Augmented Reality Based Educational Tool on Live Solar System (LSS)

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ABSTRACT

Augmented Reality (AR) has its own potential in the education field, because AR can provide a seamless interaction between real and virtual objects. Hence, it draws many researchers' interest in recent years on applying AR in the education field. This paper intends to give an overview of AR and the workflow of AR application. Besides, this paper also highlights the methodology of developing Live Solar System (LSS) based on the iterative prototype software engineering life cycle model, and the LSS overview which can be divided into software and hardware components.

Keywords
Augmented Reality, Educational tools, Iterative prototype model

1.0 INTRODUCTION

Augmented Reality (AR) superimposes virtual objects in the real environment by registering in 3D and giving real time interactivity to users (Azuma, 1997; Azuma et al., 2001). In 1965, Ivan Sutherland created the first AR by building the first Head-Mounted-Displays which can display a simple wireframe cube overlaid on the real world (Surtheland, 1965). In 1990, the term of AR was coined by Boeing in a project, with the intention of helping their workers assemble cables into aircraft (Barfield & Caudell, 2001). At the end of 1990s, few international conferences were held, such as the International Workshop on Augmented Reality (IWAR), and International Symposium on Mixed and Augmented Reality (ISMAR). These conferences were based upon AR technology, and showed that AR is increasingly being an important research field. Figure 1 shows an example of AR, which blends the virtual 3-Dimensional object in the real environment.

For the rest of the paper, we will first review the background of AR in Section 2.0, and then look at Section 3.0 which describes the problems faced by students in their learning process. In Section 4.0, we present our methodology of developing the Live Solar System (LSS). Overview of AR workflow is shown in Section 5.0. Section 6.0 discusses the overview of Live Solar System components in the form of hardware and software, and finally, Section 7.0 concludes the paper.

Figure 1: Example of Augmented Reality

2.0 BACKGROUND

A Reality-Virtuality Continuum was proposed by Milgram & Kishino (1994) to explain the relationship between real and virtual environment. According to the continuum (Figure 2), real environment is located on the left end side of the continuum and the virtual environment on the other hand, is located on the right side. AR and augmented virtuality (AV) are located in between them. In the continuum, AR position is closer to the real environment, and this means that there is a higher proportion of real environment in AR. Whereas, AV is closer to the virtual environment because of its higher proportion of virtual environment. Mixed Reality however, is a domain which contains all these elements mentioned between the real and virtual environment.

AR is a variation of Virtual Reality (VR) (Azuma, 1997), therefore, both have the same fundamental elements, namely virtual objects, real-time response and visual equipment (Jong, 2005). However, they are different in a few aspects. AR only superimposes virtual objects on the real objects, where the real environment can still be seen by users. In VR, the real environment is totally replaced with the virtual environment. Hence, VR will limit user activities within a room area because users cannot see the obstructs around them. Whereas outdoor activities can be carried out by using AR, because the real environment still exists in AR (Jung & Jong 2007). VR and AR both have a remarkable requirement differences in the depth of immersion (Milgram, Takemura, Utsumi & Kishino, 1994). The main objective of VR is a totally immersive artificial environment, which requires high level of realism of virtual environment, but that is not a necessary goal in AR (Jong, 2005).

In recent years, a number of AR applications have been widely applied in various domains, such as military, entertainment, medical and education. In storytelling, MagicBook (Billinghurst, Kato & Poupyrev, 2001) allows users to read the book and see the virtual objects through handheld displays (HHD). Without using any AR displays, users still can read the text on the book, look at the pictures and flip the pages. Augmented Chemistry (Fjeld & Voegtl, 2002) is an example of the implementation of AR in science learning. It is a workbench consisting of a table and a rear-projection screen. Augmented Chemistry has helped users to understand the molecules or atoms structure by showing the structure in 3-Dimension. Users still uses booklets, gripper and cube to interact with these molecules and atoms models. In children's education, 'The Book of Colours' (Ucelli, Conti, Amicis & Servidio, 2005) uses AR to explain the basic theory and concepts of colours through Head-Mounted-Displays (HMD). The children can interact and observe the visual feedback from 3-Dimension virtual character. AR is not only applied in formal education, but it is also applied in informal education. Orlando Science Center in US had used AR to show sea creatures. Visitors can navigate a Rover through the ocean environment, to explore reptiles and fishes in DinoDigs exhibition hall (Hughes C.E., Smith, Stapleton & Hughes , 2004).

