Technologies of Virtual and Augmented Reality for High Education and Secondary School

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Abstract. Every year there are new technologies used in the education of the younger generation. The introduction of mobile and portable devices in the educational process helps to improve the quality of educational materials by software. It complements or expands the content of textbooks and workbooks. The main trend in software development of educational purposes is the system of virtual and augmented reality.

VR and AR-technologies provide an opportunity to interact with various branches of science, ranging from virtual excursions and object studies to experiments in Physics, Biology, Chemistry, Astronomy, etc. Virtual and augmented realities are unique learning environments in various fields of science reproducing virtual models in details.

There are ready-made products designed for use in specific subject areas. Most software for learning in virtual and augmented reality have English language interface, so it's a need to develop educational software for Ukrainian-speaking students and pupils.

Keywords: Virtual reality, Augmented reality, IT, ICT, technology, mobile application, secondary school.

1 Introduction

The improvement of teaching methods and the introduction of information technologies in education are priorities for today. In order to modernize the education system and popularize science, in recent years, virtual and augmented reality technologies (VR, AR) are actively used and researched in teaching. The development and research of these technologies began in the 1950s, but the heyday of VR and AR technologies has become the last decades.

Augmented reality (**AR**) is an interactive experience of a real-world environment where the objects that reside in the real-world are "augmented" by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory [1].

The primary value of augmented reality is that it brings components of the digital world into a person's perception of the real world, and does so not as a simple display of data, but through the integration of immersive sensations that are perceived as natural parts of an environment.

Virtual reality (VR) is a popular information technology (IT) area that provides an indirect experience by creating a virtual space that interacts with the human sensory systems and overcomes spatial and physical constraints of the real world (Electronics and Telecommunications Research Institute (ETRI), 2001).

VR technology can be categorized as follows: expression technology for stimulating human sensory systems, interaction technology for interfacing reality with VR, authoring technology for developing VR content, and collaboration technology that networks multiple participants within VR (ETRI, 2001) [2].

Using objects of these technologies allows the teacher to quickly and affordably to explain a large amount of theoretical material, and students to learn effectively it develops in them a creative thinking and enhances the motivation to learn.

Scientists, teachers and students are actively engaged in technology research and concepts of virtual reality in Ukraine and abroad.

Ukrainian authors Iryna Melnyk, Nadezhda Zaderey and Galina Nefyodova in their work "Augmented Reality and Virtual Reality as the Resources of Students' Educational Activity" [3] describe not only the importance of virtual and augmented reality technologies, but also reveal the concept of unified reality (merged reality, MR), in which the boundaries between augmented, virtual and physical worlds are erased. Experts of the research division of Ericsson ConsumerLab, studied the influence of AR and VR technologies on the habits and preferences of users and were the first to come to this conclusion. In work [4], the author describes the process of using virtual reality with new opportunities in learning and education.

From the works of foreign scientists, we identified two of the most interesting – "Virtual reality: A brief survey" by scientists from India Namrata Singh and Sarvpal Singh, which was published in 2017 by "International Conference on Information Communication and Embedded Systems (ICICES)" [5] and "The Reality of Virtual Reality" (by Myeung-Sook Yoh) [6]. In these works, the authors explore the concept of virtual reality, its history and set out the ontological difference between virtuality, possibility and actuality. This makes it possible to understand the essence of virtual reality in various aspects of its use.

The offered model of the training system was tested in the classrooms of schoolchildren in the learning process at the STEM school established at Kherson State University in 2017. The "Experience of STEM-School" article (written by Nataliya Kushnir, Nataliya Valko, Nataliya Osipova, Tatiana Bazanova) [7] was written and published about the STEM school by teachers and students of the CDU; place in the educational system.

2 Description of the learning system model using VR and AR

Describe the definitions of basic concepts. By **the learning system with using VR and AR**, we understand an ordered set of interrelated elements of electronic educational resources, forms and means of planning and conducting, monitoring, analyzing,

correcting the educational process, aimed at improving the efficiency of student learning [8].

The term **"trigger image"** will be understood as any image on the pages of an electronic textbook that has the properties of a trigger for a mobile application and allows displaying elements of augmented reality on the device.

A virtual object is a 3D object that is displayed and used in a mobile application for demonstration in AR.

In **the learning system using VR and AR**, we use the following forms adapted for distance learning using information and communication technologies, namely:

- lectures;
- training manual;
- laboratory works;
- testing;
- lecture videos;
- practical tasks;
- glossary;
- presentations.

