





Ye.A. Daineko^{1,2*} , **M.T. Ipalakova¹** ,
D.D. Tsoy¹ , **A.M. Seitnur¹** 

¹International University of Information Technologies, Kazakhstan, Almaty

²Institute of Applied Sciences and Information Technologies, Kazakhstan, Almaty

*e-mail: y.daineko@edu.iitu.kz

THE ROLE OF NEW INFORMATION AND COMMUNICATION TECHNOLOGIES IN MODERN EDUCATION

The technological advances of the last 15 years have made a huge contribution to modern society, transforming education and training. Computers and the Internet allow teachers and students to work, learn, and receive information in ways that were once unthinkable. One of the latest and yet most exciting technological developments in education is the use of virtual reality (VR) and augmented reality (AR) to enhance learning opportunities. Virtual reality and augmented reality allow users to interact with computer environments, real or imagined. VR also allows users to receive visual, auditory, tactile, smell, and taste inputs in three-dimensional space.

As a result, the authors implemented a virtual laboratory with the possibility of conducting a virtual experiment, which includes practical and theoretical tasks in high school physics, as well as a set of animations. When developing the virtual electronic laboratory, agile software development methodologies, computer modeling methods, and object-oriented programming were used. As a virtual reality device, the Leap Motion motion controller was chosen, designed to track the movements of hands and fingers in space and used for human-computer interaction. The article provides UML activity diagrams for working and interacting with the application. The cross-platform Unity 3D environment, which implements the WORA (write once, run anywhere) principle, was chosen as the development platform. Thanks to this principle, a once-written application can be built for personal computers, mobile devices, mixed reality helmets, and many other platforms. The application functionality was written in the C# programming language. Graphic models were created using Substance Painter. The developed application can be used by students of senior classes of secondary and specialized schools, students of technical majors of higher educational institutions, as well as any interested users.

Key words: virtual laboratory, augmented reality, virtual reality, 3D modeling, Unity3D, C# (CSharp).

Е.А. Дайнеко^{1,2*}, М.Т. Ипалакова¹, Д.Д. Цой¹, А.М. Сейтнұр¹

¹Халықаралық ақпараттық технологиялар университеті, Қазақстан, Алматы қ.

²Қолданбалы ғылымдар және ақпараттық технологиялар институты, Қазақстан, Алматы қ.

*e-mail: yevgeniyadaineko@gmail.com

Заманауи білім берудегі жаңа инфокоммуникациялық технологиялардың рөлі

Соңғы 15 жылдағы технологиялық жетістіктер білім беру мен кадрларды даярлауды қайта құру арқылы қазіргі қоғамға үлкен үлес қосты. Компьютерлер мен Интернет мұғалімдер мен студенттерге жұмыс істеуге, оқуға және бір кездері мүмкін емес ақпарат алуға мүмкіндік береді. Білім беру саласындағы соңғы және сонымен бірге ең қызықты технологиялық әзірлемелердің бірі – білім беру мүмкіндіктерін кеңейту үшін виртуалды шындықты (VR) және толықтырылған шындықты (AR) пайдалану болып табылады. Виртуалды шындық және толықтырылған шындық пайдаланушыларға нақты немесе қиялдағы компьютерлік орталармен өзара әрекеттесуге мүмкіндік береді. Сондай-ақ, VR пайдаланушыларға үш өлшемді кеңістікте визуалды, есту, тактильді, иіс пен дәм кірістерін алуға мүмкіндік береді.

Нәтижесінде авторлар виртуалды эксперимент жүргізу мүмкіндігі бар виртуалды зертхананы іске асырды, оған орта мектеп бағдарламасының физикасы бойынша практикалық және теориялық тапсырмалар, сондай-ақ анимациялар жиынтығы енгізілді. Виртуалды электрондық зертхананы әзірлеу кезінде бағдарламалық қамтамасыз етуді әзірлеудің икемді әдіснамасы, компьютерлік модельдеу және объектіге бағытталған бағдарламалау әдістері қолданылды. Виртуалды шындық құрылғысы ретінде кеңістіктегі қол мен саусақ қимылдарын бақылауға арналған және адам-

