Conceptual model of learning based on the combined capabilities of augmented and virtual reality technologies with adaptive learning systems

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Abstract. The article is devoted to actual problem of using modern ICT tools to increase the level of efficiency of the educational process. The current state and relevance of the use of augmented reality (AR) and virtual reality (VR) technologies as an appropriate means of improving the educational process are considered. In particular, attention is paid to the potential of the combined capabilities of AR and VR technologies with adaptive learning systems. Insufficient elaboration of cross-use opportunities for achieving of efficiency of the educational process in state-of-the-art research has been identified. Based on analysis of latest publications and experience of using of augmented and virtual reality technologies, as well as the concept of adaptive learning, conceptual model of learning based on the combined capabilities of AR and VR technologies with adaptive learning systems has been designed. The use of VR and AR technologies as a special information environment is justified, which is applied in accordance with the identified dominant type of students' thinking. The prospects of using the proposed model in training process at educational institutions for the implementation and support of new teaching and learning strategies, as well as improving learning outcomes are determined by the example of such courses as “Algorithms and data structures”, “Computer graphics and three-dimensional modeling”, “Circuit Engineering”, “Computer Architecture”.

Keywords: adaptive learning systems, augmented reality, virtual reality, individual learning approach, individual learning path, educational modeling.

1 Introduction

1.1 Problem statement

The modern world is causing changes not only in the fields of economics and technology, as well as changes in the level of future students prior training, their needs and expectations. As a result, the education strategy is changing too. Virtual and augmented reality (VR and AR) technologies are the means of a fundamentally new level of human interaction with the digital world, which are playing an increasing role in the global economy, politics, social relations etc. The symbolic information world offers a wide range of ready-made patterns and styles of behavior that people choose and try to implement in their daily lives. Today, these samples are represented primarily by computer VR, virtual (computer) symbolic world, which provides the subjects of information space different motivational, cognitive, communicative, operational, creative, spiritual opportunities [63, p. 25]. VR and AR technologies have got the most serious development in the entertainment markets. This is not the limit, but only the first stage of their implementation. Products based on VR and AR technologies are promising in terms of economic effect in the fields of industry, health care, consumer services, and education. The variety of companies and institutions of higher education implementing AR and VR technologies testifies to the prospects of this technology. In particular, the Japan Online School VR was recently opened in Japan by the private institute Meisei High School [22]. Learning with AR and VR technologies could be considered a new way of knowledge transfer that corresponds to a qualitatively new content of learning and personal development of students, stimulates innovative aspects of teachers' activity and creates preconditions for the implementing new approaches to learning and improving education. AR and VR technologies are a new way of presenting information, making it much more visual and attractive. Their use helps to increase students' motivation in learning process through clarity, information completeness, interactivity and gamification of education [7].

1.2 Literature review

Some issues of design, development and application of educational software and simulators based on AR and VR technologies are considered in a number of scientific works, namely: the potential of AR to transform the educational process into smart learning [26]; development of augmented reality software for educational purposes in [2; 21; 24; 38; 61]; the use of virtual reality for learning [1; 28; 32; 42; 69]; application of augmented reality technologies for the professional training [23; 36; 49; 58; 71]; use of computer simulations and games in engineering education [3; 14; 35; 44; 48; 52; 67; 66]; application of virtual reality in foreign language teaching at higher educational institutions [59]; development an augmented reality simulator for studying algorithms [27]; features of the use of the virtual environment for the training of specialists in information technology [5; 45; 53; 57].

Application of adaptive learning systems is examined by a lot of researchers. In particular, the objects of these explorations are prospects of the implementation of

blended learning in higher education [4; 20; 43]; use of intelligent systems in teaching [6; 15; 18; 29; 37]; principles of adaptive learning [33; 39; 41; 64; 65]; adaptive testing systems [46; 47; 54]; neural technologies for individualization of learning [16; 34; 62; 68], etc.

Review of research on the combined use of AR and VR technologies with adaptive learning systems lets us to notice some works devoted to the current state and new opportunities of adaptive learning in virtual reality [70]; improving massive open online course through augmented reality, adaptive learning and gamification [9]; design implications for adaptive augmented reality based on interactive learning environment for improved concept comprehension in engineering paradigms [25].

However, combined capabilities of AR and VR technologies with adaptive learning systems has not been thoroughly considered.

The aim of the article is design of a learning model based on combination of capabilities of adaptive learning systems and AR and VR technologies.