A model of this system is shown in Fig. 4.

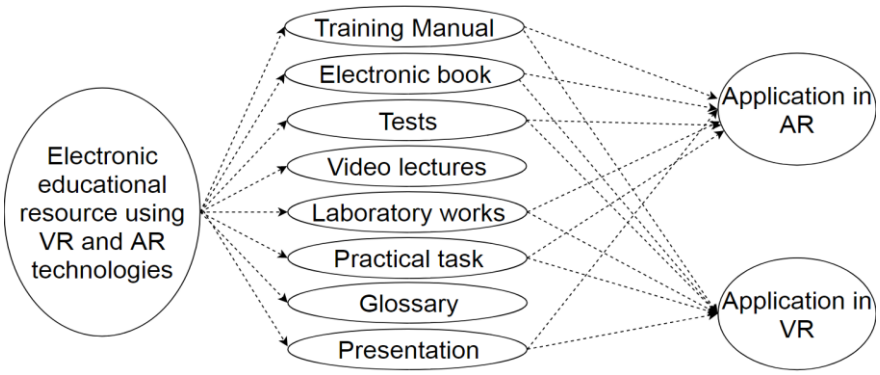

Fig. 1. Model of a learning system using VR and AR.

A training manual is a book or booklet of instructions, designed to improve the quality of a performed task. An electronic book, also known as an e-book or eBook, is a book publication made available in digital form, consisting of text, images, or both, readable on the flat-panel display of computers or other electronic devices. A test is an assessment intended to measure a test-taker's knowledge, skill. A test may be administered on a computer that requires a test taker to demonstrate or perform a set of skills. A video lesson or lecture is a video which presents educational material for a topic which is to be learned. Laboratory and Work and Practical task - one of the forms of independent practical work for students in higher, specialized secondary, and general schools. A glossary, also known as a vocabulary or clavis, is an alphabetical list of terms in a particular domain of knowledge with the definitions for those terms.

Presentation is a document or set of documents intended to represent the subject under study. The presentation can be a combination of text, hypertext links, computer animation, graphics, video, music, which are organized in a single environment.

Before creating a learning system using VR and AR, a scenario plan is required, which should include the following components:

- name of e-learning resources: e-learning resource using VR and AR technologies;
- class e-learning resources: Multimedia electronic educational resource;
- a brief description of the content of the e-learning resources: This learning system using VR and AR is designed to teach students in grades 5-7 to the basics of robotics;
- number of elements and their description: This learning system using VR and AR consists of the following elements - an electronic textbook, an electronic manual, tests, multimedia technology, a VR application, an AR application;
- list of tools used: This system is planned to be developed by means of Moodle, additional applications for VR and AR are developed by means of Unity3D, Vuforia and Autodesk 3ds Max;
- presence of interactivity and multimedia: This system contains multimedia and interactive elements - tests, videos, simulators;
- description of the user interaction with the content: User interaction is carried out through data exchange with the system server (the User can download the necessary resources and also enter data during the test);
- indication of the software required to work with the e-learning resource: Windows Vista and above, dual-core processor with a frequency of 3 GHz, 2 GB of RAM (4 GB for Windows Vista and above);

When creating an e-learning resource, the following tools are used:

- Simple means of publishing ESM, based on the use of applications Adobe Acrobat and Microsoft Office (Word, Excel, PowerPoint), as they are most convenient when creating and publishing electronic textbooks and guidelines for them.
- Adobe Flash and Adobe Animate CC are used to develop animation within the framework of ESM.
- To create VR and AR applications, multimedia technologies (3ds Max, Unity 3D, C #, JavaScript, Vuforia) are used.
- When designing the program, UML modeling tools are used (www.draw.io).

3 Technologies of Virtual and Augmented Reality in model of educational system

Let us consider in more detail the use of VR [9] and AR [10-12] technology on the example of systems for demonstrating the progress of laboratory work.

- **The system for demonstrating the progress of laboratory work in virtual reality** consists of the following elements: a VR helmet, a mobile device, an application for demonstrating the progress of laboratory work (Fig. 2).

