Lucio Tommaso De Paolis
Patrick Bourdot (Eds.)

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Editors
Lucio Tommaso De Paolis
University of Salento
Lecce
Italy

Patrick Bourdot
University of Paris-Sud
Orsay
France

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Development of Practical Tasks in Physics with Elements of Augmented Reality for Secondary Educational Institutions

Yevgeniya Daineko, Madina Ipalakova, Dana Tsoy(✉), Akmedi Shaipiten, Zhiger Bolatov, and Tolganay Chinibayeva

Department of Computer Engineering and Telecommunication, International IT University, 050040 Almaty, Kazakhstan
{yevgeniyadaineko, m.ipalakova, danatsoy, ahiko.dk, zhiger.ali, ttemirbolatova}@gmail.com

Abstract. The current work demonstrates the use of augmented reality technology for the development of an application that can be employed as an additional teaching tool within physics in secondary educational institutions in Kazakhstan. The application contains a set of problem tasks in "Mechanics". The physical processes within tasks are visualized with help of augmented reality and this helps pupils to imagine and understand deeper the studied phenomena. One of the advantages and distinctive features of the developed application is that it provides the user interface in Kazakh, Russian and English languages. This corresponds to the multilingual policy adopted by the government of the country. In the article the existing analogs worldwide are presented, development software is described and the main results of the project are discussed.

Keywords: Physics · Augmented reality · Secondary education

1 Introduction

Nowadays, it is hard to think about modern education without employing information and communication technologies (ICT) that evolves at a rapid pace. Not only higher, but secondary and even primary educational institutions apply ICT within the educational process.

Today any teacher has many opportunities to use various ICT tools during classes, such as the Internet, electronic books, dictionaries and directories, presentations, software, communication means like chats, forums, blogs, electronic mail, teleconferences, webinars and much more. Besides, application of ICT helps teachers to:

- continuously motivate pupils;
- activate cognitive abilities;
- attract passive pupils;
- accelerate educational process;
- provide up-to-date materials;
- teach pupils to work with different sources of information;

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– promote research activities;
– provide flexibility of education process.

Among the software for schools different types of virtual laboratories are worth to be mentioned. They allow not only observing, but conducting virtual experiments of various subjects [1]. Simple animations are also useful tools that can be used by pupils for deeper understanding of studied processes and phenomena. And the augmented reality (AR) is one of the technologies for developing such interactive applications. They can be used by teachers within lessons as an additional tool for visualization of the material explained.

The area of application of software with augmented reality involved is very wide. For example, with help of such programs it is possible to conduct complex physical or chemical experiments in real time absolutely safe. On the geography lesson the maps in textbooks become "alive" and are able to move showing how countries' boundaries or population are changing in time. Also there is a chance to travel across the wonders of the world sitting in class. It is possible to study historical battles or play a role of a soldier. Descriptive video onto complex biological schemas can help understand and remember studied material easily. In such countries like USA and Japan the lessons with the use of augmented reality technology have been being conducted already for a long time. The surveys show that as a result of such classes pupils are more involved into the educational process and master new material easier.

In the article the authors present a computer application that allows solving a set of practical tasks in physics, section "Mechanics". The application is implemented using the technology of augmented reality and is designed for secondary educational institutions. The application is developed at the Department of Computer Engineering and Telecommunication of the International Information Technology University, Almaty, Kazakhstan.

2 Related Works in the Field of Development and Introduction of Computer Learning Systems Based on the Augmented Reality

Modern technologies evolve very fast and nowadays the term "Augmented reality" is not fiction. AR technology is able to change the notion of the modern world and make it more convenient and interactive. The fields of application of this technology are quite wide: medicine, warfare, education, public services, etc.

In the present article the use of augmented reality in education is shown. It is generally known that human brain perceives visual images better, rather than just text. A lot of research exists [2, 3], which shows that AR technology in education enriches visual and contextual learning, improving the content of information. During lectures only 25% of information is retained, but if visual support is used 80% of information can be perceived. As a result of these studies, it turned out that application of augmented reality in education is beneficial for all people and for children especially.

Below several examples of foreign experience in using AR in education are presented.

In [4] the application of mobile augmented reality in teaching physics is shown. The obtained results showed that the using of this technology by physics teachers is rather effective. Besides, it allows developing skills to teach natural sciences in the modern world of digital technologies.

In [5] the authors studied the problem of merging of their own devices and the technology of augmented reality in education. It is shown that the use of this integration allows increasing the quality of teaching of pupils and students in any institutions at any level of education.

In [6] the application of AR technology in teaching natural sciences for pupils of 7^{th} grade of a private college was studied. According to the teachers and pupils opinion studying the subjects with this technology was pleasant, easy and useful.

