

# Augmented Reality Interfaces for Assisting Computer Games University Students

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**Abstract**— This paper proposes the use of augmented reality (AR) interfaces for the construction of educational applications that can be used in practice to enhance current teaching methods as well as for the delivery of lecture material. The interactive AR interface has been piloted in the classroom at an undergraduate module of a Bachelor of Science (BSc) degree in Games Technology at Coventry University, UK. An initial evaluation was performed with fifteen students and qualitative feedback was recorded. Results indicate that the adoption of AR technology is not only a promising and stimulating tool for learning computer graphics, but it can also be incredibly effective when used in parallel with more traditional teaching methods.

**Index Terms**—augmented reality, computer graphics, human-computer interaction.

## I. INTRODUCTION

Although current teaching methods work successfully, Universities are interested in introducing more productive methods for improving the learning experience and increasing the level of understanding of the students. The emergence of new technological innovations such as the Internet, multimedia, virtual and augmented reality technologies, was able to demonstrate the weaknesses of traditional teaching methods but also the potential for improving them. This evolution allows educationalists to make good use of a number of multimedia technologies to demonstrate phenomena's or explain complex theories to the students in a different way than the traditional methods can, thus overcoming some limitations.

Augmented reality (AR) has the ability of enhancing the real world by using computer-generated information that is projected onto the user's virtual environment. Users can visualize the superimposed information with a selection of display technologies and can interact with it in a natural manner by employing software interfaces, physical markers and hardware interaction devices. One of the earliest examples of research that applied AR to an educational context is the 'Classroom of the Future' [1], which conceptualizes how it could be possible to enhance interaction between instructor and students by employing AR technologies. Another example is the higher education collaborative AR learning system for

mathematics and geometry education Construct3D [2] that allow teachers and students to interact through various scenarios. An alternative experimental education application demonstrates the AR enhanced teaching of undergraduate geography students about earth-sun [3]. In a similar AR application educators use AR to explain to students how specific parts of a computer could work in practice [4].

In another study researchers have compared the use of AR and physical models in chemistry education [5] and results showed that some students liked to manipulate AR by rotating the markers to see different orientations of the virtual objects whereas others preferred to interact with physical models to get a feeling of physical contact. Moreover, two modules, 'Solar System' and 'Plant System', were developed for mixed reality (MR) in the classroom, "providing support for classroom teaching and self-learning" [6]. This study was influenced directly by its perceived usefulness, and indirectly through perceived ease of use and social influence, and preliminary results seemed to indicate the participants' intention to use MR for learning. Elsewhere, researchers have studied the integration of physical objects that are computationally-augmented to support and encourage face-to-face interaction between disabled students and virtual objects [7]. Initial results indicated the importance of inclusion in novel technology enhanced learning approaches for science education.

In collaborative AR environments, multiple users may access a shared space populated with digital information and thus maximizing the transfer of knowledge [8]. A good example is the use of a real physical book for the development of a visually augmented reality book, however with drawbacks that include the affordances of the book resulting in book-like interaction by the users, which creates challenges in terms of technology deployment [9]. Another collaborative approach for teachers and trainees is an AR system that simulates a web-based training and teaching environment for distance education and training. AR may be used successfully to provide assistance to the user necessary to carry out difficult procedures [10] or understand complex problems. Demonstration in lecture and seminar rooms is one of the most effective means of transferring knowledge to large groups of people [11].

The main advantage of AR over more traditional teaching methods is that learners can actually 'see' and 'listen to' supplementary digital information. Additionally, students can intuitively manipulate the virtual information, allowing them

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to repeat a specific part of the augmentation as many times as they want. One of the main aims of this research is to contribute in resolving the perceptual discontinuities [12] initiated by scattered sources of information during the learning process. To better understand these discontinuities we have developed a prototype AR learning system focused on higher education with a particular interest in computing courses. The basic idea is an AR table-top learning environment that integrates the real teaching environment (i.e. lecture theatre) with virtual learning scenarios in a student-friendly and engaging manner. Tangible interfaces are the medium used to allow students examine and experiment with the virtual teaching material in a natural manner.

This paper describes the use of a high-level AR interface for assisting teaching at University level of 2<sup>nd</sup> year computer science undergraduate students in computer games technologies. Three-dimensional information can be superimposed in a student-friendly manner into the learning environment. The interactive AR interface has been piloted in the classroom at Coventry University at fifteen undergraduate students and they were asked to comment on the effectiveness of the system and whether it should be used as an additional tool for teaching.

The rest of the paper is structure as follows. Section II describes the method of operation of the AR interface. Section III illustrates different case studies of teaching in AR. Section IV presents initial evaluation results while section V summarizes conclusions and future work.