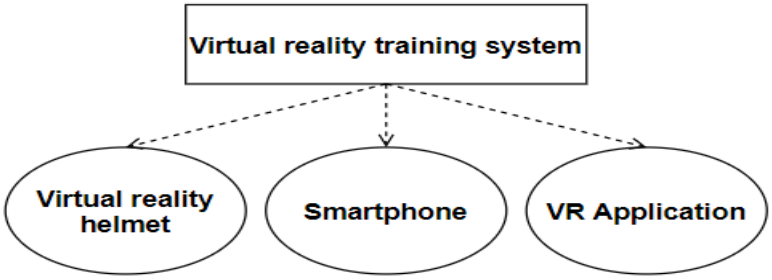

Fig. 2. Components of the virtual reality training system

Head-mounted display - a device that allows you to partially immerse yourself in the world of virtual reality, creating a visual and acoustic effect of being in a given control device (computer / smartphone) space. It is a design worn on the head, equipped with a video screen and a speaker system or a special connector for a smartphone.

The smartphone is a mobile phone, complemented by the functionality of a pocket personal computer.

VR Application is an interactive smartphone application with virtual reality glasses.

- **The system for demonstrating elements from laboratory works in AR** consists of the following elements: a textbook, a trigger image, a mobile device with a camera, an application for the demonstration of elements from laboratory works in augmented reality (Fig. 3).

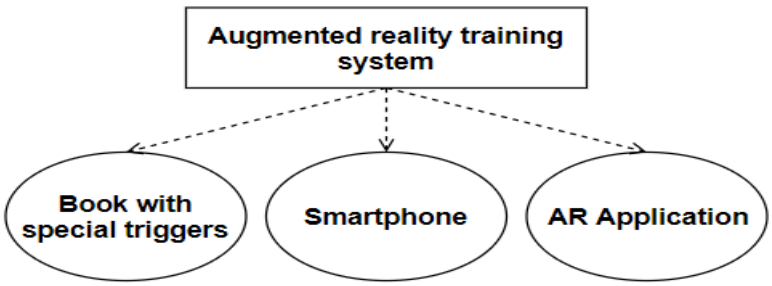

Fig. 3. Components of the augmented reality training system.

4 Software modeling and design (UML diagrams)

The application for learning using augmented reality consists of the following components:

- “Help” (instructions for this application),
- “Exit” (exit from the application),
- “View object” (the camera screen for trigger scanning appears).

The diagram of use cases for augmented reality training application is shown in Fig. 4.

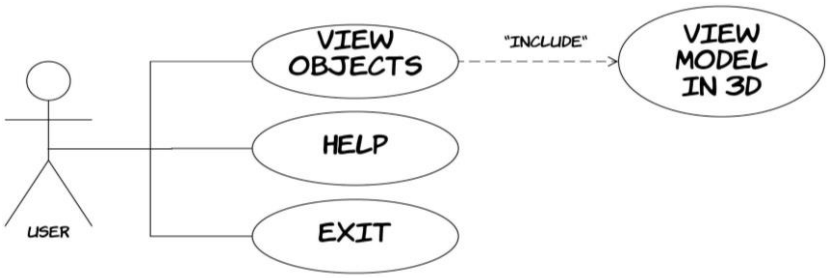

Fig. 4. Use case diagram for AR application.

The virtual reality training application consists of the following components:

- “help” (instructions for this application),
- “exit” (exit from the application),
- “levels” (opens the screen to select the level of the game),
- “level” (opens the selected level).

The diagram of use cases for the virtual reality training application is shown in Fig.5.

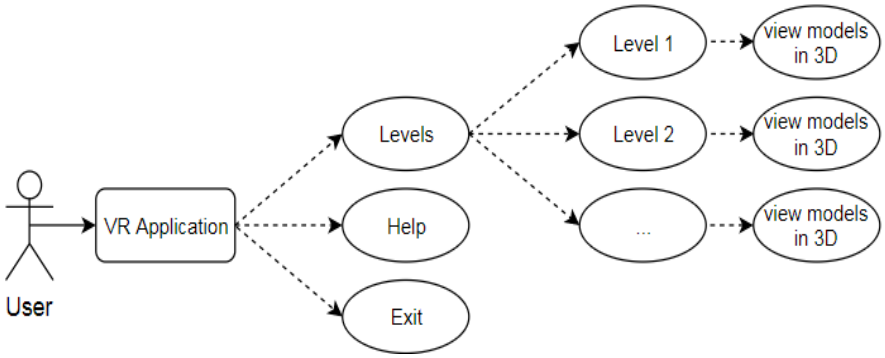

Fig. 5. Use case diagram for VR application.

The sequences of user actions when working with the application for learning augmented reality and virtual reality are shown in Fig. 6.