AR is able to enrich educational benefits by supporting seamless interaction with both the real and virtual environment, using tangible interface metaphor for object manipulation, and offers smooth transition between reality and virtuality (Billinghurst 2003). Shelton and Hedley (2002) explored the used of AR in teaching undergraduates on earth-sun relationship in terms of axial tilt and solstices, and found that AR is useful in teaching subjects where students cannot possibly experience it first hand in the real world. Besides, AR can clearly show spatial concepts, temporal concepts and contextual relationships between real and virtual objects, and all these factors enable AR to be a powerful educational tool (Woods, Billinghurst, Aldridge & Garrie, 2004).

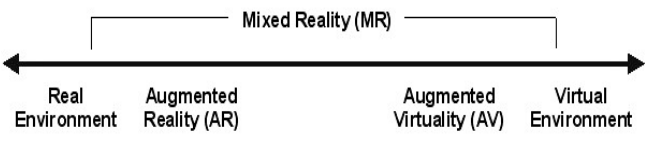

Figure 2: Reality-Virtuality Continuum
(Source: Milgram & Kishino, 1994)

3.0 PROBLEM STATEMENT

Initial analysis was carried out before the design and development of Live Solar System (LSS). An initial study based on qualitative and quantitative analysis, was carried out at two secondary schools located in the state of Pahang, Malaysia. The sample of study consisted of 100 Form 3 students and 8 science teachers. The interview and survey technique were used to determine the problems faced by students in learning the topic on astronomy. Several general problems and solutions were mentioned by the teachers. Findings of this initial study shows that the students face various problems in their learning process such as difficulty in understanding the abstractive facts in astronomy; they are weak in visualization and imagination in understanding the phenomena on astronomy. Besides, the findings of the analysis also revealed that teachers were using 3-Dimensional objects, animation and graphic in teaching the topic astronomy. This they claimed was able to help students a little in their learning process.

From the literature review conducted, there are statements from previous research that can explain and support findings of this initial study carried out. Conventional teaching had always involved a class of students without taking into account their prior knowledge. Teachers generally spend only a short time on discussion. Emphasis has always been on factual knowledge (Hannust & Kikas, 2007). Hence, this inefficient way causes students to memorize the facts (Kikas 1998; Vosniadou 1994) . Thus, they forming their own non-scientific model (Diakidoy & Kendeou, 2001).

From the initial study, students were facing some problems in learning the topic on astronomy. Using 2-Dimensional objects as teaching material has been said to decrease the understanding of students about scientific phenomenas (Dede, 2000; Feurzeig, 1994). This is because they find it difficult to transform the 2-Dimensional objects into 3-Dimensional objects (Barab, Hay, Barnett & Keating, 2000; Gotwals, 1995; Windschitl, Winn & Headley, 2001). The Solar system is a huge and unique system in the galaxy. Due to the fact that students are unable to observe similar phenomena in their daily life, they find it difficult to understand. There are many research which shows that students face problems in learning complex and abstractive concepts or phenomenas. Therefore, they need a tool to help them acquire a higher ability in imagination (Dixon, 1997; Edlson, Gordin & Pea, 1999; Pfundt & Duit, 1998; Wandersee, Nintzes & Novak, 1994).

4.0 METHODOLOGY

In order to overcome the problems of understanding abstractive concepts and phenomena, faced by students learning astronomy, a solution in the form of augmented reality technology called Live Solar System (LSS) was designed using the iterative prototype software engineering life cycle model. The objectives of the study were as follows:

i) To develop methodology of process development of LSS.
ii) To design the instructional design (ID) model for LSS.
iii) To design and develop a prototype using AR to show the solar system for the teaching and learning purpose of the topic Astronomy.
iv) To design and develop an AR module on LSS based on the Form 3 science syllabus, specifically on the topic: Stars and Galaxies.

