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Interactive Educational Content Based on Augmented Reality and 3D Visualization

Sergey. Sannikov[1*], Fedor Zhdanov[2†], Pavel Chebotarev[3‡], Pavel Rabinovich[4§]

[1] *Mordovia State University named after N. Ogarev, postgraduate in the Department of Applied Mathematics, Differential Equations and Theoretical Mechanics, Russia, Saransk, sannikov@funreality.ru*

[2] *Exciting Reality OOO, Lead Developer, Russia, Saransk, zhdanovfv@gmail.com*

[3] *School #29, teacher, Russia, Podolsk, mail@adicolor.ru*

[4]*Moscow State Regional University, Vice-rector, PhD, Russia, Moscow, pavel@rabinovitch.ru*

Abstract

The article is dedicated to implementation of Interactive Educational Content using augmented reality and 3D visualization technologies in secondary education. Methodological and technological aspects as well as architecture and elaboration algorithms are considered.

Keywords: educational content, electronic educational recourses, augmented reality, 3D, exciting reality, virtual lessons, virtual laboratories

1 Introduction

The article examines the approaches to creation of educational content using augmented reality and 3D visualization technologies (hardware and software devices) and the implementation of such educational content in secondary education in order to facilitate active forms of learning activity.

Schools are not the only source of knowledge and skills [23] in modern open information society with rapid development of informal education ([36], free educational resources [11, 15, 17, 22, 33, 41, 45], social networks [18, 28, 47], etc.)

Traditional schoolbooks do not represent the source of actual knowledge whereas creation of electronic manuals often becomes a “wrapping” of old content in a new form. Decrease of interest of children to learning as well as their overload with information is noted with this regard.

In view of above the task to motivate students to study natural science, physics and mathematics, to develop technical creativity, to implement research and project activity becomes vital.

[*] Technology aspects of the article
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Creation of interactive educational content using augmented reality and 3D visualization technologies (hereinafter referred to as “IEC”) and its implementation in secondary education is deemed to be one of the effective instruments to solve the task mentioned above.

IEC represents an aggregate of electronic educational resources (hardware and software, content), which includes texts, audio, video, virtual 3D objects, feedback forms, navigation and guidance. IEC is easily integrated into traditional printed publications (textbook, manual or book) and notably widens its didactic effect by possibility to implement various educational practices: learning of new training material, consolidation of training material learned, virtual laboratory work, study of virtual models, study appraisal, etc. IEC is one of the basic components of information and educational sphere of the school [37] and may be successfully implemented both in traditional and in electronical education [21, etc.]: while group studies or in frames of individual student’s work [e.g. 43], as well as during additional project and research activity [e.g. 36].

Efficiency of implementation of EIC is procured by the following:

- students’ interest in the content and form of the training material (visibility, involving visualization due to usage of animated 3D models, augmented reality, 3D visualisation) as well as in various opportunities of IEC application (virtual experiments where natural ones are not feasible);
- methodological and technological innovation aspect of IEC;
- accessibility of IEC for the account of usage of widely spread software (Windows, MacOS, iOS and Android);
- quality of content (images and 3D models);
- accuracy of content elements from the scientific point of view; their target being development of concrete competences, knowledge and skills, achievement of the determined result of research.

IEC provides an opportunity to implement a model of mastery learning in practice [8]. Motivation of students to learn is executed by inclusion of student into research and imitation practice as well as into various spheres of development activity. Interactive content enables to organize active forms of educational process, research and project activity [Asmolov A., Leomtiev A., Elconin D., Zaporozhec A., Kudryavcev T.].

Implementation of IEC facilitates to achieve main result of education – formation of students’ competences:

- comprehension of concepts, operations and relations;
- skills of flexible and accurate execution of operations;
- logical thinking, reflection, explanation and argumentation;
- tendency to consider the subject to be rational and useful along with belief in his own effectivity.

Didactic advantage and novelty of implementation of IEC is determined by its support of diversity and consistency of educational programmes in line with age related peculiarities and personal motivation of the student. IEC facilitates execution of research and analysis of various physical phenomenon and objects’ characteristics as well as learning of operational principles of devices and experiments in the most involving form.

2 Related work

Development of computer devices of video processing enables to manipulate with reflection on the computer screen while interacting with existing objects or adding new virtual ones (technology of augmented reality, AR). This feature is actively used in computer games and advertising. Implementation of AR in education becomes popular due to its didactic advantages. According to [12] there are five ways of implementation of AR in education (Discovery-based Learning, Objects Modelling, AR Books, Skills Training и AR Gaming). Thus, certain targets of educational process are achieved (State of Mind (Increased Motivation, Increased Attention, Increased Concentration, Increased Satisfaction), Teaching Concepts (Increased Student-cantered Learning, Improved Collaborative Learning), Presentation (Increased Details, Increased Information Accessibility, Increased Interactivity), Learning Type (Improved Learning Curve, Increased Creativity), Content Understanding (Improved Development of Spatial Abilities, Improved Memory), Reduced Costs).