An example of designing classes in the development of virtual and augmented reality applications is shown in Fig.7.

5 An example of using a learning system using VR and AR

Let us consider in more detail the process of modeling and designing VR and AR learning objects on the example of the system of laboratory work used at the STEM School of Kherson State University.

When developing a system, the book “Quick start. The first steps in mastering the Arduino. ” - Publisher: Makskit, 2015, 80 c. To use the AR and VR environments, the student needs to install two corresponding applications on his smartphone.

When application for AR launched, the student gets to the main menu of the program:

- By clicking on the “help” button you can find out the instructions for this application.
- By clicking on the “exit” button will close the application.
- By clicking on the “view object” button, the camera screen appears.

After the camera screen appears, you must aim the camera lens on the page with the task. The program recognizes the image trigger. Each trigger is unique. He links the 3D image and page of the book with the corresponding task. As a result, a moving 3D object will appear on the screen against the background of the corresponding page of the book.

When application for VR launched, the student also gets to the main menu of the program:

- By clicking on the “help” button you can find out the instructions for this application.
- By clicking on the “exit” button, it will close the application.
- By clicking on the “levels” button, a screen appears to select the level of the game that corresponds to the lab number.
- By clicking on the “level 1” button, the user is inside the virtual space, organized according to the requirements put forward to conduct this virtual laboratory work.

After the user opens a certain level, he has the opportunity to study in detail all the game 3D objects in virtual reality, their approximation and manipulation with them. Since the inclusion of a certain level of the program is in standby mode, user actions. At the moment of performing a certain action with objects, the user in the background sees clues to what is happening in front of him.

The model of the laboratory work consists of the following objects:

1. Room (4 walls, floor, ceiling);
2. Interior items (lamp, table, chair, window);
3. A set for demonstration of laboratory works (Arduino microcontroller, breadboard, wire, resistor, LED, button, buzzer);
4. Interface elements of the application.

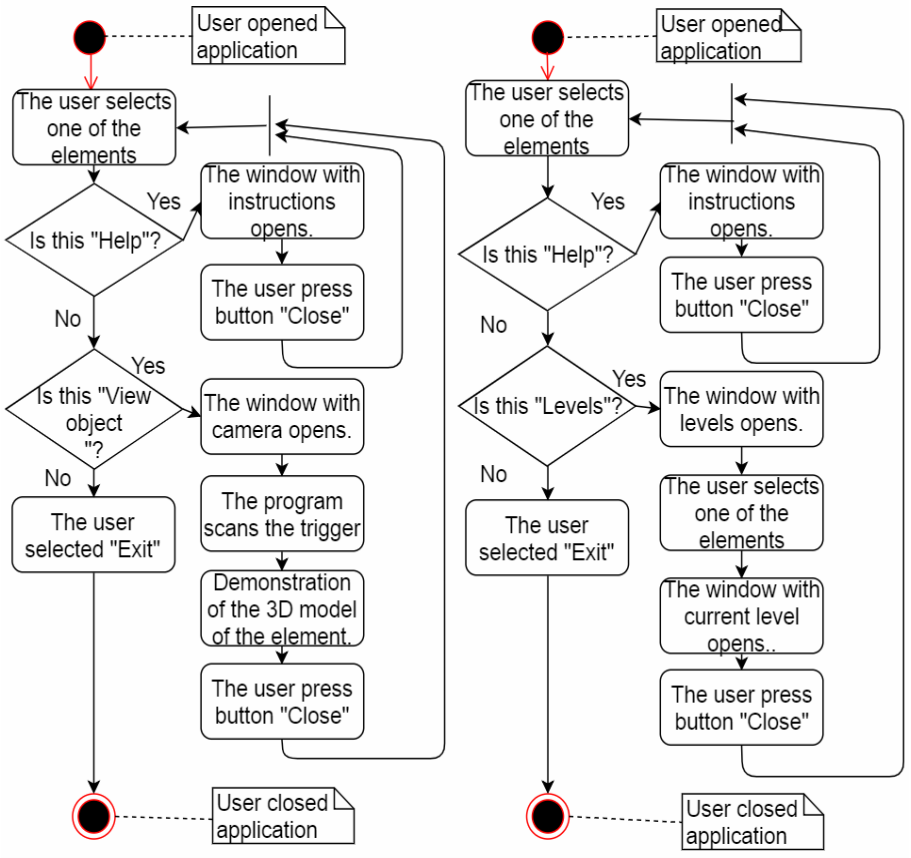

Fig. 6. a) Activity diagram for AR application; b) Activity diagram for VR application.

