Preface

Special Issue on Digital Transformation Environment for Education in the Space of CogInfoCom

We are pleased to present our second special issue dedicated to a CogInfoCom theme to our readers. Our first thematic volume published at the beginning of 2020 contained the best studies and presentations from the proceedings of the 2018 conference. The present CogInfoCom-themed issue matches the thematic outlay of the previous CogInfoCom conference held in 2019. We hope that this periodical will help readers to learn about several professional research developments leading to further consideration of the given topics.

This special issue brings together papers in the field of digital education and CogInfoCom based LearnAbility including education through online collaborative systems, virtual reality solutions and project-based education. Further topics cover the digital transformation of education and investigating capabilities for learning through modern informatics based education. This is an interdisciplinary research field and fits well in the topic of Cognitive Infocommunication. The key concept behind CogInfoCom and its application in digital education and learnability is the various levels of entanglement between humans and ICT giving rise to new forms of blended cognitive learning capabilities. The studies of this special issue present the latest research results in this scientific discipline.

1) Uniform Dispersal of Cheap Flying Robots in the Presence of Obstacles

In previous solutions, the authors considered the uniform dispersal problem (or Filling problem) in which inexpensive robots had to disperse in order to cover an a priori not known area, as well as they also examined the possibilities of solving the Filling in two-dimensional regions. The swarm entities had to collectively solve a common task using the simplified cognitive abilities of the robots (i.e., their memory, visibility, and communication capabilities were restricted). In this paper, the authors investigate the possibilities to apply the method for three-dimensional regions. The need for such a solution emerged, as nowadays the number of low-priced flying robots, e.g., quadcopters, drones, has increased heavily. The main research direction is to minimize the hardware requirements of these robots, as doing so is crucial in order to maintain their cost-efficiency. The authors demonstrate that it is still possible to solve the Filling problem in three-dimensional space in the presence of obstacles, while the robots maintain the following hardware requirements: they have a constant amount of memory, minimal visibility, as well as there is no communication between them, and the algorithm terminates in linear runtime. Finally, simulations were carried out to prove the theoretical results.

2) Advanced Assistive Technologies for Elderly People: A Psychological Perspective on Older Users' Needs and Preferences (part B)

This paper provides a general overview of the literature regarding advanced assistive technologies devoted to improve elders' life. Recent studies on assistive robots and embodied conversational agents are carefully examined in order to identify main seniors' preferences regarding their general design. While providing data on seniors' preferences about the design of assistive devices, main evidences on both robots and virtual agents appearance, abilities/functionalities, personalities and role features are summarized and commented.

3) Predictive Machine Learning Approach for Complex Problem Solving Process Data Mining

Problem solving is considered to be an essential everyday skill, in professional as well as in personal situations. In this paper we investigate whether a predictive model for a problem solving process based on data mining techniques can be derived from raw log-files recorded by a computer-based assessment system. Modern informatics-based education relies on electronic assessment systems for evaluating knowledge and skills. OECD's PISA 2012 computer-based assessment database was used, which contains a rich problem solving dataset. The dataset consists of detailed action logs and results for several problem solving tasks. Two feature sets were extracted from the selected PISA 2012 Climate Control problem solving task: a set of time-based features and a set of features indicating the employment of the VOTAT problem solving strategy. We evaluated both feature sets with six machine learning algorithms in order to predict the outcome of the problem solving process, compared their performance and analyzed which algorithms yield better results with respect to the observed feature set. The approach presented in this paper can be used as a potential tool for better understanding of problem solving patterns, and also for implementing interactive e-learning systems for training problem solving skills.

4) EEG-based Speech Activity Detection

The brain-computer interface is one of the most up-to-date communication options. The advances made in this area open up opportunities to help mentally or physically disadvantaged people. The brain-computer interface offers the possibility of re-acquiring communication skills by deaf individuals.

Electroencephalography (EEG) based speech recognition is, therefore, a novel research topic, which is an important component in communication technologies. In this article, we propose a speech activity detector algorithm, which, as expected, should improve the performance of the EEG based speech recognition system. EEG data uploaded while pronouncing 50 different phrases were classified using a feed-forward neural network. As a result of detection, a 0.82 F1 score was achieved.

5) Clean and Dirty Code Comprehension by Eye-Tracking-based Evaluation using GP3 Eye Tracker

During the observation, analysis and examination of cognitive processes, human-computer interfaces are increasingly becoming widespread. Programming could also be seen as such a complex cognitive process. This study aims to examine the efficiency of the clean code paradigm and compares to the dirty code produced without the principles formulated in this technique. In addition to the traditional knowledge level test and subjective judgment, the readability and comprehensibility of the implemented code was determined by analysing the heatmap and gaze route besides measuring and evaluating eye movement parameters. Based on the statistical evaluation, it can be stated that there is a significant difference in the average number of fixations, the average of fixation time and the average length of routes between fixations measured by studying two differently written source codes. This means that in the case of the clean code, significantly less and shorter information recording and processing were necessary to understand the code.

6) Experience of Self-Efficacy Learning among Vocational Secondary School Students

Self-study and self-efficacy are closely related concepts, and they are in connection even with lifelong learning. To develop real self-esteem in the learning process, it is important to be aware of one's abilities, weaknesses, and other characteristics that influence learning, which reinforces the foundations of learning motivation and lifelong learning. Self-efficacy and modern ICT solutions supporting self-directed learning become a more relevant role in self-learning outside the school context, ie in self-taught learning. This article examines self-efficacy in learning through a questionnaire survey for students at technical vocational secondary schools in Budapest (N = 1260) analyzing the answers to some of the self-efficacy statements based on the Motivated Strategies for Learning Questionnaire (MSLQ). The results can help to develop modern ICT solutions that effectively support learning.

7) Learner Experiences Related to Digital Education Schedules in Light of Empirical Data

In my essay I briefly introduce the theoretical foundations and main aspects of electronic learning in order to explore and evaluate the instruction schemes implemented as a result of the digital transformation. I base my findings on the analysis of a questionnaire-based survey administered to a sample of students. My research aims at examining the efficiency of the implementation of digital instruction and the accompanying challenges at various levels of the education sphere. I was interested in students' ICT preference and usage habits and whether they possess vital digital competences in their own view. The digitally scheduled education programs introduced in response to the COVID-19 pandemic could not fully reach a level required for effective learning according to research findings. The responses revealed several schools did not implement an uniform system, the educational materials were not suitable for independent learning, the given materials did not have a modular structure, the respective texts did not reflect a system oriented perspective, and it was proven that neither students nor teachers possessed digital literacy skills considered vital in the present. The most important result of this statistical analysis entails that those students were more successful in the digital home-based education who spent more time with ICT use, regularly played with or used experience-oriented software and relied on smart devices in most of their studie.

8) The Methods and IT-tools Used in Higher Education Assessed in the Characteristics and Attitude of Gen Z

In the era of digital transformation, some questions occur whether the teaching methods used in higher education are suitable for the students belonging to generation Z or these methods are appropriate enough to make them more attentive or motivated. The diverse methods of information technology have already spread into university education and a pedagogical paradigm shift can be perceived. The latest methodology, like project method, e-learning, BYOD, gamification, MOOC are available in higher education as well; however, it is a question to what extent teachers apply these methods in their teaching process. The new techniques not only make the students more motivated but also enhance them with those sorts of skills that are indispensable to be successful in the field of labor. The research was aimed to find answers about how much engineer students are satisfied with the training they are given in higher education in the 21st Century, what kind of attitude they have towards educational technology.

9) The Effectiveness of Different Sets of Learning Predictors in Moodle Machine Learning Models

Moodle is one of the world's most popular open source learning platforms with millions of users and widely used in online education. Although from its version 3.4 it is possible to create Machine Learning models within the system very few studies have been published so far about their successful applications. In this paper 16 different Moodle Machine Learning models for predicting the success of 57 full-time students enrolled in the Applied Statistics course at the University of Dunaújváros in Hungary have been developed and tested in terms of "goodness". The success can be affected by several factors. Here students' cognitive activities are examined. The type of the predictors used in the models are based on: number of view of Lecture Notes, number of views of Exercise Books, number of views of Lecture Videos, number of views of Minitab Videos (videos for problem solving with a statistical software), number of Quiz Attempts and Quiz Max Grades (best grades achieved by students on quizzes). The models differed in the number and in the types of predictors. Binary Logistic Regression was used for model training and evaluation. The target of the models indicates whether a student is at risk of not achieving the minimum grade to pass the course. The impact of cognitive predictors that are part of the Moodle core Analytics API on predictive power was also examined. Having evaluated the goodness of the different models, it was shown that students' success can be predicted purely from cognitive activities, but their predictive powers are very diverse. The predictors of quizzes have the largest impact on the success, however, supplementing the model with other even less effective predictors much better models can be made. Models built from purely Moodle core cognitive predictors give much less reliable results.

György Molnár

Guest Editor

Uniform Dispersal of Cheap Flying Robots in the Presence of Obstacles

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Abstract: In previous solutions, the authors considered the uniform dispersal problem (or Filling problem) in which inexpensive robots had to disperse in order to cover an a priori not known area, as well as they also examined the possibilities of solving the Filling in two-dimensional regions. The swarm entities had to collectively solve a common task using the simplified cognitive abilities of the robots (i.e., their memory, visibility, and communication capabilities were restricted). In this paper, the authors investigate the possibilities to apply the method for three-dimensional regions. The need for such a solution emerged, as nowadays the number of low-priced flying robots, e.g., quadcopters, drones, has increased heavily. The main research direction is to minimize the hardware requirements of these robots, as doing so is crucial in order to maintain their cost-efficiency. The authors demonstrate that it is still possible to solve the Filling problem in three-dimensional space in the presence of obstacles, while the robots maintain the following hardware requirements: they have a constant amount of memory, minimal visibility, as well as there is no communication between them, and the algorithm terminates in linear runtime. Finally, simulations were carried out to prove the theoretical results.

Keywords: uniform dispersal; distributed robotics; autonomous robots

1 Introduction

Swarm robotics differs from single robot systems in many aspects; in the first one, numerous cheap and simply constructed robots perform sophisticated tasks together, while in the latter, the main focus is on the fact that single robot systems are less scalable, reliable, and fault-tolerant than multi-robot systems. Recently published studies have focused on the behavioral, so to say cooperative, properties of simple and small robots that have the task of solving incurring problems together, as one team.

Starting from the publication of Reynolds [1], many researchers have started to investigate the issue of tasks requiring the positioning of individuals. In these works, robots did not possess a central control or coordination, as well as they, performed the same distributed algorithm for achieving flocking (collective movement of a swarm). Additionally, the algorithm provided was less complex and only relied on the local perception of the robots.

As for the concept of flocking, there have been other studies published, focusing on the problems of exploration (fully discovering an unknown area), gathering (meeting at given points in the area), pattern formation (the swarm achieving a previously defined shape), coverage (the way robots cover an area), or dispersing (reaching the state of coverage from certain starting points). These problems are included in the publication [2, 3, 4, 5, 6, 7, 8, 9, 10]; see [11, 12] for recent surveys.

In the recent past, largely the public has also been allowed to create big flying swarms by the use of small and inexpensive robots. In the case of a robot being equipped with a measuring sensor, it's possible to monitor specific values of its environment. When cleaning up toxic waste, reducing pollution, or when there is a potential risk of radiation, being present in the area itself might be of high risk for humans. This is where these drones come in handy since they could signal to the human party when a certain threshold of a dangerous substance has been reached.

The authors have already investigated the issue of dispersion when the goal is to evenly distribute robots in the area [13, 14, 15, 16]. A unique case of dispersion like this is the Filling, which was first introduced by Hsiang et al. [9], where the robots enter individually through an entry point (Door), and have to disperse from that point, covering the area subdivided into smaller cells. The Filling becomes completed when all cells contain a robot, and none of the robots collided during the dispersion process. Another requirement is that each cell must contain no more than one robot at the same time.

After they have dispersed, robots are able to measure different environmental factors with the help of built-in sensors. These measurements have to be immediately sent to the network (of robots) by the use of network coding [17], since – given their inexpensive nature – the continuous operation, communication, and measurement-making is not expected from these robots. This is similar to the sensor-bridging communication presented in [18] since the artificial swarm of robots explores the environment from a broader and more complex perceptive than the human cognitive system – for example as opposed to a human being, a robotic system is able to process a wide area at once.

The interdisciplinary area of cognitive infocommunication (CogInfoCom) investigates the connection between the areas of research of infocommunications and cognitive sciences [19]. As such, this area could be used to support any area where the central question is how artificial or natural cognitive systems could be able to work together more effectively [20]. The present paper examines the possible ways of cooperation in the Socio-Cognitive ICT, which is a subfield of CogInfoCom [19].

A simulator has already been built in [16], where a simulation environment was designed in order to examine the interaction between humans and computers. An example of this can be seen in [21] where cooperation was investigated in the VR environment. Many other studies show that these environments have a high impact on the field of CogInfoCom [22, 23], as well.

Another advantage of the simulation is its perspective in the CogInfoCom based education [24, 25, 26]. While observing and interacting with the simulated robots, the human party will have a much more immersive experience, as one of the primary goals of CogInfoCom is to create systems based on human perception, develop or return the cognitive ability of understanding and cognition to the user, all through models based on ICT engineering tools [27].

The robots evolve and learn, as well, which process is highly similar to the human learning process. Therefore, if we want to develop a robotic system, we could not avoid examining the human way of learning since we would mimic this process.

As it was previously mentioned, exploring and dispersing areas that are unsafe for humans, such as extinguishing a building on fire, the use of computer-operated robots could offer a perfect solution, despite being somewhat expensive, to saving human lives by using these robots worth way more than their price. What is more, simulating, analyzing, and testing these scenarios is also very supportive of several fields of study.

In this paper, an algorithm where robots are substituted by flying drones capable of areal movement (i.e., flying and floating) is shown and further analyzed, as opposed to the solutions proposed previously for Filing, where the robots acted in a 2D plane.

The present paper investigates the use of the Virtual Chain Method (VCM) presented in [15]. The new contribution proposed is the use of algorithms for flying drones in 3D areas. When describing and analyzing the algorithms in question, terms, and arguments introduced in [15] are used or repeated.

2 Model

The robots work in a three-dimensional area, which is connected yet unknown for the robots. The whole area is built up from small regions of space, which are virtually subdivided into smaller regions (see Figure 1), allowing no more than one robot to occupy them at any given time. These spaces can be interpreted as vertices of a graph, with having the edges between neighboring spaces. Drones are equipped with built-in compass, allowing them to be able to differentiate between the orientation of North, South, East, and West neighbor spaces horizontally, and Upper or Lower neighbors vertically. The vertices where they enter the graph are called Doors, from where drones can only move to Upper neighbors and continue from those points.

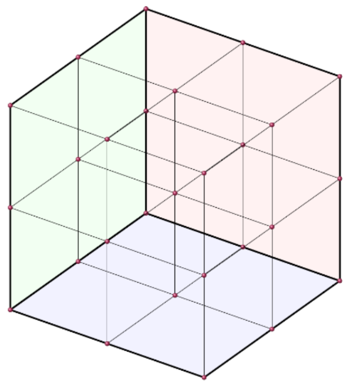

Figure 1
Three-dimensional area decomposed into small regions

Each of the drones is able to get information from its environment by using its sensors. The robots are also equipped with a computational unit, as well as have aerial locomotion capabilities, such as flying and floating. They are *autonomous* (do not have central coordination), *homogeneous* (each has the same capabilities and behaviors), and *anonymous* (they could not identify one another).

Furthermore, they have a sensor for measuring the distance between themselves and nearby obstacles. Obstacle detection can be achieved by attaching IR or ultrasonic distance sensors or any other rangefinders into 6 directions; 4 horizontal in every 90° angles, one to the top, and one to the bottom. The sensors have to tell whether the robots can move in the given direction or not since in case of an obstacle – such as another drone, a tree, or a wall – they will hit when they move in that direction.

They also have limited persistent memory of *O(1)* bits in the single Door case and *O(log k)* bits when *k*-Doors are present.

The drones act according to the general model of Look-Compute-Move (LCM), where the drones' actions are decomposed into three phases (Look, Compute, and Move phase). In the Look phase, the drones take a snapshot of their environment, in the Compute phase, they perform calculations in order to determine whether they should float in their position or fly to one of their neighboring space, and finally, during the Move phase, they implement the decision they have made in the previous phase. Their movement is atomic, i.e., it is either entirely performed and the robot appears at the destination, or not performed, meaning that the robot does not move at all.

As for the timing of an LCM cycle, the fully-synchronous (FSYNC) model is used, where all drones perform their LCM cycles simultaneously, i.e., each of them takes a snapshot of the environment, computes, as well as performs their movement at the exact same time.

The drones are placed in previously defined positions (Doors), from where they can only move to their Upper neighbor and continue dispersing. At the start of each LCM cycle, a new drone is placed there and performs its first Look-Compute-Move phases during the same cycle in case the Door is empty.

3 Areal Virtual Chain Method

In our previous paper, we described the Virtual Chain Method (VCM). This method was able to solve the problem of Filling by using the general leader-follower method [5, 6, 9, 13].

The Areal Virtual Chain Method (A-VCM) extends this latter method for robots having flying capabilities (e.g., drones or quadcopters).

3.1 Concept

One drone becomes the *Leader* and moves to unexplored areas in the given space, while the others become *Followers,* following the Leader by forming a chain by the way they move. When the Leader reaches a point where it can not move anymore, it switches to *Finished* state, and its immediate Follower becomes the new Leader which will start moving to other parts of the area they are in. These states, as well as the transitions between them, could be seen in Figure 2. In their initial state, drones can either become Leaders or Followers depending on whether, at that time, they have a neighbor or not.

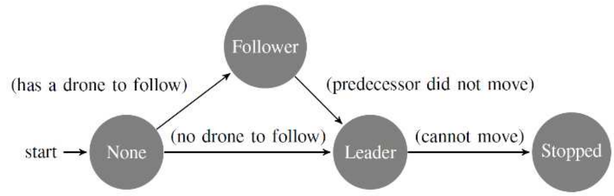

Figure 2
States and state-transitions of the drones. The edges are labeled with the condition for the transition.

3.2 Method

In the algorithm, the following tasks are performed by the drones in their respective states:

- *None*: the starting state, right after the drone has been placed at the Door.
- *Leader*: the first drone placed at the Door switches to Leader state. Only this one moves to previously unoccupied, so-called *unvisited,* vertices. We ensure that there can be no more than one Leader at any given time.
- *Follower*: drones following their *predecessor* (the previously placed drone) are in the Follower state. A Follower can only become a Leader when its predecessor switches to the Finished state.
- *Finished*: this is the final state of the drones, in which state they switch to once they detect they cannot move anymore. A Finished drone can never move anymore; it only floats in its current position. Only the leader is able to switch to Finished state.

3.3 Round Structure

Similar to the VCM, the algorithm also functions according to rounds. A *round* is a sequence of 6 consecutive *steps* where a step means one LCM cycle of the drones. Steps are called by directions of North (N), East (E), South (S), West (W), and Up (U) and Down (D). The rounds and steps are illustrated in Figure 3. During each round, a drone is either an *observer* or an *observed* one.

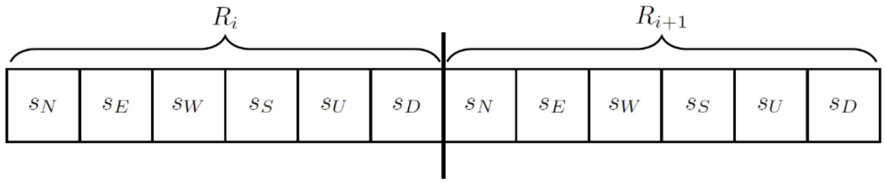

Figure 3
The round structure. Two rounds (denoted by R_i and $_{Ri+1}$) consisting of 6 steps, labeled with the corresponding direction (sN,…).

The observed one has to schedule its movement and is able to move to one of its neighbors in the direction, which is the label of the current step. At the same time, the observer drone counts the steps its predecessor has waited before moving. At the end of each of the rounds, drones switch roles (i.e., the observer becomes the observed and vice versa), however, each drone starts its actions as an observer when placed at the Door. What is more, in order to detect unvisited vertices, they also retain information about the occupancy of neighboring vertices.

Each drone is able to move every second round (in the round their state is observed). After the drones have moved, they do not move again until their next observed round. They are not allowed to backtrack, i.e., move to their previous position. The chain is defined by the current Leader drone's path from the Door, and Followers follow that path, while other drones in the area are in the Finished state.

3.4 Analysis

When analyzing the A-VCM, the area is represented by a connected graph. It is possible to repeat the arguments of the Virtual Chain Method analysis during these Lemmas. It is possible due to the generality of the VCM, meaning that apart from being connected, it did not require any particular attribute of the graph; thus, the Lemmas still hold in three-dimensional areas.

When analyzing the A-VCM, it is essential to prove that two constraints are satisfied during the whole dispersion: *i)* collisions are not possible, *ii)* there is no vertex of the graph which remains unoccupied after the termination of the algorithm.

Lemma 1. Collisions are not possible.

Lemma 2. A drone can determine if a neighboring region is unvisited by observing it for two consecutive rounds.

Lemma 3. The predecessor of the Follower is either in a neighboring vertex v, or it was in v in the previous round. In the latter case, the Follower moves to the previous position of the predecessor, which is v.

Lemma 4. Each robot in the Follower state always knows where its predecessor is.

Lemma 5. Two Followers cannot have the same predecessor.

Lemma 6. The Leader only moves to unvisited vertices.

Lemma 7. There can be at most one Leader at a time.

Lemma 8. Algorithm A-VCM fills the area (represented by the graph).

Theorem 1. By algorithm A-VCM, a three-dimensional area with a single entry point, is filled in *O(n)* rounds without collisions by drones with a visibility range of 1 hop and *O(1)* bits of persistent memory, if they are equipped with a compass.

Proof: The A-VCM fills the area (Lemma 8) without collisions (Lemma 1) if the area is represented by a graph. After placing the drone at the entry point, it is in None state. In the next round, it observes its predecessor moving, and then it moves in the third round. In the same round, the next drone will be placed at the Door. For this reason, the drones are placed at the Door in every third round; as each round consists of 6 steps, it takes $3 \cdot 6 \cdot n = O(n)$ steps to place *n* drones.

Regarding the memory requirement, the drones require to store: the index of the current step within a round, the unvisited neighbors, the direction of their predecessor (each requiring at most 6 bits of memory), and some additional information, requiring a constant amount of bits: current state, observer/observed role, entry vertex. As a result, *O(1)* bits of persistent memory is required for the Areal Virtual Chain Method.

3.5 Multiple Doors

In case there are several entry points (Multiple Doors) for a given area, the greatest challenge is to make sure that robots entering through different Doors avoid collisions. Two robots could avoid such a collision by mutually agreeing on which one will go (to the same destination) first, typically by setting a priority order. This order can either be visible externally or is communicated between the robots. To arrive to such an agreement, those robots have to 'see' one another, which means they have to have a visibility range of 2 hops; however, the drones used in the present paper are only equipped with range finders, cannot detect others' priority orders, nor can they communicate with one another. In the Multiple Door Areal Virtual Chain Method (MDA-VCM), robots from each distinct Door will form a distinct chain.

Similar to the MD-VCM, a distinct time-slot is allocated for each Door, in which they are able to execute their actions. Contrary to the single Door case, each step is replaced by *k* steps; therefore, a Round will be a sequence of *6k* steps. Each drone entering from D_i only performs their actions in $s_{i,*}$ and stays idle during the other steps.

Theorem 2. A three-dimensional area, represented by a connected graph, having several entry points, is filled by the MDA-VCM in $O(k \cdot n)$ rounds, without collisions by robots having a visibility range of 1 hop and *O(log k)* bits of persistent memory.

Proof: Similar to Theorem 1, the drones are placed in each Door every third round, given that the chain from that Door is able to move; otherwise, no further drones could be placed at that Door anymore. The worst-case scenario is when a single chain blocks all the other Doors – in this case, only one Door is used to cover the area.

As for hardware requirements, the drones do not need additional visibility, nor other equipment either. The memory increases to *O(log k)* as the round's length increases, and the current step index has to be stored.

4 Practical Usage

Formals proof has shown that the A-VCM can be utilized in three-dimensional (and also in n-dimensional) areas. This implies that there are numerous practical scenarios where the algorithm can be applied.

In the last years, we have experienced an increasing interest and rapid development of robotics, 'Internet of Things' (IoT) devices, as well as related platforms. The tremendous amount of wirelessly connected devices suggests that it is not suitable to maintain centralized communication, given that in more and more scenarios, low latency and real-time communication might be crucial (e.g., autonomous vehicle fleets, sensor networks). In these particular systems, along with real-time transmission, the intra-group data exchange is also substantial. Consequently, peer-to-peer architecture is the most suitable.

Nonetheless, peer-to-peer data exchange dramatically relies on the links between neighboring entities, especially the quality of those links. This quality can be measured easily in a flat, 2D setup; however, the same can be done more complicatedly in a 3D setup. Furthermore, performing measurements in a moving swarm of drones or a convoy of vehicles is also a high-complexity task.