In [7] the use of AR technology in math studying and exactly in studying of solids rotation was considered. The authors are convinced in advantages that AR technology provides for math studying and intend to use it for explaining the calculations of volume of rotation solids and other problems. In future the application of the technology will be widen in developing skills of spatial visualization.

The main idea in [8] is the investigation of the impact of AR on improving students' performance and their physiological state. The second year students took part in the research. They studied the course "Presentation of information on computers" using the AR technology and the Internet. The results showed that both technologies contributed to improving of students' performance.

The article [9] is about using AR technology to support "Software" course and to test various studied effects with help of interactive on-line and AR teaching strategies. The obtained results showed the potential of using AR methods for increasing students' motivation and for interaction between peers. It was concluded that when introducing of AR applications into the course, technology developers must carefully study the teaching target audience, information volume depicted on the screen of mobile phone and accessibility of training equipment and audience environment in order to archive appropriate teaching scenarios.

In [10] the efficiency of using AR technology on lectures is shown. It is demonstrated that AR has a positive effect on students learning process, increases their self-esteem and motivation.

In such a way, training software with the use of AR technology is a promising tool with completely new visualization possibilities.

3 Software Support of the Project

The main criteria for choosing the development tool for creating the application for teaching physics with help of AR technology were speed of project development, the quality of visualization and cheap cost.

3D graphics is used to display models, processes and phenomena. And as a development tool Unity 3D was chosen.

Unity 3D is a cross-platform engine for the development of interactive application with real-time graphics. This engine is most common among developers of 3D large-scale games. It has its own editor; the programming language C# is used for the

development. This allows creating applications that display complex physical processes. The development process of 3D environments is object-oriented, which means environment creation is divided into objects with behavior. The engine is implemented using C++ language, and this fact makes it fast and productive.

The Unity 3D engine meets the following requirements:

- the end product is a multimedia 3D object, embedded into an HTML page;
- the end product is an object of high level of abstraction of object prototypes;
- high quality of graphical presentation of information;
- the library of 3D objects can work with many formats of modern 3D graphics, such as *.3ds, *.dae, *.fbx, *.flt;
- the support of high level languages (C++, C#, Java);
- the license for free use for non-commercial purposes;
- the editor for software and graphical objects development;
- the possibility to connect third-party object libraries.

The Vuforia library was chosen for the realization of augmented reality functions. The library is cross-platform and free, it allows performing visual search. Vuforia simplifies scanning target object using the built-in scanner Vuforia Object Scanner. Also it is possible to include virtual buttons and map additional elements with help of OpenGL. The library is cross-platform, which means the application can be used on any device. And the time for the development of the versions is minimal.

Free license decreases the cost of project realization, which is important factor during the project implementation.

Also Vuforia allows creating various visual effects, like night vision or X-rays simulation. Another useful feature of this library is that it is possible to play video on any given surface. Occlusion control in Vuforia allows tracking objects even if they are visible only partially.

Thus, Vuforia library provides all the necessary functionality and fully justifies its use in the project.

4 Main Scientific Results

As a result of the project implementation in the International Information Technology University at the Department of Computer Engineering and Telecommunication an application with a set of practical tasks in physics for secondary educational institutions is developed. The tasks are realized with elements of augmented reality. The application meets all the requirements for such type of systems, provides realization of large number of complex effects; has simple but functional design and user-friendly interface.

One of the distinctive features of the current application is its three-language interface. A user is able to choose Kazakh, Russian or English language to interact with the system. In Fig. 1 the main window of the application with English language interface is shown.

The main idea of the current work is the development of animated tasks in physics of school curriculum, which would be closest to the real world. The problem tasks for

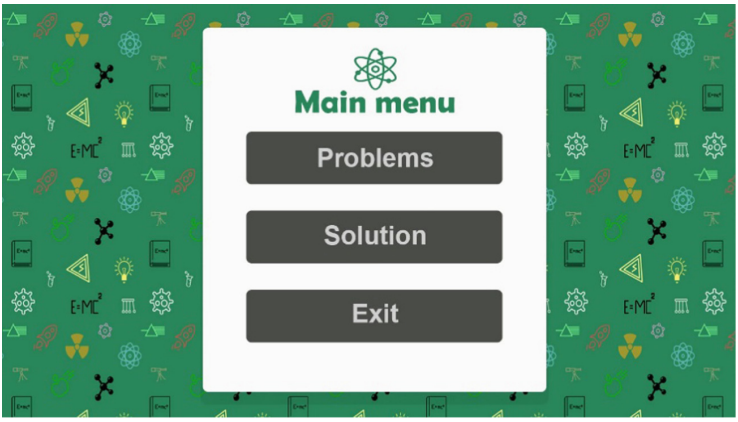

Fig. 1. Main window of the application with English language interface

the application were chosen in cooperation with the physics teacher of the Republican Physics and Mathematics School (Almaty, Kazakhstan). The tasks are taken from the pool of tasks for Olympiad in physics and require additional visual support for better understanding. The problem visualization along with its given solution allows pupils to understand thoroughly the physical nature of the studied processes and will facilitate solving similar problems independently in future. Also the application allows pupils to take part in the simulation, not only to passively observe it. He or she can change the tasks parameters, and in such a way examine the process in different conditions. Thus, visual demonstration of how the task elements depend on the physical parameters makes the material easier to understand (Fig. 3).

