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Enhancement of Learning and Teaching in Computer Graphics Through Marker Augmented Reality Technology

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ABSTRACT

In this paper the experience gained at using low-cost interactive marker augmented reality (AR) technology during course Computer graphics is presented. The preliminary exploration of AR technology adoption for teaching support and learning enhancement is done and several benefits are identified, summarized and analyzed via a model. Two learning scenarios are designed based on human-computer interaction principles to present important concepts virtually in interactive and engaging way. The students' opinion is gathered and the results describe AR as promising and effective technology that allows better understanding of theory and facts and that supports creative thinking and development of more realistic 3D models and scenes.

KEYWORDS

Augmented reality, Computer graphics, learning enhancement, teaching, technology, interactive learning environments

1 INTRODUCTION

Augmented Reality (AR) is a technology that utilizes computer vision methods to combine computer-generated virtual objects/ environments with real objects/environments, to enhance or annotate what can be discerned by the human user [1].

Virtual 2D or 3D computer graphics objects are augmented with real world creating the sensation that virtual objects are presented in the real world. The virtual objects display information that the users cannot directly detect or hardly identified with their own senses. Marker and markerless AR applications are experimented for educational purposes. More simple and low-cost solution is marker pattern creation with combination of web camera usage and computer. Computer graphics and AR authoring software tools need for creating 3D objects, marker patterns and tags, for objects rendering and positioning in 3D space. AR effect can be created without using markers, it is the so called markerless AR that uses special equipment for placing virtual elements in a digital or real world. Markerless AR techniques: the magic mirror and the magic lens have not yet advanced to the point where it's possible to provide a simple way for large-scale usage [2].

Our real world is three dimensional, but processes, phenomena and events are still explained to students through two-dimensional media: diagrams and pictures in textbooks, on boards or on

slides. AR is a technology with a possibility to transform two dimensional pictures into three dimensional computer graphics, showing spatial forms and AR is considered as a medium, combining aspects from ubiquitous computing, tangible computing, and social computing [3].

The aim of the paper is to explore the benefits of AR technology for educational sector and in particular for Computer graphics course. For this purpose, several AR applications utilized in different learning scenarios from mathematics, chemistry, biology, astronomy, automotive engineering are explored and benefits for learning and teaching processes are identified and summarized via a model. Then the possibilities for integration of AR learning objects in a learning environment are examined. Scenarios in context of Computer graphics course are carefully designed based on human-computer interaction principles so that meaningful virtual information is presented in an interactive and engaging way. The advantages of marker AR technology for enhancement of an individual's learning experience and better understanding of spatial spaces are discussed after taking the students' comments.

2 AUGMENTED REALITY IN EDUCATIONAL SECTOR

The literature overview shows that AR provides interactive interface for students to learn and explore new things in more interesting ways in different science subject domains. Also, educators are supported with three dimensional visual techniques to present theories and facts. There are many studies conducted to prove that AR implementation in classroom in different forms helps to improve the learning process and to facilitate teachers' work. A few of them are examined and summarized below.

2.1 Augmented Reality for Learning

AR in chemistry education is investigated in [4] exploring how students interact and learn with AR and physical models of amino acids. Several of students like AR technology, because the models are portable and easy to make, allowing them to observe the structures in more details and also to receive a bigger image. Other students feel uncomfortable using the AR markers; they prefer to interact with ball-and-stick physical models in order to get a feeling of physical contact. The research provides guidelines concerning designing the AR environment for classroom settings.

In the biology area, a learning system on interior human body is produced to present the human organs in details when students need such knowledge [5]. The analysis point that there is no significant difference is usage of head-mounted display and a typical monitor for visualization and students consider these systems as useful and enjoyable tools for learning of the interior of the human body.

In astronomy, the AR technology is applied as a method for better students' understanding of sun-earth system concepts of rotation/revolution, solstice/equinox, and seasonal variation of light and temperature [6]. The authors report that the usage of visual and sensory information creates a powerful learning experience for the students, improving significantly their understanding. The analysis implies that learning complex spatial phenomena is

closely linked to the way students control the time and way they are able to manipulate virtual 3D objects.