By using A-VCM, different multi-dimensional drone setups could be created with the communication links between the nodes that can be measured and monitored.

4.1 Sensor Data Propagation

A final goal is that, in the given area, the dispersed drones have to perform constant measurements and maintain continuous surveillance. A problem could arise from the fact that these drones are built by using cheaper components, therefore they might malfunction, hindering communication between them or making them land by leaving their positions. These drones could be seen as nodes in a network, with local information provided by their sensors whose task is to send those data to the network. A method was described in [28] where the nodes could lose network availability or fail permanently, as well as a dynamic repair mechanism allowed them to maintain integrity between data.

Applying the same method to drones, a network of flying sensors could maintain data propagation even in cases when some of the drones malfunction, or could be used for various problems where the constant monitoring is required even by leaving out human presence, as this one being too dangerous or impossible, e.g., in the case of dangerous environments.

5 Simulation

A simulation framework based on [16], called the RobotCore, is currently under development which is to simulate complex distributed algorithms. With the simulator, the purpose is to validate the formal proofs made in the previous section.

During the simulations, the focus is on the runtime of the algorithm in different areas. First, the runtime was examined by using randomly created three-dimensional grids with obstacles having different sizes in them. The size means the number of cells in the area. Then, the same areas were examined with multiple entry-points. Finally, a large area with 100 drones and cells were filled using more and more Doors.

The graph generation procedure: for a graph with n vertices take a cuboid-shaped three-dimensional area with approximately $2n$ cells. The cuboid has a width of x, a length of y, and a height of z cells. First, x and y are randomly generated between 1 and the square root of $\sqrt{n}$. Then z is chosen, so $x \cdot y \cdot z$ will be closest to $2n$: $z=2n-x \cdot y$ rounded up. From these $2n$ cells, randomly remove n, so the final area has only n cells. Finally, k Door vertices will be added as Doors (and k cells removed from the cuboid). Note that the removed cells can be considered as obstacles in the area.

5.1 Runtime with single Door

In the single Door case, Theorem 1 has shown an $O(n)$ runtime, meaning that, based on the size of the cells, there is a linear growth in the running time. The simulation results can be seen in Figure 4. The horizontal axis shows the number of vertices in the area from 1-1000; the vertical shows the required number of turns to complete the Filling. For each size, graphs were randomly created with the given vertex count, then it was tested how many rounds were required until each vertex was occupied. As it was expected, the runtime has shown a linear growth.

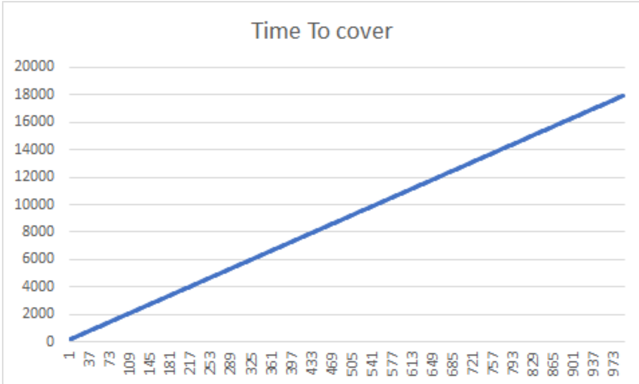

Figure 4

The horizontal axis shows the number of vertices in the area; the vertical shows the required number of turns to complete the Filling.

5.2 Runtime with multiple Doors

In the second test scenario, the claim that multiple Doors can increase the runtime was tested. In some cases, it necessarily improved the runtime, as the robots might have blocked others coming from different Doors. However, in general, the runtime was reduced, which can be seen in Figure 5.

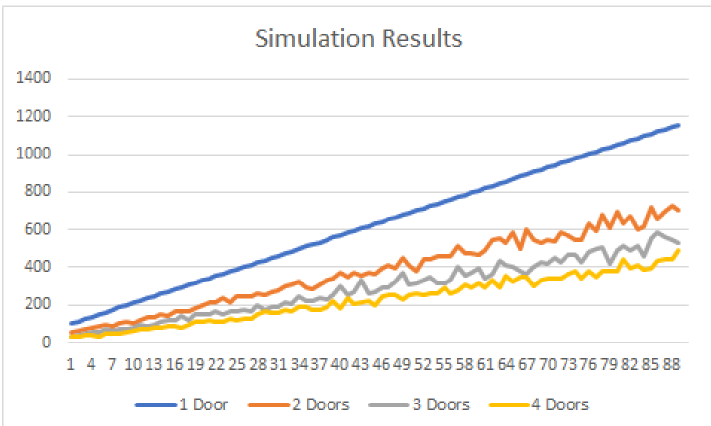

Figure 5

The horizontal axis shows the number of vertices in the area; the vertical shows the required number of turns to complete the Filling

5.3 Runtime reduction test with multiple Doors

When introducing more and more Doors, the runtime can be reduced by a factor of k if the number of Doors in the area is k. During the last test scenario, the authors were curious whether this runtime improvement is achieved or not. The simulation results can be seen in Figure 6, which proves that the runtime is approximately k-times faster with k Doors in the area. In these simulations, an area consisting of 100 vertices was Filled by robots entering through k Doors, where k is from 1 to 100.

Note: this means that more and more vertices become Doors, and in the extreme case of 100, all the vertices are Doors. In such a case, it might not be possible to add enough Doors; thus some of the vertices will be simply treated as Door vertices. This high rate of Door vertices among non-Door vertices become more and more impractical as the rate rises since robots placed on them will just get stuck and become Finished. The simulation is only to validate the *1/k* characteristic of the runtime improvement.

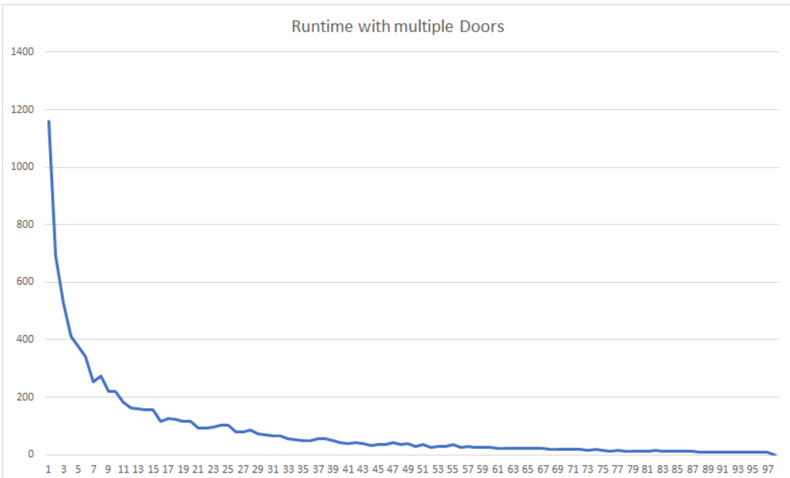

Figure 6

The horizontal axis shows the number of Doors in the area; the vertical shows the required number of turns to complete the Filling

Conclusions

In this paper, an extended version of the Virtual Chain Method was demonstrated for solving the Filling problem in 3D-areas. The algorithm's hardware requirement regarding visibility and communication range is optimal, and it is asymptotically optimal for the memory requirement. As a result, flying drones are able to solve the Filling problem even when they are present in an open space.

The drones do not have to be supplied with more equipment than a range finder in 4 horizontal directions, and 2 for vertical directions, *O(1)* bits of persistent memory, a compass, as well as a timing unit for achieving full synchrony. After they have dispersed, robots could provide a subservience or monitoring system in the given area, even in cases when human presence would be dangerous or impossible. Simulations then back up the theoretical results: the correctness, as well as, the runtime of the algorithms is tested. The correctness was validated as no collisions occurred, and the problem was solved completely every time. The performance tests also validate the linear runtime of the algorithm.

In the future, this work could lead to the investigation of possibilities of interaction between humans and robots (HCI) within the same field. Given that with the help of human assistance, it is possible to further improve completely autonomous robot-systems, in which case the human being will not only be a passive participant in the situation, but will also an active one engaging in the robot system itself. This outcome could be hugely beneficial in situations where the framework or the environment is likely to change at a quick pace, and the human being, given its more complex cognitive abilities, is able to adapt faster than the swarm algorithm. Moreover, with the assistance of the simulator, the inter-cognitive communication (communication between parties having a different level of cognitive abilities) between the robots and the human party can be further exploited, for example, by manually controlling a single member of the swarm.

The usage of a game engine in the simulator should also be mentioned since it allows the implementation of gamification elements, i.e., using game elements in non-game contexts [29]. With the help of this, the cooperative development process of the algorithm can be less intimidating and more inclusive for the user; as well as with automation and machine learning algorithms, the development of learning methods will be faster than before.

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Advanced Assistive Technologies for Elderly People: A Psychological Perspective on Older Users' Needs and Preferences (Part B)

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Abstract: This paper provides a general overview of the literature regarding advanced assistive technologies devoted to improving elders' life. Recent studies on assistive robots and embodied conversational agents are carefully examined in order to identify main seniors' preferences regarding their general design. While providing data on seniors' preferences about the design of assistive devices, main evidence on both robots and virtual agent's appearance, abilities/functionalities, personalities, and role features are summarized and commented.

Keywords: older user; assistive technology; robot; virtual agent; design; preferences

1 Introduction

There is a general agreement that the successful incorporation of assistive social technologies (e.g., virtual agents, robots) in everyday life can positively influence the well-being of elders by affecting their psychological characteristics, e.g., mood, motivation, autonomy, self-determination, and coping abilities [1].

If a user's needs and expectations are accurately and appropriately addressed and aligned with the agent's (or robot) behaviors, physical appearance, and role, then seniors and vulnerable people may be in favor of accepting and using such every day assistive technologies [2, 3].

This paper reviews the literature on advanced assistive technologies aimed at improving older people's well-being, focusing on assistive robots and embodied conversational agents, in order to discover seniors' main preferences regarding the general design of such technologies, including appearance, functionalities, and attitudes.

2 General Designs of Assistive Devices and Seniors' Preferences

Following the premise of "customization needs" as a basis for developing assistive technologies for seniors' uses, it follows that personalization (also referred to as one-to-one marketing) is of significant concern in designing both robots/virtual agents' appearance, as well as defining the services, behaviors, and attitudes these technologies can offer to their end-users. These design-related features aim primarily at engaging and maintaining user engagement throughout interactions with the device [4-6]. The main findings regarding seniors' preferences about these design features are described below, distinguishing evidence regarding robots by those related to virtual agents.

2.1 Appearance

Seniors' preferences and opinions about the appearance of assistive devices, both robots and virtual agents, were broadly investigated with controversial findings.

2.1.1 Robot

Several reasons were identified related to a robot's physical appearance and why this is considered a significant factor for potential users' acceptance. How a robot or a virtual agent appears affects the way individuals appraise the agent/robot functions, abilities, desirability, accessibility, and expressiveness [2, 7].

To this aim, inconsistent evidence has been reported on whether a robot should have a human- or animal-like appearance.

Broadbent et al. [2] highlighted that since both soft (used in health care and designed to resemble animals, e.g., Hopis) and humanoid robots (designed for companionship) have proven to be either disliked or popular, a good match between animal-like robots and companionship seems to be suggested.

De Graaf et al. [8] has shown that seniors seem to welcome the idea of some animal-like robots so that they are comforting to hold and pet them while being able to communicate and perform other activities.

Conversely, Hutson et al. [9] and Robinson et al. [7] showed that elders negatively evaluate animal-like robots (e.g., Pleo and FurReal Cat) because they expected them to act like real pets and express dissatisfaction when their behavior is different. According to these authors, animal-like robots are characterized by a toy-like appearance and older people do not appreciate the contrast between their fluffy appearance and the seriousness of the tasks they are required to perform.

Similarly, to what extent a robot should have a human-like appearance is a hotly debated issue. Some evidence showed that older adults prefer human-like appearing robots [10], while other findings reported little preference for them [2, 11]. Based on these data, some authors concluded that seniors do not appreciate human-like robots because their anthropomorphic shape is less socially acceptable in comparison to robots that looked more like machines [2, 11, 12].

This rejection can be motivated by the user's cultural and/or religious background [13]. It has been argued that seniors are not attracted by robotic devices with human-like features and appearances because they are more religious than their younger counterparts [14].

Other investigations reported that elders prefer creative robots with human traits, humanoid robots, and mechanized human-like robots that incorporate in their design anthropomorphic facial features so that they look like familiar objects in their home setting [11, 14].

Regarding the size, seniors seem to approve small-sized rather than human-sized robots since the former can be easily integrated into users' home environment (e.g., into the existing furnishings; the television and the system could be contained in the same device) in a non-intrusive way, and are simultaneously not cumbersome, discreet robust, and effortlessly manageable by users with reduced mobility [9, 14, 15]. Additionally, seniors seem to prefer slowly moving, and non-threatening robots, entrusted with a feminine voice. These characteristics are likely to reduce anxiety related to distrust and a lack of confidence in robots' abilities [2, 16].

2.1.2 Virtual Agent

The external appearance of the virtual agent (i.e., its representation as human-like, animal-like, or anything else like) determines the potential degree of seniors' willingness to cooperate with them [17]. Bickmore et al. [4], emphasized that the extent to which virtual agents appear is a fundamental design element to be accounted for by all developers of robotic devices for domestic use.

In the health care and well-being domains conclusive evidence exists that seniors prefer female human-like rather than animal-like or other non-human like virtual agents [3, 18-22].

Realistic human design tends to elicit a sense of trustworthiness and competence.

Therefore, increasing the human-like qualities of virtual agents increase users' trust and compliance, and this is particularly true for virtual agents involved in health care services [23-26]. As further support to the abovementioned results, several empirical studies had shown that users aspire to interact with virtual agents resembling them, aligned with their own personalities (based on introversion vs. extroversion according to displayed text messages) and their own body shape, suggesting that a human-shaped virtual agent is the most appropriate digital interface for a social collaborative behaving system [4, 27-29].

However, seniors are not strict in these preferences and are willing to accept also agents with non-human like appearances. To this aims, seniors have shown positive attitudes also for fictitious cartoon-like (Smiley) (human-like appearances were less popular), animal-like (e.g., GeriJoy), and flower-like (Flowie) characters all considered to convey cooperation and warmth, and purposely serve as supportive friends [3, 17, 30, 31].

2.1.3 Human-like Appearance and Related Issues

It should be noted that specific issues related to human-like appearances also exist, such as the "uncanny valley" effect [32]. According to this phenomenon, a robotic virtual agent device resembling a living creature too closely is expected to behave like that particular creature, and the failure in doing so elicits discomfort, potentially breaking down the success of the user–agent interaction. Furthermore, it has been found that as artificial constructs become increasingly sophisticated in their visual design, human beings' positive emotional responses to them decrease. In particular, agents/robots too similar to humans have been found to elicit distrust because their design represents something interpreted as being alive and not alive at the same time [3, 25]. This can be particularly true for seniors contending with dementia, having difficulties in distinguishing the agent/robot from a human being. Thus, a highly realistic human appearance can be potentially problematic since an extreme human-like appearance can be seen as a kind of deception and raise ethical issues, as impaired seniors (e.g., suffering from dementia) can be disoriented by interacting with these types of devices [11, 14, 25, 33].

Thereby, robotic or virtual agent devices designed to strongly resemble to human beings can be judged fraudulent and, unethical, since the proposed benefits of the relationship depend on the user's willingness to engage with an illusory representation of a human being [34].

2.2 Abilities and Functionalities – Robots

Whether and to what degree a robotic device is accepted is closely associated with its functionalities. For elderly person's these functionalities must aim to provide practical help for daily issues, promote healthy behaviors and wellness, offer health monitoring and preventive care, as well as carry out household activities.

2.2.1 Practical Help for Current Issues and Household Activities

Older people often expressed that they would like a robot to be able to carry out tasks that support their independence in the performance of their daily activities. Seniors appreciate a robot able to find objects, pick them up from the floor, manage information, manipulate items [35-37]. Also, the robot should be adept at controlling appliances, cleaning the house (especially in the case of older adults with mobility impairments), making calls, doing shopping online (especially if needed in relation to an illness or injury), planning outings, simplifying internet access, fetching and organizing objects, and doing household tasks like laundry, and trash disposal [11, 38-40].

2.2.2 Promoting Wellness

Regarding well-being, a robotic device should be capable of performing useful functions that promote wellness. These might include communicative services that allow users to remain socially active (e.g., video calls, email) and facilitate their communications with family members, friends, doctors, nurses, and caregivers, as well as allowing contacts with the world beyond the home environment, increasing and strengthening social interactions and relationships. In addition, robotic devices should be able to promote creativity through intellectual stimulation and provide assistance for new learning and engaging in hobbies reducing loneliness, bridging distances, and facilitating exchanges [9, 11, 40-42].

Entertainment functionalities are also highly appreciated by older users, such as playing music (either from their own collections or a radio), audiobooks, and fitness instructions [8, 35].

2.2.3 Health Improvement, Monitoring, and Safety Functions

Seniors require a robot be able to promote healthy behaviors, have the potential to give dietary and exercise advice, offer cognitive support by providing reminders for appointments, and taking medications, address concerns regarding side effects and dosage changes, and send information to users' health practitioners, propose directions, motivations, and cues for daily acting (i.e., suggest what to eat or which movie watch), and several types of mental stimulation including memory training, card games, music, audiobooks, and videos that could support cognitive awareness to compensate for mild cognitive impairment (e.g., finding misplaced items, offering reminders) [7, 8, 11, 36, 40, 43].

Other functionalities considered useful to prevent health problems and accidents are risk prevention and health care applications for detecting falls, managing critical events, calling for help, and monitoring locations [2, 11, 44].

2.3 Abilities and Functionalities – Virtual Agent

Seniors' attribute to virtual agents similar robotic skills and functionalities including assistance in performing daily activities that promote well-being and execute functions for health improvement and monitoring.

2.3.1 Practical Help for Current Issues and for Household Activities

Within tasks considered useful for virtual agents there are daily schedule management, support in routine activities (e.g., maintaining a personal up-to-date daily plan and providing appropriate reminders during the day); managing personal agenda, using interactive calendar creating new entries and reminders of events (e.g., a reminder about social engagements or dental or medical appointments); provide dietary advice, helping to locate recipes based on ingredients already available at home [3, 15].

In addition, virtual agents are required to be able to simplify seniors' exploitation of ambient intelligent environments, acting as simplifying interfaces. This kind of agent is seen as a virtual butler, able to answer any user request and need of exploiting a computing device, as well as, simplifying elderly uses of smartphone interfaces, for example replacing fonts, or using voice to substitute complex menus that usually characterize smartphones [45-47].

2.3.2 Promoting Wellness

Older adults enjoyed agents functioning as automated coaches that would motivate them to perform activities to promote their wellness, such as taking walks, performing relaxation exercises or playing brain-training games [30, 48].

Additionally, agents can promote seniors' physical and mental well-being, suggesting to drink more water, eat meals, and reminding them to make contact with friends and family members [3, 31].

2.3.3 Health Improvement, Monitoring, Safety Actions

Older users living alone at home were especially interested in virtual agents able to perform safety measures such as monitoring the home to identify dangerous situations (e.g., loud noises, fallen objects, fallen people) and help them to improve their health status, remembering them to take medications on time [3].

In addition, the agent should be aware of the user's location and identify inconsistencies between what the older adult was supposed to be doing at a particular time and what she/he was doing instead, in case of discrepancies. Moreover, if something was wrong, it should be able to notify medical services, the user's relatives, and caregivers, or other specified individuals via email, or phone calls [3, 47].

In this regard, specific agents (e.g., Frederick) were designed to represent a medical doctor, assisting patients with specific illnesses or health conditions that need to be daily monitored (e.g., for patients with type 2 diabetes, the agent is able to keep track of their blood sugar levels, issue reminders, check blood-sugar levels over time, and share that data with external reviewers) [17].

2.4 Assistive Devices' Personalities and Roles

The success of the deployment of an assistive device depends not only on its usefulness but also on its social intelligence, namely its capability to show personality traits, attitude, social skills, and emotional aspects of face-to-face interaction in a comfortable and socially acceptable way [3, 18].

2.4.1 Robot

Studies have indicated that whether users will take the robotic device seriously can depend on the personality they perceive it to have [7]. For example, some evidence suggested that certain character traits like a sense of humor and being curious, in addition to having a serious side, can make a difference with regard to the robot's acceptance [2, 9]. Some studies also had shown that seniors are more likely to follow exercise routine instructions delivered by a serious robot's character rather than a playful one, although the playful robot is more positively rated, suggesting that seniors are less likely to take advice from robots that are not perceived as serious devices (e.g., Ifbot and Hopis) [7, 49]. Regarding preferred roles, seniors are more likely to accept a companion a robot able to communicate by voice and touch. Additionally, it should respond to the user and the environment (audio or visual recognition), recognize and respond to a user's feelings and mood (possibly from their tone of voice) and alter its own "mood" in response [9]. Results from studies using social robots (e.g., Paro, a soft "seal" robot; AIBO, a "dog" robot) demonstrated that interacting with the device as a social entity decreases users' loneliness, reduces depressive disorders, and improves seniors' quality of life, as evidenced data showing a marked improvement in seniors' speech, attitude, outlook, and behavior [7]. This was shown to be true also for seniors living in rural locations that felt the robot like a companion making them less alone at home [50], and for mild cognitive impaired individuals who perceived the robotic companion as a pleasant distraction and a friendly company for lonely people [11].

Regarding robot's conversation ability, seniors expressed the desire for robots to be able to collect stories from them and send them to their grandchildren or keep them as memories of themselves. Additionally, they required robots to be enabled with comprehensive conversation abilities (such as weather forecast and recommendations for local events), be socially responsive, not repetitive in the interaction, and able to interact through the user's native natural language [8, 9].

Further evidence described older rural patients enjoying when they heard the robot spontaneously speaking, for example, wishing the user a happy birthday [50].

2.4.2 Virtual Agent

Conveyed by its voice, words, and facial gestures, a virtual agent's personality is important in the user acceptance process [17].

Older users stressed that it was important to them interact with an agent characterized by a friendly face and voice, and able to show a discrete range of pleasant emotions such as happiness and contentment. Seniors required the virtual companion to be characterized by emotional understanding, to communicate in a human-like way with natural language and non-verbal conversational behavior (i.e., facial expressions) and to show a supportive, joyful, and practical personality, accompanied by a professional attitude [3, 18, 51].

Regarding a virtual companion's behavior, the evidence described older adults as identifying two preferred personalities, depending on the tasks the agent has to perform. They wanted a less formal, friendly companion to remind them of appointments and a professional one reminding them about medications to take [3].

Regarding preferred roles, older people preferred the virtual partner act as a companion or friend; others thought its role should be as a family member and the personal assistant in the home [18]. Seniors strongly appreciate a virtual agent assisting them in deciding daily activities, giving advice rather than directives (i.e., the virtual agent offers suggestions), and showing a passive (i.e., only the user can initiate a conversation) rather than a proactive behavior [18]. Seniors also appreciate agents able to operate as preventive caregivers, supporting free conversation (responding to the user giving comfort, warnings or advice) on everyday life topics, and able to detect users' emotions or moods along the conversation [52, 53].

Main topics discussed by older users with their conversational agents were family, weather, and storytelling [54]. Other conversational topics include discussing plans, asking agents questions about their functioning and future development, statements regarding agents' supportive role, agents' position in the user's social network, users' personal feelings of being connected with the agent, past events, new activities, attitudes about aging, and social ties [54, 55].

Seniors' negative reactions are observed when the agents' lack realism, deploy trivial interactions, and are entrusted with insignificant functionalities [54]. An agent that actively engaged users, especially by spoken-language interaction, seemed to reduce the acceptability barriers [56]. Users were displeased if they perceived the agent's topics to be irrelevant or repetitious; this was similar to how they would react to a companion who failed to listen to them or talked about themselves too much [55].

Similarly, a lack of variability in the agent's dialogue had a negative effect (e.g., the agent uses the same language in every situation). When the agent exhibited a variety of behaviors and demeanors over time, older adults were more likely to continue the interaction [4, 57]. In addition, when the agent presented the narrative as autobiographical stories (i.e., its own life story rather than presenting the narrative as stories about a friend), especially when "cliffhanger" techniques were used, older users reported greater enjoyment and increasing long-term engagement in their relationship with the agent [4].

Finally, within crucial factors affecting the quality of interaction with a virtual agent, the importance of latency (i.e., potential delays between system input and expected and desired output) should be mentioned. It was found that older users may perceive the quality of interaction and the natural flow of dialogue according to this factor and that a high degree of latency can confuse the user and be interpreted as the agent's inability to understand the user [17].

3 Gender Preferences

The considerations noted here as interacting with acceptance by older users of assistive robots and virtual agents have occasionally been noted as dichotomous, with some individuals having a strong opinion in favor of one alternative and others feeling equally stronger in favor of the other. Clearly, other variables, possibly demographic variables, explain these differences. In relation to these assistive technologies, it is also important to address differences associated with gender, at the very least addressing binary gender preferences. In at least one study, males have been found to be more accepting of robots deployed in healthcare settings than females [58], but other studies have shown no gender effect among elderly (or other age groups) on preferences for the degree of human qualities in assistive robots [59].

