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Visualization for Increased Understanding and Learning Using Augmented Reality

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ABSTRACT

Augmented reality allows the superimposing of computer-generated images over real scenes in real time. This paper describes a project in which an interactive solar system was developed to help middle school students in the sciences understand spatial concepts using augmented reality. The marker-based augmented reality application works by using a camera to read a marker, then calculates the camera position in 3D space, and superimposes the solar system. With a webcam and a laptop, augmented reality application development is highly accessible.

The visualization application research detailed here will be used for formal pedagogical research examining whether students benefit from this method by conducting both pre-event and post-event assessment surveys. The surveys will gather valuable feedback from middle-school science students concerning whether the augmented reality method is effective for teaching and learning. Preliminary feedback from students and educators indicates that this visual teaching method is effective.

Categories and Subject Descriptors

H.5.1 **[Information Interfaces and Presentation]**: Multimedia Information Systems, *3D graphics, Augmented Reality, and Virtual Reality.*

General Terms

Experimentation

Keywords

Augmented Reality, Computer Science Education, and Visual Learning.

1. INTRODUCTION

A good definition of augmented reality (AR) defines this concept as a variation of virtual reality [1]. Virtual reality refers to the situation when the user is completely immersed inside a synthetic environment. While immersed in the environment, the user cannot see the real world around him/her. In contrast, AR allows the user to see the real world with computer generated objects superimposed upon the real world. Therefore, AR *supplements* reality rather than *replacing* it. This paper explains a research project underway on augmented reality. The primary purpose of this research is to create an interactive solar system that can be used as a learning tool in the middle school sciences, encompassing grades 6 to 8, to help students better understand spatial concepts and make learning more effective and interactive.

2. PREVIOUS WORK

Augmented reality technology has been used in fields [1] as varied as medicine, robotics, manufacturing, machine repair, aircraft simulations, entertainment and gaming [2]. This research presented concentrates on the use of augmented reality in education.

Several authors [3, 4] suggested that virtual reality increases motivation, contributes to better learning, and enhances the educational experience for students. Although AR applications for education have been in place, its impact on learning has only now begun to be explored.

2.1. AR in Chemistry Education

A recent study [5] investigated how chemistry students interacted with augmented reality and physical models and evaluated the student perceptions regarding these two representations in learning about amino acids. Although there were students who liked using AR to learn about the amino acids because it was portable and easy to make, allowed the students to observe the structures in more detail, and provided a bigger image, others felt uncomfortable using the AR marker because it wouldn't work if the student flipped the marker since it works on marker recognition. The study suggests that using a cube to covey the AR recognition pattern might be a solution to addressing the issue associated with flipping the marker. This research provides guidelines concerning designing the AR environment for classroom setting [5].

The application shown in Figure 1 includes both an AR marker and a physical model, which are placed on the desk side by side. They showed ball-and-stick models of the acids. Participants could choose from the AR marker or the physical model to learn about the acids. One paper [5] compares the use of AR marker and a physical model to see which one is more effective in helping students learn about the acids, as demonstrated in Figure 1.

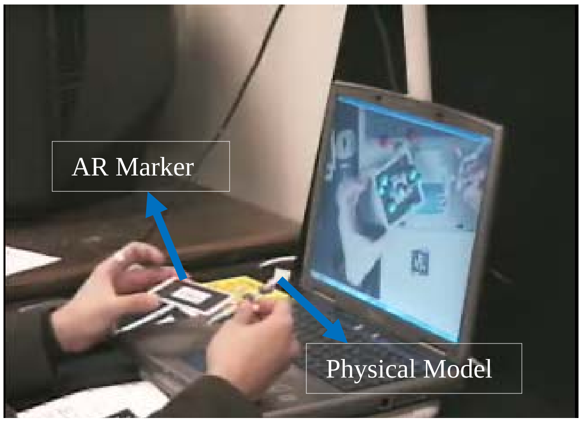

Figure 1. An AR system and the physical model [5]

2.2. AR in Mathematics

An AR application, Construct 3D, is a three-dimensional geometric construction tool specifically designed for mathematics and geometry education [6]. This application allows multiple users to share a virtual space. Students wear head-mounted displays capable of overlaying computer-generated images onto the real world. The results showed that the AR application tool is easy to learn, encourages experimentation with geometric constructions, and improves spatial skills.

Figure 2. Students working with Construct3D inscribe a sphere in a cone.

2.3. AR in Teaching

SMART (*S*yste*m* of *a*ugmented *r*eality for *t*eaching) is an educational system which was developed in Portugal by Rubina Freitas and Pedro Campos [7]. This system uses augmented reality for teaching 2nd grade-level concepts such as the means of transportation and types of animals. This system superimposes three dimensional models and prototypes such as a car, track and airplane on the real time video feed shown to the whole class. Since many children spend a great deal of time playing digital games, game-based learning has been shown to be one way to involve children in learning [7].

