Augmented Reality Application to Support Visualization of Physics Experiments

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***Abstract*—Teaching physics is going through groundbreaking digital transformation. Teaching methodologies are quickly changing because of pandemic situation, which took place two thousand twenty and increased demand for digital practices of teaching physics with augmented reality. In article, I considered teaching methods in mobile application named «Physics Lab Augmented Reality", designed for using augmented reality based physics laboratory experiments and demonstrations on high school physics lessons. Application demonstrates augmented reality technologies with three dimensional graphics features and special effects. In addition, it shows unseen factors of physical phenomena such as waves and sounds. This application is developed at university with promoting development small forms of lab experiments in physics classes.**

***Keywords*—augmented reality; physics; education; pedagogy.**

I. Introduction

Because of television, computers, mobile phones and internet, students lost interest to process school learning. This situation inevitably leads to a deterioration in the quality of knowledge acquisition at high schools. To make schooling once again interesting at school, it is necessary to promote captivating entertainment during the learning process [1]. Development contemporary computer video processing allows teachers to operate the image view of the surrounding world on the screen, interacting with existing objects and adding new virtual 3D objects. This technology is known as Augmented Reality and is already widely used in computer games and advertising industry. In this case, the application of 3D technology to display augmented reality-based objects, allows students to enhance the effect of combining real and virtual reality based worlds and achieve total immersion student into the educational process. Appropriateness of augmented reality based augmented reality application many times mentioned by pedagogical researchers. Pedagogical research in the field of improving the efficiency of physics experiments shows that students are not able to achieve any progressive effects without technological solutions in augmented reality. Application of these augmented reality technologies provides completely new opportunities for organizing high school learning, doing learning process comprehensible and interactive. This kind of approach is better meets the expectations of students at high school. The way of visualization is the most understandable and familiar to the new generation [2]. Due to integrated development of pedagogical and technological solutions can be provided with high quality but new phase of educational technologies. In addition, the opportunities of augmented reality allow conduct experiments in those cases, when physical experiment cannot be carried out according to objective such as nuclear physics and subjective reasons like an absence in necessary laboratory tools. With the support of Al Farabi National University a scientific and research and development work, purpose which was development educational and methodical mobile application for use of augmented reality-based laboratory experiments on the high school physics course using augmented reality. This application allows to a large extent increase visibility and fascination teaching physics. The application must be applicable in lessons for demonstrations, self-guided lab experiments in classroom and for individual work at home. Unlike existing mobile applications, this application is conducting demonstrations and laboratory experiments, while developing of this application the task was set with exciting visual graphics. Such 3D models and augmented reality, significant degree raise involvedness of students in the learning process. Compulsory condition was necessity for development technological decisions and educational and methodological sets providing maximum educational effects [3]. To achieve the learning goals, it is necessary could generate application configurations and develop mobile application for augmented reality technology implementation. By methodical parts it was necessary to develop about a hundred scenarios for augmented reality based laboratory mobile application and demonstrations, optimized under being developed mobile application.

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Therefore, it should show high quality images with mobile augmented application.

II. METHODS

Augmented reality is one of the advanced technologies in which human and computer interaction allows programmatically visually combine the two of initially independent spaces. This means real world objects mixed with virtual reality, which is created on computer.

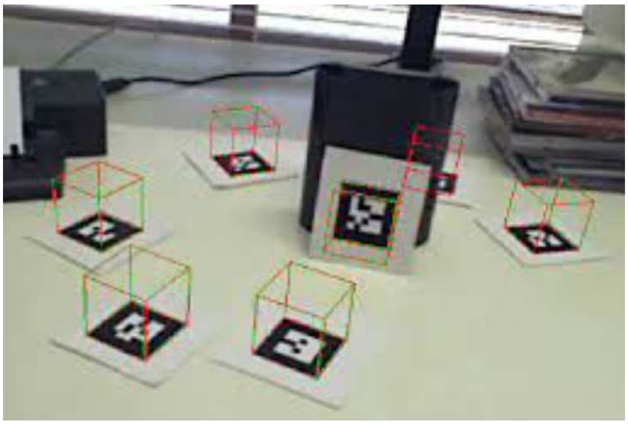

Figure 1. Testing augmented reality application with markers for recognition of the code.

New augmented reality-based environment formed by overlaying programmed augmented reality based objects on top of the video signal from the camera, and becomes interactive, by using special markers. This technology is based on special mathematical algorithms, which bind camera, tags and computer into a single interactive system [4]. The main task of the system is to determine the three dimensional position of a real label using markers according to its picture taken with help cameras. The marker recognition process takes place in several phases. In the first phase, an image will be taken from the camera. Then the program recognizes spots on each frame of the video in searching for a given template the marker frame. Video transmitted in format 2D; therefore, marker frame is defined as a 2D. As only the camera detects in the surrounding space frame, its next task is to determine what exactly shown inside the frame. As soon as the last step, a task systems build augmented reality based 3D model in 2D image coordinate system cameras and bind it to the label (Fig. 1).