In some cases, both user genders have a preference for seemingly gendered assistive technology. For example, it has been shown that both males and females prefer virtual agents to have a female voice [21]. In other work, there was a significant preference for female users (representative of both a general population of users or elderly users) for female agents, but no significant difference in preference of agent gender for males [60]. In another study, older users did not show particular preference, but caregivers preferred a female agent [18].

Further, given that gender is a socially conditioned construct, one may anticipate that gender effects among the elderly may vary over time. This means that the study of gender preferences must be resumed periodically.

Conclusions

The evidence that older users' preferences varied across assistive devices' functionalities, appearance, and roles suggest that any generalization regarding the preferences of older users, even when tasks are related, should be carefully considered in the design of assistive robotic technologies [40] and that the accurate evaluation of older users' needs and opinions is critical.

Conversely, several criticisms were that professionals who design these forms of assistance often do not take into account the end-users' individual backgrounds, needs, and opinions, exploiting stereotypes of older users' behaviors (i.e., as ill, dependent, or reluctant to try new technologies) that negatively influence the system's design process [13, 61]. These design-related aspects should be carefully taken into account in order to maintain user long-lasting engagement with the device [4-6].

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Predictive Machine Learning Approach for Complex Problem Solving Process Data Mining

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Abstract: Problem-solving is considered to be an essential everyday skill, in professional as well as in personal situations. In this paper, we investigate whether a predictive model for a problem-solving process based on data mining techniques can be derived from raw log-files recorded by a computer-based assessment system. Modern informatics-based education relies on electronic assessment systems for evaluating knowledge and skills. OECD's PISA 2012 computer-based assessment database was used, which contains a rich problem-solving dataset. The dataset consists of detailed action logs and results for several problem-solving tasks. Two feature sets were extracted from the selected PISA 2012 Climate Control problem solving task: a set of time-based features and a set of features indicating the employment of the VOTAT problem-solving strategy. We evaluated both feature sets with six machine learning algorithms in order to predict the outcome of the problem-solving process, compared their performance and analyzed which algorithms yield better results with respect to the observed feature set. The approach presented in this paper can be used as a potential tool for better understanding of problem-solving patterns, and also for implementing interactive e-learning systems for training problem solving skills.

Keywords: machine learning; data mining; predictive model; problem solving

1 Introduction

The first Programme for International Student Assessment (PISA) assessment was conducted in the year 2000 and since then it is repeated every three years measuring the scholastic performance of 15 years old students in reading, mathematics, and science literacy. The number of participating countries has reached 80 in the year 2018, with more than 540,000 students taking part in the assessment worldwide. A full set of responses from individual students, school principals and parents for each PISA assessment since the year 2000 is available for researchers to engage in their own analysis of the data. Nowadays PISA is one of the most recognized international large-scale educational assessments and continues to inspire many research projects in various scientific fields.

The computer-based PISA assessment datasets are particularly significant source of information for scientists researching cognitive skills and cognitive processes of students [1-4] because besides the results of tests and questionnaire answers, these datasets also contain steps taken while working on solving a given task. Cognitive skills and processes can be studied in the field of cognitive infocommunications, where it can be analyzed how cognitive processes can co-evolve with infocommunications methods [5]. The computer-generated PISA datasets were also found very interesting by informatics researchers, especially in the fields of data mining and machine learning, where exploring of new methods for extracting information and predicting the successfulness of task solving are the most popular research topics [6-8]. Because the PISA 2012 CBA (computer-based assessment) problem-solving dataset captures in detail the sequences of actions taken by the students while performing complex problem solving, it is especially suitable for extensive analyses of behavioral processes that underlie successful and unsuccessful performance [4].

The computer-based instrument for problem-solving assessment was designed to contain tasks based on real-world situations and to engage students' higher-level cognitive processes [9]. This method of measurement allows analyzing each step of the applied problem-solving strategy. The exploration of cognitive processes allows identifying the possible mistakes of human cognitive systems, especially the preprocessing type of mistakes, such as pattern recognition. It also allows observing the mistakes of higher-level cognitive processes, like problem-solving and reasoning. With the employment of Assistive Technology and intelligent games [10] in cognitive skills training it is possible to bridge the gap between capabilities and expectations, if not completely then at least to some extent [11]. Examination of cognitive capabilities also gives the opportunity to put into use adequate learning games from the socio-cognitive ICT storehouse, for which the difficulty levels are estimated in advance [12].

A significant research topic in the problem-solving field of educational computer-based assessment is the analysis of behavioral data and strategic behavior while solving a complex problem. Most of the research in this area builds on the work of Tschirgi [13], who investigated the differences in reasoning between adults and students while trying to solve a task based on the manipulation of variables. The given task was set in an everyday situation, presented as a short story containing a specific problem to solve. For each story three different answers were offered, where each answer represented a distinct approach, or rather a strategy for solving the task. The three strategies embedded into the answers were vary-one-thing-at-a-time (VOTAT), hold-one-thing-at-a-time (HOTAT), and change-all (CA). Tschirgi noted that subjects employing a specific strategy are often not aware of its logical structure. Recent research has extensively investigated the use of the VOTAT strategy in complex problem-solving tasks set in a computer-based environment [4, 14-15]. In [14] it was examined whether the prior knowledge of VOTAT strategy from a pen-and-paper environment is relevant for solving an unfamiliar problem in a computer-based environment. While they found that the prior knowledge of a strategy is important, it is not sufficient for application on an unfamiliar problem in a new environment. The effective use of strategic behaviors while solving complex problems was researched in [15]. Their study examined the use of VOTAT and NOTAT (vary no-thing-at-a-time) strategies, finding that students employed an adaptive behavior: when the chosen strategy was effective, students used it with increasing rates, and when it was ineffective, the strategy was used with decreasing rates. VOTAT as an optimal exploration strategy for the Climate Control task on the PISA 2012 computer-based assessment was investigated in [4]. Their results provide important insight for our study, as well as for the research field of complex problem-solving. It was stated in [4] that the application of VOTAT strategy is an indicator of a broader set of strategic competencies and that it increases the overall proficiency in problem-solving.

In this study we are examining the Climate Control problem-solving task from the PISA 2012 computer-based assessment using data mining techniques. Two sets of features were engineered by extracting time spent on different activities while working on the task, and by extracting actions taken while working on the task which employed the VOTAT problem-solving strategy. We compared six different techniques for predicting the successfulness of solving the given problem-solving task and analyzed the importance of the extracted features. Furthermore, we investigated extensively the deep learning algorithm, as it proved to be the best fit for both feature sets. In accordance with this, the following research questions were formulated:

1) Which machine learning algorithm is best suited for predicting the outcome of the Climate Control problem solving task from the PISA 2012 computer-based assessment, considering our datasets are assembled from raw log-file databases?

2) Can the feature set constructed from raw log-files by extracting the actions employing the VOTAT strategy while working on the problem-solving task serves as a predictor for the outcome of the task?

3) Can the feature set constructed from raw log-files by extracting time spent on activities while working on the problem-solving task serves as a predictor for the outcome of the task?

4) Is it possible to further enhance the prediction performance by optimizing the machine learning algorithm most fitting to work with both feature sets?

Section 2 of this paper describes the chosen problem-solving task from PISA and the initial dataset. Section 3 introduces the machine learning algorithms, feature extraction, and assembly of the final dataset. Research results are discussed in Section 4, while Conclusions are drawn in the last section of the paper.

2 PISA Problem Solving Task

The objective of the Climate Control task of the PISA 2012 problem solving computer-based assessment is to discover how to operate a new air conditioner appliance, given that it was delivered without any instructions. The air conditioner unit has three input control sliders (top, central, and bottom), which affect two output parameters - temperature and humidity. The student has two parts of the screen available to work with: the top screen part is graphically representing the air conditioner unit with control sliders (Figure 1), where the behavior of the air conditioner can be explored, and the bottom screen part where the student has to draw the relation between the input and the output variables. The task is considered to be solved correctly when the student draws the exact relation diagram (Figure 2).

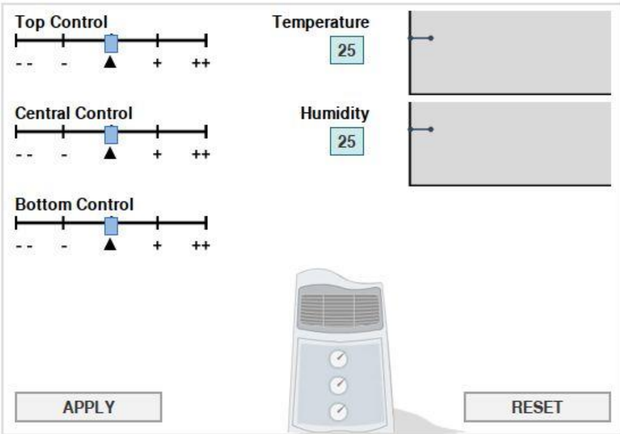

Figure 1
Climate Control problem solving task in PISA 2012 computer-based assessment

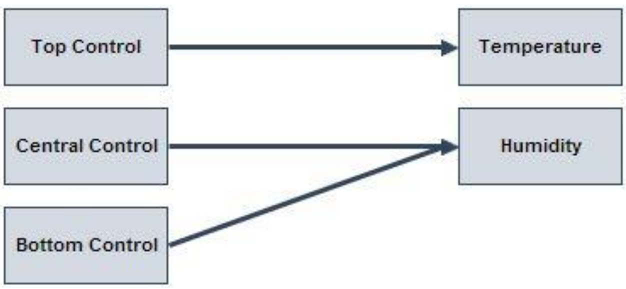

Figure 2
Relation diagram in Climate Control problem solving task

The Climate Control task itself consists of two questions, but in this work, we have considered only the first question (PISA Unit Item Code CP025Q01), which is described above. The problem-solving computer-based assessment of PISA 2012 was undertaken by 44 countries. In the initial preprocessing phase, we have extracted from the PISA dataset only the entries relevant for the Climate Control task. The initial Climate Control CP025Q01 study dataset was congregated from two files: the scored cognitive item response data file which contained assessment results for each individual student, and the problem-solving data files. The latter files contained a record of all steps taken while working on the task: the position of each control slider, which button was clicked, and what actions were taken to draw the relation diagram. For every entry in the data files a sequence order number and a timestamp were assigned.

3 Methods, Features, and Final Dataset

In this research, six machine learning models are built and compared for predicting the students' climate control problem-solving success. These models were built using the following classification algorithms: Naïve Bayes, logistic regression, deep learning, decision tree, random forest, and gradient boosted trees. Classification by machine learning is a widely adopted approach occurring in scientific research focusing on many areas of modern life [16-18]. It is also commonly used in educational research. Educational data mining as an emerging discipline often utilizes machine learning methods in a broad range of research subjects from an educational setting, involving examination of students' performance. Commonly referenced analysis methods are decision trees [19-20]. An extensive review of related research was given in [21]. A comprehensive study of recent research interests, problems, and techniques associated with data mining in education was conducted in [22]. Classification based on data mining techniques, namely decision trees were used in [23-24] to find the factors which influence students' success at the most. Classification and regression trees were used in [25] to predict student performance from activity data on Moodle learning platform, and also for analyzing large scale data from OECD educational indicators and PIRLS (Progress in International Reading Literacy Study) Curriculum Questionnaire in [26]. Classification by support vector machine model on PIRLS data is reported in [27]. Data from the results of TIMSS (Trends International Mathematics and Science Study) was used for classification and prediction of students' successes using machine learning techniques in [28-31].

Classification techniques have various advantages and disadvantages, they behave differently, and generally, their performance highly depends on the dataset. The six chosen classification techniques were evaluated in terms of accuracy, classification error, recall, F-measure, the area under the ROC curve, and runtime.

All of the models were tested in prediction performance. In [32] the PISA assessment dataset was used to compare regression models and neural networks as predictor models. The artificial neural network with two layers had better performance in prediction than regression models. In [33] classification of results of mathematics in PISA 2012 assessment was described. The observed dataset contained mathematics assessment results of Turkey, and decision tree models were built for classification. A logistic regression model was used in [34] to reveal which features have an impact on the success of the reading assessment in PISA 2009. Various models of decision trees are among the most used techniques for examining PISA data sets [35-37]. Often used are also logistic regression models [38-39]. Many papers compare different techniques to find the one yielding the best prediction performance with the given dataset [40-41]. Results of the PISA 2012 mathematics assessment for Finland and for all other countries participating in PISA are analyzed by machine learning methods in [42]. In [43] the mathematics assessment results were analyzed by machine learning methods in the sample of Australia. The database from Turkey's PISA 2015 scientific literacy assessment was used to compare the performance of data mining methods in [44].

This research uses and processes the raw log-file databases for PISA 2012 computer-based items, and analyzes the direct actions of students to uncover the relations between the strategies and the cognitive, problem-solving capabilities of students. All countries participating in the PISA 2012 problem-solving assessment were taken into account. In [4] it was shown, that the VOTAT combination of the switches is in correlation with the success of the problem-solving task. Here, the features used as predictors based on the VOTAT strategy are: V_1, V_2, V_3, and V_4 (1) (2) (3) (4). The number of control slider apply events where two control sliders were set to initial position, and only one control slider was set to a different position, related to all apply events were computed for all three control sliders, the top, the central and the bottom control slider. *Nb* is the number of apply actions when only the bottom switch is changed, others are 0. *Nt* is the number of apply actions when only the top switch is changed, others are 0. *Nc* is the number of apply actions when only central switch is changed, others are 0. As the fourth feature, a total number of apply action is taken (*AN*).

$$V_1 = Nb / AN \tag{1}$$

$$V_2 = Nt / AN \tag{2}$$

$$V_3 = Nc / AN \tag{3}$$

$$V_4 = AN \tag{4}$$

Figures 3, 4 and 5 represent histograms of relative usage of the respective control on the air conditioner device in the Climate Control problem solving task of PISA 2012 computer-based assessment. Figures compare the number of students who finished the task successfully (TRUE), and those who did not (FALSE).

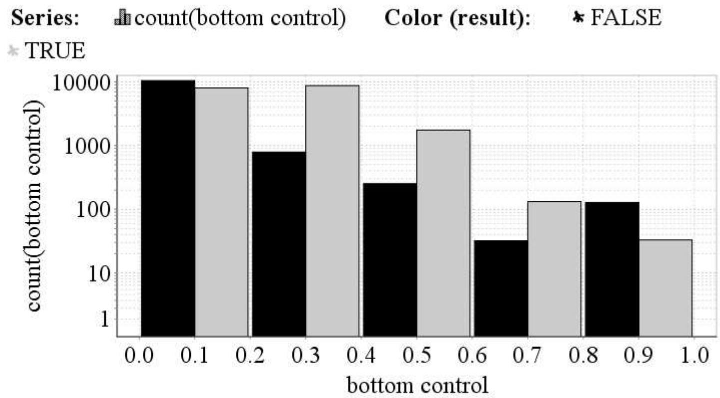

Figure 3

Histogram of relative usage of bottom control based on feature V_1

The horizontal axis shows the percentage ratios of the respective control apply steps on a normalized scale, relative to the total number of apply actions in the problem-solving process. The vertical axis represents the number of students on a logarithmic scale.

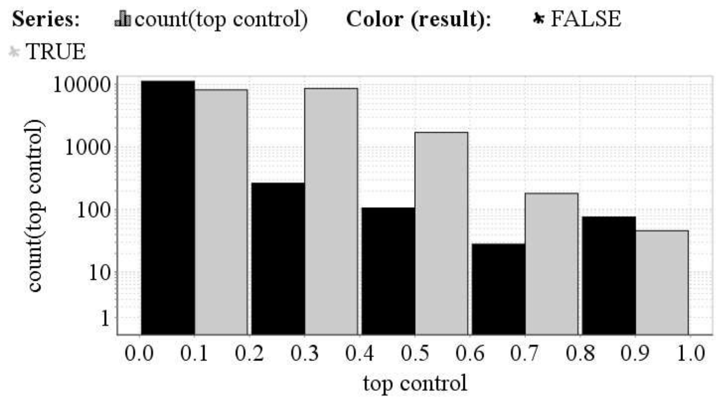

Figure 4

Histogram of relative usage of top control based on feature V_2

Evaluation of histograms reveals that students who tended to experiment with all three controls evenly had the most success in solving the task. This is noticeable when observing histogram bars at a value of 0.3 on the vertical axis, which represents 30% of the relative usage of the respective control. The TRUE/FALSE ratio of successfully solving the task is here the highest. Students who concentrated on experimenting with two controls have also achieved high rate of success.

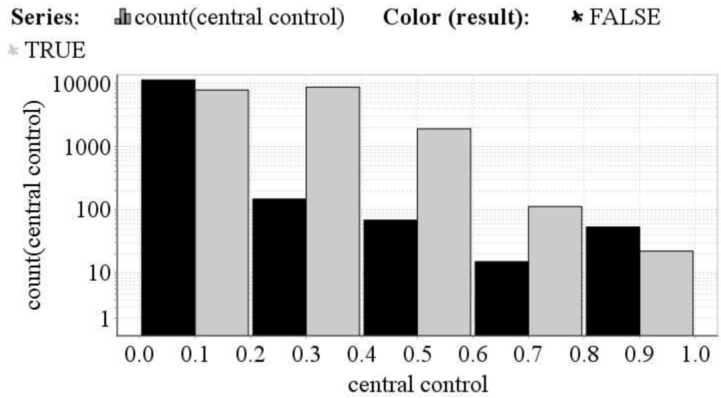

Figure 5
Histogram of relative usage of central control based on feature V_3

We have also considered whether a particular VOTAT-based feature is a good predictor for the given model. There was no single feature equally important across all models. For the Naïve Bayes and the logistic regression models, the relative usage of the central control had the biggest impact on the successful prediction outcome of the model. In more complex models, for instance, the deep learning, the bottom control had the highest importance, while the central control was the least important.

The climate control problem-solving workflow can be divided into three phases: first, reading the instructions of the task and thinking about the problem before taking any action, second, experimenting with the control switches, and third, drawing the relation diagram to explain the relation between input and output variables. These phases were analyzed in the dimension of time. Paradata, a by-product of computer-based data collection was extracted from the problem-solving log-files to get information about features related to the dimension of time [45-46]. The time spent on reading the task can be a good predictor, feature F_1 (5), since students who carefully read the instructions have more chance to finish successfully than students who do superficial reading and do not gain enough insight to the problem. In [47] regression model was built to predict the task completion success, where the regression coefficient showed that the longer the reading time, the bigger the likelihood of success. The second time-related feature was the time spent on experimenting with the switches. This measure was divided by the entire time spent on experimenting and drawing the results by a particular student - feature F_2 (6). The third feature has been computed as the time spent on actions while drawing the results on a diagram, divided by time spent on experimenting and drawing – feature F_3 (7). The entire time normalized through the whole number of students participating in the task was the fourth feature F_4 (8). In [47] the speed of actions was investigated in the PISA climate problem-solving task, and a high correlation was found with the success of the completion.

The number of apply actions divided by the time spent on experimenting was represented with the fifth feature F_5 (9).

$$F_1 = (Faats - Fts) / (Lts - Faats) \tag{5}$$

$$F_2 = (Laats - Faats) / (Lts - Faats) \tag{6}$$

$$F_3 = (Lts - Fdts) / (Lts - Faats) \tag{7}$$

$$F_4 = (T - \min(T_1 : T_k)) / (\max(T_1 : T_k) - \min(T_1 : T_k)) \tag{8}$$

$$F_5 = AN / (Laats - Faats) \tag{9}$$

Timestamps used were: First timestamp (*Fts*), First apply action timestamp (*Faats*), Last apply action timestamp (*Laats*), First diagram timestamp (*Fdts*), Last timestamp (*Lts*). The number of apply actions is *AN*, while the number of samples is *k*.

Further analysis of the time-based features was conducted by constructing several histograms. Figure 6 depicts the distribution of feature F_1, which is relative time spent on reading the instructions for the problem-solving task with regards to the time spent on experimenting and drawing the relation diagram.

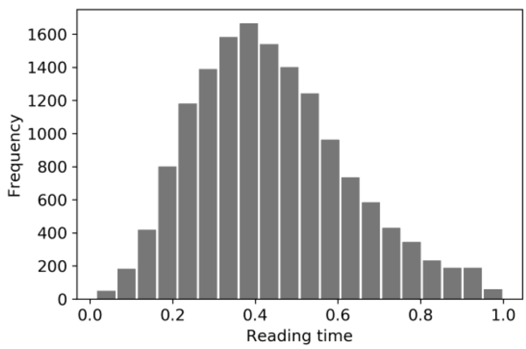

Figure 6
Histogram of relative time spent on reading based on feature F_1

The reading time was 60% shorter than the time spent on experimenting and drawing, thus the reading time was about 30% of the entire spent time on task in the case of most of the students.

Figure 7 is showing the distribution of time spent on experimenting with the control switches relative to the entire time spent on experimenting and drawing the relation diagram.

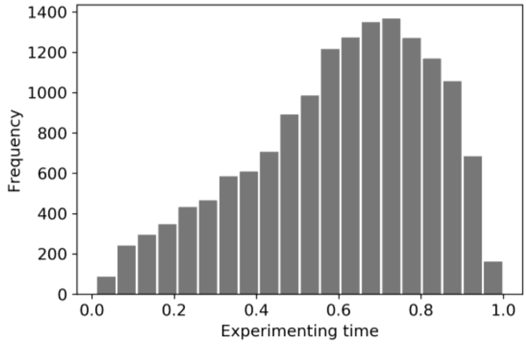

Figure 7

Histogram of relative time spent on experimenting based on feature F_2

Figure 8 depicts the distribution of time spent on drawing the relation diagram for the problem-solving task with regards to the total time spent on experimenting and drawing. These histograms are based on features F_2 and F_3.

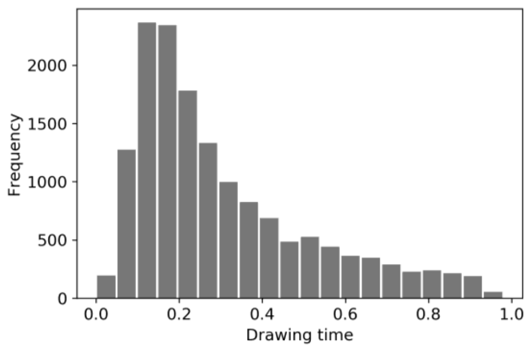

Figure 8

Histogram of relative time spent on drawing based on feature F_3

Figure 9 shows the distribution for feature F_4, namely the time spent on experimenting with control switches and drawing the relation diagram, normalized across the entire set of samples.

Figure 10 depicts the distribution of the number of clicks onto the Apply button in the unit of time. The horizontal axis of the histogram represents the number of clicks per second. According to the histogram, the rate of clicking the apply button is very low. The vast majority of the students carefully considered their next action before clicking the apply button, hence at least a few seconds passed between two clicks to apply button.

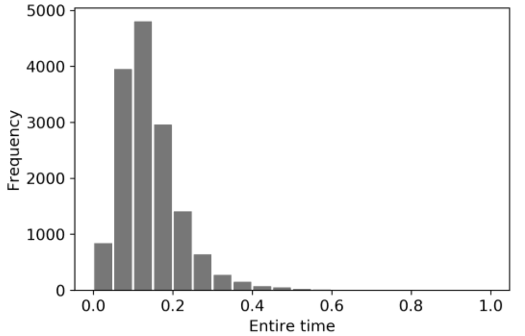

Figure 9
Histogram of entire time spent on task based on feature F_4

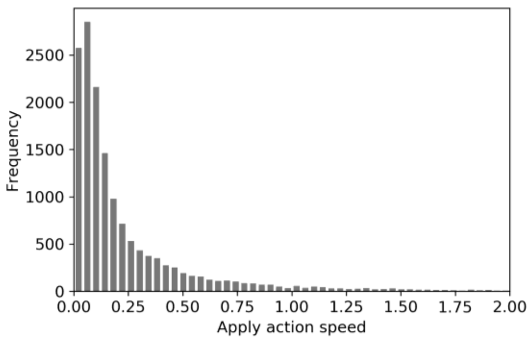

Figure 10
Histogram of apply action speed based on feature F_5

The resulting dataset was combined with the PISA file containing information about the success of the task. In the prediction preprocess phase, the success of students was split into two classes. Upon cleaning the data, downsampling was done to reach balance a between the two classes. After blending the two datasets, preprocessing and eliminating corrupted entries the final dataset had 15194 entries left.

4 Results

The performances of six predictor models are evaluated by accuracy, AUCROC, class recall, class precision, F-measure, classification error, and runtime.

The performance of models using the VOTAT-based set of features is shown in Table 1. In the Naïve Bayes model, feature V_3 (central control usage ratio) had the biggest impact on the classification. As the relative ratio of using the central control increased, the probability of successfully completing the problem-solving task became higher. The logistic regression model also showed that the most important feature was the percentage of central control steps.