компьютерлік өзара әрекеттесу үшін қолданылатын Leap Motion қозғалыс контроллері таңдалды. Мақалада UML қосымшамен жұмыс істеуге және өзара әрекеттесуге арналған әрекеттер кестесі берілген. Әзірлеу платформасы ретінде WORA (write once, run anywhere) жұмыс принципін жүзеге асыратын Unity 3D кросс-платформалық ортасы таңдалды. Осы қағидаттың арқасында бір рет жазылған қосымшаны дербес компьютерлер, мобильді құрылғылар, аралас шындық шлемдері және басқа да көптеген платформалар үшін жинауға болады. Leap Motion қозғалыс контроллері виртуалды шындық құрылғысы ретінде пайдаланылды. Қосымшаның функционалдығы C # бағдарламалау тілінде жазылды. Графикалық модельдер Substance Painter көмегімен жасалды. Әзірленген қосымшаны орта және мамандандырылған мектептердің жоғары сынып оқушылары, жоғары оқу орындарының техникалық мамандықтарының студенттері, сондай-ақ кез келген мүдделі пайдаланушылар пайдалана алады.

Түйін сөздер: виртуалды зертхана, толықтырылған шындық, виртуалды шындық, 3D модельдеу, Unity3D, C# (CSharp).

Е.А. Дайнеко ^{1,2*}, М.Т. Ипалакова ¹, Д.Д. Цой ¹, А.М. Сейтнур ¹

¹Международный университет информационных технологий, Казахстан, г. Алматы

²Институт прикладных наук и информационных технологий, Казахстан, г. Алматы

*e-mail: y.daineko@iitu.edu.kz

Роль новых инфокоммуникационных технологий в современном образовании

Технологические достижения последних 15 лет внесли огромный вклад в современное общество, преобразовав образование и подготовку кадров. Компьютеры и Интернет позволяют учителям и студентам работать, учиться и получать информацию таким образом, который когда-то был немислим. Одним из последних и в то же время самых захватывающих технологических разработок в области образования является использование виртуальной реальности (VR) и дополненной реальности (AR) для расширения возможностей обучения. Виртуальная реальность и дополненная реальность позволяют пользователям взаимодействовать с компьютерными средами, реальными или воображаемыми. VR также позволяет пользователям получать визуальные, слуховые, тактильные, запаховые и вкусовые входы в трехмерном пространстве.

В результате авторами реализована виртуальная лаборатория с возможностью проведения виртуального эксперимента, в которую включены практические и теоретические задания по физике программы средней школы, а также набор анимаций. При разработке виртуальной электронной лаборатории применялись гибкие методологии разработки программного обеспечения, методы компьютерного моделирования и объектно-ориентированного программирования. В качестве устройства виртуальной реальности был выбран контроллер движения Leap Motion, предназначенный для отслеживания движений рук и пальцев в пространстве и используемый для человеко-компьютерного взаимодействия. В статье приведены UML диаграммы деятельности для работы и взаимодействия с приложением. В качестве платформы разработки была выбрана кроссплатформенная среда Unity 3D, которая осуществляет принцип работы WORA (write once, run anywhere). Благодаря этому принципу единожды написанное приложение может быть собрано для персональных компьютеров, мобильных устройств, шлемов смешанной реальности и многих других платформ. Функционал приложения был написан на языке программирования C#. Графические модели были созданы с использованием Substance Painter. Разработанное приложение может быть использовано учениками старших классов средних и специализированных школ, студентами технических специальностей высших учебных заведений, а также любими заинтересованными пользователями.

Ключевые слова: виртуальная лаборатория, дополненная реальность, виртуальная реальность, 3D-моделирование, Unity3D, C# (CSharp).

Introduction

In the age of information technology, modern society is faced with their continuous penetration into all spheres of its life. Industry, medicine, entertainment, services, and others are influenced by the rapidly developing modern technologies, which in turn is due to the continuous progress in the field of ICT (information and communication technolo-

gies). Development of new means and technologies of communication, robotics, sensor technologies, computer vision, software and hardware for modern computers, artificial intelligence, etc. on the one hand, makes it easier for a person to fulfill his professional tasks, but on the other hand, sets more and more ambitious goals for him.