Besides, the tasks are implemented with 3D scenes, so that experiments are shown in space. A user can control an experiment by him/herself by modeling various situations of its conducting. For example, he/she is able to move in space of a task and watch its simulation from any position or angle of view. It helps to perceive and assimilate the material. A keyboard and a camera are used to control the simulation and rotate the 3D scenes in different directions. Also it is possible to zoom out the objects for more detailed observation. The dialog window is refreshed when a view point and position are changed. The visual representation is the main advantage of the application, which provides visibility and quick assimilation of the material. Moreover, in the application it is possible to make mathematical calculations of experiments within problem tasks.

Let us consider the problem task, which is presented in Fig. 2.

After a user has chosen the problem task above, its camera is turned on and needs to be pointed on a special marker. A scene with problem task simulation will appear on the screen (Fig. 3). At the beginning a stone and two textboxes appear. Using them it is possible to set the velocity and the angle of the stone throw. The simulation changes depending on these parameters.

After the parameters of the task are set, using the key U on the keyboard it is possible to throw the stone. The directions of the velocity and stone gravitational force

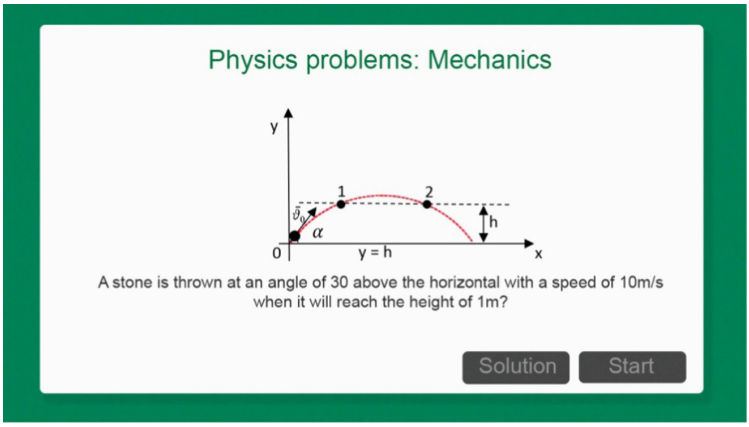

Fig. 2. The application screenshot with a problem task

Fig. 3. The application screenshot with the problem task simulation at the starting point

are displayed using arrows on the next scene. Also the angle of the stone throw appears. Since the solution of the problem is the time after which the stone reaches a certain height, in the scene after the throw the points where this height is reached are marked and the time is shown (Fig. 4). After the simulation using the keyboard it is possible to proceed to the problem task solution.

The main feature of the developed application is visualization using augmented reality. This approach makes pupils involved in experiments and the game form of the application allows delivering material in a simple and easy way (Fig. 5). Besides, such experiments will be much better mastered thanks to the interaction of the application virtual elements and real physical objects.

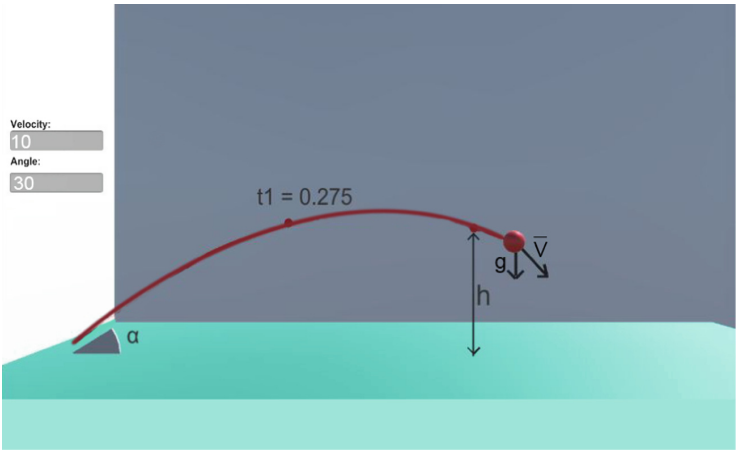

Fig. 4. The application screenshot with the problem task simulation at the end point