The default deep learning model has 2 hidden layers with 50-50 neurons and rectifier activation in each of two hidden layers, with Bernoulli distribution function and cross-entropy loss function. The decision tree model was optimized. After optimization, it was found that the highest performance of the model is reached at tree depth = 7. Random forest and gradient boosted trees models outperformed all other models in terms of accuracy, both achieving 94.1%. However, their computing runtime was by far the longest among all models.

Table 1

Performance comparison of models using VOTAT-based features

Model	Measures					
	Accu-racy	*Run-time (s)*	*AUC*	*Class. Error*	*Recall*	*F-measure*
Naïve Bayes	87,8%	45,0	0,920	13,2%	92,5%	88,5%
Logistic Regression	89,7%	47,0	0,933	10,3%	93,3%	93,3%
Deep Learning	93,9%	81,0	0,947	6,1%	99,7%	94,3%
Random Forest	94,1%	153,3	0,950	5,9%	99,9%	94,5%
Decision Tree	93,4%	48,0	0,950	6,6%	99,9%	93,8%
Gradient Boosted Trees	94,1%	291,1	0,950	5,9%	99,8%	94,5%

Decision tree and deep learning achieved also very good accuracies, 93.4% and 93.9% respectively, with much shorter computing runtimes. Further performance comparison of the two algorithms has shown that deep learning achieves better classification results with *F-measure* value of 94.3%.

Table 2 contains performance measures for the used prediction models based on time-based features.

Table 2

Performance comparison of models using time-based features

Model	Measures					
	Accu-racy	*Run-time (s)*	*AUC*	*Class. Error*	*Recall*	*F-measure*
Naïve Bayes	69.8%	49.0	0.743	30.2%	69.7%	70.3%
Logistic Regression	74.3%	41.2	0.743	25.7%	74.3%	74.1%
Deep Learning	77.1%	98.9	0.847	22.9%	77.1%	77.1%
Random Forest	69.8%	171.5	0.740	30.2%	69.5%	69.7%
Decision Tree	73.1%	42.8	0.780	26.9%	73.1%	73.1%
Gradient Boosted Trees	75.7%	311.3	0.830	24.3%	75.6%	75.6%

The deep learning model has achieved the best results with time-based features in all classification performance measurement categories. Computing runtime expectedly took about twice the time compared with the fastest models – logistic regression, decision tree and Naïve Bayes. However, we have focused rather on the classification performance than the model speed, and experimented further with optimization of the neural network in order to achieve even better results. An active field of research in the field of machine learning is automatization of neural network structure optimization [48-50]. In our case, the suboptimal neural network structure was searched by a genetic algorithm using a fitness function defined as the sum of *AUCROC* and *F-measure* values.

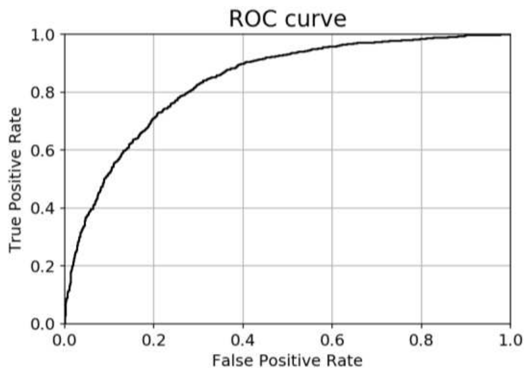

Figure 11
ROC of the neural network optimized by genetic algorithm

In the case of time-based features, the number of generations was set to 10, the number of solutions per population was set to 20 and the number of parents mating to 4, the best structure with the lowest number of neurons had 18 neurons in the first hidden layer and 14 neurons in the second hidden layer. The number of epochs to train the neural network was set to 190. In case when the number of generations was set to 20, solution per population set to 20 and the number of parents mating to 8, the best structure with the lowest number of neurons was with 28 neurons in the first hidden layer and 26 neurons in the second hidden layer. The number of epochs to train the neural network was set to 190. In both cases, the AUCROC was 0.857 and the accuracy 77.9%. The ROC curve of the deep learning model is shown in Figure 11.

When the number of epochs was set to a low value (50 epochs), the best individual was that with the largest number of neurons: in the first hidden layer 38 and in the second hidden layer 22 neurons.

In the case of VOTAT features, the best structure was a network with 20 neurons in the first hidden layer and 23 neurons in the second hidden layer. The accuracy was 94.9%, the AUCROC 0.958. Table 3 summarizes the performance of the optimized deep learning models.

Table 3
Performance comparison of optimized deep learning models

Feature set	Measures				
	Accuracy	*AUC*	*Class. Error*	*Recall*	*F-measure*
VOTAT-based	94.9%	0.958	5.1%	94.8%	94.9%
Time-based	77.9%	0.857	22.1%	77.9%	77.9%

Conclusions

In this study we have built six different machine learning models for predicting the success of students in the Climate Control problem-solving task from PISA 2012. The prediction models were tested with two distinct feature sets: first based on features indicating the use of the VOTAT problem-solving strategy, second based on time-based features. A dataset constructed from a raw log-file database was used for measuring performance of a Naïve Bayes, a logistic regression, deep learning, a random forest, a decision tree, and a gradient boosted trees prediction model. *F-measure* was used to evaluate the performance of these models. Four related research questions were deliberated.

Our first research question was "Which machine learning algorithm is best suited for predicting the outcome of the Climate Control problem-solving task from the PISA 2012 computer-based assessment, considering our datasets are assembled from raw log-file databases?". To answer this question, we have evaluated each model with both datasets and computed the respective *F-measure* value for comparison. Overall, the best suited machine learning algorithm for both of our feature sets is deep learning, whose *F-measure* score is 94.3% with VOTAT-based feature set, and 77.1% with the time-based feature set. The random forest and the gradient boosted trees model both scored slightly higher with the VOTAT-based feature set, 94.5%, but scored significantly lower with time-based features than deep learning, 69.7% and 75.6%. Generally, all six models performed well, especially with the VOTAT-based feature set.

The second research question was "Can the feature set constructed from raw log-files by extracting the actions employing the VOTAT strategy while working on the problem-solving task serve as a predictor for the outcome of the task?". The performance results in Table 1 clearly indicate that the employment of the VOTAT strategy is a strong predictor of the successful outcome of the problem-solving task. All six of the models showed high prediction accuracy with *F-measure* scores above 88.5% when evaluated with the dataset based on the VOTAT-based features.

Answer to the third research question, "Can the feature set constructed from raw log-files by extracting time spent on activities while working on the problem-solving task serve as a predictor for the outcome of the task?", is based on the results displayed in Table 2. Evaluation of the models with the time-based features has also yielded good results in the context of predicting the outcome of the problem-solving task. While the overall *F-measure* scores are lower compared to the VOTAT-based feature set results, all models have scored between 69.7% and 77.1%. These results confirm the time-based feature set as a good predictor.

To answer the fourth research question, “Is it possible to further enhance the prediction performance by optimizing the machine learning algorithm most fitting to work with both feature sets?”, we have taken into account the answer for the first research question, and optimized the neural network structure of our deep learning model for both feature sets using a genetic algorithm using a fitness function defined as the sum of *AUCROC* and *F-measure* values. After optimizing the deep learning model, the *F-measure* score has reached 77.9% with time-based features and 94.9% with VOTAT-based features, which is an increase of 0.8% and 0.6% respectively. Hence, it is possible to enhance the prediction performance by optimizing the machine learning algorithm.

Models built on time-based features might have more potential for further research and applications, as they could be used to enhance interactive e-learning environments. A predictive model using both types of features, VOTAT-based and time-based, could serve for building an effective learning environment with online assistance while improving attention [51] and training learning [52] and problem-solving skills using CogInfoCom supported education methods [53]. Based on the interaction times with the learning environment, or the absence of VOTAT strategy employment, the computer-based learning system could advise to take a specific action or change the strategy in order to increase the likelihood of successfully solving the problem at hand.

As future work, we plan to further study the possibilities of improving the outcome prediction of the PISA problem solving tasks, by evaluating different problem-solving tasks, enhancing the data pre-processing of time-based features and fine-tuning the deep learning model.

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EEG-based Speech Activity Detection

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Abstract: The brain-computer interface is one of the most up-to-date communication options. The advances made in this area open up opportunities to help mentally or physically disadvantaged people. The brain-computer interface offers the possibility of re-acquiring communication skills by deaf individuals. Electroencephalography (EEG) based speech recognition is, therefore, a novel research topic, which is an important component in communication technologies. In this article, we propose a speech activity detector algorithm, which, as expected, should improve the performance of the EEG based speech recognition system. EEG data uploaded while pronouncing 50 different phrases were classified using a feed-forward neural network. As a result of detection, a 0.82 F1 score was achieved.

Keywords: electroencephalography; speech activity detection; EEG-based speech recognition; brain-computer interface

1 Introduction

Electroencephalography (EEG) is a method for measuring brain electrical signals on the head surface. The advantage of EEG is that it is a non-invasive technique that facilitates the use of the brain-computer interface (BCI) technology without implantation of electrodes by neurosurgery. We are convinced that speech investigation from the brain's electrical impulses leads to the BCI communication enablement [1].

Speech activity detection from EEG signals is based on the speech information look up in the brain's electrical signals. EEG devices can capture part of these signals on the head surface. However, they are weakened, degraded, or mixed with several sources or artifacts after crossing the skull [2]. Another problem of searching for such a speech signal from EEG is that we are still unable to record a clear EEG signal that consists solely of speech information. The presence of EEG signals from different sources, which are formed and transmitted simultaneously, makes speech signal detection very difficult. Although the EEG subject focuses only on producing speech during the scanning of his brain, the recorded EEG is still a mixture of impulses from many sources.

Speaking is a complex process that requires the involvement of several brain areas and articulatory organs to create a specific sound. Verbal language is created in the brain for several hundred milliseconds before the speech. A study [3] suggests that the brain needs an average of 600 ms to produce a word. Words and sentences include several kinds of abstract information that are lexical, grammatical, phonological, and graphic information. These components are stored in brain speech centers. Before the word is formed, the individual components are linked together and sent information about the articulation to the motor center, which controls the correct movement of the articulatory organs. Because speech is represented in the human brain as a cluster of information that is transmitted by nerve cells by electrical impulses, we can investigate the speech from the nerve perspective using the brain-computer interface [4].

Our speech recognition system from EEG signals was discussed in [5]. The study described the effort to find a suitable speech recognition algorithm. The experiment consisted of EEG signals processing from 10 subjects that read 50 different phrases. When recognizing these 50 phrases using the Hidden Markov model, the best result was achieved when training a single subject model at 53.4% accuracy. The cross-subject experiment showed a significantly dropped accuracy of recognition to 6%. Based on the results of the experiment we started to create an algorithm for speech activity detection, an analogy to Voice Activity Detector used in ASR, which could help to achieve higher results of speech recognition from EEG signals. An appropriately designed speech activity detector from EEG signals could be an important part of the EEG based speech recognizer.

Speech activity detection from EEG, and generally from BCI, has so far been very poorly reviewed. In addition to many BCI-based speech recognition kinds of research, speech activity detection from brain waves is still a very little solved and published problem, although it is very close to this field.

One of the few BCI speech activity detection studies has been presented in [6]. Functional Near-Infrared Spectroscopy (fNIRS) signals to detect speech from the brain were used. The study was executed on normal audible speech, silent speech, imagery speech. The result of the study was an F1 score of 0.7. This study confirms that speech can also be detected using BCI devices, which can greatly help develop speech recognition in the BCI field.

Another study discusses speech activity detection from EEG, suggests the use of such a system to improve classical speech recognition in a noisy environment. The study [7] demonstrates adding EEG-based speech activity detection can improve the performance of a voice activity detector that could be used to detect an acoustic noisy signal. The use of an EEG speech activity detector can also help predict whether a person wants to speak or not.

EEG based speech research contributes significantly to CogInfoCom discipline. Speech detection from EEG signals can greatly aid in the development of new forms of communication, combining computer science and cognitive science. [8].

In this paper, we present an EEG-based speech activity detection algorithm and a comparison of different EEG signal processing methods and their impact on improving the detection of speech in the EEG signal. The proposed algorithm was evaluated and tested on a pattern recognition neural network with a speech EEG corpus with a larger dictionary. Speech activity detection searches for a brain signal pattern that is generated before the word is formed or when it is spoken. The speech activity detector can help improve the performance of the aforementioned EEG-based speech recognition by eliminating false alarms in word recognition.

2 Methodology

2.1 EEG Recording

The spread of electrical pulse from the brain through the skull and scalp causes the electrical signal captured on the surface of the head to be attenuated, distorted, and dispersed. EEG signals on the scalp are diffused because the secondary electrical currents are spreading between different mediums of the head such as cerebrospinal fluid, skull, and scalp tissues, which have noticeably different conductivities. The lower SNR in the EEG is justified by the fact that the distribution of electrical potential on the head surface is more dispersed [9]. Due to the diffusing of the signal on the scalp, we used the electrode placement over the entire head and record signals from more scalp areas.

2.2 Brain Waves

In the published experiment [5] it was stated that the results of speech recognition were better in dividing the signal into wave frequencies. In this experiment, it has been shown that potentially the greatest amount of speech information is carried by the beta alpha and gamma waves. From the study [10] we can assume that different frequencies carry different types of information. Slow waves were more represented in simpler or calmer brain processes. Faster waves have been observed in processes requiring concentration and greater cognitive activity. When designing the EEG signal processing methods, we were inspired by these findings. In the experiment, we used the decomposition of EEG signals on 5 frequency bands. If the different frequency components are responsible for different brain activities, we can assume that the speech activity we are looking for will be easier or more clearly detectable in the distributed EEG waveform [11].

3 Experiment

In the experiment, we designed an algorithm for speech activity detection from EEG signals. In the signal processing part, we divided the experiment into two parts: in the first one, we focused on signal processing from the perspective of frequency waves. In the second part, we decided to describe the EEG signal from the cepstral region. Both of these signal processing approaches were finally trained and tested using a neural network and the results of such processing compared. Figure 1 shows a block diagram of a speech activity detection experiment.

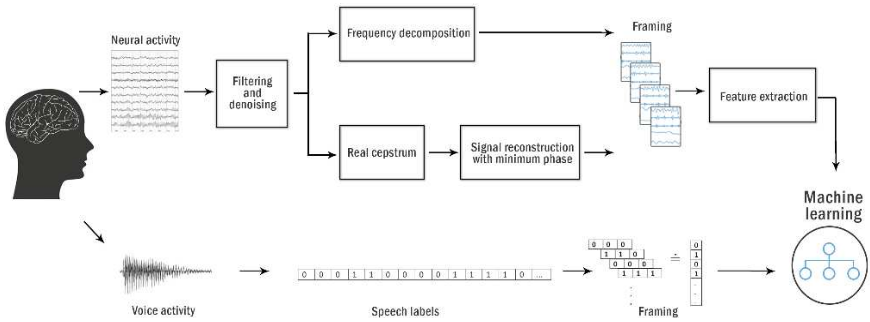

Figure 1
Block diagram of speech activity detector. Signal processing as performed in two separate parts: frequency decomposition and reconstruction from real cepstrum. These parts were considered separately.

3.1 Data Acquisition

EEG signals were recorded with a 16-channel OpenBci Ultracortex Mark III EEG cap [12]. The EEG device is based on sensing brain signals using dry electrodes configured according to the 10/20 system [13] [14]. The EEG device is mobile and the signal is transmitted from the head surface to the computer via Bluetooth. It captures the brain waves with 250 Hz sampling frequency. For recording brain signals, this device incorporates 16 channels namely Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2 according to the international 10/20 system as shown in Figure 2, where two reference electrodes are positioned above the ears. For signal recording, open-source graphic user interface OpenBCI GUI compatible with the used EEG cap was used [12]. All signals were recorded to format .txt, which simplifies the work of further signal processing.

The participant of the experiment to which EEG was measured was right-handed speaking Slovak, without any reported neurological disease. The participant followed the pre-agreed instructions during the recording. He was sitting motionless and tried to focus solely on speech processes. After starting the EEG recording, the participant read loudly phrases showed him on single charts one by one.

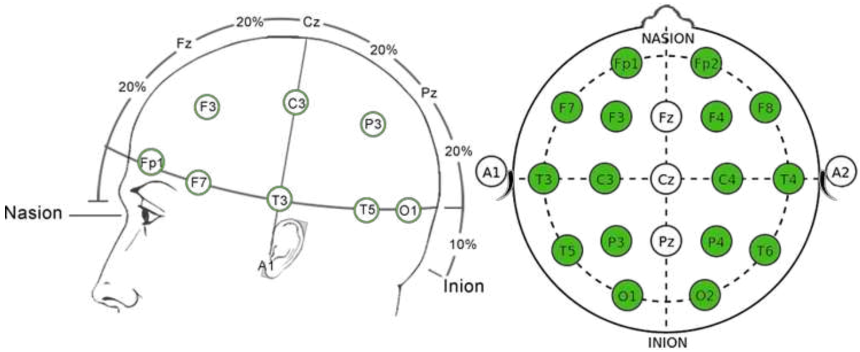

Figure 2

Electrode placement according to 10/20 international system

A dictionary created for the experiment contains 50 various phrases, there were 14 one-word phrases, 20 two-word phrases, and 16 three-word phrases. The EEG signals were recorded in 9 sessions. To create speech labels, we also recorded an audio signal while recording EEGs.

3.2 Signal Preprocessing

The EEG signal was browsed to remove excessive noise at first. Evident noise was found mainly in the sections at the beginning and the end of the sessions. These parts were manually removed from the EEG as well as from audio recordings. In Figure 3 we see noise-infected parts of the EEG recording of one session.

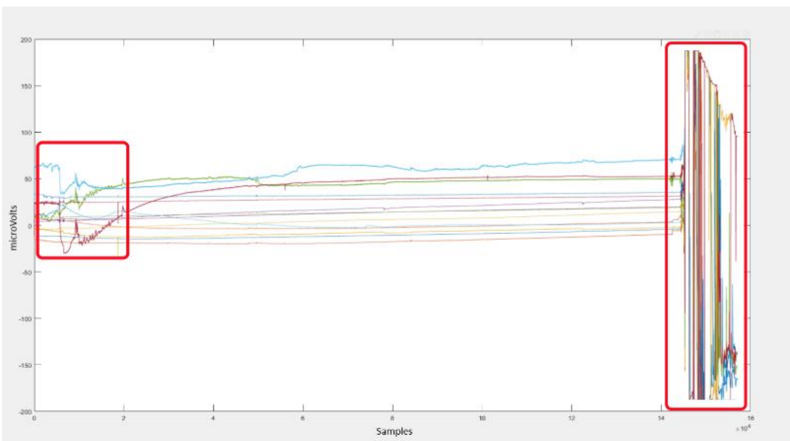

Figure 3

Example of noise in the EEG signal of one session

During EEG recording, the signal is mixed with artifacts. Some types of artifacts can be prevented by using appropriate methods to record brain activity, but obtaining a perfect signal without artifacts is not yet possible.

An artifact of power line interference is commonly found in the EEG signal. It has a frequency of 50 Hz, and it is easy to remove using frequency filtering [1]. For this purpose Butterworth filter was used because it has it an extremely flat frequency characteristic in passband range, and compared to other filters it contains lower passband ripples [15] [16]. Unlike the experiments [5] [17], other artifacts filtering was omitted, which could cause potential loss of speech information in the EEG signal.

3.3 Frequency Decomposition of the EEG Signal

The EEG signal from each channel into 5 frequency components in the first part of the experiment was divided. These separate components were combined into a matrix with a width of 16x5. Figure 4 shows a portion of the signal waveform from channel F7 in separate frequency bands.

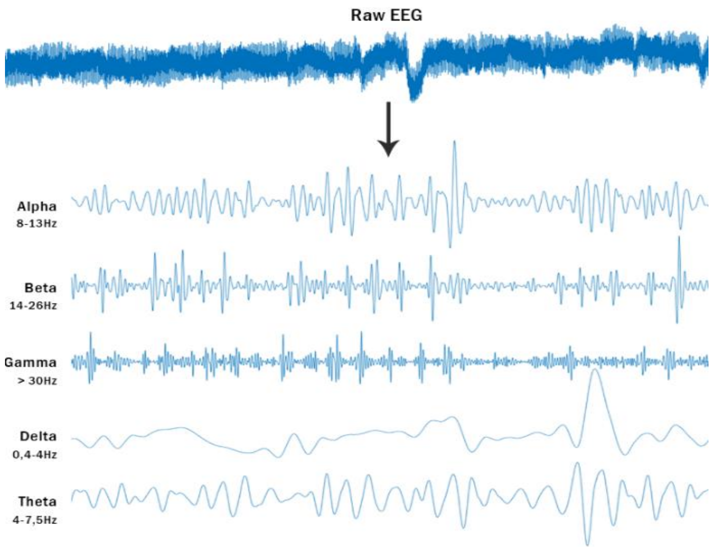

Figure 4

EEG signal decomposition into five frequency bands according to normal brain rhythms

3.4 Signal Reconstruction from Real Cepstrum

The second part of the experiment consists of a cepstral reconstruction signal. Real cepstrum was calculated from the EEG signal for each channel. The reconstructed signal had a minimum phase property [18]. Figure 5 is the reconstructed EEG signal in comparison with the original raw EEG signal from channel F7.

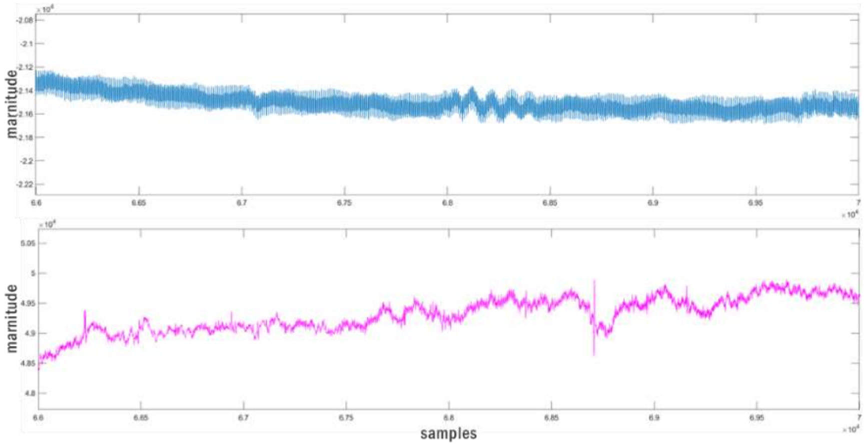

Figure 5
EEG signal after reconstruction. Blueshape- raw EEG signal. Magenta shape – reconstructed EEG signal with minimum phase

3.4 Feature Extraction

The reconstructed EEG signal was split into 240 ms frames with a 50% overlap. For each frame following features were calculated. The set of features was extracted from the frequency and time domains. Table 1 shows the features extracted from the EEG signal. The feature selection suitable for speech activity detection was influenced by the studies [19] [20]. The publication [19] describes methods of selecting features for describing EEG seizures. The study used the feature used in ASR from an audio signal.

The *mean* value of the frame is an average value of signal partis. A *standard deviation* is a measure of the amount of variation or dispersion of a set of values. The *skewness* factor indicates the measured lack of symmetry of the distribution. We can say that the data set is symmetrical when it looks equal on the right and left sides of a given central point. Using the *kurtosis* coefficient we determine whether the data are peaked or flat in comparate to the normal distribution. The average *band power* summarizes the contribution of the frequency band to the overall power of the signal [21]. When dealing with information content, the *Shannon entropy* is often considered as the foundational and most natural one. Entropy, regarded as a measure of uncertainty, is the most paradigmatic example of these information quantifiers. [22]

Table 1
Features extracted from the EEG signal and their descriptions.
μ is the mean of the signal x(n), δ is the standard deviation of the signal x(n), E represents statistical expectation, x_i is the coefficient of the signal in an orthonormal basis.

Feature	Description	Domain	Equation
Mean	Mean value of a local	Time	$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i$
STD	Standard deviation	Time	$\delta = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$
Skewness	Local skewness in a frame	Time	$skew = E\left[\left(\frac{(x(n)-\mu)}{\sigma}\right)^3\right]$
Kurtosis	Local kurtosis in a frame	Time	$kurt = E\left[\left(\frac{(x(n)-\mu)}{\sigma}\right)^4\right]$
RMS	Root mean square	Time	$rms = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\lvert x_i\rvert^2}$
Band power	The average band power	Frequency	$P = \lim_{T\to\infty}\frac{1}{2T}\int_{-T}^{T}\lvert x(t)\rvert^2\,dt$
Shannon entropy	Amount of information in a variable	Information theory	$Shannon = \sum_{i=1}^{n} x_i \log_2 x_i$

Based on the set of features, EEG signals were described. Features were calculated for each signal channel from 60 samples, which at a sample rate of 250 hz represents a frame of 240 ms. Hence, overlap was set to 50%, the features were recalculated for the 30 previous samples. These 7 feature values calculated for each recording channels were merged into a row matrix of shape (112.1). In the case of the decomposed signal, it was the matrix of shape (560.1), since we calculated the symptoms for 16 channels divided into 80 waves.

3.5 Speech Labels

Speech and non-speech segments in EEG data were labeled manually. Finding speech activity in EEG data is not possible due to the complexity of the signal. Therefore, audio was recorded and synchronized with EEG data. Speech labels were labeled from the audio signal, which is a simple task.