Figure 2. Physics laboratory experiment tools in augmented reality.

To develop an augmented reality application in smartphones, I need architectural mobile application modules (Fig.2). It is necessary to visualize in correct orders for all laboratory experiments demanding visualized explanation though mobile augmented reality.

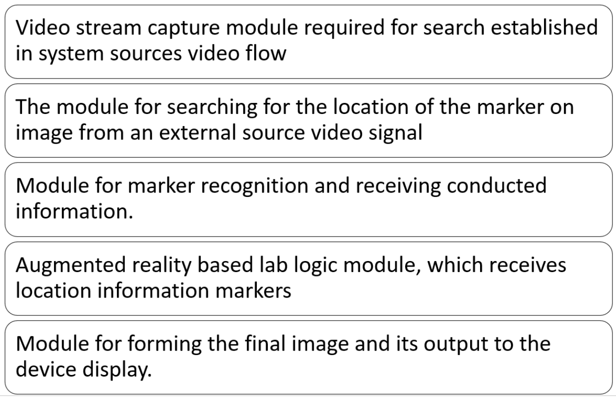

Figure 3. Architectural mobile application modules

Everybody modules work in framework one applications and possess necessary interfaces for interaction action. As a basis for working with augmented reality and implementation interactions first three modules, the ArUco library was chosen, written on the basis of the open library OpenCV, which brought together almost all modern computer vision algorithms [5]. This library contains algorithms to search markers and decoding information, recorded in them. This developed application library ArUco is responsible for receiving the video stream from video cameras, the definition in the video image of last finding marker, scanning areas marker and transcripts his code. Basic environment rendering models, them integrations with an augmented reality system and mobile application peacekeeping logic scenarios, was selected system Unity3D is a multi-platform tool for development three-dimensional applications [6].

Technologies that allow you to see three-dimensional images on flat devices playback, such how projection screens and monitors are called stereoscopic or 3D stereoscopic. Principle actions data

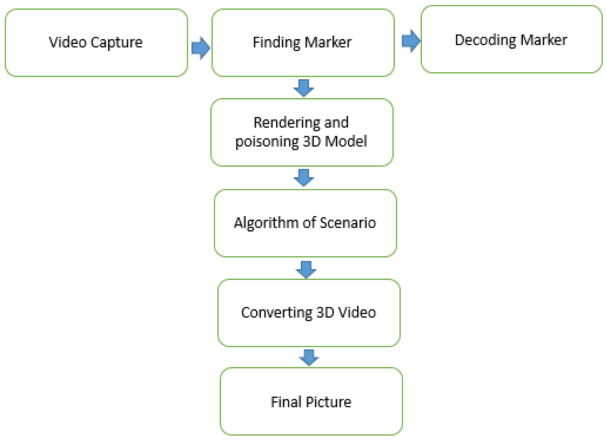

Figure 4. Scheme of interaction of architectural program modules applications.

Technology is to separate the image or video stream into two channels for their separate perception each eye. Person, in natural conditions, each eye perceives a little various picture, which is different on small, your angle of view. Accordingly, we get two slightly different pictures that our brains restore into one volumetric three-dimensional section. There are currently several widely common video display technologies current in 3D stereo format. Evaluating all the pros and cons each of them, in the application was implemented holding shutter and polarizing 3D systems. Polarizing 3D technology working on principle separation Images for left and right eyes with help polarization of light such as linear polarization and circular polarization. In addition, the shutter 3D technology on principle more rare synchronous display images for each of the eyes [7]. The choice of these technologies is determined low cost and ease of installation of devices based on them, as well as a wide range of directions them applications. Based on these systems, support was implemented all the main modes of 3D-stereoscopy in position like chess, interlaced, vertical and horizontal stereo pair, and anaglyph.

This project "Physics Lab Augmented Reality" applied innovative technology computer recognition of the movement of the hands, implemented based on the Leap Motion controller representing is a desktop version of the contactless device PC control like Microsof Kinect (Fig. 4). The device is positioned as a replacement for the traditional mouse controller, focused on management using hands and tools such as a pencil or pens [8].

By the number of degrees of freedom, this device much surpasses usual computer thorn mouse: move in 3 degrees of freedom along movement and three axes of rotation of the palm, against two degrees of freedom of an ordinary mouse. Finger recognition allows give various managers commands. An SDK is used to create mobile applications, allowing to use this input device, including and at developing applications in Unity 3D environment. The integration of this device into the prototype kit allowed user to interact with interface objects, and with scene objects without use mice. The LeapMotion device is located on the working table in front of the user [9]. When making hands user within the range of this device, on augmented reality-based hands appear on the augmented reality-based stage, through which it interacts with located on stage objects. For user operation with this device need some practice and use it for industrial applications requires some improvements, However, application can be completed limited to this device in exceptional cases to increase its interactive component and achieving a greater effect during the demonstration.

