out on organizational and pedagogical support in the process of their learning in the conditions of inclusive learning.

In the second task, we will consider the content of teaching the discipline "digital literacy" in primary schools in the country in order to study existing approaches and determine the conditions for teaching digital literacy in the direction of the project.

Project-oriented learning technology-as for the formulation of one task for students on the basis of the plan of the discipline "digital literacy" for personality characteristics:

- access to computer systems;
- providing initial information about modern digital devices and their role in society;
- formation of students ' skills in computing, collecting and programming robots, searching, collecting, processing, storing and disseminating information using information and communication technologies;
- contribute to the formation of students ' skills to present their ideas using various applied programs;
- aims to be able to work in groups and individually, to develop a wide range of skills, such as problem solving and decision-making.

According to the principles of inclusive education, educational organizations must meet the diverse needs of all students. That is, teachers provide assistance using differentiated, variable methods based on the adaptation of curricula, taking into account the individual characteristics and capabilities of students.

4. Discussion

The control group included students of the 4th grade of the city of Astana, KSU "Gymnasium school No. 87 named after Abai Kunanbayuly", inclusive. The features of the study of Group, inclusive and individual teaching of robotics by children in need of special knowledge are shown.

For the next chapters in the discipline" digital literacy", the following project-oriented topics were selected:

Part 1, Scratch –creating a project in a programming environment;

Part 2, programming LEGO Mindstorms EV3 training robots;

Part 3, Creating a project in the VideoPad editor environment;

Part 4, computers of the future project.

Practical implementation of project-oriented teaching of Computer Science in inclusive education.

Fig. 2: Implementation of project-oriented teaching of informatics in inclusive education
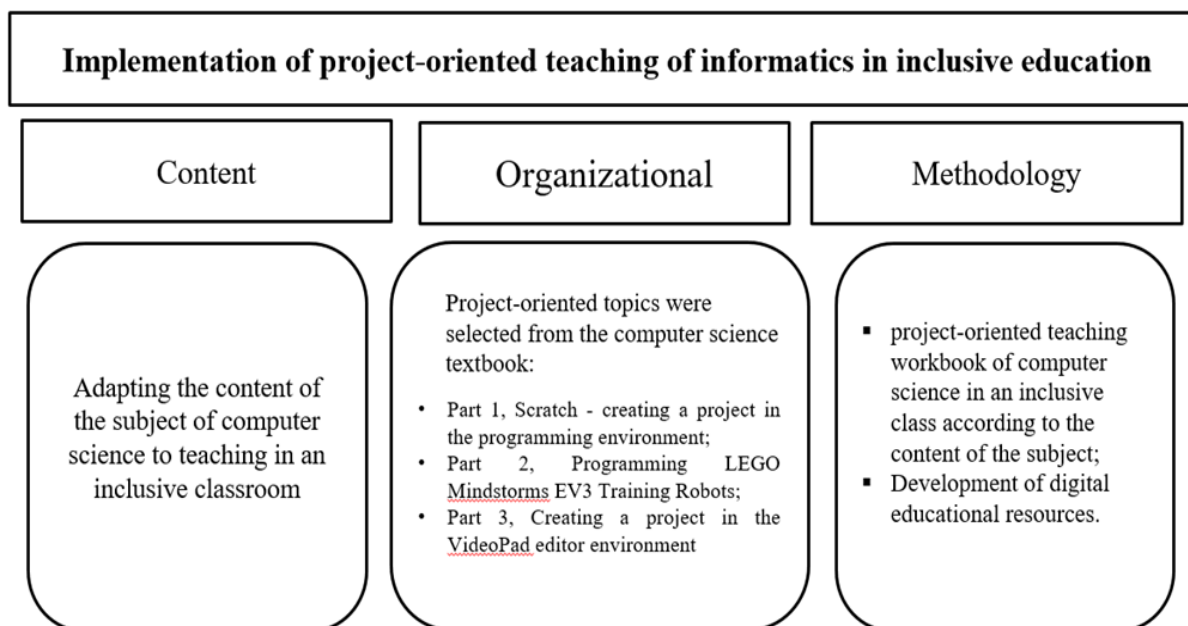
Source: authors

4.1 Pedagogical system

According to the second task, a digital educational environment "project-oriented training of robotics in an inclusive group" has been developed.

The experimental group was attended by students of the 4th grade of the inclusive group of school-gymnasium №87 named after Abay Kunanbayuly, Astana. In total, there are 25 students in the group.

It was found that project-oriented teaching of computer science in inclusive education has a positive effect on the formation of a student's motivation for success to a certain extent. The theoretical foundations of project-oriented computer science training in inclusive education have been identified. A study of existing approaches to project-oriented teaching of Computer Science and identified conditions was done.

One of the tasks of project learning technology involves the formation of services for independent assimilation of knowledge and the ability to solve professional tasks, as well as integration knowledge and research, developing the competence of project thinking, cognitive skills of children in need of special knowledge.

The formation of creative work skills, independent decision-making is carried out in individual, group and project research work of students. Students master the information and Communication Technology of project cognitive learning through Group division, and develop projects on the topics of digital literacy. Carried out in the design of laboratory work, homework, individual and group Project Research tasks.

Thus, the support of students with special needs in mastering the discipline "Computer Science" is carried out on organizational and pedagogical support in the process of their learning in the conditions of inclusive learning.

Project-oriented learning technology - students are taught one task, grouped according to their personal characteristics. As for the accuracy, in teaching, the student is guided by sight,

hearing and remembering by ear, which leads the student to self-Search, development of abilities. From these theoretical studies, it was found that the subject of digital literacy in incisive education can be taught project-oriented.

Adaptation of the forms of Organization of teaching students in inclusive classes. It is known that the main organizational form of training is a lesson. The teacher has the opportunity to organize classes based on a mixed learning model with the help of modern technologies. In the process of organizing the educational process in a mixed learning system, the material is distributed through online and offline sections. The use of digital resources at all stages of training will certainly bring positive results. In the process of using robotics tools in the classroom, special attention is paid to the health of children. The lesson plan includes elements such as physical and dynamic pauses, eye exercises, and the use of health technology elements.

The proposed methods and approaches provide the basis for adapting the methodological system of teaching digital literacy to students in general education institutions in conditions of inclusion.

Contributes to improving the quality of digital literacy training, the formation and development of an educated, creative person, a qualified and competitive specialist who meets the needs of the modern labor market.

5. Conclusion

In conclusion , the successful implementation of continuity between children, parents, teachers, families and general education institutions will be one of the prerequisites for the social adaptation of the individual, that is, we need to create conditions for students who need special knowledge to feel the involvement and necessity of their actions. Inclusive education helps students who need special knowledge to become full members of society and realize their creative abilities.

Within the framework of inclusive education, each teacher-teacher must know the category of students with special needs and master teaching methods in accordance with their capabilities. Subject teachers who carry out inclusive education in general education schools, and the group of psychological and pedagogical support of a child with special educational needs includes specialists-psychologists, social teachers, defectologists, speech therapists, instructors, in case of absence, the administration of the educational organization should conduct teachers of inclusive education courses

We express our firm belief that conscious citizens and citizens will come out of children who need special knowledge in the future, not to let them be restricted from society, depressed − not only the duty of certain organizations, but also the main duty of the environment, the masses!

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