For this purpose, we utilized the tool Transcriber for segmenting, labeling, and transcribing speech [23]. The audio record was divided into time segments. Each segment by the start and end times of the pronounced word or the silence was bound.

The proposed EEG speech activity detection model consisted of EEG data recorded during the speech activity generation. The speech of a subject consisting of 50 different phrases has been tagged with values 1 and 0 indicating segments of speech activity or non-speech activity of brain waves.

3.6 Neural Network Training

The EEG signal described by selected features was fed to the input layer to the neural network. We have compared two neural network models with two different signal processing approaches. The first was the frequency decomposition of the EEG signal into 5 waveforms of normal brain rhythms. The second one consisted of signal reconstruction from real cepstrum.

In the experiment, the 2-layer feed-forward neural network was used. Various numbers of hidden neurons were tested. The best results were achieved with 60 neurons on a single hidden layer. The neural network consist of a single tanh activated hidden and binary output sigmoid activated output layer. We trained the network with Scaled conjugate gradient backpropagation, with binary cross-entropy as the loss function. Output pseudo probabilities were thresholded with a 0.5 decision boundary.

4 Results

The proposed EEG speech activity detection model consisted of EEG data recorded during the speech activity generation. The speech of a subject consisting of 50 different phrases has been tagged with values 1 and 0 indicating segments of speech activity or non-speech activity of brain waves.

In the experiment, we tried to get the best possible result of speech activity detection. Therefore, we compared different approaches to EEG signal processing to find information about speech using the Neuron network.

In the baseline experiment published in [16], the same method of Feed-forward neural network training was used. The EEG signals were processed in different methods. The best result reported for the F1 (F-speech) score was 0.77. Despite relatively good F1 results, the trained model had a problem with the prediction of zero segments (non-speech).

Table 2 shows the results of speech activity detection by the neural network in comparison with various signal processing approaches. These results were achieved on the same EEG database. We thought that decomposing the EEG signal into different frequency bands could result in an improvement. However, the detection results achieved by this approach were comparable to those of the preceding experiment.

The speech activity detection best result with signal reconstruction with minimum phase was achieved. The F1 score value was 0.82. An improvement of 0.05 absolute in the F1 score compared to the preceding experiment was achieved. The inclusion of feature extracting functions in signal processing has yielded a better analysis of the speech EEG signal.

Table 2
Features extracted from the EEG signal and their descriptions

	Accuracy	**Precision**	**Recall**	**F1 score**
Baseline experiment	0.45	0.69	0.87	**0.77**
Wave decomposition	0.67	0.72	0.82	**0.77**
Reconstruction with minimum phase	0.77	0.79	0.84	**0.82**

Figure 6 shows an example of a graphical representation of speech activity detection output compared to input targets. The blue shape shows input targets indicating speech activity and the red shape shows output segments of speech activity predicted by our proposed algorithm.

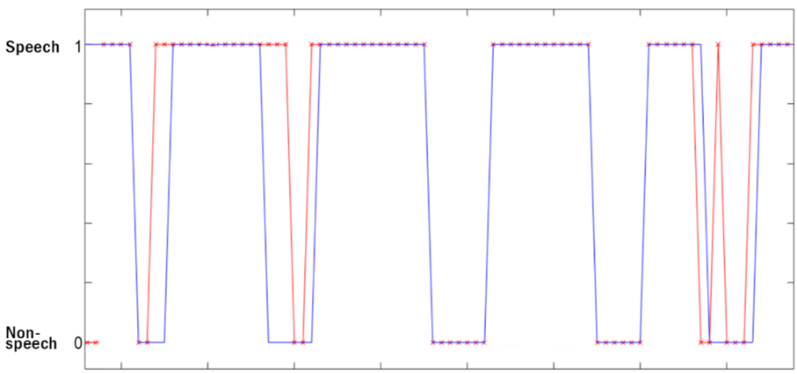

Figure 6
A portion of output targets in comparison with input labels. The blue shape represents input segmentation. Red crossed shaper represents ground truth

Conclusions

This study examined speech activity in EEG signals. The results show that speech can be detected using EEG technology. A significant difference in EEG signal processing has been demonstrated in creating a speech detector model using a reconstructed minimum phase signal. From the results, we can assume that the cepstral area of EEG signals contains a greater amount of speech information. In this study, we used, among other methods, the method of reconstructing the EEG signal from real cepstrum with minimum phase, which has not yet been investigated in a relation to finding a speech pattern.

The results obtained in this paper can, in collaboration with other research dealing with speech and brain signals, contribute to solving the problem of EEG speech recognition. The method of signal processing based on cepstral reconstruction brought interesting results in our research. Although research has focused on speech detection, signal processing methods can be used and investigated in other research related to EEG and speech, such as [24] .

In our future work, we would like to explore this area of EEG signal processing. In the course of further research, we would like to execute also more experiments with speech detection using RNN and CNN models, which could deliver better results in this field.

Acknowledgment

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Clean and Dirty Code Comprehension by Eye-tracking Based Evaluation using GP3 Eye Tracker

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Abstract: During the observation, analysis, and examination of cognitive processes, human-computer interfaces are increasingly becoming widespread. Programming could also be seen as a complex cognitive process. This study aims to examine the efficiency of the clean code paradigm and compares it to the dirty code produced without the principles formulated in this technique. In addition to the traditional knowledge level test and subjective judgment, the readability and comprehensibility of the implemented code were determined by analysing the heatmap and gaze route besides measuring and evaluating eye movement parameters. Based on the statistical evaluation, it can be stated that there is a significant difference in the average number of fixations, the average fixation time, and the average length of routes between fixations measured by studying two differently written source codes. This means that in the case of the clean code, significantly less and shorter information recording and processing were necessary to understand the code.

Keywords: eye-tracking; programming; clean code paradigm; dirty code

1 Introduction

Since every segment of our life is now supported by software, the quality and usability of software products have become paramount. During the observation, analysis. and examination of cognitive processes, human-computer interfaces are increasingly becoming widespread. Programming could also be seen as a complex cognitive process. In the spirit of usability, the field of Human-Computer Interaction (HCI) has evolved since the 1970s, while various software life cycle models have emerged due to designability and traceability. Countless variants of these models have emerged over the years, but since 2001, agile development has dominated. Laying down agile guidelines has led to the development of numerous methodologies (e.g., Scrum, Kanban, XP) that provide guidance (like clean code) to industry actors to create quality software products.

1.1 Theoretical Overview

The aim of the clean code paradigm applied in the field of programming is to support the executing of a software code base during a software implementation that facilitates easy overview and understanding as well as contributes to effective testing and development. To write codes with this structure, programmers need to be familiar with concepts as Don't repeat yourself (DRY) applicable for methods or Single Responsibility Principle (SRP) concerning classes. [1] Today, developments in the research field of Human-Computer Interaction (HCI) allow the observation and examination of various cognitive processes. [2, 3] Thus, by now, the clean code paradigm briefly described above can be examined by applying various HCI-based procedures. One of such analysis possibilities is the examination of the parameters of eye movement, with which the characteristics that can also be related to programming can be observed, the recorded results can be evaluated, and finally, connections can be determined.

The study [4] focuses primarily on the mechanism of reading source code. The method of reading a traditional text-based document and a source code describing the operation of software while observing, recording, and evaluating eye movement parameters were compared with the contribution of test subjects. The results of the research show that reading a source code is much less linear than that of a traditional text document, and experienced programmers read a code base less linearly than beginner programmers. Further research [5-8] shows that novice programmers spend much more time reading comments than their advanced peers to understand the code. The results of these researches can be related to the principles of clean code, because when compiling these types of code bases, the source file must be strived to be as a newspaper article, that is it should contain high-level concepts and algorithms, while details should be emphasized going downwards and the lowest level functions should be placed at the end. Informative nomenclature should be applied to minimize comments. [1] In the research [9] on source code review, the visual attention of the test subjects was examined in an industrial environment, where the recorded results showed that the test subjects with programming skills had more efficient eye movement features; for example, better code coverage, attention span and error lines as well as comments. These features are particularly important in effective error detection, i. e. in code review activity. In [10], the possibility of more effective education in programming is analysed and, through empirical research, the eye movement parameters of expert programmers are examined during modelling and debugging tasks. Other studies [11-15] focused on the planning phase preceding the implementation phase of the software development life cycle, where the intelligibility, arrangement, planning and application of Unified Modeling Language (UML) diagrams with eye-movement tracking technology were examined. In this study the effectiveness of the clean code paradigm through gaze tracking is aimed to be examined with the involvement of test subjects. In addition to examining eye movement parameters, the two techniques were also compared in the form of a traditional test, with which the objective and subjective responses and opinions of the test subjects were also evaluated.

2 Research Goal and Applied Methodology

During the examination, four smaller source codes were applied; two of them were made with the clean code paradigm, while the other two ignored the methodology recommendations. To observe and examine various eye movement parameters, a Gazepoint GP3 eye-tracker hardware unit, and to record the metrics the OGAMA software package were applied.

The examinations were carried out using the source codes detailed in Chapter 2, applying the Gazepoint GP3 eye-tracker hardware unit and the OGAMA software package as well as by completing tests. The test subject had to observe a source code compiled on the basis of clean code paradigm and a dirty code-based code base. The first source code to be studied was selected randomly from the four available implementations. The second code base to be observed varied depending on whether the test subject had analysed a clean code or a dirty code during the first test. If the first examined source code was based on clean code paradigm, only a dirty code could be analysed during the second round. As the aim of the study was to compare the two techniques, no changes were made to the source code elements apart from the methodological differences, so to avoid that the results obtained in the first study influence the results of the second examination, different abstraction was applied. For example, if someone started with a User modelling source code in the first round, they could only continue with the Employee modelling code in the second round and vice versa. Overall, in the case of each test subject, the two techniques were compared at a different level of abstraction, thus avoiding the use of knowledge from the first test in the second test round. The test subjects had 120 seconds to study each code base and then they had to answer questions concerning the code. For displaying the code lines, an LG 22M45 type with1920x1080 resolution and 22" diameter monitor was used.

2.1 The Test Subjects

A total of 23 university students between the ages of 19 and 22 (M=20.78, SD=1.28) who declared themselves to be healthy, including 11 females and 12 males, participated in the study. The test subjects volunteered for the study, which had two conditions. The first one was the successful completion of the courses' Introduction to Programming and Programming 1, as these subjects describe and demonstrate the skills that are essential for completing the task. The second one was the lack of knowledge required to implement clean code.

2.2 The Applied Test Source Codes

During writing the source code, it was taken into account that only elements familiar to test subjects from their previous studies would be used. In Figure 1, the UML class diagram of the source of the Acta.Clean.User project can be seen. The source code was made in compliance with the clean code paradigm, which includes, among others, the proper naming of classes, properties, variables, methods, etc. (using correct parts of speech and talkative identifiers, avoiding noise words, etc.), readable implementation of functions (the principle of single liability, maximum didactic, no side-effects), the avoidance of applying the switch expression (using polymorphism with overridden method), omitting comments (informative, applying expressive use of names), correct code formatting (newspaper metaphor, indent level less than 3). In total, in the case of the Acta.Clean.User project, 5 classes, of which one is an abstract and one is an enumerator were implemented. The total length of the Acta.Clean.User source code is 55 rows. The source code itself can be found in Appendix 1.

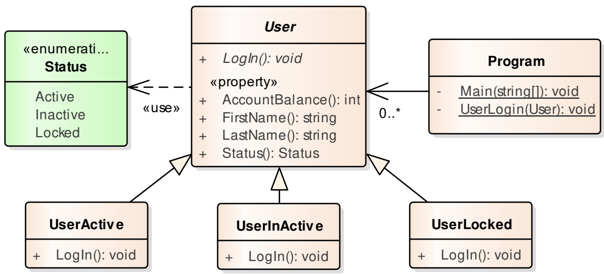


Fig. 1. The UML class diagram of the source code of the Acta.Clean.User project

Figure 2 shows the UML class diagram of the source code of the Acta.Dirty.User project. The source code ignores most of the recommendations listed in the clean code paradigm. The total length of the Acta.Dirty.User source code is 43 rows. The source code itself can be found in Appendix 2.

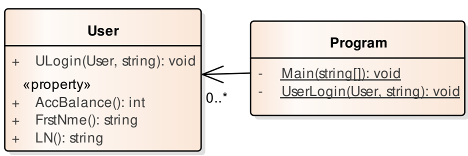


Fig. 2. The UML class diagram of the source code of the Acta.Dirty.User project

Figure 3 shows the UML class diagram of the source code of the Acta.Clean. Employee project. The source code was made following clean code paradigm, which includes those described in the Acta.Clean.User project. In this case, too, 5 classes, of which one abstract and one enumerator were implemented. The total length of the Acta.Clean.Employee source code is 57 rows. The source code itself can be found in Appendix 3.

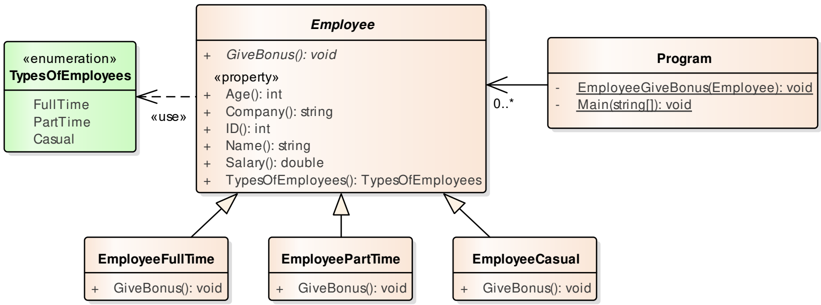


Fig. 3. The UML class diagram of the source code of Acta.Clean.Employee project

Figure 4 shows the UML class diagram of the source code of the Acta.Dirty.Employee project, which, like the Acta.Clean.User project ignores most of the recommendations listed in the clean code paradigm. The total length of the Acta.Dirty.Employee source code is 44 rows. The source code itself can be found in Appendix 4.

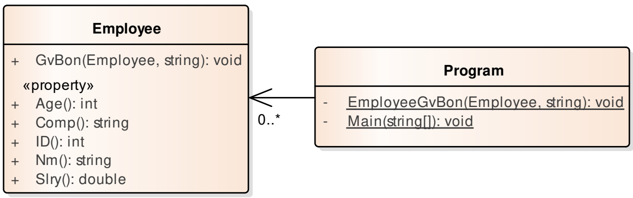


Fig. 4. The UML class diagram of the source code of Acta.Dirty.Employee project

2.3 The Gazepoint GP3 Eye-Tracker Hardware Unit

During the research, the Gazepoint GP3 research-grade eye tracker hardware unit (Fig. 5) was used to observe and examine eye movement parameters, which had been successfully applied in several previous research. [16-22] This unit can also be installed on the monitor and it detects and tracks gaze applying image processing by 60Hz sampling with infrared cameras.

Fig. 5. GP3 Eye Tracker

2.4 The OGAMA Software Package

During the examination, an open-source application, the OGAMA (OpenGazeAndMouseAnalyzer) was applied to record eye movement parameters observed and detected by the Gazepoint GP3 eye-tracker hardware unit, which supports other eye-tracking devices in addition to the hardware unit used in the research. The software package had been successfully used in several research applications. [22-25]

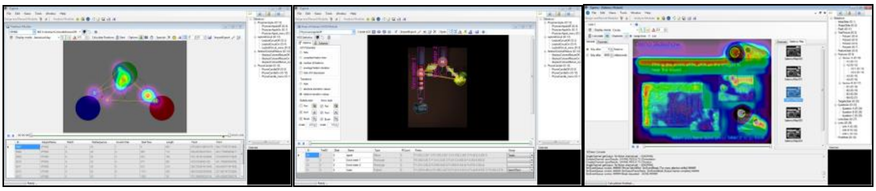


Fig. 6. Structure of OGAMA software

2.5 The Stages of the Examination

Before the research, the Gazepoint software package was downloaded and installed from the official manufacturer's site, and after successful installation, the GP3 eye-tracker hardware unit was connected via a USB port. After successful connection, the device was placed under the monitor about 65 cm from the eyes of the test subjects. When finding the right position, the gaze-date server was started and configured for real-time information retrieval and proper client server-based operation. After the server was functioning properly, the OGAMA software was launched and the Record Module was selected. After the successful launching and configuring of the OGAMA, the source code made with adequate technique and abstraction for the test case was opened in the Visual Studio Community development environment, where we tried to place it in a way that filled the screen as best as possible. Following proper preparation, the test subjects were provided all the necessary information related to the examination, and their important data, such as age or gender, were saved for further processing. After the successful data recording, in each test case, the calibration of the eye tracking device had to be done individually, during which the test subjects had to follow a circle moving their eyes from the left top of the monitor without moving their head. Calibration may have to be performed in the case of a test subject several times to achieve the best possible result. After successful and proper calibration, the test subject could begin to study the source codes. During the test, the eye movement parameters supported by the hardware unit and the OGAMA software were observed and recorded, and after the completion of the study, the data were saved in a database for further statistical evaluation. After successful data backup, the test subjects had to complete a test on the source code. With this method, we also tried to assess the difference between the two techniques and to test the subjective opinions of the test subjects. A schematic diagram of the testing environment is shown in Fig. 7.

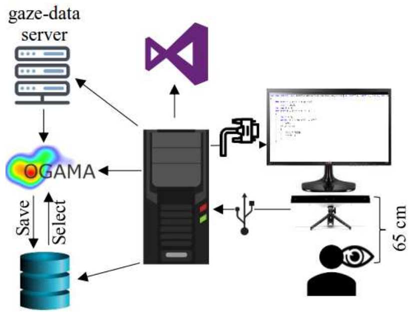


Fig. 7. A schematic diagram of equipment setup.

4 Results

The determination of the results started by evaluating the traditional tests. Each test consisted of 12 questions, identical on each test, of which 7 were used to check the readability and comprehension of the source code, and 5 questions were made to ask about the subjective opinion of the test subject.

4.1 The Evaluation of the Results of the Traditional Knowledge Level Tests

In the case of the source code based on the principles of clean code, all test subjects answered the questions on code readability and comprehensibility. The results show that most of them, five test subjects answered the fifth question, which asks how the whole code works, incorrectly, that is the 21.74% of the test subjects, while all of them could answer the fourth question, which asks some part of the code works, correctly. For the total sample, M=2.86, SD=1.77 incorrect answers were received, which corresponds to a total of M=12.42, SD=7.71 percent.

Even in the case of the dirty code test questions, all test subjects answered the questions on code readability and comprehensibility, were in the worst case 8, which is the 34.78% of the test subjects, answered to question 3 incorrectly, while one person gave an incorrect answer to question 2. Concerning the total sample, M=5.29, SD=2.29 incorrect answers were given, which corresponds to a total of M=22.98, SD=9.95 percent.

Table I. summary table shows the number and percentage of the incorrect answers in the knowledge level test regarding the clean code and the dirty code.

TABLE I.
A SUMMARY TABLE ON THE NUMBER AND PERCENTAGE ON THE INCORRECT ANSWERS/INCORRECTLY ANSWERING TEST SUBJECTS REGARDING THE CLEAN AND DIRTY CODE (*N*=23)

Clean Code				Dirty Code			
Min	Max	Mean	SD	Min	Max	Mean	SD
0	5	2.86 (12.42%)	1.77 (7.71%)	1	8	5.29 (22.98%)	2.29 (9.95%)

4.2 The Evaluation of Test Subjects' Subjective Opinion

A five-question survey was administrated to test subjects who participated in the examination to elicit their opinion on the clean and dirty codes, using a five-point Likert-type scale of "A": not at all; "B": slightly; "C": moderately; "D": pretty; "E": completely. Based on the above, five questions were formulated (Qs):

Q_1: How much did you feel reading an article while reading the code?

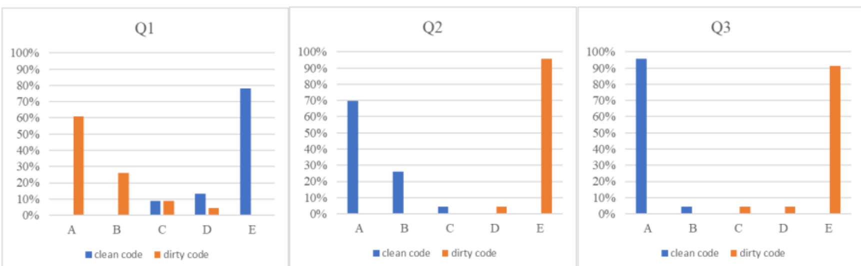
Q_2: How difficult was it to understand the source code?

Q_3: To what extent did you feel the need for comments?

Q_4: How uncertain was the code?

Q_5: How much did you feel the lack of precision?

According to the test subjects, the clean code is easier to read and better to understand without comments than the dirty code. Furthermore, the clean code was felt to be much more precise, causing much less uncertainty in their understanding. The evaluation of the results can be seen in Fig. 8.



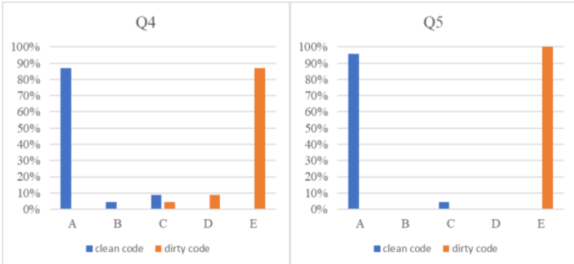


Fig. 8. Responses to questionnaire.

4.2 Evaluating the Parameters of Eye Movement

During the evaluation of the eye movement parameters, the heatmaps that the OGAMA software can generate in the Scanpath module were first examined along displaying the gaze route. After observing, examining, and evaluating the heatmaps, fixation numbers, average fixation durations, and Fixation Connections Lengths were also analysed and evaluated.

4.2.1 Evaluating the Recorded Heatmaps

Fig. 9. (1) and (2) show the heatmap and the route of gaze following the clean code paradigm, while Fig. 9. (3) and (4) shows a heatmap of the source codes and the route of gaze where these principles are disregarded, randomly selected but are generally characteristic of test subjects. The maps show that the code reading was non-linear and the variability, the return to previous code lines was much less observable at the clean code than at the dirty code, as according to the gaze routes, the test subjects returned to the beginning of the source file more times, presumably because of comprehension problems. All in all, the examination of the codes seems much more uncertain in the case of the dirty code and reflects that the test subject was unable to fully comprehend the text even after repeated reading.

The colours used on the heatmap have the following meaning:

- transparent area: observed and focused area not at all or only for a very short time.
- green: observed, focused area for a short time.
- yellow: observed, focused area for a medium-length time.
- red: observed, focused area for a longer period.
- yellow lines: the route of the gaze.

(1) (2) (3) (4)

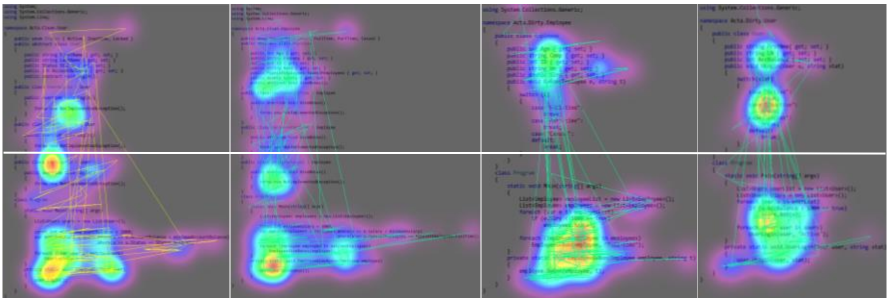


Fig. 9. The heatmap of a randomly selected test subject with gaze route following regarding Acta.Clean.User, Acta.Clean.Employee, Acta.Dirty.User and Acta.Dirty.Employee source codes.

Although the differences can be seen based on the heatmaps, they can only be quantified by using the Area Of Interest (AOI) tool of the software, which is used to link eye-movement measures to parts of the stimulus used. In this examination, the code was a single area.

4.2.1 The Evaluation of the Index Numbers of Eye Movement

The first evaluation was carried out on the interval scale with respect to the number of fixations. In the case of the source codes written in different ways, the Shapiro-Wilk test results applied during the examination of the normality of the data are not significant, in the case of the clean code it is ($D(23)=0.948$, $p=0.262$), in case of the dirty code it is ($D(23)=0.917$, $p=0.057$). As the data show normal distribution and we compared the fixation amount of the same test subjects in a group, the paired-samples t-test was applied to show that there is a significant difference in the mean number of fixations measured at the clean code and the dirty code ($t(22)=- 3.528$, $p=0.002$ (2-tailed), $d=0.942$). The test subjects in case of the clean code showed on average fewer information captures ($M=382.29$, $SD=157.37$) than in the case of the dirty code ($M=520.61$, $SD=135.42$). The confidence interval for the mean of the fixations is shown in Fig. 10.