Development of AR books contributes to enhancing the learning process too, allowing the final user to experience a variety of sensory stimuli while enjoying and interacting with the content [7]. In a preliminary evaluation with five adults the author founds the AR book's features impact learning in several ways: enhance its value as an educational material, easier understanding of the visualized text, audio-visual content is more attractive than standard text books.

AR books technology is currently suitable to implement in storytelling, giving possibilities for visualization of 3D animation virtual model appearing on the current pages using the AR display and interacting with pop-up avatar characters from any perspective view [8].

2.2 Augmented Reality in Teaching Practices

AR technology for teaching mathematics (multi-variate calculus) to underground students with aim the level of theory understanding to be improved and students to be encouraged to apply acquired concepts and relate them to every-day life is presented in [9]. The results confirm the usefulness of AR for teaching Calculus improving the different dimensions of understanding (method, purpose, contents and form). AR in the area of electrodynamics is used to visualize the 3D electromagnetic fields with an AR display after their computing with the finite element method [10]. The authors agree that AR is a vivid method for visualization of electromagnetic fields. They conclude that AR is suitable technology for better understanding of electromagnetic field theory when students and experts easily connect the characteristics of the fields with the physical object.

AR as a visualization tool is experimented in Computer-Aided Design (CAD) lectures [11]. According to students' opinion this technology facilitates understanding of the forms and volumes of objects and also, students comprehend the space positions of objects and its relations with others. An AR system for automotive engineering education is developed to support teaching/learning of the disassemble/assemble procedure of automatic transmission of a vehicle. The system consists of vehicle transmission, set of tools and mechanical facilities, two video cameras, computer with developed software, HMD glasses, two LCD screens and software that provides instructions on assembling and disassembling processes of real vehicle transmission. Overlaying of 3D instructions on the technological workspace can be used as an interactive educational step-by-step guide. The authors conclude that this AR system makes educational process more interesting and intuitive, the learning process is easier and financially more effective [12].

2.3 Identified Benefits of Augmented Reality for Education

Several advantages to integrate AR technology in education are identified during the examination of AR implementation in educational practices. Utilizing AR for learning stimulates creative thinking among students, enhances their comprehension in concrete subject domain and increase the understanding of spatial spaces. In

several unattractive science subjects AR technology can stand as a motivation tool for conduction of students their own explorations and as a supportive tool of theory learning in an interesting and enjoyable way. AR proposes a safe environment for students to practice skills and conduct experiments.

The key benefits of AR technology are summarized in [13] : excels at conveying spatial and temporal concepts; multiple objects can be placed in relative context to one another or relative to objects in the real world; maximizes impact, creates contextual awareness, enhances engagement, and facilitates interaction; heightens understanding with kinesthetic learners; provides a high degree of engaging, self-paced interaction, and maintains interest; improves communication, learning retention, and interaction with others; includes both professionally built content and an AR content building tool suite.

Several AR system affordances are described in [14] in context of environmental design education: rapid and accurate object identification, invisible feature identification and exploration; the layering of multiple information sources; readily apparent object relationships; and easy manipulation of perspectives.

A generalized model about the benefits of AR technology for learning and teaching is summarized via Figure 1. A student (alone or in a group) can be involved in a learning process according to preliminary defined learning objectives (Bloom taxonomy is used here) utilizing environment with learning resources/services (including marker AR learning objects (LO)) and achieving knowledge/skills taking advantages of AR technology.

3 Augmented Reality for Teaching and Learning Computer graphics

AR is a promising technology in educational sector, but it is important to ascertain whether it can support learning in Computer graphics subject in an effective way. The following hypothesis in this study is suggested: marker AR can be effectively combined with traditional learning methods to help students understand complex concepts and analyze spatial spaces during practical laboratories where they create 3D models and scenes. Two interactive scenarios are designed and demonstrated to Computer graphics course. The first scenario is called “Project-based learning” and it represents a gallery of 3D models and scenes to introduce students to possible problems in their project working. The second one is called “Learning by AR representation” and the tutorial is designed consisting of several marker AR learning objects about vector and raster hardware input, output and interactive computer graphics devices. The participants are students in the second year of their bachelor degree from Computer Science and Electronics specialty. They are divided administratively in three groups of 20 students. Qualitative responses are collected from the students based on the “thinking aloud” technique [15] and the method of “informal interview” [16].