Modern education is no exception. Information technology also has a huge impact on this area. And

it includes not only the computerization of all business processes of higher and secondary educational institutions, as well as any organizations, but also the introduction of new methods and teaching aids based on modern technologies. In the latter direction, a prominent place is occupied by computer training systems, for example, such as virtual laboratories.

Computer modeling within the framework of virtual laboratories allows you to thoroughly investigate the studied phenomena, processes, or substances at minimal cost, without exposing the students to any danger. Three-dimensional visualization helps to observe the process or phenomenon in space, it is also possible to look inside the studied phenomenon, which is not always possible in reality. The undoubted advantage of virtual experiments is that they can be repeated many times without additional financial costs, which certainly increases the effectiveness of such training. Physics is one of those courses for which experiments can be simulated on a computer.

In the development of this field in Kazakhstan, the authors have achieved certain success. A virtual physics laboratory (PVL) was developed with a set of three-dimensional physical experiments from a course in general physics for students of technical universities. It has been successfully introduced into the educational process of teaching physics at the International Information Technology University and other universities in Kazakhstan [1, 2].

However, not only higher, but also secondary educational institutions need such educational tools. Moreover, at this level of education, the task is not only to represent visually the process or phenomenon being studied, but also to present the material in an interesting, exciting way in order to captivate schoolchildren, who, unlike students, are not always motivated due to their age and lack of understanding of the importance of learning.

Nowadays, learners' perception can be improved with new visualization elements and gestures that modern digital technologies offer. Thus, with the technologies of augmented (AR – Augmented Reality) and virtual (VR – Virtual Reality) reality, new ways of learning come to the fore, which make it possible to reveal the student's interest in the subject being studied, stimulate positive emotions, speed up the learning process and help better assimilation. AR and VR bring a game element to the learning process, which certainly has a positive effect on the results of students.

This article is devoted to the development of a virtual electronic laboratory with a set of practical

and theoretical tasks, as well as animations with elements of augmented and virtual reality technologies for the study of physics in secondary educational institutions.

Materials and methods

Fundamentals of augmented and virtual reality technologies

Augmented reality is one of the newest and most promising technologies of the 21st century, which can also be used to develop virtual laboratories. Its applications are very broad: from game development to medicine. Augmented reality allows you to embed virtual objects in the three-dimensional field of human perception in real time, while the added objects are perceived as elements of real life. Thus, reality is supplemented by the introduction of virtual information into it [3]. Interactivity, accessibility, realism and innovativeness are some of the reasons for the increasing popularity and demand for augmented reality technology.

Several methods are used to generate virtual content using augmented reality technology. The first way to display virtual information is through a head mounted display (HMD). In this case, the user sees virtual information on the display screen, and the real environment through it [4]. Another way to work with augmented reality technology involves using a device with a camera (for example, a smartphone, tablet, or smart glasses) and special software. When you point the camera at an object, the program recognizes it using computer vision technology. Next, the device downloads the virtual information associated with this object and overlays it directly on the object in 3D. Thus, it turns out that the user sees both real and virtual information. The recognized objects are usually images with QR (quick response) codes, which are called markers. When the user moves or rotates the marker, the virtual image also moves and rotates. Unnecessary information disappears, and new information appears [5].

The development of augmented reality technology plays an important role in many areas of activity. Examples of the use of this technology in medicine [6, 7], industry [8, 9], tourism [10, 11] can be found.

Virtual reality (VR) is a simulation that creates a virtual yet realistic world using computer graphics. Moreover, the reproduced surrounding world is not static, but reacts to the user's input stream (gestures, verbal commands, etc.) [12]. Real-time interactivity is one of the essential distinguishing characteristics of virtual reality. This assumes that the computer is

able to detect the incoming stream from the user, interpret it and immediately change the virtual environment.

Virtual reality technology requires 3D head-mounted displays (virtual reality glasses), as well as stereoscopic hand and body tracking technologies and binaural sound. Thus, this technology can be defined as multisensory. Virtual environments, microworlds or virtual worlds are other equivalent names for VR technology.

Virtual reality is also increasingly used in such areas as scientific visualization, architecture, pilot training, medicine, entertainment [13, 14].