The methodology is as indicated in Figure 3 and all elements of AR and multimedia, such as 3-Dimensional virtual objects, texts, graphic and video will be carefully intergraded seamlessly with the requirement specification obtained from the initial analysis. For instance, 3D models which are used in AR should not be high-resolution models. This is because high-resolution models has high polygon count and will consume a lot of computer resources like memory and CPU in real time rendering. At the first phase, Prototype Requirement Specification (PRS) will be determined, by reviewing all requirements and limitations of LSS components. The PRS consist of software components and hardware components. They are briefly discussed in section 6.0.

At the second phase, the instructional design model will be taken into consideration when developing the Prototype Design Specification (PDS). The prototype will be evaluated after development and checked to see whether it fulfills the design specification. If the design specifications of the prototype is not met, it will have to undergo the building process. In building process, the prototype will be refined according to the evaluation results. This iteration process will terminate when the prototype has finally fulfilled the objectives and design content specifications in the PRS as well as the PDS .

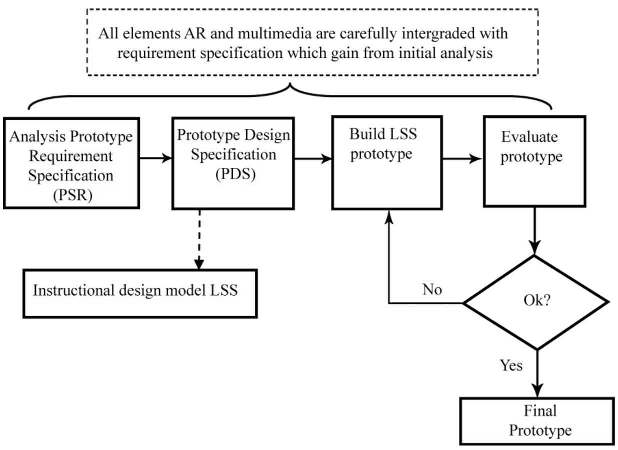

Figure 3: Iterative prototype development model for Live Solar System (adapted from Halimah, 2008)

5.0 OVERVIEW OF AR WORKFLOW

ARToolkitPlus is an extended version of ARToolkit, which is the most widely used tracking software library for developing AR applications. The basic workflow is outlined in Figure 4, and the explanations are as follow:

1) An image is read from the video stream which is captured by webcam. This image will be used as an input image to the tracking system.

2) The tracking system threshold the input image by a constant value. The other unnecessary data such as noise, will be threshold out, leaving the potential marker.

3) The detection process can be divided in two stages. In the stage of unique feature, the system detect the marker by searching four points of the rectangular shape in the image. In verification or identification stage, the system will identify the marker by checking with a set of known marker in the system. (Fiala 2005)

4) Once the marker is found, the system calculates the relative camera position and orientation by using matrix fitting. By using the square line of the marker, the system will iteratively refine the pose and position estimation, so that the virtual object can be rendered correctly.

5) The virtual object is then rendered on the marker and send out as an output image. The output image will be displayed on the PC monitor or HMD. Steps 1-5 will be repeated to each video frames which is captured from the webcam.

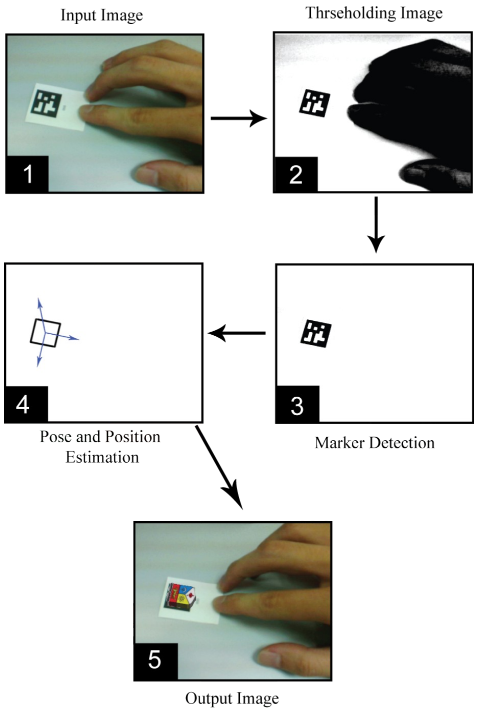

Figure 4: Basic workflow of an AR application.