Researches of implementation of AR technology [2, 5, 9, 12, 13, 16, 17, 20, 27, 30, 35, 39, 42, 46, 48, etc.] as well as 3D visualization [1, 6, 6, 25, 26, 24, 29, 31, 32, 40, etc.] in education were executed while execution of the respective surveys.

Following the result of researches, certain hardware and software devices were chosen for elaboration of multiplatform IEC, which enables to increase the degree of students' involvement into educational process.

3 Technological aspects of elaboration of the Interactive Educational Content

Let me reveal technological aspects of elaboration of IEC by the example of creation of hardware and software complex "Exciting Reality" (producer - Exciting Reality OOO, http://funreality.ru).

Hardware and software complex is composed by the following modules:

- module of video-stream capture;
- module of searching of area of special marker in captured video-stream ,
- module of marker decoding and obtaining of coded information,
- module of logic of virtual laboratory works, which uses 3D models and applies scenarios of current laboratory work to them (scenarios of interaction of objects with the scene and with each other) based on the information regarding marker's positioning,
- module of creation and reproduction of ultimate image (incl. 3D).

Algorithm of interaction is reflected on the Figure 1.

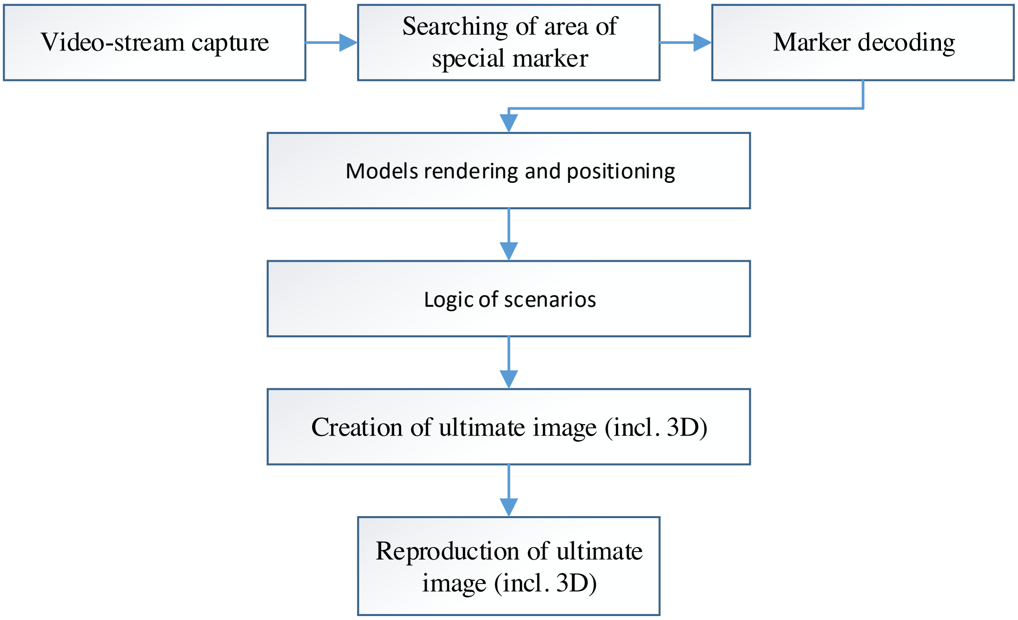

Figure 1 - Algorithm of interaction of modules of IEC

Multiplatform system of elaboration of 2D and 3D applications Unity [44] was chosen as the basic среды рендера моделей and their integration with AR and logic of scenarios. This instrument was chosen due to simplicity of its elaboration, flexibility and support of lots of platforms. Namely, Unity supports native libraries, which enable to create modules of high capacity for implementation of AR.

Libraries Vuforia [36] were used while creation of mobile versions of IEC; whereas ArUco [3, 20] - open realization of system of распознавания специальных (fiducial) маркеров - was used while working on the stationary platforms. Vuforia supports mobile platforms on the basis of operational systems Android and iOS and was chosen due to its high capacity along with satisfactory recognition accuracy. ArUco was chose for support of stationary platforms in view of its acceptable license policy (BSD); the library being a part of Open CV currently. Modules of definition (determination) object position on the scene are implemented in form of native uncontrolled plugins since operation in real time with high complexity of computation is required.