Technological basis

The virtual lab implementation is based on the Unity Game Engine [15]. Unity Game Engine is a cross-platform computer game development environment from Unity Technologies. It allows you to create virtual reality applications that run on personal computers, mobile devices with iOS and Android operating systems, and Internet applications. The Unity editor has a simple Drag&Drop interface, which is easy to configure, consisting of various windows, so you can debug the game directly in the editor. The engine supports two scripting languages: C# and JavaScript. Physical calculations are performed by the PhysX physics engine from NVIDIA.

The Vuforia library was chosen as a library for the implementation of augmented reality functions due to such qualities as cross-platform compatibility, the ability to work for free, tracking 3D objects, and visual search.

The Vuforia library makes it easy to scan targets with the built-in Vuforia Object Scanner. It is also possible to enable virtual buttons and map additional elements using OpenGL. Cross-platform allows you to work on different platforms, which means a wider audience coverage and ease of use of the program.

As a virtual reality device, the Leap Motion controller was chosen, designed to track the movements of hands and fingers in space and used for human-computer interaction. The device includes three infrared LEDs and two cameras, and its tracking principle is stereoscopy (the reflected light from the LEDs is visible from two different points of view, and the distance from the sensor is calculated accordingly). Thanks to the SDK libraries, you can get information about tracking both hands in the space above the device at a height of 15-60 cm. The library's routines can recognize both hands and transmit information about the location of each bone segment.

Results and discussion

Development of virtual laboratory work

When developing the virtual electronic laboratory, agile software development methodologies, computer modeling methods, and object-oriented programming were used.

A virtual electronic laboratory was developed, which includes practical and theoretical tasks from the high school physics curriculum, as well as a set of animations. Practical tasks are implemented in the form of separate applications that provide access to three-dimensional visualization of the studied processes using augmented and virtual reality technologies, as well as solutions to problems. A set of 3D animations is presented in the form of an electronic textbook.

Figure 1 shows a component diagram that describes the internal structure of the application. The start/input point label is highlighted in red, the main program components are highlighted in green, and the auxiliary modules are highlighted in yellow.

The starting point is the launch of the application itself. It consists of four main components: visualized practical tasks, visualized theoretical tasks implemented in the form of laboratory works, animation of physical processes, and test questions. There are also auxiliary modules that ensure the operation of the main ones. These are folders with shared three-dimensional models, program code, and prefabs – special elements that can be reused in different scenes, while allowing you to provide a single interface and logic. In addition, there are separate folders in which there are elements required in a separate task or laboratory work. Another module is a module for the operation of the Leap Motion controller, which allows you to control the virtual laboratory work and its elements with your own hands inside the virtual space.

Figure 2 shows the class diagram of the electronic virtual laboratory. It demonstrates the logic that ensures the operation and interaction during the execution of the application. The diagram presents the classes in the application and their relationships. The main components are the laboratory itself, the user interface, and the control controller inside the laboratory. According to these elements, there are the classes: UIContoller, ProblemController, LeapHandModelController, Leap HandModel Base, and Leap Hand Model. All of them are derived from MonoBehaviour, the base class in Unity. Three classes belong to Leap Motion and provide its logic and control.