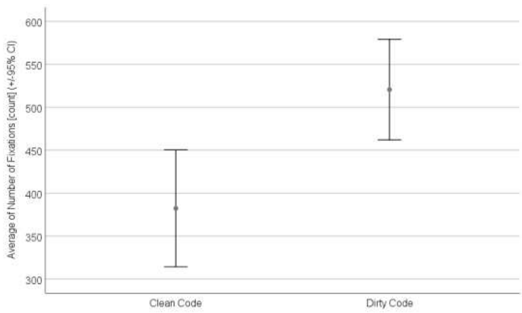


Fig. 10. The confidence interval for mean of the number of fixations.

The second evaluation was also performed on an interval scale with respect to the fixation time. In the case of differently written source codes, the Shapiro-Wilk test results used during the examination of the normality of data are not significant in case of the clean code, but in the case of the dirty code, they are significant. In the case of the clean code, it is ($D(23)=0.961$, $p=0.492$), while in case of the dirty code it is ($D(23)=0.777$, $p<0.001$). As the data do not follow a normal distribution in case of the dirty code and in one group the fixation time is compared at the same test subjects, the Wilcoxon-test was applied, according to which it can be determined that there is a significant difference between the average fixation time measured at the clean code and the dirty code ($T=37$, $Z=-3.072$, $p=0.002$ (2-tailed), $r=0.64$). The test subjects on average in case of the clean code spent less time studying the code ($Mdn=314.89$) milliseconds than in the case of the dirty code ($Mdn=335.04$) milliseconds. The distribution of the average fixation duration is shown in Fig 11.

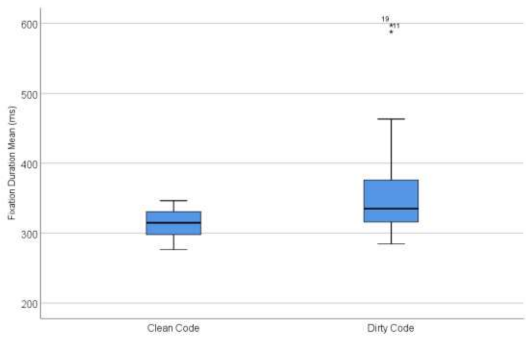


Fig. 11. The distribution of average fixation duration.

The third and final evaluation was carried out on an interval scale regarding Fixation Connections Length. In the case of the source code written in different ways, the Shapiro-Wilk test results used to test the normality of the data are not significant, in the case of the clean code it is ($D(23)=0.922$, $p=0.073$), while in the case of the dirty code it is ($D(23)=0.926$, $p=0.090$), as in the case of evaluating the number of fixations, a paired-samples t-test was applied, which shows that there is a significant difference in the average length of the routes measured between the fixations in the case of the clean code and the dirty code ($t(22)=-3.869$, $p<0.001$ (2-tailed), $d=0.995$). In the case of the clean code, the test subjects followed a shorter route between the fixations ($M=44779.354$, $SD=17876.352$) pixels than in case of the dirty code ($M=61377.328$, $SD=15371.635$) pixels. The confidence interval for mean lengths of fixation connections is shown in Fig. 12.

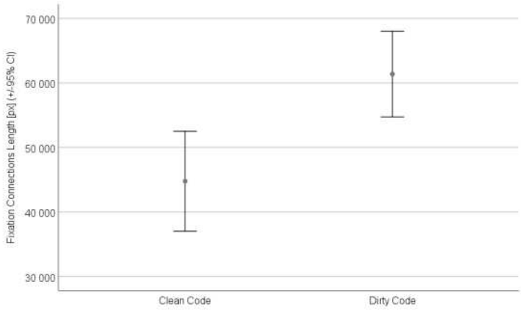


Fig. 12. The confidence interval for mean of the length of the fixation connections.

5 Discussion

After evaluating the results, it can be stated that the test subjects after studying the source files written using the clean code paradigm, achieved better results regarding the tests measuring the effectiveness of learning. As a consequence, it can be claimed that in the field of education, it is worthwhile to introduce and teach these types of codes from the beginning, in order to increase the efficiency of knowledge transfer and learning.

Based on the evaluation of subjective opinion questions, the test subjects felt that the top-down build of the source code following the principles of the clean code is well implemented and better suited to human information processing than the dirty code. In their opinion, the clean code besides easier readability is much easier to understand, and they did not feel the lack of comments, which cannot be stated in the case of the dirty code. In addition, they believe that uncertain codes often confusing programmers, in the case of the clean code were minimally or not at all present, which was attributed to accuracy.

Considering the results of the heatmaps observed by the OGAMA application, it can be concluded that in the case of the dirty code, the gaze is much more varied, and the test subjects focused more on parts of the source file that are less significant regarding code operation. Ultimately, this could also lead to the poorer results of the knowledge tests on understanding the dirty code, leaving them less time to study the more important code lines. However, with proper informative nomenclature, ignoring noise words, and applying top-down construction, that is, placing the more prominent parts at the end of the code, the source code reviewer can focus on the more important parts of the code line that affect the operation of the application. It is also confirmed by the results of the knowledge level measuring tests on the understandability of the clean code besides the heatmaps. The results examined in the research [4] show similarity with the results of the current research since the reading of the codes was not linear, but the variability and the return to the previous code lines is much less observable in the case of clean code. This result may also mean that a novice programmer with more observable linear reading ability [4] can understand the clean code much more easily. This is also confirmed by the positive results of the clean code learning tests evaluated above. Overall, attention is less scattered with source code written using the clean code paradigm, and linearity is much more present in reading than in the case of the dirty code-based source files. These facts are confirmed by heatmaps and gaze routes generated from the recorded eye movement parameters.

After evaluating the eye movement parameters, it can be stated that there is a significant difference in the number of fixations, the duration of fixations, and the fixation connections length when comparing the two code types. This means that in the case of the clean code, significantly less and shorter information recording and processing were necessary to understand the code, and the distances between the fixation points were also significantly shorter. The importance of this is also related to the clarity of the code and its linear readability since the longer route means that test subjects had to return much more times to a more distant point of the code lines in order to understand its operation. Overall, the use of less informative names, the incorrect switch instruction, more frequent information recording, the longer information processing phase and the gaze route between longer fixations led to diverse attention and the more important parts from the aspect of the operation of the application were less focused. The effects of these can be seen in the results of the knowledge acquisition tests evaluated above.

Conclusions

Today, HCI-based technology is increasingly present in the analysis and examination of cognitive processes. In addition to general knowledge level questionnaires and subjective opinions, in this research, the efficiency of readability and understandability of the clean and dirty codes were analyzed with the eye movement parameters (fixation number, fixation duration, and fixation connections length) and the observation, examination, and evaluation of the generated heatmaps and the gaze route. The results show that source files written using the clean code paradigm are more readable and easier to understand than source codes ignoring this technique, which ultimately provides a more efficient testing opportunity and can greatly simplify application development and maintenance. As a result of the research, it can be stated that besides using subjective, traditional knowledge level tests, with the application of eye movement tracking systems, the understandability, readability and the quality of a source code can be examined and these can predict the difficulty of testing and further developing of the application. In education, pedagogical methodologies such as project-based education, in which students can learn in real-life contexts, [26] have been introduced due to the increasingly difficult and complex coding systems. Studies in [28, 29] primarily focus on developments that accompany the entire life cycle of a product. In addition to the modern pedagogical approaches used today [27], HCI-based systems [30] could also function as a kind of learning [31] and education support system besides using modern learning environment [32-37] such as MaxWhere [38, 39]. In the future, in addition to the techniques and principles based on experience, eye movement parameters can serve as a support system for generating high-quality source code, which may become necessary to be applied in the field of industry besides education due to increasingly difficult and complex source files.

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Appendix

```
using System;
using System.Collections.Generic;
using System.Linq;

namespace Acta.Clean.User
{
    public enum Status { Active, Inactive, Locked }
    public abstract class User
    {
        public string FirstName { get; set; }
        public string LastName { get; set; }
        public Status Status { get; set; }
        public int AccountBalance { get; set; }
        public abstract void LogIn();
    }
    public class UserActive : User
    {
        public override void LogIn()
        {
            throw new NotImplementedException();
        }
    }
    public class UserInActive : User
    {
        public override void LogIn()
        {
            throw new NotImplementedException();
        }
    }
    public class UserLocked : User
    {
        public override void LogIn()
        {
            throw new NotImplementedException();
        }
    }
    class Program
    {
        static void Main(string[] args)
        {
            List<User> users = new List<User>();

            const int minimumAccountBalance = 1000;
            var matchedUsers = users.Where(u => u.AccountBalance < minimumAccountBalance)
                                    .Where(u => u.Status == Status.Active);

            foreach (User user in matchedUsers)
                UserLogin(user);
        }
        private static void UserLogin(User user)
        {
            user.LogIn();
        }
    }
}
```

Appendix 1. The source code of the Acta.Clean.User project

```
using System.Collections.Generic;

namespace Acta.Dirty.User
{
    public class User
    {
        public string FrstNme{ get; set; }
        public string LN { get; set; }
        public int AccBalance { get; set; }
        public void ULogin(User u, string stat)
        {
            switch(stat)
            {
                case "Active":
                    break;
                case "Inactive":
                    break;
                case "Locked":
                    break;
                default:
                    break;
            }
        }
    }
    class Program
    {
        static void Main(string[] args)
        {
            List<User> userList = new List<User>();
            List<User> users = new List<User>();
            foreach (var u in userList)
                if (u.AccBalance < 1000 == true)
                    users.Add(u);

            foreach (User user in users)
                UserLogin(user, "Active");
        }
        private static void UserLogin(User user, string stat)
        {
            user.ULogin(user, stat);
        }
    }
}
```

Appendix 2. The source code of the Acta.Dirty.User project

```
using System;
using System.Collections.Generic;
using System.Linq;

namespace Acta.Clean.Employee
{
    public enum TypesOfEmployees { FullTime, PartTime, Casual }
    public abstract class Employee
    {
        public int Age { get; set; }
        public string Company { get; set; }
        public int ID { get; set; }
        public string Name { get; set; }
        public TypesOfEmployees TypesOfEmployees { get; set; }
        public double Salary { get; set; }
        public abstract void GiveBonus();
    }
    public class EmployeeFullTime : Employee
    {
        public override void GiveBonus()
        {
            throw new NotImplementedException();
        }
    }
    public class EmployeePartTime : Employee
    {
        public override void GiveBonus()
        {
            throw new NotImplementedException();
        }
    }
    public class EmployeeCasual : Employee
    {
        public override void GiveBonus()
        {
            throw new NotImplementedException();
        }
    }
    class Program
    {
        static void Main(string[] args)
        {
            List<Employee> employees = new List<Employee>();

            const int minimumSalary = 1000;
            var matchedEmployees = employees.Where(e => e.Salary < minimumSalary)
                                  .Where(e => e.TypesOfEmployees == TypesOfEmployees.FullTime);

            foreach (Employee employee in matchedEmployees)
                EmployeeGiveBonus(employee);
        }
        private static void EmployeeGiveBonus(Employee employee)
        {
            employee.GiveBonus();
        }
    }
}
```

Appendix 3. The source code of Acta.Clean.Employee project

```
using System.Collections.Generic;

namespace Acta.Dirty.Employee
{
    public class Employee
    {
        public int Age { get; set; }
        public string Comp { get; set; }
        public int ID { get; set; }
        public string Nm { get; set; }
        public double Slry { get; set; }
        public void GvBon(Employee e, string t)
        {
            switch (t)
            {
                case "Full-time":
                    break;
                case "Part-time":
                    break;
                case "Casual":
                default:
                    break;
            }
        }
    }
    class Program
    {
        static void Main(string[] args)
        {
            List<Employee> employeeList = new List<Employee>();
            List<Employee> employees = new List<Employee>();
            foreach (var e in employeeList)
                if (e.Slry < 1000 == true)
                    employees.Add(e);

            foreach (Employee employee in employees)
                EmployeeGvBon(employee, "Full-time");
        }
        private static void EmployeeGvBon(Employee employee, string t)
        {
            employee.GvBon(employee, t);
        }
    }
}
```

Appendix 4. The source code of Acta.Dirty.Employee project

Experience of Self-Efficacy Learning among Vocational Secondary School Students

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Abstract: Self-study and self-efficacy are closely related concepts, and they are in connection even with lifelong learning. To develop real self-esteem in the learning process, it is important to be aware of one's abilities, weaknesses, and other characteristics that influence learning, which reinforces the foundations of learning motivation and lifelong learning. Self-efficacy and modern ICT solutions supporting self-directed learning become a more relevant role in self-learning outside the school context, i.e. in self-taught learning. This article examines self-efficacy in learning through a questionnaire survey for students at technical vocational secondary schools in Budapest (N = 1260) analyzing the answers to some of the self-efficacy statements based on the Motivated Strategies for Learning Questionnaire (MSLQ). The results can help develop modern ICT solutions that effectively support learning.

Keywords: self-efficacy; cognitive conditions; Motivated Strategies for Learning Questionnaire

1 Introduction

Cognitive conditions determine how effective an individual during the learning process is, namely how much time is needed for achieving new knowledge, and how quickly and what the person can acquire [1], [2]. Within this, there are three important factors. The first is prerequisite-knowledge, which is a kind of ability wherewith old knowledge can be connected with newly acquired knowledge. The result of the learning process is the change in the extant knowledge, in which basic knowledge is a priority because, without this, the expansion of the knowledge is not available [3]. Higher existing basic knowledge will produce better results, and students with less basic knowledge are dropping more and more behind.

The second factor which is necessary to complete a learning activity requires a mental preparational level. The learning ability refers to the level of mental preparation required to complete a learning activity [4]. These include general abilities, like reading skills, but advanced abilities as well, like taking notes or sketching abilities. Knowledge and application of learning techniques, education methods, strategies are an important factor in the system of learning abilities [5] [38]. One of the most important learning abilities is metacognition, which is the knowledge about our knowledge, and the ability to direct it [6]-[7]. The third falls into the category of generic supplementary elements such as perception, memory, imagination, thinking concepts, which determine the learning process and its effectiveness [8]. The modern ICT possibilities effectively could support these findings using the advantages of VR and AR [9]-[12], cooperative methodologies together with gamification [13]-[16] and take the advantages of Cognitive Info-communications and similar emerging technologies [17]-[19].

In the case of self-efficacy learning, it is difficult to make examinations without touching similar areas that are related to the learning process and to areas that influence the learning process. For example, in the case of self-regulated learning, both factors are linked to lifelong learning. In a narrower sense, the self-efficacy of learning is fundamentally dependent on the learning strategies of the individual involved in learning, which concept is currently a subject of many studies. Initially, approaches to learning strategies took place mainly in terms of information layout and processing approaches [20], later with metacognitive aspects [21] [22].

There are various ideas for grouping learning [23], but one of the most relevant and universal is Pintrich's study [24]. Research also addresses maladaptive learning strategies, which are strategies that inhibit success [25], among here can we rate, for example, looking for excuses or striving for perfectionism. These are most often observed when solving a given task exceeds the individuals' capabilities, successful completion of the task is unlikely, or when students feel threatened by their self-esteem [26]. Students attach different importance to learning, have different learning goals and are, therefore, differently satisfied with the quality of education, as well as their performance [27]. It is precisely these measures of student satisfaction, self-evaluations, and reflections that can help students improve their learning effectiveness, also the learning outcomes and, indirectly, lay the foundations for lifelong learning [28].

In this research, we are adapting previous works that examined motivational factors [7]. Of course, in Hungary, asking Hungarian students, the survey should be interpreted in the current education system and learning environment [39].

However, the reliability and validity of the questions should also be examined, which were done with the appropriate statistical methods after sampling, however, due to the length of the article, we cannot take advantage of the possibility of writing these in detail.

In the case of training that takes place within the school context, such as by vocational secondary school training, a teacher can experience, that the effectiveness of the learning process on many students is often inefficient, so education itself is a great challenge for the teachers themselves, starting with creating the motivation [29]. Also, in the case of vocational secondary schools, the development of those competencies that are highly valued and prioritized by the labour market is of utmost importance [30]. Nowadays modern information and communication technologies (ICT) are of great importance in acquiring knowledge. These ICT tools provide the basis for even more effective lifelong learning, the most important of which is learning to be independent of time and place. Today, learning information, learning materials, explanations, and even the level of knowledge acquired can be accessed and controlled almost anywhere, anytime [31]. An important part of the ICT tools is knowledge assessment systems, which measure the cognitive performance of students. Problem-solving competences of students are nowadays thoroughly researched so those specific problem-solving strategies can be identified and reinforced amongst students [32]. The use of ICT tools attempts to support the school and independent learning, but this approach also has its difficulties [33]-[34]. Therefore, if the willingness to learn is given, but the learning strategy is inadequate, then there is time and energy invested into learning, but there are still no expected results. All this leads to increased anxiety and stress for the students, and later on, the desire to learn and the motivation diminish. These may be somewhat offset by virtual and electronic learning environments and systems that are better suited to the needs of the digital generation, and by atypical modern teaching methods [35]-[36].

The present research was based on earlier research [21]. The current study does not address learning strategies, but primarily examines self-efficacy factors in statements in such a way that the matching degree with them are summarized as results. Our research was carried out among students of vocational secondary schools of one of the vocational training centres in Budapest (N=1260). From the processing of the answers, we can conclude to what extent the learning-related factors of self-efficacy are present concerning the students. We believe that developing self-efficacy among students in our pedagogical work can also help in their endeavours in lifelong learning [37].

2 Methodology

The study aims to evaluate the self-efficacy of learning among students in a vocational secondary school in Budapest [21]. Because self-efficacious learning is an important factor in adult autonomous lifelong learning, therefore, the results obtained in the context of self-efficacy learning may lead to such conclusions, which support the pedagogical work as effectively as possible to make the learning process as effective as possible.

The survey was carried out among students of 7 schools from a total of 13 member institutions of the Budapest Machinery Vocational Center (BGéSZC) by means of a voluntary questionnaire. The BGéSZC includes technical vocational secondary schools and thus reflects the institutional characteristics of vocational secondary schools and the characteristics of technical schools.

The member institutions were selected based on cooperative affinity based on prior requests. Due to incomplete member institution coverage and volunteering, the sample of students in schools is not complete, however, due to the sample number (N = 1260), a hundred percent sampling would probably not have resulted in significantly different results. This assumption is also reinforced by the fact that the results of the institutional breakdown not included in the study due to their low relevance did not result in differences between schools.

The questionnaire contained several sets of questions, including self-regulatory questions based on the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich and DeGroot, 1990). The questionnaires were completed on paper and the results were subsequently digitized. A total of 1260 evaluable questionnaires were completed in 81 classes. The statements in the questionnaire that examine student opinion are listed in Table 1.

Table 1
Learning self-efficacy statements based on MSLQ (Pintrich és DeGroot, 1990)

No	Question	Scale
1	Compared with others in class I expect to do well.	1-5
2	Compared with the others in my class, I think I´m a good student.	1-5
3	I think I will receive a good grade for this project compared with my classmates.	1-5
4	I know I will be able to learn the material for this project.	1-5
5	Compared with my classmates I perform better.	1-5
6	Usually I´m certain I can understand the teacher's explanations.	1-5
7	I am sure I can do an excellent job on the problems and tasks assigned for this project.	1-5
8	My study skills are better compared with others in this class.	1-5
9	Compared with other students in this class I think I know more about some of the subjects.	1-5

The questionnaire was filled in anonymously, and students could only be distinguished by their school, class, and gender. The scale used was a five-point Likert scale, with responses representing the degree of identification with a given statement. (1- never true for me, 2- sometimes true for me, 3- true for me about half the time, 4- frequently true for me, 5- always true for me).

In the questionnaire, questions related to learning self-efficacy were not declared directly for the topic, i.e. no questions were labeled, students encountered the statements only during the completion. Another important fact is that e.g. the self-efficacious learning statements did not follow one another but were mixed with other topics in the questionnaires to be completed.

2 Results and Discussion

Of the students enrolled in the survey, 93% are male and only 7% female, which of course reflects the gender distribution of the students in vocational secondary schools in the technical area. The rate can be explained by the fact that these types of vocational training are generally considered to be more popular with boys, - the same is the case for the participating students of the vocational secondary schools. The students gave 1260 answers, among them were 1168 boys and 92 girls. Of course, this ratio can be different for other types of (non-technical) vocational secondary schools. In vocational secondary schools, in general, the gender ratio is close to equal, with the proportion of boys being 52.8% (KSH, 2018).

The distribution of the students of each member institution of the Budapest Machinery Vocational Center is shown in Table 2. Due to data protection considerations, the actual names of the secondary schools are not listed in the table. That is, it is not our intention to draw conclusions about schools and compare them based on pupils specifically linked to schools.

Table 2

The sample numbers of the participating institutions

Vocational secondary schools	Number of students	Number of classes
Voc. secondary school 1	141	11
Voc. secondary school 2	191	10
Voc. secondary school 3	157	8
Voc. secondary school 4	209	12
Voc. secondary school 5	416	28
Voc. secondary school 6	52	6
Voc. secondary school 7	94	6
Total	**1260**	**81**

The bar graph in Figure 1 shows that the number of students participating in research is significantly lower above the age of 25, but it is important to look at the views of these students because they are already involved in adult education. So the participating students were mainly from the pre-baccalaureate (82%), however, we also addressed students after mature vocational training courses. As the comparison of results by education training types did not result in significant differences, responses and results will be treated together later.

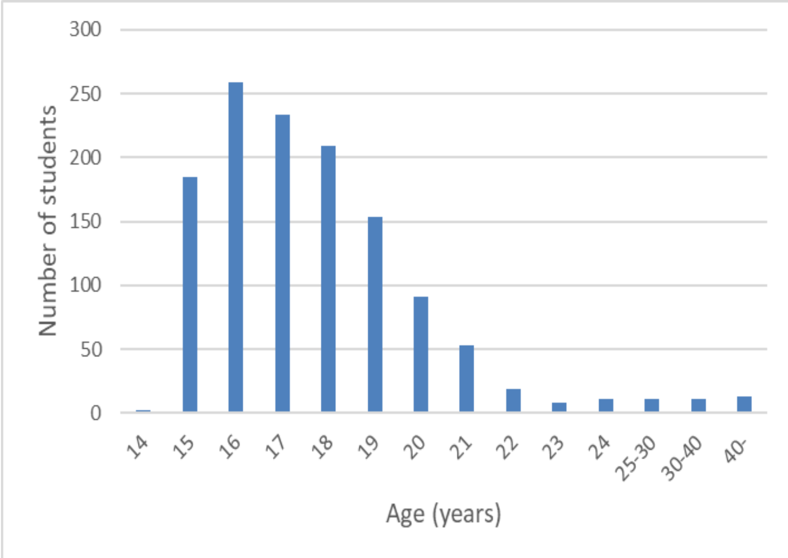

Figure 1
Distribution of research participating students by age

The study average of the respondents (based on the values described by the students, self-declaration), given to one decimal place, may be important for the research, the distribution of the data is shown in Figure 2.

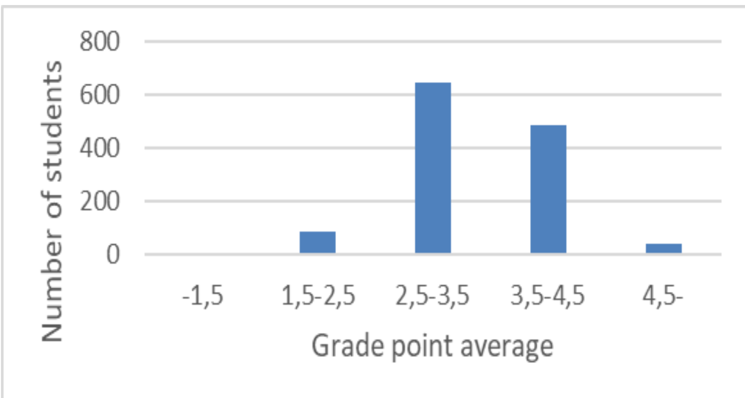

Figure 2
Distribution of study averages among students participating in research

Table 3 summarizes the relative frequencies of the answers to 9 questions related to learning self-efficacy.

Table 3
Relative frequencies of answers to self-efficacy statements

Nr.	Statement	1	2	3	4	5
1	Compared with other students in this class I expect to do well.	11%	27%	**28%**	23%	12%
2	Compared with the others in my class, I think I´m a good student.	14%	**33%**	24%	20%	9%
3	In my opinion I receive good grades compared with my classmates.	12%	**33%**	27%	21%	7%
4	I know I will be able to learn the material for this project.	2%	11%	27%	**35%**	24%
5	Compared with others in my class I usually do better.	11%	**39%**	26%	18%	6%
6	I´m certain I can understand the teacher explanations related to the project work.	3%	20%	**35%**	33%	8%
7	I am sure I can do an excellent job on the problems and tasks assigned for this project.	8%	27%	**33%**	22%	10%
8	My study skills are better compared with others in this class.	10%	**36%**	28%	17%	8%
9	Compared with other students in this class I think I usually know more about some of the subjects.	6%	**35%**	25%	27%	7%

The frequency of the answers for each question is shown in the bar graphs in Figure 3-11. Based on the frequencies, a brief evaluation of each statement is summarized after each figure.