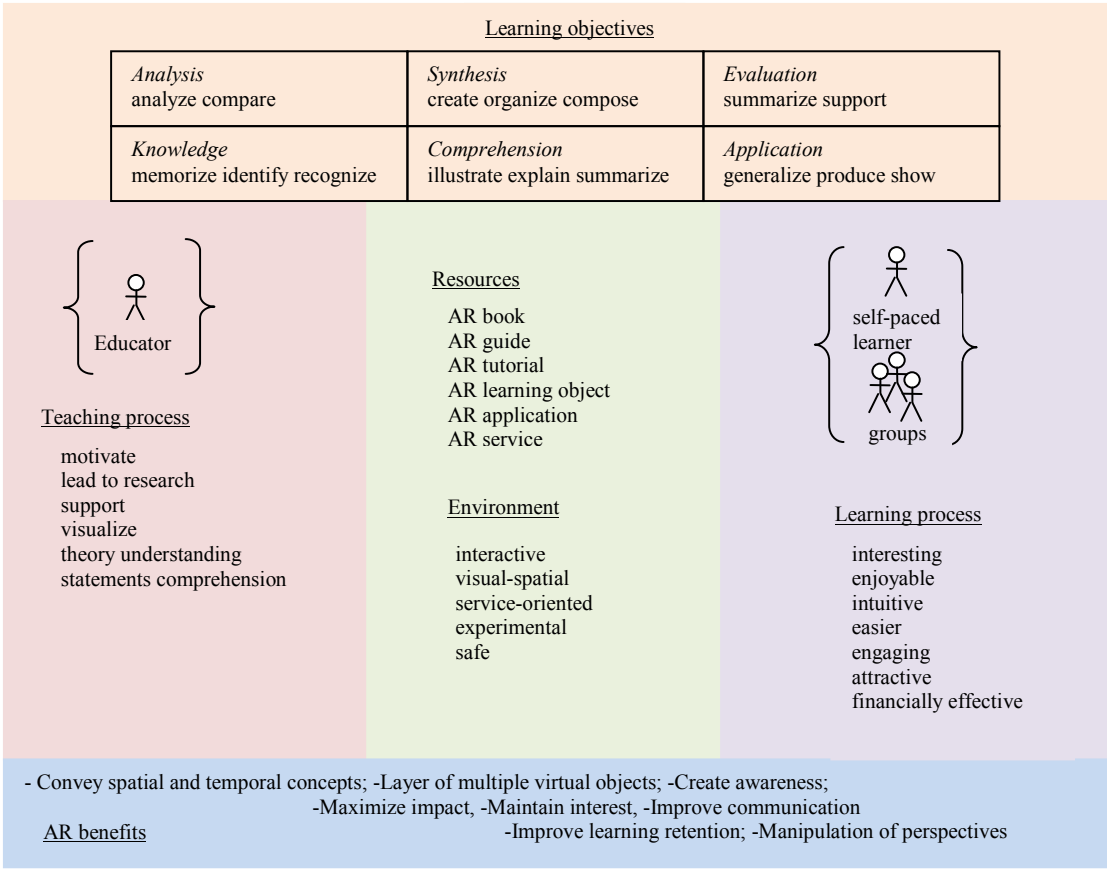

Figure 1. Benefits of AR technology for education

The project based learning (PBL) is an important factor for generic (problem solving, communication, creative thinking, decision making, management) and specific technical skills acquired by students studying Computer graphics course [17]. It enables them to understand in details given topics reconstructing complex models and scenes from the real world (interior, exterior) or creating new imaginary solutions (e.g. cosmic scene). The PBL model proposed in [18] is applied and includes the following steps: (1) Introducing students to the state of the art problems and showing the huge potential of working topics; (2) Identification of challenging problems and solving the problems by students; (3) Setting up the driving questions what has to be accomplished and what content has to be studied; (4) Introducing students to the environment for problem solving (including collecting and managing its main components when students organize their PLEs) with 3 main components: digital resources (marker AR gallery, tutorials, best practices, papers), web-based applications/tools and free hosted services; (5) The process of the actual investigation is performed: how the tasks can be completed that require higher-level and critical thinking skills, such as analysis, synthesis and evaluation of information; (6) Guidance is provided when students need it (through student-educator interactions, peer counseling,

guiding, project templates, etc.); (7) Assessment of the students' knowledge and competences as a result of the project work.