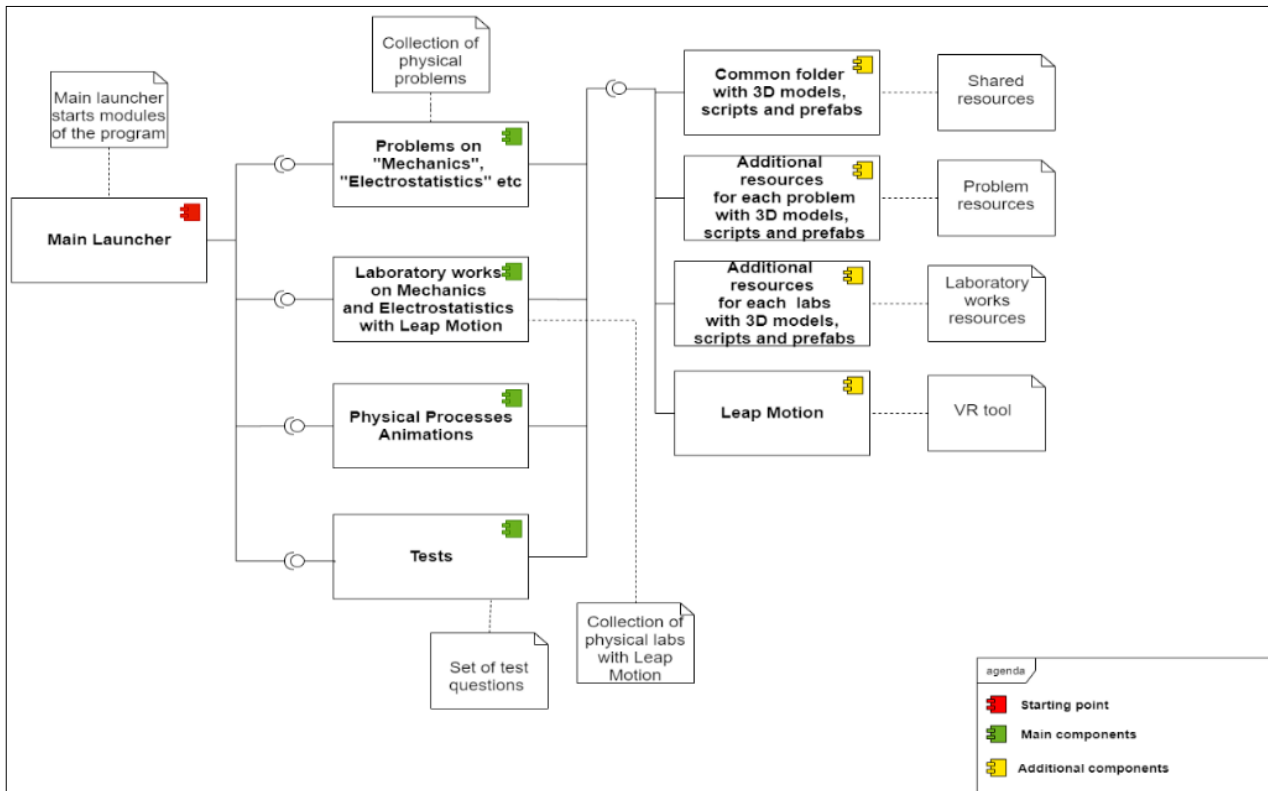


Figure 1 – Component Diagram

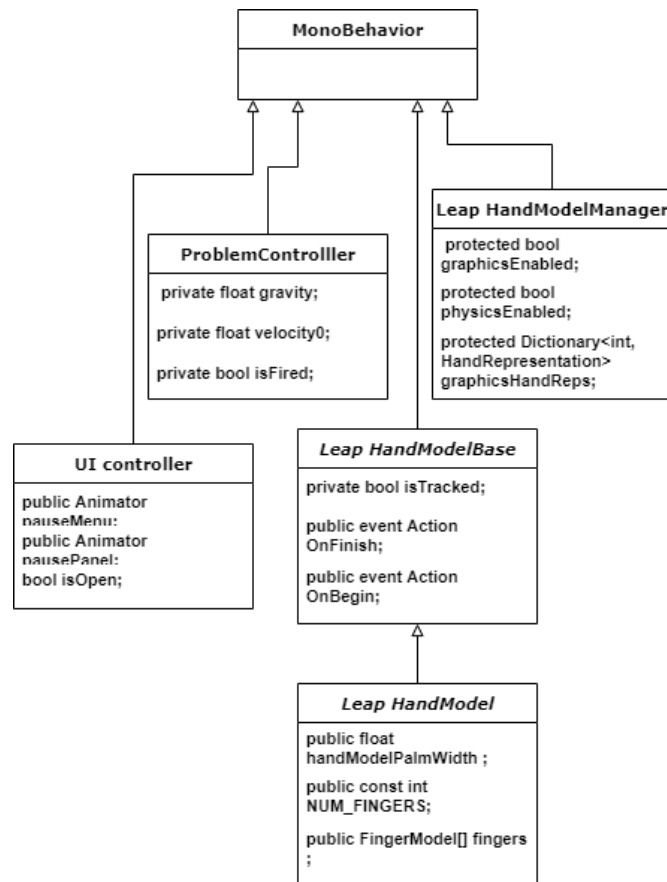


Figure 2 – Class diagram

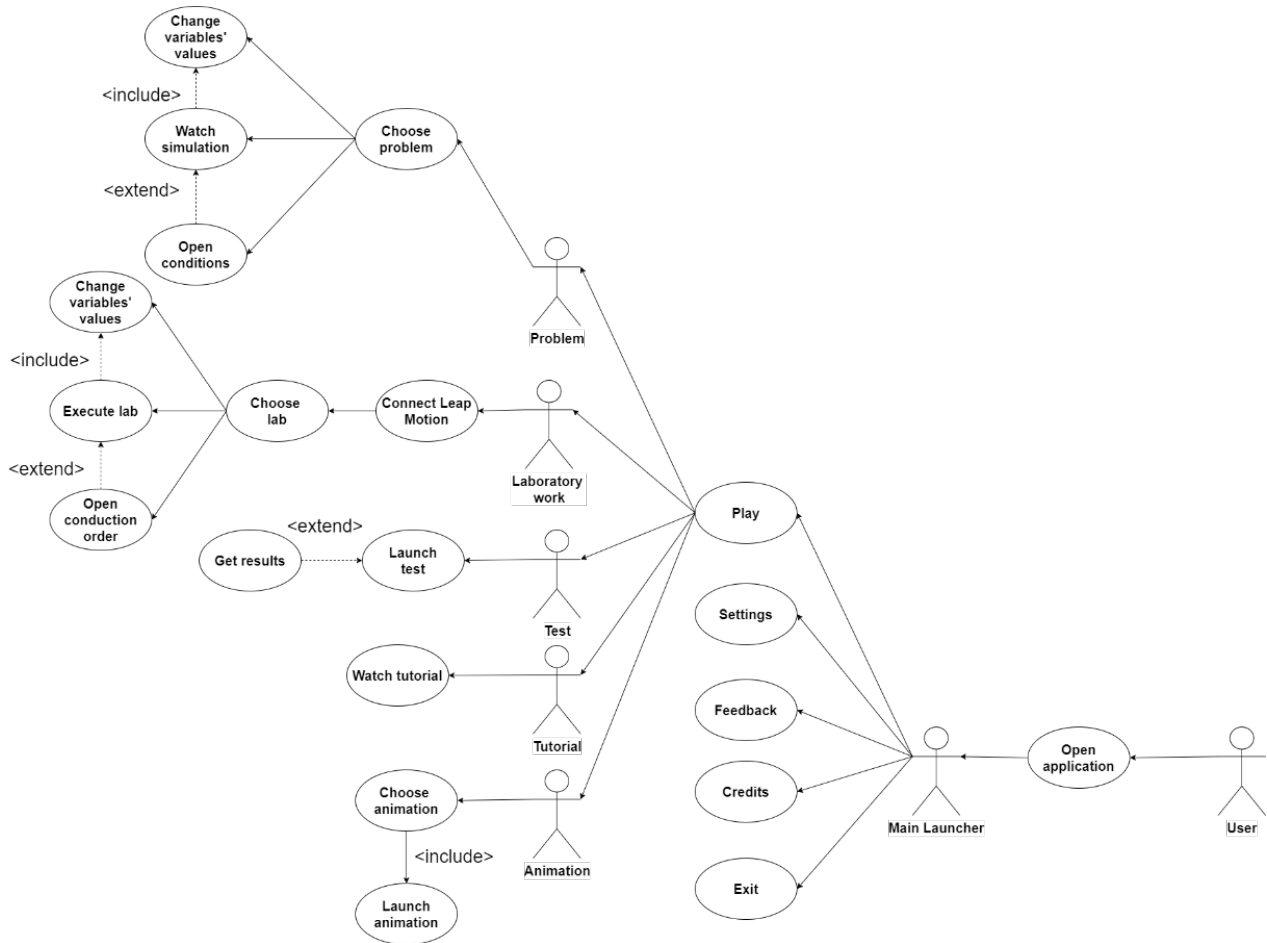


Figure 3 – Action Diagram

Figure 3 shows an action diagram. It reflects a user and the system as actors, with ellipses showing possible actions. So, the diagram shows the user who can launch the application, change settings, send feedback, learn about the development team, and exit the application. After launching the app, the user can choose to run a virtual lab, test, tutorial, animation, or task. Within each of these modules, certain possible actions are available, which can also be seen in the diagram.