Each statement can be matched with a set of keywords resulting from the statements, which can be a subset of self-efficacy, respectively:

- self-expectation: comparing one’s performance with the classmates’
- self-diligence: comparing one’s diligence with the classmates’
- efficiency: positioning one's results and ordering in an imaginative row compared with the classmates’
- subject motivation based on one's abilities
- overall learning performance: comparing the overall performance with the classmates’
- classroom effectiveness and feedback about activity during the lesson
- comparing the performance of the community and cooperative work with the classmates’
- comparing learning abilities with the other students in the class
- comparing knowledge as a learning outcome with the classmates

These individual concepts can also be grouped around the three factors (prerequisite knowledge, mental preparational level, general supplementary elements) related to self-effective learning described in the introduction that influences the effectiveness of the learning process. As self-effective learning belongs to the area related to motivation, the issues examined are mostly related to the topic of general supplementary elements. Of the learning theories, the humanistic learning theories discuss motivational factors the most.

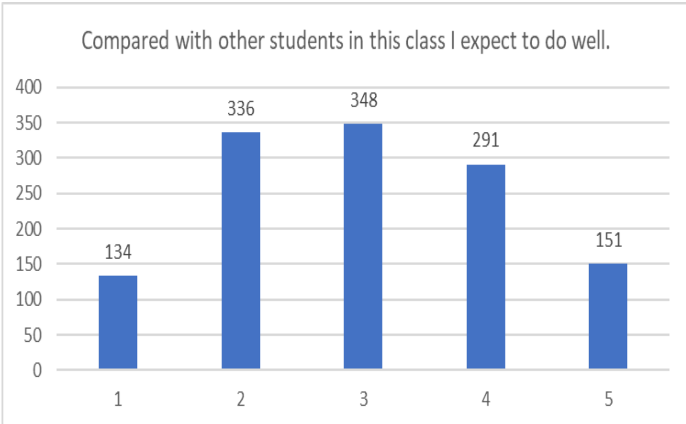

Figure 3
Distribution of frequency of answers to statement 1 of self-efficacy

The content of the statement involves two factors: one is self-expectation, it is based on the presence of an inner level, and the other is a comparison with classmates. The basis of comparison does not necessarily focus solely on knowledge but can include any school and learning aspects.

The distribution of the scale values of the responses is strikingly similar to the symmetric distribution, however, scale values 2 and 3 represent almost the same value and the value of 4 is almost double the distribution of the outer values of 1 and 5.

The answers thus reflect that values 2, 3, and 4 are by far the most common. By reversing thinking, value 1 was probably given by almost completely unmotivated students, and the number 5 was probably considered too "geeky" by many.

The second statement also relates to comparisons with classmates. However, there is little sense in the underlying attribute of the word "more diligent", or the degree of diligence. It is simply about whether, by comparison, I can say that I am diligent or not. That is, whether the feature exists or not.

The distribution of scale values of 1 is relatively low, about half of the values of scale 2, which is by far the largest and accounts for a third of the answers. Subsequent scale values decrease almost linearly.

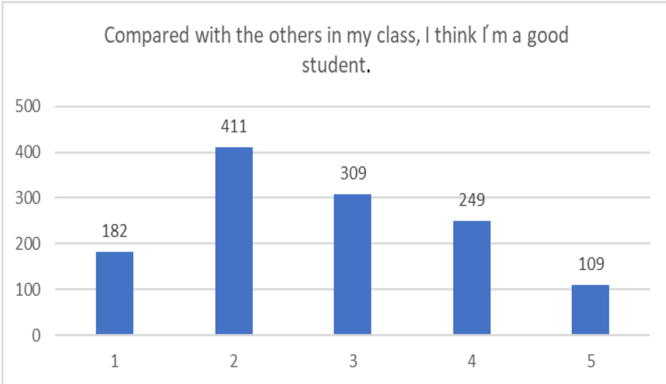

Figure 4
Distribution of frequency of answers to statement 2 of self-efficacy

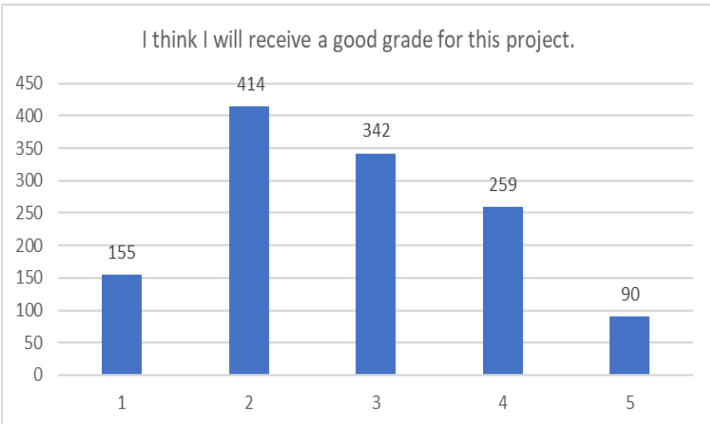

Figure 5
Distribution of frequency of answers to statement 3 of self-efficacy

This statement is also based on a comparison with a self-assessment in the background. In other words: based on the information available (since I obviously cannot know all the marks of all my classmates) do I get good grades, where do I place myself in this imaginary ranking? The statement is not considered further, but this statement can also be used to test the existence of student motivation.

The distributions of the answers are almost identical to the values given for the previous statement. It should be emphasized that in the original questionnaire the two statements did not follow one another, that is, the respondents did not automatically answer "set" to one response value.

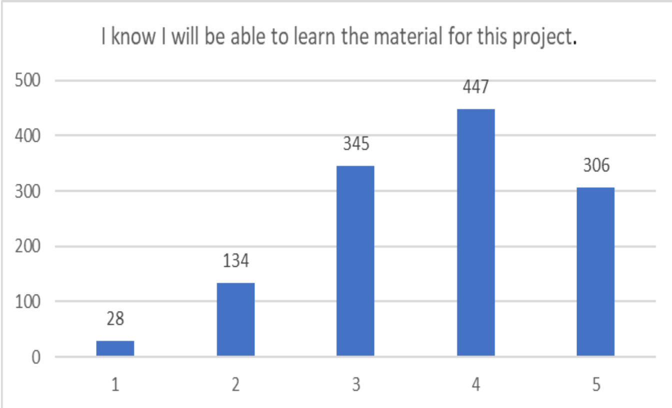

Figure 6
Distribution of frequency of answers to statement 4 of self-efficacy

The statement can also be related to motivation and self-esteem. It can also be related to self-efficacy because if the student approaches the curriculum with the promotion that it is impossible to learn because of many factors, on the one hand, will also find an excuse for not studying, on the other hand, reduces the effectiveness of learning to almost zero untimely.

If the student is aware of his/her abilities, the amount of time invested, the energy, and the proportionate expected results, in other words, its efficiency, and based on that, he/she knows that can meet expectations, it can have significant positive effects on the learning process: getting feedback on efficiency, motivation, time management, etc.

The distribution of responses increases steeply from a negligible value of 1 to the scale value of 4, which accounts for more than a third of the answers. One-quarter of the answers were answered with a scale value of 5. That is, almost two-thirds of the respondents indicated values 4 and 5.

Based on the results obtained, it can be assumed that students have significant self-confidence, they have a strong motivation level that can be relied upon during the pedagogical work.

The comparative nature of the statement is clear, but here the answers give no longer merely the presence or absence of the characteristic, such as. question 2 for diligence, but it must be clearly decided whether the respondent is better performing than his or her classmates in general or not. This "fulfillment" is not declared for a specific act but is meant generally.

The marked responses of the student values can be compared by the distribution of questions 2 and 3. The bars in the chart are very similar in appearance, respectively.

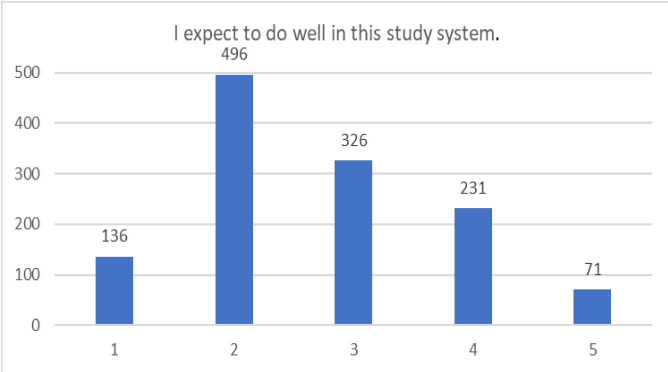

Figure 7

Distribution of frequency of answers to statement 5 of self-efficacy

More than a third of students answered with a value of 2 and a quarter of the participated students with a value of 3.

Essentially, the statement provides feedback from the learner's perspective on classroom effectiveness. If the student can acquire the knowledge of the curriculum from both the teacher and the book, then the learning process is provided by two sources, and of course, this is a more effective way to acquire knowledge (assuming that the teacher does not read aloud from the book during the lesson; in all other cases, the two aspects are met). Any decrease from these two will impair the effectiveness of learning.

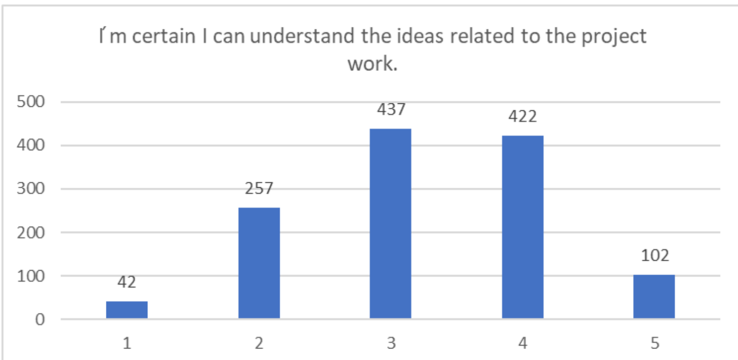

Figure 8

Distribution of frequency of answers to statement 6 of self-efficacy

In the answers, the distribution of the two external scale values is almost negligible compared to the other scale values. The highest values are 3 and 4 almost equally, which give the two-thirds coverage of the answers. The scale value 2 not mentioned above represents one-fifth of the answers. That is, the weight of the answers is above the average level of scale value 3, which is later confirmed numerically by the mean and standard deviation table, too. The results obtained can be said to be gratifying and this result can also be indirectly evaluated from the teacher's point of view as a measure of classroom effectiveness.

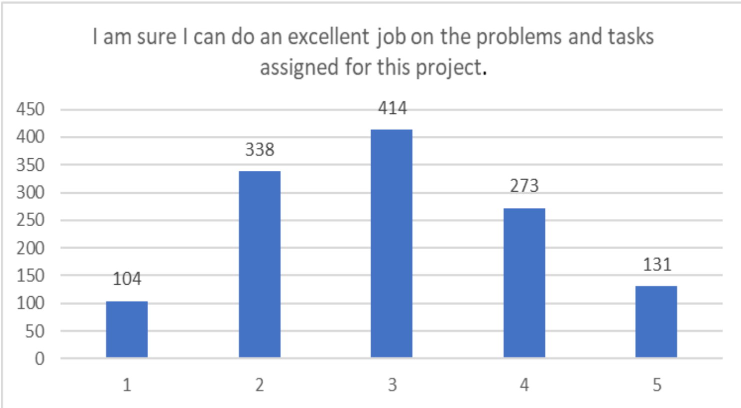

Figure 9
Distribution of frequency of answers to statement 7 of self-efficacy

The statement can be interpreted in several ways: on the one hand, based on a class community perspective, on the other hand, it also means the attitude of the students in cooperative learning or project assignments. We are talking about comparisons again and we can examine the basics of a community role.

The bar graph representation of the answers resembles the centre reflection of the answer distributions of statement 1. The two external scale values show a small distribution, the middle scale 3 represents one-third of the answers, however, values 2 and 4 are not symmetrical, but symmetry is shifted towards value 2. Accordingly, it can be stated that students identify with the statement in a completely average way.

A parallel can be drawn between statement and question 5. Here, too, as a responder, we can decide by comparison whether our abilities are better than those of our classmates'. Of course, learning abilities are not explained, they are only general, and we do not examine whether the answers are truthful or not. Learning abilities obviously affect the effectiveness of learning. These abilities can be developed and there are many techniques to improve them.

After examining statements 2, 3, and 5, the response values of statement 8 follow the same pattern and the same description can be repeated for the presentment of extremely similar distribution values.

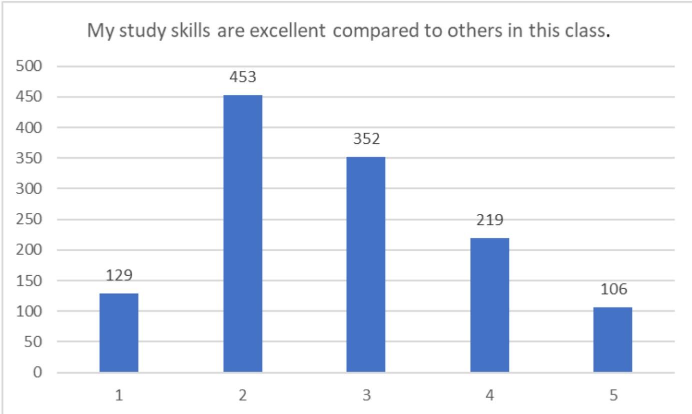

Figure 10

Distribution of frequency of answers to statement 8 of self-efficacy

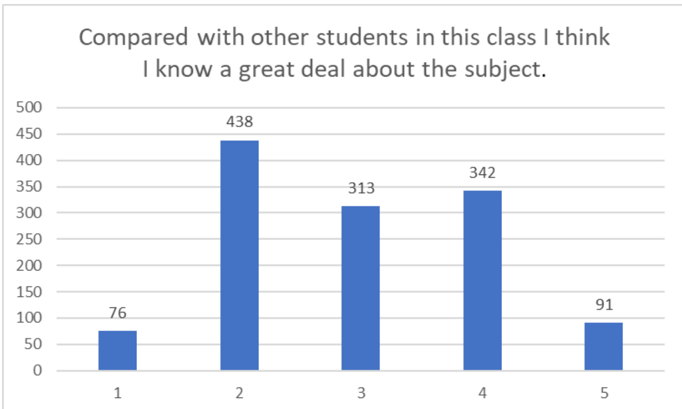

Figure 11

Distribution of frequency of answers to statement 9 of self-efficacy

The statement also includes in the background that I am better than the others, thus there is a decision in the comparison: am I better than average or not. At the same time, the statement does not examine the expense, the amount of energy invested, the path it takes, and the efficiency with which it compares the student with others, but focuses only on the actual outcome of the learning process.

Therefore, the statement is also a comparison and we would almost expect that the column values of the distribution values would produce similar results to the other statements (2, 3, 5, 8). This is true in a way, that the columns corresponding to the two external scale values are low (small distribution), and a scale value of 2 is the highest and also represents about a third of the answers. On the one hand, however, in this case, there is no "downturn" for the scale value of 4. It represents the second-highest value with more than a quarter of the answers, the scale value 3 is almost exactly the same as the numerical quarter of the answers.

Conclusions

It can be read both in the statement-related keywords and in the statements themselves that many are based on a comparison with classmates' properties. Accordingly, prior to the evaluation, it could be predicted that there would be similar distributions for some statement.

Without any software evaluation, it can be stated that, statements 2, 3, 5, and 8 show very similar results. All of these involve some comparison, but not all such statements are equally distributed. In these cases, after a minor value of 1, responses culminate on a scale value of 2 and they decrease almost linearly to the scale value of 5. The reason for this is probably that the participated students for some reason have avoided the extreme level representing the value of 1. A scale value of 2 indicates the answer is "sometimes true for me" and is related to students' self-esteem, that is, the values of 4 and 5 were largely felt to be exaggerated, which is why they were most likely responded with values of 2 and 3, respectively.

In the case of statement 1 (Compared with other students in this class I expect to do well.), The answers show similar results to normal distribution.

In the case of statement 4 (I know I will be able to learn the material for this project.), we can consider the results as a right-shifted normal distribution with a maximum scale value of 4.

Statement 6 (I´m certain I can understand the explanations related to the project work) is similarly related to students' self-confidence, however, the result values show something else, then as for statement 4, it can be stated that a slightly better than average result can be realized (average of 3.23, second highest).

In the case of statement 7, a slightly distorted form of the normal distribution can be observed.

All in all, the evaluation with a statistic software confirmed the results described above, i.e. the deviations from the normal distribution:

- self-expectation: comparing own performance with the classmates';
- classroom effectiveness and feedback about activity during lessons.

These factors should be developed from a pedagogical point of view, they are not crucial areas.

Similar to Gaussian distribution, but the results are slightly worse by the following factors:

- comparing the performance of the community and cooperative work with the classmates'
- comparing knowledge as a learning outcome with the classmates'

These factors provide a good basis for pedagogical work as in the previous category and do not require drastic pedagogical intervention.

The following, already discussed factors show a decreasing response-tendency after the scale value of two:

- self-diligence: comparing your own diligence with the classmates'
- efficiency: positioning one's results and ordering in an imaginative row compared with the classmates'
- learning overall performance: comparing the overall performance with the classmates'
- comparing learning abilities with the other students in the class

These factors require further pedagogical development.

First and foremost, actual performance needs to be taken in consideration in order to get a realistic picture and to exclude the distorting effect on responses that derive from lack of self-confidence. Based on these, the mentioned skills can be developed through the presentation and the awareness of learning strategies, which can deliver results in the medium and in the long term in terms of student success. We do not intend to make specific recommendations because of the scope of the study.

A good pedagogical factor can be the subject related motivation based on their own abilities, which shows that students have the needed self-confidence and they want to acquire knowledge.

Further analysis of the results and comparison with self-regulated learning may lead to further important findings. We plan to carry out these analyzes in the future.

The cognitive interpretation of the results, that is, the cognitive-centred approach, suggests that the self-efficacy form of acquiring knowledge is truly one of the highest levels of learning. Of the direct factors of cognitive ability, attention, and of the indirect factors, memory, are the most relevant to self-directed learning.

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The Methods and IT-Tools Used in Higher Education Assessed in the Characteristics and Attitude of Gen Z

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Abstract: In the era of digital transformation, some questions occur whether the teaching methods used in higher education are suitable for the students belonging to generation Z or these methods are appropriate enough to make them more attentive or motivated. The diverse methods of information technology have already spread into university education and a pedagogical paradigm shift can be perceived. The latest methodology, like project method, e-learning, BYOD, gamification, MOOC are available in higher education as well; however, it is a question to what extent teachers apply these methods in their teaching process. The new techniques not only make the students more motivated but also enhance them with those sorts of skills that are indispensable to be successful in the field of labor. The research was aimed to find answers about how much engineer students are satisfied with the training they are given in higher education in the 21st Century, what kind of attitude they have towards educational technology.

Keywords: teaching-learning startegies and techniques; up-to-date teaching methodology; educational technology; generation Z learning style and attention; engineering education; career development

1 Introduction

In our digitalized world, it is beyond dispute that higher education has to keep pace with the methods and educational technology used widely in the 21st Century. Also, it is a contemporary and relevant issue that university professors have to adjust themselves and accept the fact that the students belonging to Gen Z require other teaching aspects and approaches. As far as the survey presented in this paper is concerned, we would like to show how engineer students see their education at the university these days.

The visions and attitudes of Generation Z are completely different from that of the previous generations not to mention their values of life and the priorities they set for themselves. The problem-solving methods they use and multitasking operation are just two of the features the would-be engineers have and use during their studies while fulfilling their tasks [1-3].

In the paper, after reviewing the relevant theoretical background we are introducing research carried out in two countries, the goal of which was to find out the correlation between the attitudes and features of Gen Z and the digital technology used in higher education.

2 Theoretical Background

2.1 Modern Learning Theories and Techniques

At the end of the 20th Century, but mostly at the beginning of the 21st Century, the changes both in science and in technology created a situation when new learning circumstances and merely new spaces occurred that implicitly altered the methods, the tools, and the techniques of learning. For these reasons, learning theories have gone through a change and new ones appeared or at least they are constantly developing as the circumstances and people are transforming. Experts in education have always been interested in the objectives and reasons for behavior, acts, processes, etc. since mankind teaches younger ones to gain information about the surrounding world. In the following, some modern learning theories will be listed and shortly described to help better understand the mechanism of educational procedures in the latest few decades.

Out of the 20th Century learning theories regarding Generation Z and their learning techniques, it is worth mentioning constructivist learning theory and connectivist pedagogical attitude [4-6].

2.2 Contemporary Teaching-Learning Strategies and Methods

We are going through a digital transformation in every step of daily life. The digital transformation is literally at hand in the shape of smartphones, laptops, and tablets. [7]. As Racsko determines the process of digital transformation is the fact while ICT-literacy is materialized by the usage of human support technology tools via the spread and the integration of the technologies of the information society. [8] In the course of this procedure, the tools and their virtual environments are highlighted, and the competencies are emphasized with which these can be applied confidentially to the teaching-learning procession creating new learning environments for educational goals [9]-[11]. With this phenomenon not only the learning theories have altered much, but also the teaching-learning strategies and techniques have gone through a huge change [12].

We as educators and experts have to be aware of the fact that those young people studying at the universities these days have grown up in a glaringly different learning environment if we compare it with the classrooms of two decades ago. [13] The question arises, is Gen Z using these tools and opportunities effectively for reaching the desired goal for their education and for gaining their future professions.

In the following, we would mention some contemporary teaching-learning strategies and techniques that are used with success in educational practice following the list of strategies offered by Muhi et al., [14]. Firstly, Self Training, when students acquire the material according to their own pace and the most suitable methods for them [15]. This strategy requires the tools, resources, and aids that are inevitable for accessing new knowledge. Secondly, Experimental Learning, which can be perceived as a cyclical development process in which the participants gain some experience then it is interpreted and analyzed [16]. In this way, the individuals' activity is formed and the gained knowledge is tried out in a new environment. After this, the cycle restarts. Thirdly, Free, Independent Learning, when there is no formal space or control in the procedure [17]. The only thing that determines the process is the skills and opportunities of the learner. The fourth is the On the Job Training. This strategy is one of the most goal-oriented teaching strategies, it is like an internship. The fifth is External Learning, in which the participants do not have to enroll in a formal course rather the learning process is acquired via e-learning or distant learning methods. Distance Learning or Distance Education is very similar to the previous one but its feature is that the teaching-learning mechanism can be solved with the help of an IT device that can be the tool between the teacher and the student. The following is Digital Education in which the medium is the technical device via which the knowledge is gained and this medium is primarily a computer and software [18]. Last but not least, the Blended Learning method, which is about mixing the above-mentioned possibilities to reach a complex mixture of traditional and digital methods [19]. Using mobile tools (laptop, tablet, mobile phone) in the process of education is diversified and at the same time an exciting, challenging possibility in the hand of educators. In higher education MOOC (Massive Open Online Courses) [20] is common but we have to admit that it is popular mostly abroad not in Hungary.

Another commonly used technique is BYOD (Bring Your Own Device) when the students' own devices are used in the classroom for educational purposes [21]. It can also be a path to decrease the digital divide, mostly when the tool is provided by the institution. In Hungary there are two models how the above-mentioned method is applied by the institutions: 1. the mobile tool is owned by the school, 2. the tool is owned by the student. The most common and realistic way concerning Hungarian society is the first version when the mobile tools (laptop, tablet) are owned by the institution. Regarding higher education, the access of the Internet and WiFi is provided freely for users. University students have become used to accomplishing tasks with the help of their smartphones, laptops, and tablets.

Using different kinds of platforms and tools for learning, educators need to motivate students in some other ways, as well. Generation Z has different ways of motivating and learning procedures. Motivational methods, such as gamification, have become more and more popular, which are built in the learning pursuit and can develop students' digital competencies while using the elements of the game to increase learners' commitment to learning [22]. Gamification could be a part of the motivational procedure which can enrich the teaching-learning mechanism. These days there are best practices in higher education for using the game for enhancing students' efficiency in learning used by some exceptional educators who want to apply new approaches for motivating the Generation Z students in the classroom and outside of it.

We must admit that applying the above-described methods requires additional competencies from teachers besides the basic ones. Digital competence is one of the competencies teachers need if they wish to use modern techniques embedded in their lessons [23].

According to Ala-Mutka [24], digital competence is far more than just one skill. It involves more additional skills, such as communication skills, cooperation [25], creativity, critical thinking or even problem solving [26]. In the classrooms, ICT devices as completion of traditional methods are getting more and more popular to be integrated into the educational process by teachers [15]. The question occurs whether teachers are skilled enough to use these tools in class or not. In the USA, the standards that are appropriate for measuring and qualifying both teachers and teacher training institutes have been mapped out [27].

From another aspect, Prievara suggests that teachers need five important skills in the 21st Century classroom: collaboration, building knowledge, using ICT tools, problem-solving and innovation, and self-control. [28] Firstly, the participants in the classroom (or with the help of modern technology outside of it) should work together, collaborate to reach the desired aim. Building knowledge must be an evident terminology for outsiders but it is meant in a way that the student is only given the information and he/she has to reproduce it again while creating new knowledge in merely novel situations. The usage of ICT devices in our digitalized world is inevitable (MaxWhere3D platform, gamification, BYOD, etc.). Problem solving and innovation are the two skills that were always in the education needed to help the process. Teachers need to be innovative and ready to solve occurring problems from time to time. Reflecting on our work, giving feedback to self-development means self-control at the same time. Teachers need to adjust to digital transformation to be able to understand future generations.