The following basic architectural programme modules are used for integration of AR into IEC:

- native uncontrolled libraries of AR (Vuforia, ArUco) ;
- interfaces for interaction of the AR libraries with Unity,
- module of virtual objects' behaviour without AR ,
- level of virtual objects' abstractive behaviour ,
- logic of scene behavior,
- user interface.

All the modules operate in frames of a single application and incorporate interface sufficient for interaction with each other (Figure 2).

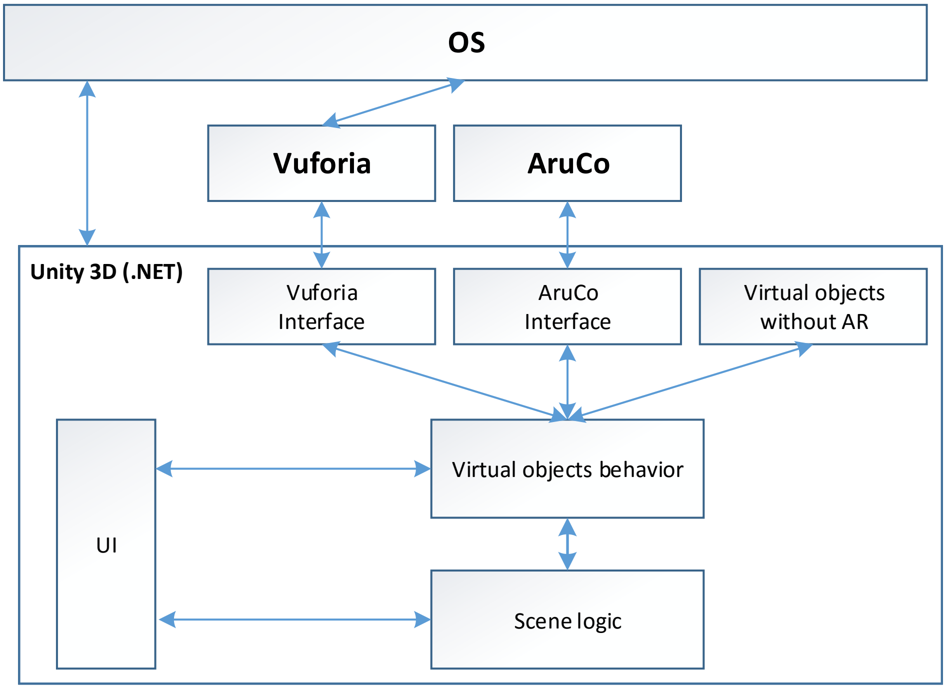

Figure 2 - Interaction of architectural software modules of IEC

Addition of supplementary level of abstraction of action of interactive objects enables to switch the system of AR processing or to turn it off with simultaneous substitute by pre-recorded animation or with possibility for a user to point objects' position by him without webcam in real time. This feature leads to notable simplification of description of the logic of development of the scene. The sequence integration stage of scenario of laboratory work into IEC is developed in line with elaborated architectural schedule of interaction of IEC modules and detailed specification of scenario for applying of educational content (execution of laboratory work).

3D visualization technology was used while visualization of objects for intensification of effect from superimposition of real and virtual realities and achievement of absolute penetration of the student into the subject. Technology of active and passive 3D-stereoscopic polarization was chosen for reflection of video in 3D format in IEC on the basis of common practice of usage of 3D visualization in education. Support of the following basic modes of 3D visualization in the IEC is implemented on the basis of above mentioned technologies: interlaced, above/below / side-by-and anaglyph stereo-pair. Swift between these modes is possible without IEC reload.

Scene (image) rendering from two virtual cameras for each of eyes separately is used in order to create the effect of 3D image as usage of a single camera does not provide 3D video image. In this case video-stream may be place at any distance from the screen; parallax of texture coordinates being set independently for the left and right cameras. If no parallax is set video will be treated to be at the same distance as the screen reproduction device. In order to create a comfort 3D effect 3D stereo parameters are to be set in such a way to ensure virtual objects being closed compared to the video surface. Connection of two cameras (or one stereo camera) as well as enhancement of the module of stereo image reproduction are required in order to reach 3D effect. It is noted that distance between the real and virtual objects is to be identical otherwise the effect of scene elements immersion/extension takes place.

In view of the fact the increase of students' interest in learning is one the targets of creation and implementation of IEC, the latter is created on the basis of game oriented approach. Thus, an interface similar to a computer game and a gameplay with increscent level of difficulty of tasks are used. Students feel complicity and his personal input into mutual activity, interest to achievement of stated targets. It is noted that a consistent and measurable feedback is used in IEC for dynamic correction of user's behaviour and prompt familiarization with gameplay potential.