Figure 4 shows the activity diagram, which reflects the logical relationship between the actions that the user performs inside the application.

As a result, the application provides the user with all the necessary information within the framework of the presented material, is completely safe, and demonstrates complex physical phenomena and concepts.

Conclusion

Thus, the use of new information and communication technologies in modern education opens new

opportunities and prospects for creating learning resources and tools at a qualitatively different level, especially in the current circumstances of the forced transition to distance learning.

This article provides an example of developing a software application for a virtual electronic laboratory with elements of augmented and virtual reality technologies, which includes a set of practical and theoretical tasks in physics in the form of laboratory works, as well as animations, and tests. All components of the virtual electronic laboratory are made in the form of separate modules with three-dimensional visualization of the studied processes and phenomena. The user documentation and the description of each laboratory work and the entire system are also provided by the authors. The developed virtual laboratory has been tested in the educational process.

The authors believe that the created virtual laboratory for the physics course meets the requirements of modernity and is effective in the study of this subject. Currently, we are constantly working on the development of new practical tasks and laboratory works for their integration into the laboratory.

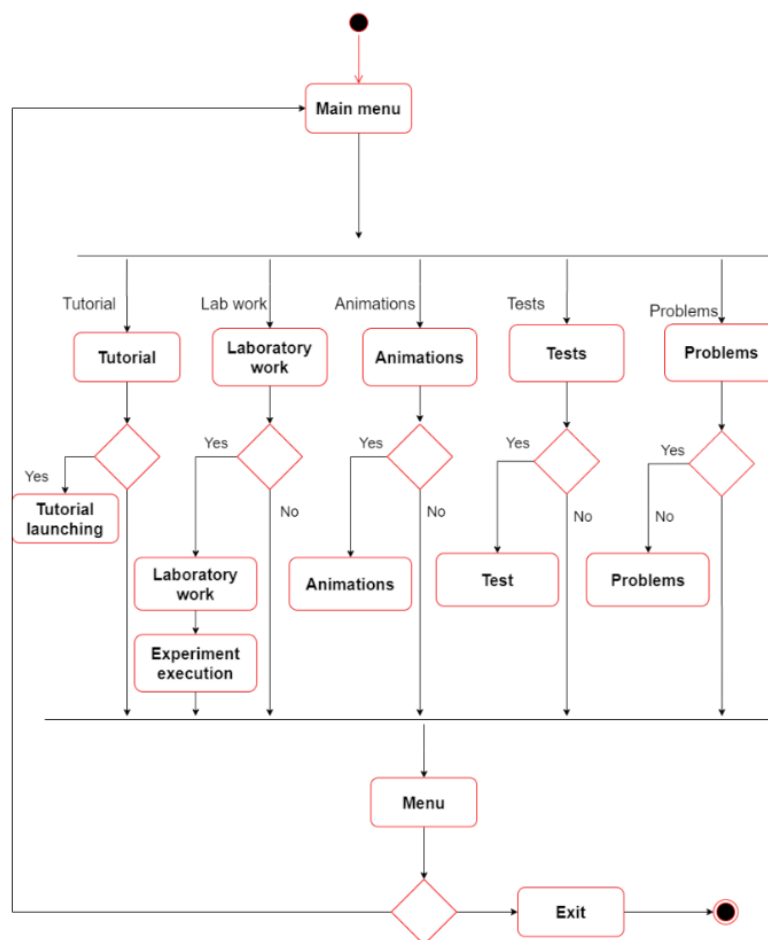


Figure 4 – Activity Diagram

Acknowledgment

The work was carried out with the financial support of the Committee of Science of the Min-

istry of Education and Science of the Republic of Kazakhstan under the program of grant financing of scientific research for 2020-2022 years, grant №AP08857146.