III RESULTS

Educational and methodological application "Physics Lab with Augmented Reality" called up contribute in education schoolchildren new technological possibilities, so beloved modern students. Appointment given mobile application and mobile application is check augmented reality-based laboratory experiments on school physics, which maybe to be used for progress next goals:

• Demonstration processes, phenomena, laws etc. at carrying out lessons.

• Individual tasks of students in classroom.

• Individual tasks of students at home.

Usage mobile application "Physics Lab with Augmented Reality" shapes at students understanding of the material in the scope of the studied topics and involves students in learning process per check the fascination and entertainment of the periods, due to use contemporary interactive technologies and decisions

Benefits application are:

- Entertainment and fascination for students;
- Visibility conducted experiments;
- High detail of the structure and properties of the objects under study;
- Deep dive students in wire- smoke experiments;
- Interactivity direct interaction action with augmented reality based objects;
- Usage advanced technologies and decide.

In total, the application is integrated about 53 augmented reality based lab scenarios experiments and 71 scenarios demonstrations, in which more than 300 interactive 3D models involved. These materials allow for learning demonstrations and perform laboratory experiments on following sections physics course:

- Physical measurements;
- Mechanical phenomena;
- Thermal phenomena;
- Electrical phenomena;
- Magnetic phenomena;
- Electromagnetic phenomena;
- Fluctuations and waves;
- Light phenomena;
- Quantum phenomena.

The application is reliable, safe, and easy to learn and use. It can work on most widely used equipment configurations.

Figure 4. Test mode for augmented reality application.

It was carried out trial application in conditions close to operational, at the pilot sites of Almaty, as which were made by some educational high schools. Each of them had open lessons in physics were held using lab experiments developed in application [10]. The greatest interest was the possibility of conducting precisely theoretical lessons and mass demonstrations using the capabilities of the application to reveal difficult to explain topics such as electromagnetic induction, nuclear reactions, thermal and electrical phenomena. Teachers used applicable ready to use technologies augmented reality for confirmation blocks theoretical information, given audience, visual elements, literally in the space of the working audience, which aroused genuine interest on the part of the listeners, and on the part of the givers [11]. By results tests, in first turn, it should be noted that there is a high interest in the application with the crowns of the end consumer -

teachers and students, which makes it possible to judge the achievement of the main goal developed application.

IV. CONCLUSION

Educational and methodical application can be used in the field of physics education with augmented reality-based labs experiments in high school. It could be applied on lessons to demonstrate independent task in the classroom, laboratory work, self-study at home including for students on home study. Basic functions of the application used in educational methodical mobile application is versatile which is allowing students to use it not only for conducting physics lessons, but also easily scale the application to study others science disciplines, such as chemistry, mathematics, history, biology, astronomy. In the future, the technologies used in this application can be applied in related field's scientific general educational disciplines, or in specialized developments for profile education.

REFERENCES

[1] W. Carroll, "Industry 4.0 Leaders' Educational Requirements – A New Focus on Leadership", *HuffPost Contributor*, vol. 10, No. 12, pp. 312-345, 2019.

[2] P. Fisk, "Education 4.0 the future of learning will be dramatically different in school and throughout life," *Peter Fisk*, vol.37, No.7, pp. 265-291, 2020.

[3] F. V. Kreijns, M. Acker, H. V. Vermeulen, "What stimulates teachers to integrate ICT in their pedagogical practices? The use of digital learning materials in education", *Computers in Human Behavior*, vol.29, No.5, pp. 217-225, 2013.

[4] I. Dror, "Technology enhanced learning: the good, the bad, and the ugly", *Pragmatics Cognition*, vol.2, No.2, pp. 215-223, 2008.

[5] G. Martin, E. Diaz, T. Sancristobal, "New technology trends in education: Seven years of forecasts and convergence", *Computers & Education,* vol.57, No.3, pp. 1893-1906, 2011.

[6] C. Bronack, "The role of immersive media in online education", *Journal of Continuing Higher Education,* vol. 59, No.2, pp. 113-117, 2011.

[7] P. Milgram, H. Takemura, A. Utsumi, F. Kishino, "Augmented reality: a class of displays on the reality - virtuality continuum", *Proc. the SPIE: Telemanipulator and Telepresence Technologies*, vol.23, No.51, pp. 282 – 292, 1994.

[8] R.T. Azuma, "A survey of augmented reality", *Presence - Teleoperators and Virtual Environments*, vol.6, No.4, pp. 355 – 385, 1997.

[9] T.H. Höllerer, S.K. Feiner, "Mobile Augmented Reality", *Telegeoinformatics: Location-Based Computing and Services*, vol.31, pp. 392-421, 2003.

[10] H. Kaufmann, "Collaborative augmented reality in education", *Proceeding of Imagina Conference*, vol.21, No.3, pp. 11-17, 2003.

[11] Z. Baigunchekov, M. Kalimoldaev, M. Utenov, B. Arymbekov, T. Baigunchekov, "Structural and dimensional synthesis of parallel manipulator with two end—effectors", *Mechanisms and Machine Science*, vol.37, No. pp. 15–23, 2016.