For a better understanding of the technical characteristics inherent in the objects used in this model, consider the description of meta-objects, objects in the real world and objects used in laboratory work.

Let us give an example of the description of the characteristics of meta-objects used in laboratory work in virtual and augmented reality:

Arduino microcontroller: length, width, weight, operating voltage, input voltage, number of digital outputs, number of analog outputs, maximum output load current, size of program memory, size of data memory, size of nonvolatile memory, clock frequency, availability of Ethernet controller , the availability of data storage devices, materials;

Development board: length, width, height, number of points, distance between points, manufacturer, materials;

LED: length, diameter, glow color, glow angle, voltage, current consumption, manufacturer, materials;

Here is a description of the characteristics of objects used in laboratory work in virtual and augmented reality:

- Arduino microcontroller: length, width, height.
- Development board: length, width, height;
- LED: length, width, height;

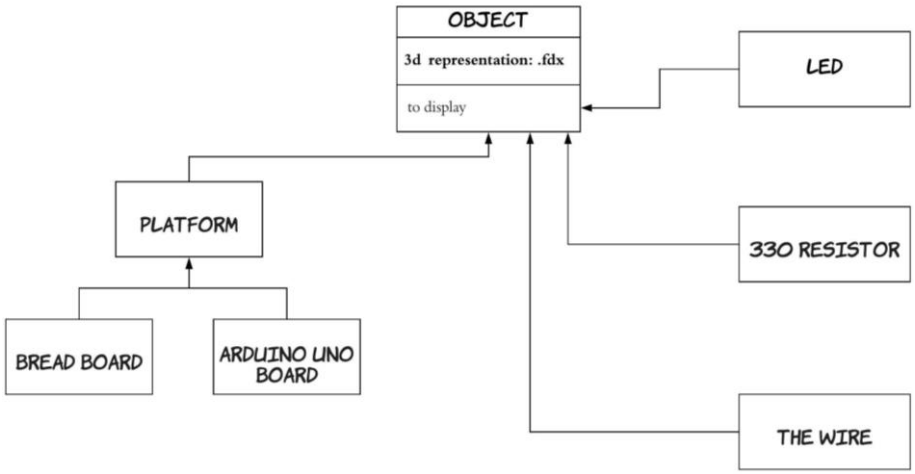

Fig. 7. Class diagram for VR and AR application.

The interaction of objects occurs after the user clicks on certain control buttons that trigger the trigger set on the interaction between objects.

Consider the interaction between objects on the example of laboratory work №1 "Connecting the LED". A fragment of the interaction of objects in the laboratory work is as follows. After pressing the button of the subsequent action, the "LED" object is connected to the "prototyping board" object, then the application is in the standby mode of the subsequent pressing of the button of the subsequent action. Also, the user can personally perform actions with objects by rotating and moving in space.

We conducted classes at STEM School using VR and AR. At the end of the lesson, the students passed a social survey on whether they would like to use VR and AR technologies in the classroom.

1. Do you know what VR and AR technologies are?
2. Do you want to use VR and AR technologies at school?
3. Do you have an experience of using VR and AR technologies?
4. What do you think, are VR and AR technologies interesting to use it on classes?
5. Have you used VR and AR technologies before?
6. Did you use VR and AR technologies in the classroom?
7. Do you want to study robotics using VR and AR technologies?

8. Do you think that the use of information and computer technology can make preparation for classes easier and allows teacher to diversify them?
9. Do you like to use the new technologies on classes?
10. What do you think - is it necessary to introduce the VR and AR technologies on robotics classes?

These 10 questions were asked to 34 pupils from STEM school. The research was conducted and showed next results on Diagram 1.

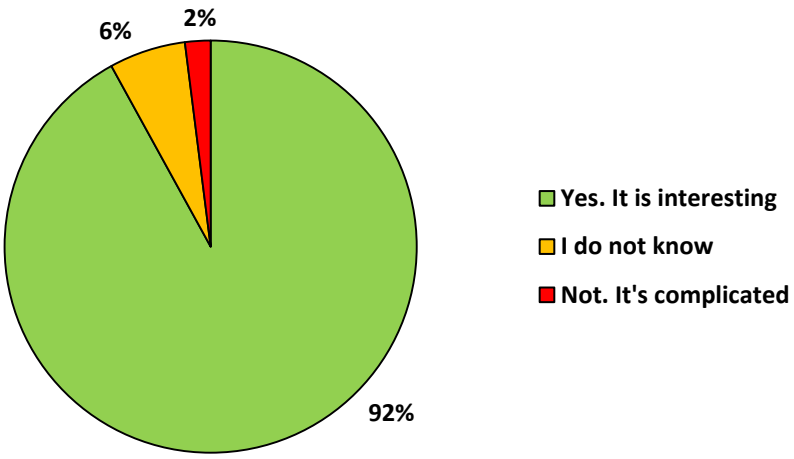

Diagram 1. Social survey at STEM-school.