2 Research results

2.1 Learning model based on combination of capabilities of adaptive learning systems and virtual/augmented reality technologies

New orientations and values of modern education necessitate the understanding student as unique individual with his/her own individual learning needs. Therefore, educational content presented to students should be adapted to their personal skills and needs, as well as be interactive and dynamic. However, in recent years, distance e-courses are aimed at the simultaneous learning of a large number of students [60]. Therefore, significant heterogeneity of students' educational outcomes is noticed. This fact necessitates research in the field of individualized learning and improving of distance education.

We will focus on improving e-learning through the combining capabilities of AR and VR technologies and adaptive learning systems. These means have recently been adopted in various learning models and have shown a significant impact on students' learning experiences.

For our study, we chose AR and VR technologies because according with up-to-date research they make educational content more interactive, individualized, and motivating. AR and VR technologies provide interaction with real and virtual objects. Such content visualization keeps students active during the learning, as it increases their ability to understand and process information, as well as adds elements of gamification to learning environment. This is a prerequisite for internal motivation of students to study the material and do tasks, and for getting success.

Adaptive learning systems provide a wide range of tools for individualized training. Therefore, it necessitates development of measures to make learning experience of all participants more successful and to meet the diverse educational needs of students.

Using the combined capabilities of adaptive learning systems and AR and VR technologies, in our opinion, will provide the best results, because taking into account individual psychological and cognitive characteristics of students effects on their

awareness and understanding of educational material. Flexible settings of testing tools provided in adaptive learning systems make possible to identify the psychological characteristics of the cognitive structure of personality for the best selection of educational content at the initial stage.

According to the Fleming's VARKH model the learning process is based on student interaction with educational content [17, p. 137]. It offers to classify students by main channel of perception of educational information:

- visual learners perceive the main part of the educational material by eyes. For this psychotype, it is advisable to get information through visual images. Such students need to see them to make it easier to remember or analyze;
- aural learners perceive information through sounds preferably, for example through audio lectures. Such students should listen to educational content or sound it for better memorization and assimilation;
- read-write learners prefer information presented in the form of words, text. These students should read and write educational content by different means;
- kinesthetic learners perceive educational material on a perception basis and tend to apply their knowledge.

Each category of students has its own preferable method of receiving and processing educational content [51]. So, design of individualized educational content should take into account the preferred channel of obtaining information and the dominant type of thinking of students. Conservative methods of content delivery (fixed video, audio, scripts) are not personalized and interactive, so advanced teaching methods are to be implemented to provide a more interesting experience for students. Based on the classification above, it can be considered that students who have visual or kinesthetic channel of obtaining information will best experience the educational material organized with the technology of AR and VR. So, it is desirable to deliver them educational content by simulators using AR and VR technologies.

The use of combined capabilities of adaptive learning systems and AR and VR technologies will provide the most adapted and individualized educational content to the student.

We offer a graphical representation of the model illustrating the combined capabilities of these methods in the learning scenario to create interactive, individualized and more interesting content (fig. 1).

Learning process based on using AR and VR technologies to deliver educational content has excellent opportunities to be gamified, in particular through awards and distinctions that motivate students. The game method, applied in learning environment created by means of augmented or virtual reality technologies, is a full life cycle of the educational process, which transforms and improves students' learning experience.

Curricula created using AR and VR technologies have a high potential for stimulating influence on the process and operational characteristics of students' thinking, creativity, the formation of specific cognitive motivation and interest in learning, creating positive, harmonious mental states. The developmental effect of AR and VR technologies is determined by three-dimensional objects, images of

recognizable objects, a wide range of actions with objects, the effect of presence, interactivity, visualization of abstract models and more.