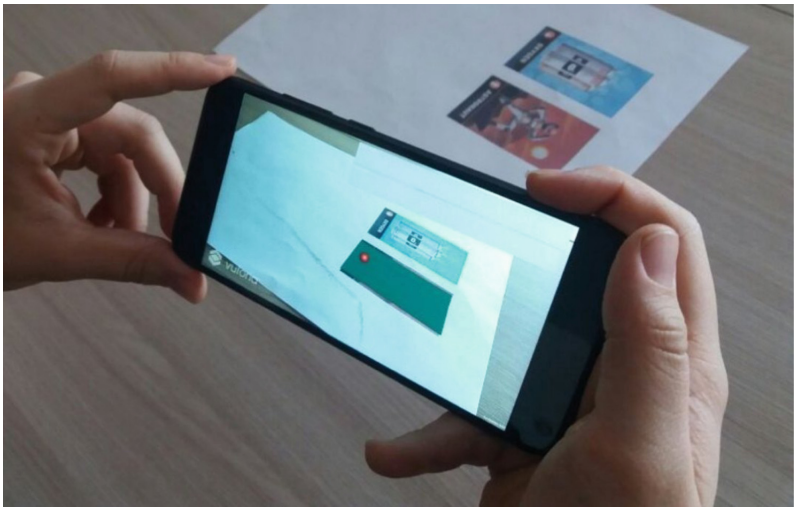

Fig. 5. Demonstration of the developed application

In the application there is an access to the set of problem tasks from "Mechanics" section so far. Currently 12 problem tasks are implemented. The problem tasks from "Electricity" and "Optics" sections are under the development right now and will be added to the application in the near future. New problem tasks can be easily integrated into the application. All the tasks are taken from the physics course of a secondary school curriculum. Each task contains an animated scene and a solution.

For each problem task a separate 3D model was created and a physical engine was implemented. The engine calculates the interaction of the model's objects. The models were realized in Blender, and the main functionality is implemented in C#.

In Fig. 6 the component diagram of the application developed is displayed. All the components can be divided into 3 groups: (1) starting point; (2) problem tasks – main components; (3) additional components, which are problem tasks solutions. The main project part is a set of 12 problem tasks. Each problem has an access to the shared collection of 3D objects. Besides, all the problem tasks follow the common structure of classes.

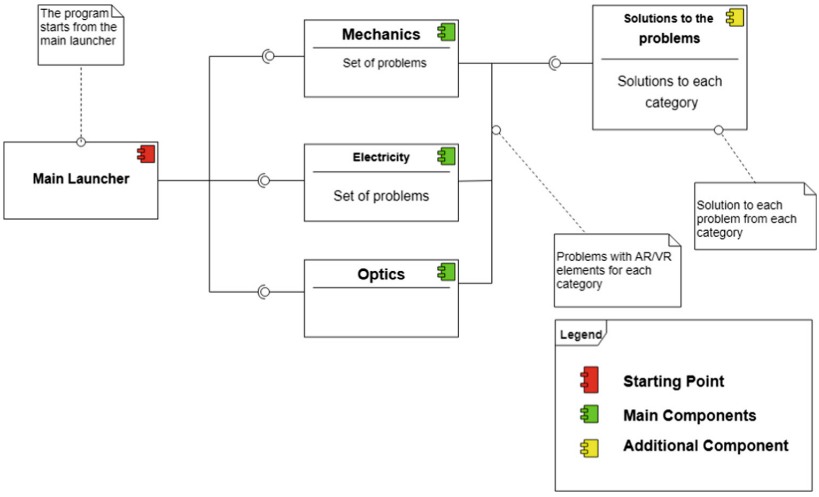

Fig. 6. The component diagram of the application

5 Conclusion

The efficiency of the developed application was estimated in the following way. 20 pupils of the 9th grade of the RFMW were interviewed. The question was "Is the application with augmented reality effective supplementary learning tool to study physics?". The results of the interview are presented in the Table 1.

Table 1. The results of the interview

Possible answer	Percentage of pupils
Not effective at all	1,2
Rather not effective	3,7
Do not know	6,1
Rather effective	27,4
Very effective	61,6

The interview shows that 89% of the respondents believe that the developed application is effective and convenient in use. The pupils noted that such application increase the interest in physics in general.

In such a way, new information technologies open wide perspectives for improving the quality of education. Such technologies like Augmented Reality allow transforming the process of solving traditional physical problem tasks into an interactive game. Thus, pupils become more involved into the studied process. Such visualization helps in understanding the problem and solving it. And as a long-term result pupils become more motivated and interested in the subject in general.

The authors continue to work on the current project and develop new animated problem tasks from other physics sections to be integrated into the application.

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