AR gallery is developed to support the first step of PBL model when students have to choose a topic for implementation. AR gallery consists of free available 2D pictures of models and scenes, created with 3DSMax software and also the previews works of alumni. The students from past years in this first step were involved in 3D realistic modeling via these 2D pictures, talking about shapes, space, perspectives, light and rendering effects, color patterns, materials and maps. This year, the AR gallery is presented to students giving them access to marker AR learning objects and possibility to interact with 3D models/scenes as long as they wish to understand the physical phenomena, art techniques or engineering methods (Figure 2). This allowed the exploration of the potential benefits of AR technologies for learning in Computer graphics course. AR gallery could be viewed locally or over the Internet, using only low-cost system of webcam and computer.

One part of students prefers to work on their projects in self-paced mode and others are grouped in two or three. Self-paced learning is chosen by individuals who wish independently to direct the processes of doing and learning and they feel bored and frustrated when they have to work in a group. Group-based learning is characterized with agreement among students about the pieces that can be created, with good communication, ideas transferring and decision making. It removes the barriers of individual thinking and understanding and offers students with multiple arguments which encourage thinking in different aspects and learning from each other. It also forces and motivates weaker students to improve their work/learning and to join the collaborative union that eventually helps them to feel stronger in a given topic.

In the second scenario the main strategy is based on learning by AR representation. According to the curriculum of the Computer graphics course, one topic is devoted to the understanding of input, output, interactive raster and vector devices. To present a more engaging way of learning, 3D representations of the hardware is combined with human-computer interaction techniques. Students are able to examine the 3D information about raster and vector concepts and their realizations in a given hardware solution. The aim of these marker AR learning objects (organized in a tutorial) is to combine traditional methods (i.e. textbook reading with 2D pictures) with interactive AR technologies to understand how such computer graphics hardware devices look like in reality from different perspectives. The 3D representations are available for students and they are able to perform basic interactions on them such as rotations, translations and scaling operations. Several 3D models in this tutorial are created by students and educators, others are found through Google search as free available models.

The AR patterns are presented to the students in the lecture time and they have a possibility to interact with AR models during laboratory practices and at home in informal way in time they wish. Experimentation with AR technology is done through software package Autodesk 3DMax and installed ARMedia Plugin. The solution is chosen after detailed examination of several

possible software platforms and tools, because of the following reasons: (1) Autodesk 3DMax environment is well-known by authors and it is studied by students during the course Computer graphics. In this case the students can play a role not only of content consumers, but also can be involved in authoring and learning process, working on their projects (including AR technology). (2) ARMedia Plugin is easy and fast for installation and configuration by educators and students. (3) AR LO can be visualized on any computer with the freely available ARmedia Player, without the need of having Autodesk 3DSMax and the Plugin installed (if they are consumers).
The free hosted learning management system Edu20 is utilized for students' facilitation of learning scenarios, access to AR content/patterns and social interactions (Figure 2). The created two folders under the panel Resources include .max files with 3D models and scenes and a marker. Students just have to download and open .max files and print the marker to experiment with AR technology.

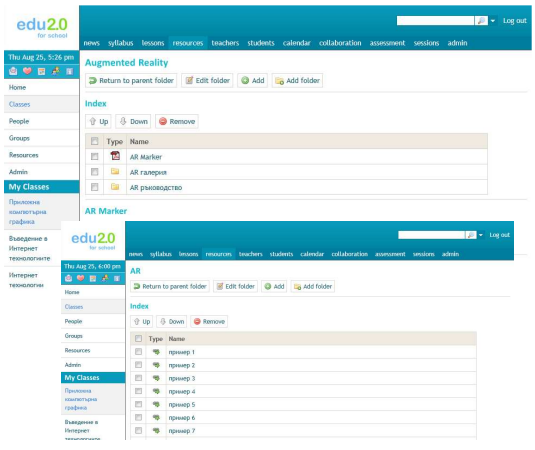

Figure 2. AR resources in EDU20

4 Results

The students' opinion after experimentation about effectiveness of marker AR technology for learning in the designed learning scenarios is gathered. The students are asked to comment on the effectiveness of AR learning objects in their preparation for project working and studying of topic about computer graphics hardware devices. More of them (75% of students) answer that AR technology helps to understand different concepts in computer graphics field (Figure 3).