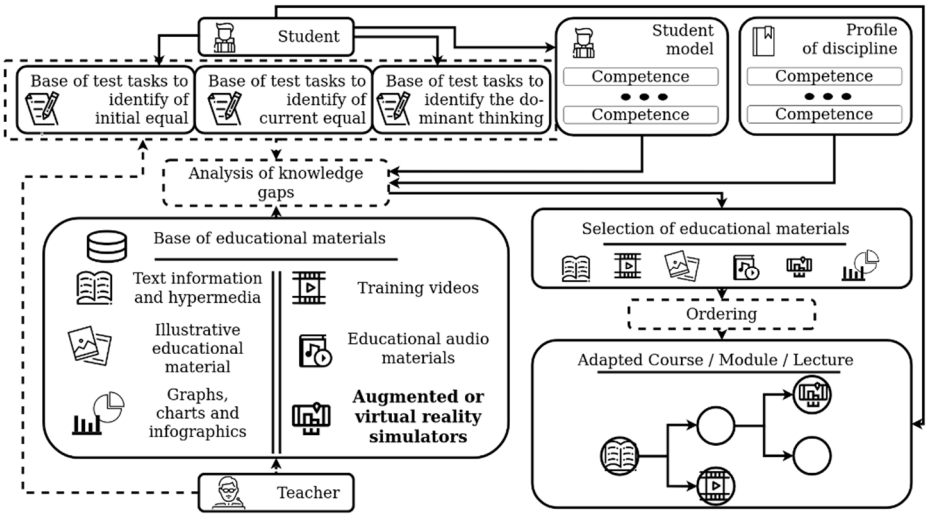

Fig. 1. Conceptual model of learning based on the combined capabilities of augmented and virtual reality technologies with adaptive learning systems.

2.2 Opportunities and perspectives of virtual and augmented reality technologies

At the present stage, augmented reality technologies affect the organization of learning, enrich tools and methods, expand didactic opportunities. Setting virtual objects in a specific environment allows to simulate unusual educational practices, get new ways to explore objects and related space, ensure better interaction. At the same time, augmented reality technologies are still an "exotic" tool for educational and methodological support of disciplines [19]. This is largely due to the limitations and features of human-computer interaction through the screen and graphical user interface. Learning is always more effective when there is interest in the subject and the process of cognition. This causes the desire of teachers to use elements of augmented reality for student training activities.

The latest research proves the effectiveness of implementing AR and VR technologies in the educational process. For example, Cerevrum Inc. [8] conducted an experiment in which 153 recipients took part: students aged 15-17 and their relatives. The study was carried out physics lesson in virtual reality. A test was conducted to check the remaining knowledge. Participants were also asked to evaluate the effectiveness of using virtual reality as a learning environment. According to the results of the study, 91.5% of participants passed the test successfully, and 97.4% of them reacted to using this technology in the educational process positively.

Examples of successful use of augmented reality in training are provided by the ideal partner Coimbra and Mateus [12], Shirazi and Behzadan [55], and others. In particular:

- insertion additional information to the educational content (compressed biographies, historical facts, photos from places of events, visual 2D and 3D models, etc.), that makes the animated content interesting and modern, contributes to a deeper understanding of the subject;
- support of tasks and educational text with teachers' methodological recommendations: students can scan certain elements of the book and receive text, audio/video advice or useful information about the schedule of studying the topic, control tests, ways to communicate with other students for discussion of training issues;
- visualization of complex objects in a 3D model with the ability to interact (setting transparency, color scheme, style) facilitates the perception of abstract information and understanding of the text (mathematics, physics, chemistry, drawings, technical science, etc.);
- addition of educational content with “teasers” (puzzles), problem or game task that helps to activate attention, develop intellectual abilities, stimulate positive emotions and interest in learning activities.

2.3 Combining virtual and augmented reality technologies with adaptive learning systems in Computer Science courses

AR and VR technologies are widespread in many education areas. However, in the process of teaching computer science, they are used rarely [11; 30; 40; 56]. Visualization of personal computer components (chipset, motherboard and other components) is mostly used in “Computer Architecture” course [13; 50]. Another approach is the use of videos, links, texts tied to labels.

In some educational institutions it is possible to study computer components on physical examples or specialized stands. However, this possibility is not everywhere, and in the case of distance learning, the student may not have such an opportunity at all, because not everyone has a motherboard or video card unnecessary, old or non-working. In such cases, it is advisable to use the simulator for clarity and visualization of the research topic. An example of the interactive manual for studying personal computer architecture by means of augmented reality is shown below (authors: E. Medvedev, master's degree student, 2 year of study, specialty 122 Computer Science and A. Marinov, master's degree student, 1 year of study, specialty 015.10 Professional education (Computer technology); scientific supervisor V. S. Kruhlyk) [31] (fig. 2).

The “Circuit Engineering” course can be supported by means of AR and VR technologies also. Simulators based on augmented or virtual reality technologies can help to design, create and configure electronic circuits.