6.0 LIVE SOLAR SYSTEM COMPONENTS OVERVIEW

The requirement specification for the development of LSS was one of the tasks undertaken during this phase. The LSS components encompass both hardware and software and are as shown in Figure 5.

6.1 Software

ARToolkitPlus is a software library for building AR applications. It is an extended version of the well-known ARToolkit where its library can be used to calculate camera position and orientation relative to physical markers in real time (ARToolkitPlus, 2008).

Virtools from Dassault Systèmes is a 3D authoring software for developing interactive and real-time 3D application. In Virtools, the interactive content can be simply built by linking these building blocks which are predefined by Virtools. Besides the predefined components, Software Development Kit (SDK) allows the developer to develop their desired applications and custom extensions. For example, VirtoolKit 1.0 Beta is a set of Virtools extension which are integrated from ARToolkitPlus (Mirevicast 2008).

Virtools is not a modeling software, thus we need other modeling software like 3ds Max to do modeling and texturing of virtual 3-Dimensional objects in LSS. They were then imported into Virtools for developing interaction (Virtools 2008).

6.2 Hardware

The LSS need other hardware components before it can be used by users. Below are the essential components required:

i) Webcam was used to capture image and also required by the AR system to detect and track the marker. This is important to ensure accurate 3D registration on the associated markers.

ii) Head-Mounted-Display (HMD) was used to display the composite images. The output images were processed to overlay virtual 3-Dimensional objects. The output resolution of HMD should be fitted with the same or larger resolution of the Webcam. However, the monitor can be an alternative choice if the user is unable to afford the cost. Figure 6 shows the eMagin Z800 HMD which was used in the development of this research.

iii) The Marker is a popular element of most vision-based tracking system. It is a fiducial image which is placed in the physical environment, in support of the tracking, alignment and identification of the image (Owen, Xioa & Middlin 2002). This is quadrilateral, in black and white colour marker and have their own ID in the AR system.

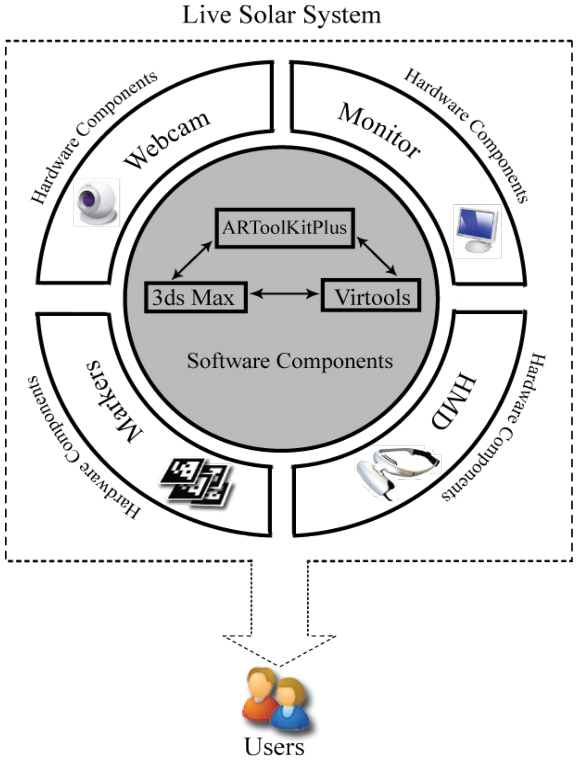

Figure 5: Prototype Requirement Specification Model for LSS.

Figure 6 : Head Mounted Display

7.0 CONCLUSION

Augmented Reality which is overlaid virtual objects on real objects offers a new interactive approach that can be conducted between users and the computer. The characteristics of an AR allow it to be a new approach in teaching and learning. Many research has been done on this field to help learning in various subject matters.

In this research, the Live Solar System (LLS) is an AR based educational tool with the purpose of helping students learn astronomy. This new approach gives a a new and more engaging learning experience process for the students.

LSS adopted the iterative prototyping methodology in designing and developing the prototype. All the elements involved were carefully and seamlessly integrated. Various softwares were used in developing the prototype, such as modeling software, AR authoring software and AR library. Users needed additional hardware in order to use the prototype and these include the Webcam, marker, HMD or monitor. They are essential components in the implementation of LSS.

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