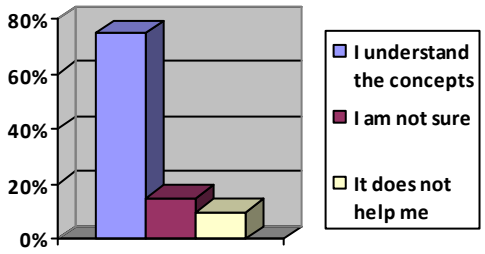

Figure 3. How well does AR technology support the theory understanding?

Their answers on the question "What are the benefits of AR technology" show that the main advantages of AR are interactivity and the attractive way for learning and teaching according to 85% of students. Other benefits are voted as following (Figure 4): stimulation of conceptual thinking and receiving greater sense of 3D space (80%), theory understanding (75%), representation and perception enhancement (70%), receiving more fun (70%).
The students are asked to share their opinion about the potential of AR technology usage as an additional tool for learning the Computer graphics course.

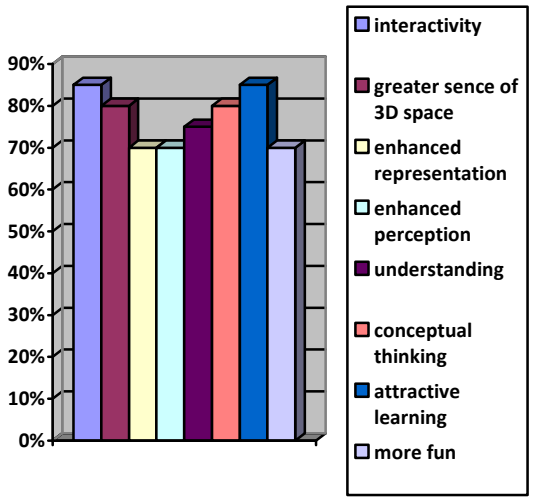

Figure 4. What are the benefits of AR technology?

As far as the students' feedback is concerned, all of them agreed the presented technology is very promising and should be applied in the classroom in the future. Most of them are impressed with the ease of use, the flexibility and the capabilities of the learning interface. They commented that the marker AR LO can enhance interaction and engagement with the subject matter. The spatial spaces can be examined in details that support creation of more realistic 3D models and scenes. Several students pointed out that the use of AR technology is an impressive method for easier learning, memorizing and understanding the theories and concepts in Computer graphics. Among the advantages of AR technology students include the possibility to observe supplementary digital information, to see the model details and the opportunity to manipulate intuitively the virtual information, repeating LO as many times as they need. However, almost all students make benevolent comments about the fact that only a few scenarios with several LO are implemented. Several of them express their enthusiasm and ideas to prepare models and scenes that could be utilized as parts of AR gallery and AR tutorial.

5 Conclusions

In this paper, a low-cost interactive environment including AR technology for teaching and learning improvement is presented. The innovation of the solution is that it can propose students high interactive human-computer interface for models manipulation and thus observing the details in 3D space. Autodesk 3DSMax is utilized for 3D scenes creation and for augmentation through ARMedia Plugin. The effect of this approach is increased of the fact that students are involved not only in interaction with AR learning objects, but also in an authoring process of 3D learning objects. The results of the case study show the positive opinion of students about the future usage of marker AR technology in the course Computer graphics. They are impressed by the possibility of multi-modal visualization, practical exploration of the theory, and an attractive and enjoyable way for learning. The AR technology can be applied in self-paced learning, where individual learners are able to manage their directions of exploration as well as in group-based learning where communication, ideas sharing and interaction among participants are among the main methods for learning.

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