Software interface for each of the laboratory work (lesson) represents a topical subject animated in game oriented manner (for general game like impression) which facilitates emotional involvement of student. Thus, a physics laboratory equipment in relevant surrounding is situated in the centre of the screen; dynamic parameters of experiment as well as navigation menu being situated on both sides of the screen. Parameters of experiment may be also reflected on the animated measuring devices (ammeter, Geiger counter, dynamometer, etc.), which are connected to the experimental equipment. All the parameters are variable depending on the current status of the experiment, what makes the process active and requires attention and reactions of student in real time. With the help of AR the game like interface becomes spry – by tilting and turning tablet student may look onto experimental equipment from various points; whereas support of multi touch gestures enables to zoom the object closed or further (example on Figure 3).

Figure 3 - Example of game like interface for laboratory work

In order to improve visual perception and to attract student's attention virtual persons, who accompany student on each of the unit of laboratory work by voice and animation if required, were introduced into software. 2D animated persons spry fit the interface and may be used both in frames of interface elements (by mutually represented dialogue windows) and separately on the scene with objects.

Laboratory works are divided into units with increscent level of difficulty of tasks, where, like in a computer game, student receives points for completed tasks; the latter being additional motivating element. All educational results are stored in the data base, which a teacher may use for analysis of topic adoption and further correction of educational trajectory for each of the students.

Notwithstanding a game like implementation of visual presentation of information in IEC dynamics of the experiment processes is based on real physical and mathematical models of phenomenon. For example, in laboratory work "Estimation of Efficiency of Equipment with Electric Heating" software amination of the process of heating of equipment and dynamic parameters of experiment process are calculated by special script AnimationElectricScript.cs on the basis of physical laws. Calculation is executed by method Calculation(), example of original code

```
private IEnumerator AnimationV() {
float step = 43f; while (step >= finalStepArrowV) {
step = step - speedArrowV; arrowV.transform.localRotation = Quaternion.Euler(11.45908f, 0.9753198f, step); yield return new WaitForSeconds(0.01f);
} }
void Calculation() {
mWater = 0.15f; t0 = 21f;//U = 300f; //I = 4f;
r = time; t = levelTemperature;
161
P=U*I;A=P*r; Q = 4200f * mWater*(t-t0); n = Q / A;
}
```

Figure 4 - Interface of laboratory work “Estimation of Efficiency of Equipment with Electric Heating”

It is noted that game like interface is not overloaded by irrelevant information in order to avoid low performance of software of working stations or tablets loading IEC. In view of the above IEC is capable to operate on the basis of low costing tablets and smartphones (with no need for loading of 3D visualization function) based on the applicable software.

The following requirements to hardware exist for IEC operation (in groups or individually): graphic station (min 1 GHz CPU, min 1 Gb RAM, min 1 Gb free space on HDD, min 64 Mb memory video card, sound card), 3D webcam (or two classic webcams connected), device for 3D stereo reproduction (monitor, TV or projector with a complex of polarizing glasses).

4 Conclusion and Future Work

This article represents approaches to creation of interactive educational content on the basis of augmented reality and 3D visualization technologies.

The basic results of the research are the following:

- developed architecture of software modules of IEC;

- formed tools set for creation the IEC (rendering of virtual models, integration of modules with AR and logic of scenarios, libraries for mobile and stationary platforms, creation of user interface);
- developed content and scenarios of its presentation for virtual lessons and laboratory works in physics;
- designed algorithm of creation of IEC and recommendations for requirements to hardware;
- worked out methodological basis of implementation of IEC in secondary education.

Universalism of developed approaches enables to create and implement IEC for various sciences (physics, chemistry, biology, astronomy, mathematics, history, geography, etc.)on various hardware platforms online and offline, what is important for schools.

Practical implementation of IEC was executed in schools of the Moscow region, Mordovia and Bashkiria regions. Physics lessons were held with the help of IEC. Opportunity to hold theoretical lessons and visual demonstration for explanation of complex topics (electromagnetic induction, nuclear reactions, thermal and electrical phenomena, etc.) caused great interest of both students and teachers. Practical implementation confirmed the largest capacity of 3D classes based on AR and implemented IEC of 30 students. Various configurations of hardware including compatibility with interactive boards were examined as well.

Direction of further research and development of the authors is determined by the noticeable interest of students, parents, and teachers to IEC.

- development of IEC which complies with the basic educational programme of secondary education in natural science;
- harmonization (integration) with schoolbooks;
- development of methodological recommendations for teachers related to practical implementation of IEC (incl. compilation of virtual and real experiments, organisation of individual work with virtual models);
- development of memos for parents related to usage of IEC at home;
- holding of open events aimed at increase of teachers' qualifications in implementation of IEC.

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