References

- 1 Daineko Ye., Dmitriyev V., Ipalakova M. Using Virtual Laboratories in Teaching Natural Sciences: An Example of Physics // *Computer Applications in Engineering Education*. – 2017. – №25(1). – P. 39-47.
- 2 Daineko Y.A., Ipalakova M.T., Bolatov Zh.Zh. Employing Information Technologies Based on .NET XNA Framework for Developing a Virtual Physical Laboratory with Elements of 3D Computer Modeling // *Programming and Computer Software*. – 2017. – №43(3). – P. 161-171.
- 3 Milgram P., Kishino A.F. Taxonomy of Mixed Reality Visual Displays // *IEICE Transactions on Information and Systems*. – 1994. – №E77-D (12). – P. 1321-1329.
- 4 Chi-Yin Yuen S., Yaoyuneyong G., Johnson, E. Augmented Reality: An Overview and Five Directions for AR in Education // *Journal of Educational Technology Development and Exchange (JETDE)*. – 2011. – №4(1).
- 5 How augmented Reality works, Harvard Business Review, January 28, 2018 [Electronic resource]. – 2018. – URL: <https://hbr-russia.ru/innovatsii/tehnologii/a24121> (accessed 14.10.2020).
- 6 Medical Graphics Research Group [Electronic resource]. – URL: <http://medical-graphics.org/projects/palpsim/> (accessed 14.10.2020).
- 7 MITK Pille [Electronic resource]. – URL: <https://www.electrictv.com/?p=13212> (accessed 01.10.2018).
- 8 Shelton B.E. Augmented reality and education // *Current projects and the potential for classroom learning*. New Horizons for Learning. – 2002. – №9(10).

- 9 Daubit Programmierung Service GmbH [Electronic resource]. – URL: <https://www.botta-design.de/> (accessed 14.10.2020).
- 10 HP Reveal [Electronic resource]. – URL: <https://www.hpreveal.com/> (accessed 01.10.2018).
- 11 Google Quest Visual [Electronic resource]. – URL: <http://questvisual.com/> (accessed 14.10.2020).
- 12 Burdea G., Coiffet P. *Virtual Reality Technology*. 1st ed. – New York: John Wiley & Sons Ltd, 2003.
- 13 Earnshaw R., Gigante M.A., Jones, H. *Virtual Reality Systems*. 1st ed. – New York: Routledge, 1993.
- 14 Riener R., Harders M. *Virtual Reality in Medicine*. – Springer-Verlag, 2012.
- 15 <https://unity3d.com/company>

References

- 1 Ye. Daineko, V. Dmitriyev, M. Ipalakova, *Computer Applications in Engineering Education*, 25(1), 39-47 (2017).
- 2 Y.A. Daineko, M.T. Ipalakova, Zh.Zh. Bolatov, *Programming and Computer Software*, 43(3), 161-171 (2017).
- 3 P. Milgram, A.F. Kishino, *IEICE Transactions on Information and Systems*, E77-D (12), 1321-1329 (1994).
- 4 S. Chi-Yin Yuen, G. Yaoyuneyong, E. Johnson, *Journal of Educational Technology Development and Exchange (JETDE)*, 4(1) (2011).
- 5 <https://hbr-russia.ru/innovatsii/tekhnologii/a24121> – How augmented Reality works, *Harvard Business Review*, January 28, 2018. (accessed 14.10.2020). (in Russ)
- 6 <http://medical-graphics.org/projects/palpsim/> – Medical Graphics Research Group (accessed 14.10.2020).
- 7 <https://www.electrictv.com/?p=13212> – MITK Pille, (accessed 01.10.2018).
- 8 B.E. Shelton, Current projects and the potential for classroom learning. *New Horizons for Learning*, 9(10) (2002).
- 9 <https://www.botta-design.de/> – Daubit Programmierung Service GmbH (accessed 14.10.2020).
- 10 <https://www.hpreveal.com/> – HP Reveal (accessed 01.10.2018).
- 11 <http://questvisual.com/> – Google Quest Visual (accessed 14.10.2020).
- 12 G. Burdea, P. Coiffet, *Virtual Reality Technology*. 1st ed., (New York, John Wiley & Sons Ltd, 2003).
- 13 R. Earnshaw, M.A. Gigante, H. Jones, *Virtual Reality Systems*. 1st ed., (New York, Routledge, 1993).
- 14 R. Riener, M. Harders, *Virtual Reality in Medicine*, (Springer-Verlag, 2012).
- 15 <https://unity3d.com/company> – The leading platform for creating interactive, real-time content.