2.3 Generation Z Learning Style and Attention

Today students in higher education belong to Generation Z. However, there are debates about clustering generations and there are also some categorizations made by researchers based on the date of birth of people. What is sure that nowadays learners' views of life, expectations, values, and norms are different from that of the previous generations. Although former generation members often see its drawbacks, we do not have to think as if it were either advantageous or disadvantageous. Only we need to adjust and accept this development and try to understand and help the up-growing generation.

According to Jukes and Dosaj [29], the digital inborn students can be characterized as follows: they can access information via different media; they use simultaneous information processing and as it is often called multitasking; this generation mainly prefers pictures, sound, and videos instead of texts; they apply non-linear elaboration; gen Zers are adopted to the preference of simultaneous interactions; they need inner learning motivation; they are immediate feedback orientated, and last but not least they prefer useful, immediately used information. Generation Z's learning style and focus are varied. Based on surveys, it can be stated that they did not have an off-line childhood. In the virtual world, they had to get used to immediate feedback, accessing information quickly and that is why they expect the same circumstances from the real – off-line – world, too. [30]

Nowadays students are connected to each other mostly 7/24 in the online space. They can also perfectly surf the net and use devices for their own goals and everything is just from one 'click' from them. They are able to use digital devices naturally but it is not evident if they are aware of some of its required competencies, such as ethical behavior in the virtual world, protection of data, understanding deeply the content of a text, accessing relevant and not fake information, just to mention some. [31] Although there are substantial challenges working with Generation Z in education, this new situation espouses a wide range of potentials and numerous questions to investigate and answer in order to have all its advantageous virtue.

Today one of the biggest and could hardly be answered questions is how a teacher could be able to grab students' attention in class, how they are able to raise their interests [30]-[32] There are surveys to examine the use of the collaborative method in the altering learning environment, which are used effectively with the help of innovative tools and methods to enlarge the learning space and adjust to the features and needs of Generation Z [33].

In some cases, new models are described to support the university students' attention, inner drive and effectiveness in their studies. For example, Benedek and Molnár presented in their study an innovational ICT-based infrastructure and its affects on collaborative e-learning platform used in higher education with students belonging to Generation Z. [34] Another tool that perfectly suits the needs of

Generation Z is 3D Internet, which provides immersive online experience for the users [3]. The digital materialization of 3D Internet in education is the software MaxWhere, which has been used in some universities, including the University of Dunaújváros. MaxWhere is a 3D system, developed by Hungarian scientists, which not only allows uploading and storing both 2D and 3D objects, from texts to audio and video files, but also makes the teaching-learning process more effective with better remembering and shortening collaborative workflow time. [35] Most of the time teachers have to face the fact that students are becoming impatient if they do not get immediate feedback, quick information as they become used to during their daily online presence. [28] These e-learning spaces can have the solution to this problem and can equal the division between generations, too.

Using the Internet and searching for information on the world wide web influences Generation Z brain activity. According to professor Small's experiment [36], in the brain of people who spent minimum one or two hours a week searching on the Internet changes could be detected: their brain activity became more widespread on a particular territory; neural pathways supporting traditional mental functions, such as book reading, become weaker, while new connections are forming [37]. Small [36] declares that searching on the Internet make human brain work, just like doing crossword puzzle; however, that intensive brain work may prevent deep thinking and learning if it becomes the primary way of thinking. Continuous mental coordination and decision making derive human attention from the interpretation of texts, so while reading on the Internet, we sacrifice our skill that enables deep reading, and we could become the pure decoders of information. [37]. Based on the studies, Szőke-Milinte [38] states that the attention of Generation Z is changing.

Working memory, as a sort of short-term memory, plays a significant role in transforming information into long-term memory, and so in formulating our knowledge. The working memory can store only a small amount, 7 pieces, of information. On the other hand, information stored only in the working memory quickly disappears. The depth of our intelligence depends on the fact whether we are able to transform information from working memory into long-term memory. [37] Due to web 2.0 applications, people, especially Generation Z members, meet the flood of information that working memory is unable to handle it and could transfer only a small amount of information into the long-term memory. Moreover, the transferred information is so diffuse and mixed that the brain cannot find and recall it. It means that the working memory is so burdened that it cannot maintain its ability to store and elaborate information, to fit new information into the long-term memory, and to form links between the new and the old information [38].

3 The Research

3.1 The Research Process and Method

The international research was conducted at a Russian and a Hungarian university. The Russian, the Ural Federal University is a huge institute with several tens of thousands of students and is situated in Ekaterinburg, while the Hungarian one, the University of Dunaújváros is a small university with about 1,600 students. However, both higher education institutes have an engineer study program. The survey was carried out in spring 2019 with a self-administered questionnaire among the engineer students (mechanical and IT engineering) who study in the third and fourth forms of their university training. The questionnaire was elaborated by the Russian colleagues in the Russian language and was translated then into Hungarian and adapted (and a bit modified) to the Hungarian higher education system and its attributes. Russian students were given the digital form of the questionnaire, while Hungarian students answered a paper questionnaire. After receiving all the answers, the data from the two subgroups were incorporated into one united file. The analysis of the data was done by SPSS 22.0 statistical program.

The research is considered to be a pilot one, as the sample is not so big: altogether 117 engineer students took part in the research from the two countries; the number of the Hungarian sub-sample is 64 people, while that of the Russian one is 53 people. Regarding respondents' gender distribution, there is a difference between the two sub-sample: in the Russian subsample, the ratio of males and females was nearly the same (52.8% males, 47.2% females). On the other hand, the Hungarian sub-sample presents a much more uneven distribution: 90.6% of all Hungarian engineer students were males. The fact that male students are overrepresented not only in engineer study programs and careers, but in most STEM training and jobs may refer to the attitude of Hungarian society towards STEM subjects, study programs, and jobs.

3.2 Research Results

The questionnaire wanted to receive answers about engineer training from several different aspects:

- on the basis of which factors students choose the higher education institute;
- what factors have an impact on the quality of the training;
- how high the prestige of engineer training;

- how easy to find a job after taking the degree;
- what priorities they have regarding their future professional and personal life.

During the process of choosing a higher education institute, students consider many several aspects to make their decision. Respondents had to decide whether the given factors play a very important or not important role in the decision making process. The results of the questionnaire show difference between the opinion of Hungarian and Russian students: while 66% of Russian students stated the prestige of university was very important, only 45% of Hungarian students thought the same. However, Hungarian students found material factors much more important: about two-third (73.4%) of them implied that the factor 'after taking the degree to find a good and well-paid job' is significantly important – while about half (53%) of Russian students evaluated this factor very important. Taking into consideration the influence of the family, less than 10% of Russian students chose the university due to their relatives' opinions who studied there earlier. On the other hand, this variable was considered very important by 25% of Hungarian students.

Analyzing the result with crosstable, the chi-square test indicated a significant difference between the opinion of Russian and Hungarian students in case of five variables: the prestige of the university ($\chi 2=7.855$; $p<0,05$), the costs of the training ($\chi 2=10.329$; $p<0.01$), after the degree it is easy to find a good and well-paid job ($\chi 2=0.001$; $p<0.01$), having a kind of privilege in admission ($\chi 2=7.486$; $p<0.05$), and the high quality professional practical training ($\chi 2=8.511$; $p<0.05$). While the factors of the prestige of the university and having a privilege were significantly more important to Russian students, significantly more Hungarian students prioritized the costs of the training and gaining a well-paid job after graduation. Although more Hungarian than Russian students declared that high-quality practical training is very important, the difference between the two sub-samples is only 9%. Nevertheless, twice more Russian (41.5%) than Hungarian (18.8%) students answered that they cannot decide the significance of this factor. Based on the results, it can be stated that Hungarian students are more committed to the significance and the relevance of professional practical training and internship.

The quality of higher education training can be influenced by several different factors. Researchers listed some of them in the survey, and students had to indicate what importance they assign to each variable (very important – not important – cannot say). Regarding these variables, the opinion of Hungarian and Russian students demonstrated very few differences. Both subsamples labeled the technological base of the university and the availability of laboratories very important, as well as the close connection between the knowledge gained at the university and the professional requirements of the labor market. The former factor was considered very important by the 78% of Hungarian and 89% of

Russian students, while the latter variable was implied really important by 73% of Hungarian and 91% of Russain students.

However, there are some differences between the two sub-samples: the chi-square test showed a significant difference between Hungarian and Russian students' opinions in the case of 5 factors out of the 12. Significantly much more Hungarian (64.1%) than Russian (39.6%) thought it very important that students can study both full and part-time and can combine work and study without a negative impact on their advancement ($\chi2=7.237$; $p<0.05$). On the other hand, significantly more Russian (83%) than Hungarian (53.1%) students find it very important that partner employers should be involved in the training programs. At the same time, five times more Hungarian (28.1%) than Russian (5.7%) students evaluated this factor as not important ($\chi2=13.078$; $p<0.01$). Moreover, more Russian (72%) than Hungarian (41%) students consider that the opportunity to participate in student mobility programs is very important. This factor is evaluated as not important by one third (36.5%) of Hungarian students – more than three times more than the Russian ones (11.3%) ($\chi2=12.5348$; $p<0.01$).

Table 1

Factors influencing the quality of education – comparison of Hungarian and Russian students

Factors influencing the quality of education	Hungarian	Russian
Education is available in various forms.	64%	40%
Opportunity to study under an individual curriculum.	61%	62%
Opportunity for professional development during internships.	75%	76%
Existence of students' councils and professional unions.	31%	25%
Availability of massive open online courses.	41%	51%
Availability of inter-university student exchange programs (Erasmus).	41%	72%
Connection of the knowledge gained with the real work in the profession.	73%	91%
Individual work of teachers with students.	59%	72%
Technology base, availability of modern equipment in laboratories and classrooms.	78%	89%

Regarding two factors ('the opportunity to study according to individual curriculum' and 'supplementing training programs with e-learning and distance learning technologies'), the chi-square test presented a significant difference between the two sub-samples. Examining the details of the crosstable analysis, it can be stated that a very small difference can be found between the number of Hungarian and Russian students evaluating these factors very important – in the former case 1.4%, in the latter one 11.6%. However, nearly or exactly three times more Hungarian than Russian students found these factors not important that is why the difference between the two sub-samples was a significant opportunity for an individual curriculum ($\chi2=7.869$; $p<0.05$); availability of e-learning and distance learning technologies ($\chi2=10.702$; $p<0.01$).

The results raise some questions about the attitude of Hungarian students. Why do they not appreciate the involvement of partner employers in their training program? What is more, in Hungarian higher education institutions, especially, at the University of Duanújváros, the process of incorporating industrial and business companies into university programs has started: students do laboratory work in special labs supported and maintained by well-known and significant business employers, the employees of some IT companies have academic lessons, and students have the opportunity to do dual raining throughout their university training. That is why it is not clear why they did not find this factor important. On the other hand, Hungarian students are not really interested in student mobility programs either, they are less willing to take part in them. The reason behind this result could be the fact that many Hungarian students' foreign language proficiency is not high enough to learn professional subjects.

Most of today university students, especially the ones who study in full-time education, belong to Generation Z. Being born in the online world, the members of this generation have got used to the speed of the web and instant feedback in social media, and they expect similar conditions in the off-line world, too. One of the biggest challenges of today's education system is how teachers could catch and maintain the young generation's attention that was developed in the fast and instant online world with a slower pace and delayed feedbacks of the off-line reality. As Generation Z uses digital technology without any difficulties both for entertainment and for learning; multitasking, as their usual existence in everyday life, is built in their learning process; moreover, as they prefer learning in groups and with gamification methods [39], working interactively and being in contact all the time, they find reasonably boring usual and old-fashioned school activities and 20^{th}-Century teaching-learning methodologies. If teachers do not want to compete with students' digital gadgets and their activities in the virtual space, they should acquire how to use 21^{st}-Century teaching techniques and how to use smart devices for learning in the framework of the education system.

Researchers asked students' opinions on how frequently various teaching methods and activities are used in education and how effectively they develop students' competencies. Respondents had to evaluate 9 different methods on a four-grade scale regarding the frequency of their usage. Number 1 means they are not familiar with the method/activity, while number 4 means it is commonly used in the teaching-learning process. According to the result of Figure 1, there are differences between Hungarian and Russian university practice using various methods and activities. In the Russian university, the most frequently used method is project work (3.77) but professors frequently involve e-learning (3.38) and online courses (3.53) in the learning process. On the other hand, these methods are less frequently used in the Hungarian university; however, their value is nearly 3.00 or over 3.00, which means that they are used minimum sometimes.

Regarding different forms of learning activity, such as peer, active, and self-paced learning, Hungarian students use it more often than the Russian ones.

The question is if students exactly knew the definition of these concepts when they answered the question. As for peer learning, it refers to the activity when students work collaboratively and cooperatively supporting each other in the learning process and taking the responsibility for their own and their peers' learning. The forms of peer learning are peer support groups, peer teaching, peer tutoring, and peer-assisted learning. [40] Active learning implies students' activity when they do meaningful learning activities and personally engage in the learning process in the form of short course-related individual or small-group activities. Active learning is usually contrasted to traditional professor-led lectures, where students generally passively receive information [41]-[42] The concept of self-paced learning means more than just student's decision when, how quickly, and in what orders they learn the material. Self-paced learning refers to a learning process, where the curriculum is determined by students' abilities rather than being fixed by the teacher [43] and dynamically generated by students themselves, according to the fact of what they have already learned [44]. Researchers think that while peer and active learning were properly understood by the respondents, they did not really know the essence of self-paced learning.

The results show that Hungarian students are more frequently involved in modern learning activities: peer, active, and self-paced learning. As many Hungarian students belong to the historically based student community where they follow, preserve, and practice very old student traditions from the era of Queen Maria-Teresia, they support their student-fellows in learning, too. Moreover, peer learning appears in virtuality as well as students often have special closed groups in social media, where they discuss and share learning materials. However, researchers think that under the concept of self-paced learning students understood only the fact that when, how long, and how intensively they could learn. The curriculum at the Hungarian university is rather fixed, regarding the subjects, the order of subjects, the compulsory materials, and competencies that must be acquired by the end of each semester, which means students cannot modify it. That is the high frequency received from the Hungarian questionnaire could be deceiving.

What is annoying according to the results that gamification is significantly rarely used by both Hungarian and Russian universities. Gamification is a technique when gameplay elements are included and used in non-game settings and processes to engage and motivate participants Although it was first applied in the HR field, it is now used in the education process, too. According to the results, some students do not know this method at all and many of them have not even heard about it nor have they ever been involved in a lesson like that. The question is raised again: whether students properly know what gamification means. Many teachers use one or more learning applications, such as LearningApps, Kahoot, Mentimeter, built in the teaching process. According to literature, the teaching process using applications sometimes cannot be called gamification.

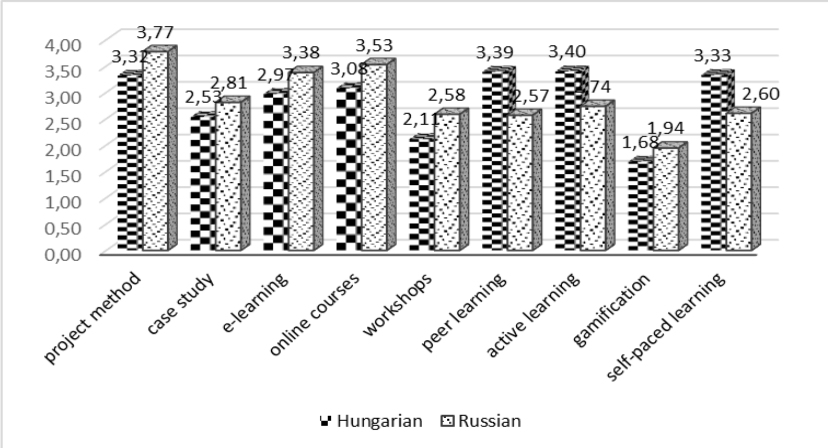

Figure 1
Frequency of using methods

Based on broad interpretation, gamification is called when game-like elements are regularly incorporated in the teaching-learning process, and their results form a part of the final assessment; e.g. the result of Kahoot done in each lesson gives a particular proportion of the final grade. On the other hand, real gamification is considered when the whole teaching process is built from game-like elements: students collect points. and on the basis of the number of their points they could reach a particular level – while competing individually or in groups with their peers. [21] Regardless of the fact whether students know the proper definition of gamification or not, the result deserves attention: out of the 117 student-respondent, only 6 of them mentioned that gamification is a common practice and another 24 students implied that this method has sometimes been used.

Comparing the frequency of using methods and learning activities, differences can be found between Hungarian and Russian students' opinions. Crosstable analysis and chi-square test presented that in case of seven out of the nine variables, the difference is significant: project work ($\chi2=28.229$; $p<0.001$), e-learning ($\chi2=8.644$; $p<0.05$), online courses ($\chi2=13.357$; $p<0.01$), and workshops ($\chi2=16.399$; $p<0.01$) are significantly more frequently used at the Russian university. On the other hand, peer learning ($\chi2=21.764$; $p<0.001$), active learning ($\chi2=13.608$; $p<0.01$), and self-paced learning ($\chi2=14.001$; $p<0.01$) are significantly more often appear in the Hungarian teaching-learning process. Regarding workshops and gamification, there is no significant difference between the two sub-samples' opinions.

Except for how frequently methods and activities are used in the teaching-learning process, the other essential factor is how effective they are, especially what students think of the efficiency of various methods. Researchers listed 10 variables and students had to evaluate them on a ten-grade scale based on their efficiency, where 1 means the least and 10 – the most effective. The list contained both traditional higher education teaching-learning activities, the ones referring to practice, and some more up-to-date ones, such as examinations and lectures, laboratory works and field experience, as well as online courses and projects. Since the Russian and the Hungarian higher education systems work in a bit different way, some original Russian variables must have been modified and adjusted to the Hungarian system. While in the Russian questionnaire, researchers listed Masterclasses (Мастер-классы) and Business games (Деловые игры), in the Hungarian questionnaire, researchers mentioned instead College for Advanced Studies (so-called: Szakkollégium) and Mobile learning (using laptops, smartphones in education). The analysis of the results of the whole sample is given without these two variables. However, the results of the two different variables will be mentioned separately by the nationalities.

Table 2
Effectiveness of methods and activities – whole sample

lectures	online courses	practi-cal lessons	labora-tory works	individual work	projects	intern-ship, dual training	exami-nations
6.59	6.06	7.29	7.18	7.11	7.33	7.54	6.11

According to all students' opinions, internship, dual training (7.54), and practical lessons (7.29) are consideredthe most effective learning activities; while examinations (6.11) and online courses (6.06) the least effective ones. As the research was conducted among engineer students, their opinions present that they prefer the practical parts of their training and suppose them the most significant and effective ones. On the other hand, the traditional teaching-learning activity, examination, was thought to be not really effective. However, it must be mentioned that online courses, which are considered an up-to-date method, are assessed the least effective. In the background of the low score, the reason can be that students connected online courses with theoretical subjects, and they believe that practical elements are much more important for their future career.

Comparing the Hungarian and Russian results, there are some differences, they are not significant, though. Hungarian students regard the practical part of the training (practical lessons and laboratory works) as more effective, while Russian students prefer projects and individual work. On the other hand, Hungarian students think examinations and online courses more effective than Russian ones. Moreover, online courses are believed by Russian students to be the least effective of the seven factors. This result is a bit surprising as online courses are rather frequently used in the Russian university: the frequency score is 3.53 on the four-grade scale – the second highest score out of the listed 9 variables (Figure 1). It means that although online course education is often used by the Russian university, it is considered not really effective by students.

As far as the two different variables are concerned, the Russain questionnaire contained master classes and business games. They were evaluated by students medium effective and received scores 6.70, 6.89. Hungarian students evaluated the variables of College for Advanced Studies and Mobile learning. According to their opinion, these activities are thought to be the least effective out of the ten ones: mobile devices: 6.11, college for advanced studies 5.79. Regarding mobile learning, the result is not surprising: activities that can be linked to mobile learning (e-learning and gamification) is not frequently used in the teaching process. Students do not have enough experience with these techniques so they do not evaluate their effectiveness high. However, colleges for advanced studies are in practice at the Hungarian university, especially in the fields of engineering and IT. The problem might be that only a few students are involved in their work and the majority do not realize its effectiveness in the learning process.

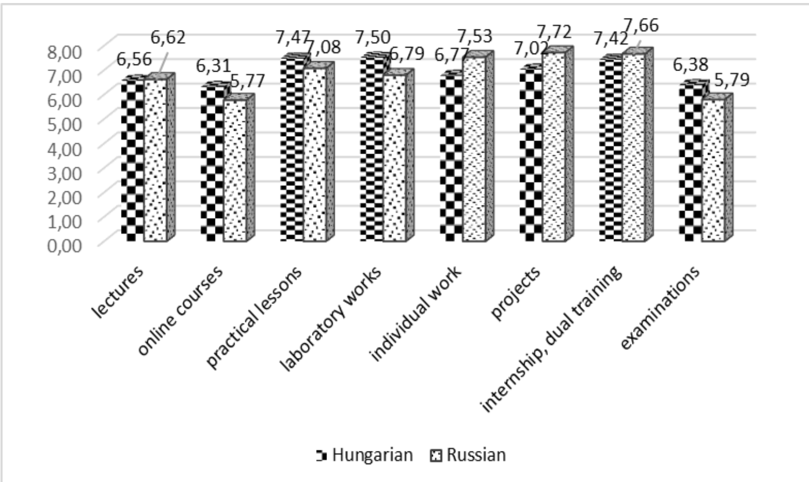

Figure 2

Effectiveness of activities – comparison of Hungarian and Russian data

Even the bar chart (Figure 2) shows that there are small differences between the evaluation of Hungarian and Russian students. Comparing the result with a crosstable, the chi-square test indicated that there is no significant difference between the two sub-samples.

The data implies that Hungarian students appreciate the practical parts of their training: practical lessons, laboratory work, internships. Examining the result of method and activity effectiveness, especially the proportion of students who assessed effectiveness very high (i.e.: gave 8, 9, or 10 points), the tendency is clear. Table 3 represents the summarized percentage of the highest three categories.

According to the result, Hungarian students considered that the most effective activities are practical lessons, work in the laboratory, and internships or dual training. Comparing these data with the means of the ten-grade scale question, similar opinions can be recognized; the same three variables show the highest mean: practical lessons (7.47), laboratory works (7.5), and internships and dual training (7.42). Comparing these results with the factors influencing the quality of the training, Hungarian students emphasized the significance of the practice, too. The factors that are evaluated very important by most students are the opportunity of professional development during internships, connection of the knowledge gained with the real work in the profession, and technology base of the university, availability of modern equipment in laboratories and classrooms. All these results indicate that Hungarian students find the practical elements of the training the most significant and the most influential in the quality of the training and the most effective in their professional development.

Table 3

Effectiveness of activities by Hungarian students – highest three categories summarized (%)

lectures	online courses	practical lessons	laboratory works	college for adv. stud.	mobile learning	individual work	projects	dual training	exami-nations
4.7	36.0	60.9	62.2	28.1	32.8	40.6	45.2	50.0	34.3

However, they do not assess the importance and the influence of modern methods and activities very high. The variables of the availability of e-learning and online courses, that of MOOCs, and the opportunity of academic mobility of students were considered not very important. Parallel with this, they neither evaluate the effectiveness of online courses and mobile learning very high. It means that Hungarian students adhere to the good-old, well-known practical training.

Conclusion

Today's generation of students is techno-savvy: they are significantly adaptable to innovation trends and immediately use emerging and up-to-date technologies, as well as info-communication devices both in their studies and work. They prefer audio-visual materials and consider learning more effective with sharing information through video format content. Regarding teachers, they have to face the challenge to meet the needs of the digital generation through applying new technology, implementing it into the teaching-learning process, and so, changing teaching methodology. There are many modern technologies are available for teachers, especially in higher education. [45]

The results of the research show some contradiction with the expectations. Students, especially the Hungarian ones, prefer the practical elements in their training: they declared that the factors most affecting the quality of their training are closely related to laboratory work, internship, and labor market expectations.

On the other hand, the availability of e-learning and access to MOOC are considered to be much less significant. Regarding the methods used by the teachers, students evaluated the most effective the ones that are in connection with practice: internship and practical lesson – while the least effective online courses. What is more, online courses are assumed less effective them lectures and examination – the good-old teaching methods, which have been existed in higher education for centuries.

This contradiction draws the focus on some problems and makes researchers ask some questions – which, of course, needs further examination. Do teachers apply the digital methodology in their lessons or they think it is time-consuming and nothing but having fun with students? Do online courses that are available for the majority of students meet the needs of today's students using 21st-Century technology and providing a platform for interactivity and collaboration? Researchers assume that professors of engineer faculties would need training focusing on the application of up-to-date technology, as well as teaching methods and work forms.

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