6 Conclusion and future work

The improvement of teaching methods and the introduction of information technologies in education are priorities for today.

The research showed the active development of STEM education in Kherson State University and around the world.

The use of STEM, AR and VR technologies allows the teacher quickly and affordably explain a large amount of theoretical material, and students learn effectively. It develops creative thinking in them and increases motivation to study.

This direction is able to realize the need for engineering personnel and specialists in the field of information technology. In this regard, we proposed a model of a learning system using virtual and augmented reality technologies.

The direction is very promising in the system of higher and secondary education. Teachers and students can use this electronic resource both at school and university classes, and at home.

A survey conducted among STEM school students showed the willingness of students to work with virtual and augmented reality technologies.

The developed model should be used as a means to create a basis for future research, development and dissemination in the system of educational institutions.

The offered model of the training system was tested in the classrooms of schoolchildren in the learning process at the STEM school established at Kherson State University in 2017-2018.

In the future, we plan to introduce a system that uses virtual and augmented reality technologies into the STEM school educational process at Kherson State University.

References

1. Virtual reality. https://en.wikipedia.org/wiki/Virtual_reality
2. Sang Su Choi, Kiwook Jung and Sang Do Noh. Virtual reality applications in manufacturing industries: Past research, present findings, and future directions. (2015). Access mode: https://www.researchgate.net/publication/273514630_Virtual_reality_applications_in_manufacturing_industries_Past_research_present_findings_and_future_directions [accessed Mar 25 2019]
3. Iryna Melnyk, Nadia Zaderei, Galyna Nefodova. Augmented Reality and Virtual Reality as the Resources of Students' Educational Activity. Proceedings of Information technology and computer modelling (2018). Access mode: http://itcm.comp-sc.if.ua/2018/melnuk.pdf
4. Trach Yu.V. VR technology as a method and learning tool. Educational discourse. No 3-4, P. 309-322 (2017). Access mode: http://nbuv.gov.ua/UJRN/osdys_2017_3-4_26
5. Namrata Singh, Sarvpal Singh. Virtual reality: A brief survey. IEEE Xplore (2017). Access mode: https://ieeexplore.ieee.org/document/8070720
6. Myeung-Sook Yoh. The reality of virtual reality. IEEE Xplore (2002). Access mode: https://ieeexplore.ieee.org/document/969726
7. Nataliya Kushnir, Nataliya Valko, Nataliya Osipova, Tatiana Bazanova. Experience of Foundation STEM-School. Proceedings of the 14th International Conference on ICT in Education, Research and Industrial Applications. Integration, Harmonization and Knowledge Transfer. Volume II: Workshops. Kyiv, Ukraine, May 14-17 (2018)
8. Pietro Cipresso, Irene Alice Chicchi Giglioli, Mariano Alcañiz Raya, and Giuseppe Riva. The Past, Present, and Future of Virtual and Augmented Reality Research: A Network and Cluster Analysis of the Literature. Frontiers in Psychology (2018). Access mode: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6232426/
9. Stephen Khan. What is augmented reality, anyway? The Conversation (2018). Access mode: https://theconversation.com/what-is-augmented-reality-anyway-99827
10. Ole Baunbæk Jensen. Getting Started with Virtual Reality in Research. iMotions (2018). Access mode: https://imotions.com/blog/virtual-reality-research/
11. Jun He, Peng Han, Huan Liu, Shiying Men, Lu Ju, Pu Zhen, Ting Wang. The research and application of the augmented reality technology. IEEE Xplore (2018). Access mode: https://ieeexplore.ieee.org/document/8284781
12. Tony Liao. Future directions for mobile augmented reality research: Understanding relationships between augmented reality users, nonusers, content, devices, and industry. Mobile Media & Communication (2018). Access mode: https://journals.sagepub.com/doi/abs/10.1177/2050157918792438?journalCode=mmca