Several experiments were performed with students in three different schools by Rubina Freitas and Pedro Campos in Portugal with 54 students (32 females and 22 males). The results indicated that the education system, SMART, helps increase motivation among students. SMART was also shown to have a positive impact on the learning experiences among students, especially the less academically successful students [7].

3. SOFTWARE

To build the web-based AR application presented here, the following tools are needed:

FLARToolkit (*Fl*ash *A*ugmented *R*eality *Toolkit*) is an open source code library for building AR applications in Flash. FLARToolkit detects a marker using a webcam from the input message, and calculates the camera position in three dimensional space. This is shown in Figure 3(a), an illustration of AR application called "Smart Grid" from General Electric (GE) which demonstrates that the "smart grid" technology could revolutionize electric power in the United States. In the figure, the user is holding the marker to the webcam, generating an interactive 3D model display on the screen with the implementation of the GE smart grid.

Papervision3D, a 3D rendering engine for Flash that provides 3D scenes. FLARToolkit in conjunction with Papervision3D makes it possible to create an AR application.

ARToolKit Marker Generator is used to save the marker as a pattern file. This pattern file is what the FLARToolkit detects and uses to augment the 3D model as shown in Figure 3(b)-(d).

Adobe Flex Builder, a development tool for coding and designing Internet and desktop applications, can also be used to create the AR application for the web. While FLARToolkit is freely available, Papervision3D and Adobe Flex Builder are available only commercially, although educational licenses are supported.

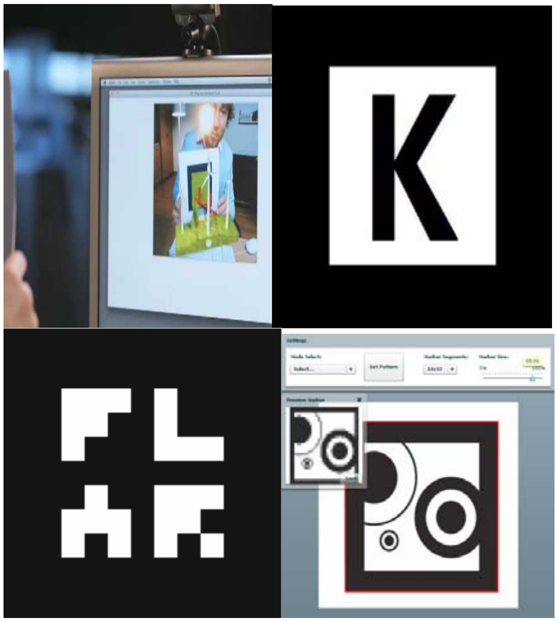

Figure 3. (a) (upper left) Example of a Web-based augmented reality application from GE, (b) (upper right) and (c) (lower left) two different markers, and (d) (lower right) ARToolKit Marker Generator, an Adobe AIR application, used to save a marker to a pattern file.

4. METHODOLOGY AND RESULTS

AR requires ActionScript with Flash libraries, FLARToolkit and Papervision3D libraries as well as Adobe Flex Builder to create the AR application. Blender, an animation software, is required to create the 3D solar system animation. The solar system objects (earth, mars, moon etc.) are imported into Flex Builder. Once the objects are imported, Papervision3D libraries are used to create rotations, zoom in/out, color and text (which will provides details about each solar system object, such as its distance, and mass). With FLARToolkit, a user can hold the marker to the webcam to allow the solar system rotate/animate on the screen. FLARToolkit combined with Papervision3D allows the user to see the virtual objects (in this case the solar system) augmented onto the real world. A webcam is required to test and demonstrate the application, and nowadays webcams are frequently found in educational settings, particularly middle schools.

The result is a demonstration of augmented reality with a marker. The demonstration shows how marker recognition permits the 3-D model to be augmented directly onto the screen. This demonstration requires a modest amount of equipment: a laptop, a webcam, and a marker printed on a piece of paper. Observers are able to see for themselves how augmented reality visualization assists in their understanding of the solar system. Preliminary data gathered from students and educators have identified this as a highly portable system, expected to be of great benefit for teaching and learning.

5. FUTURE WORK

Plans are underway for further development of the prototype, taking into account middle school curriculum objectives. An augmented reality interactive application is being built, which displays relationships among the planets of the solar system included the earth and sun. Once the application is complete, a formal assessment survey will be conducted with middle school science students to see if there is measurable improvement in student understanding of solar system. Each student who participates in the augmented reality exercise will complete a pre-assessment and post-assessment survey. Both assessments will have similar questions related to the solar system and the earth-sun relationships. The answers provided by the students on their assessments will help determine if the inclusion and use of augmented reality improves middle school science students' comprehension, understanding and motivation in learning science.

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