## II. METHOD OF OPERATION

The technical details of the interactive AR interface have been previously presented [13], [14]. The AR interface allows for the natural arrangement of virtual information anywhere inside the interior of the classroom (lecture or laboratory) or any other type of indoor environment. An overview of the system in operation is illustrated in Figure 1.

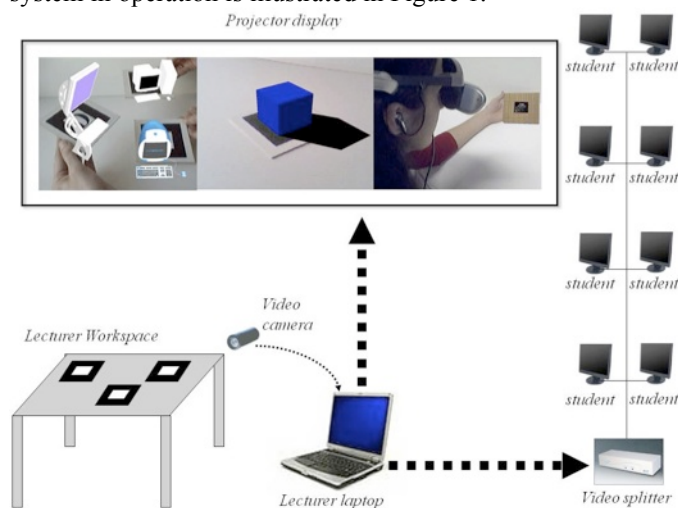


Fig. 1. Operation of the system.

In this configuration, a laptop computer with a USB web-camera, a video splitter, a plasma screen and a set of trained marker cards were employed. Depending on the capabilities of the splitter different configurations can be supported

depending on the level of immersion and collaboration required. In terms of software technologies, the interactive application consists of a set of C++ classes which are in charge of controlling the tracking, visualization and interaction. In particular, the AR environment uses the vision tracking libraries of ARToolKit [15] while the graphics operations are built on top of the OpenGL API.

The lecturer can control the sequence of the AR presentation in a table-top environment according the student's pace. Pre-designed three-dimensional models can be selected and superimposed in the table top environment and students can either interact in their desks or in a collaborative environment (Figure 1). It is worth mentioning that this technology is used in conjunction with the traditional methods used (i.e. lecture notes, PowerPoint presentation, etc).

## III. TEACHING IN AUGMENTED REALITY

The scenarios proposed are focused on enhancing the teaching and learning process for higher education and in particular for a Bachelor of Science (BSc) degree in 'Games Technology'. With this purpose in mind, computer graphics AR scenarios for a module called "3D Graphics Programming" have been designed to assist the lecturer to transfer knowledge to the students in other ways than traditionally has been the case. The AR interface offer the ability to use sophisticated techniques to achieve better user interaction with teaching material and complex tools. The provision of an interactive augmented presentation allows students a high degree of flexibility and understanding of the teaching material. Moreover, students do not need any previous experience to operate the AR interface technology successfully. To prove the feasibility of the application, different teaching scenarios from computer graphics theories have been investigated and implemented, including: *shading*, *transparency*, *hard shadows* and *environmental mapping*.

Shading in computer graphics is used for determining the pixels' color based on lighting computations [16]. There are three basic types of shading including flat, smooth and Phong shading, but only the first two were implemented because they are directly supported by OpenGL. In flat shading (Figure 2, a) the color of one particular vertex is duplicated across all the primitive vertices. This method is very simple and works very fast but it does not give a smooth appearance to curved surfaces because all pixels in the polygon as shaded the same. On the other hand, smooth shading, also known as Gouraud shading (Figure 2, b), is one of the most popular shading algorithms which interpolates light intensities across the face of a polygon using values taken from its vertices [16]. Gouraud shading is slower than flat shading but it produces a smoother appearance across polygons as it can be illustrated from Figure 2.

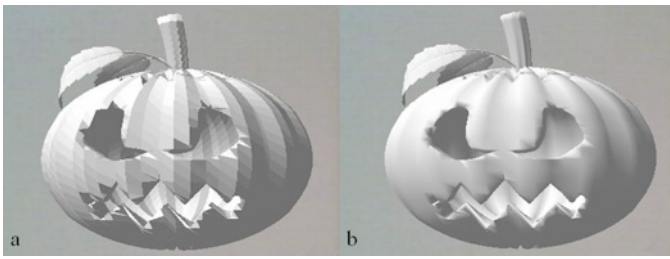


Fig. 2. Shading in AR (a) flat shading (b) smooth shading.