It should be noticed that art professions have also migrated to the virtual environment. A lot of artists have chosen the path of XR art. For example, Liz Edwards, a designer from Montreal, Australian artist Stuart Campbell, known by the pseudonym Sutu. Exploring the relocation of contemporary artists to a virtual environment, it is

worth noting the experience of Giovanni Nakpil, Art Director at Oculus VR, who teaches sculpting at the Online tutorial resource mold3D Academy. Based on his experience, it is possible to reorganize the process of studying the disciplines of “Computer Graphics” and “Three-dimensional modeling” [10] also in the direction of virtualization.

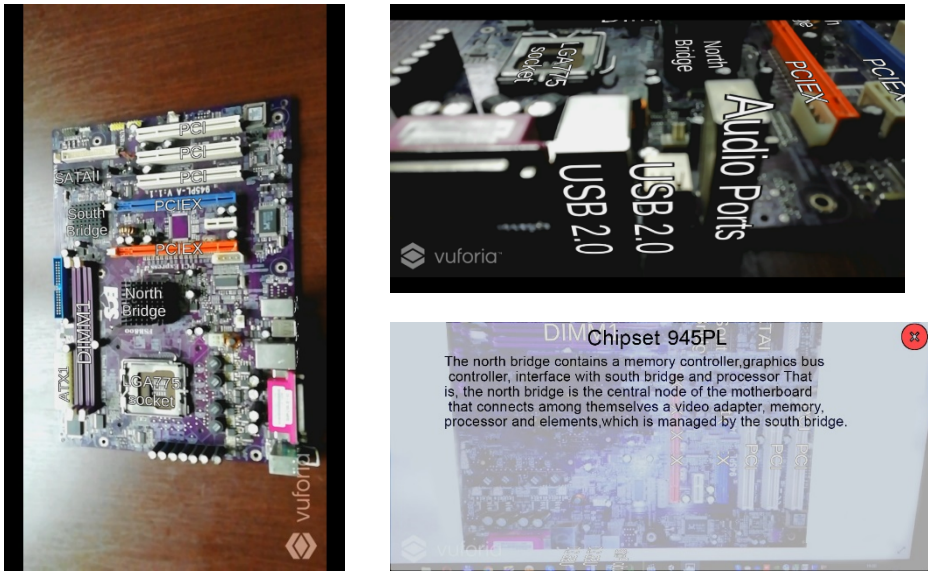

Fig. 2. Interactive manual for studying personal computer architecture.

It is appropriate to use virtual and augmented reality technologies for training students in “Algorithms and data structures” [53]. Augmented reality technologies could significantly improve students' knowledge, for example through visualization of sorting algorithms, such as bubble sorting. Visual maintenance of sorting process and using of simulator with augmented or virtual reality increase students' interest in this topic.

Let us give more detailed review of using adaptive learning in combination with AR and VR technologies on the example of studying the topic “Sorting algorithms” in “Algorithms and data structures” course. As a result of mastering this topic, students should have knowledge of sorting algorithms, such as bubble sorting, permutation sorting, insert sorting, and others, as well as skill to use them in professional activity. For example, student already has an idea about bubble sorting algorithm. This information was obtained from the student model as a result of testing previous knowledge, or was recorded as a successfully acquired skill from the previous course. So, it should not be taught again. Another part of information obtained from the student model is that the preferable channel of information perception is kinesthetic. Taking this into account, it is appropriate to choose educational content based on augmented reality, where student gives an opportunity to explore the principles of insert sorting and permutation sorting through simulation. Using student model allows to provide tasks and materials that are the best for perception. Gamification of training process

decreases risk of student's disappointing in case of a failed attempt to reproduce examined algorithm. Student can be provided with additional video information of how such algorithms are implemented. After watching the video, the optimization component sets the student to the initial situation in the simulator. The user can now be succeeded in completion of learning task. Student model is updated according to results obtained during all of activities. It allows to ensure the optimization of the overall learning experience.

3 Conclusion

Based on the results of the research, an approach to creating an adaptive learning environment in the context of virtual reality is presented. It is founded on taking into account the goals, preferences, knowledge and dominant type of thinking of each individual student. The use of AR and VR technologies in conjunction with the capabilities of adaptive learning systems provides the best conditions for individualization of learning. As a result, it provides a better quality of educational process. Visualization is one of the key features of the proposed learning model based on the combined capabilities of the adaptive learning system and virtual and augmented reality technologies.

Prospects for further research are seen in the development of educational and methodological materials and improving the content of educational and methodological complexes for using the combined capabilities of adaptive learning systems and virtual and augmented reality technologies in the educational process.

Funding. This research was funded by a grant from the Ministry of Education and Science of Ukraine (state registration number 0120U101970).

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