Texturing is used in computer graphics and modern games for increasing realism. Figure 3 illustrates the same textured object with different levels of transparency. Figure 3, (a), shows a 3D model with the alpha value close to unity (80% or 0.8) blending while Figure 3, (b) presents the same 3D model with alpha value close to zero (20% or 0.2) blending. This effect is very useful when occluding 3D objects are overlaid in the real environment. Similarly, to 3D games, using transparency it is possible to make the virtual object that occludes the others so that all objects are visible.

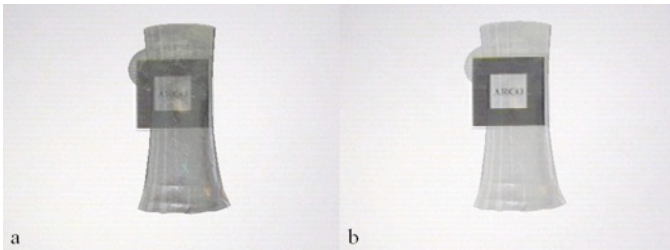


Fig. 3. Transparency levels in AR (a) less transparent (80% alpha blending) (b) more transparent (20% alpha blending).

Shadows play a very important role for the generation of a realistic scene in computer games. In reality, all objects have their shadows so augmented objects should have them as well [16]. In this work, only hard shadows were implemented. Two example screenshot that illustrate a 3D representation of the shadows generated from a simple AR cube (Figure 4, a) and an AR tree (Figure 4, b) are illustrated in Figure 4.

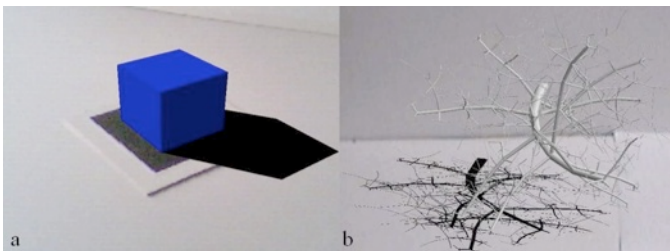


Fig. 4. Hard shadows (a) Canonical shape (cube) (b) Non-canonical shape (tree).

Environmental mapping (also known as reflection mapping) is a simple and effective method of generating approximations of reflections in curved surfaces [16]. It is usually classified as category of texturing technique and can be considered as a simplification of ray tracing [17]. The main advantages of this technique are that: (a) it is simple to implement and (b) it provides a rough estimation of reality. Two example screenshots illustrate how spherical mapping can be applied

on a textured 3D model (Figure 5).

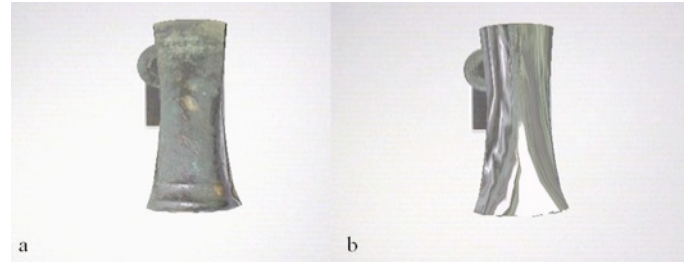


Fig. 5. Environmental mapping (a) simple texture mapping (b) sphere mapping.

Figure 5, (a), illustrates an augmented 3D model with simple texturing applied, while Figure 5, (b) illustrates the same 3D model with sphere mapping.

#### IV. INITIAL EVALUATION

The AR application was presented to fifteen second year undergraduate students, studying the “Games Technology” degree at Coventry University. Different graphics scenarios were presented during lectures and laboratory sessions and feedback was recorded. This can be categorized into three types including: *visualization experience*; *interaction and movement*; and *usefulness in learning*.

As far as ‘usefulness in learning’ is concerned, all students agreed the presented technology is very promising and should be applied in the classroom. Most students were impressed with the capabilities of AR and liked using it for exploration and learning. In particular one said “by far the most interesting lecture I have ever had and made me want to explore more and more”. Three students mentioned that 3D perception in a classroom is much better than 2D because it helps to visualize the atmosphere in a better way and looks closer to reality. Another said that the system sometimes was ‘jumpy’ and this could cause problems to people with visual impairments.

However, the feedback received for visualization and interaction varied. In terms of interaction, the majority of students were impressed with the interactivity of the AR tangible interface and noted that this provides an exciting means of collaboration between the lecturer and the students. Most of the students mentioned that interaction seems to be very easy a very enjoyable compared to other software tools (i.e. Flash, Authorware, etc) and one said that it is “the most interactive interface that I have experienced in the classroom”. One stated that it is much better to interact with 3D objects using markers in AR rather than interacting using the mouse and keyboard. Another student said that it is better than traditional methods since it is closer to reality. Only, one student said that the interaction is confusing and suggested to use other manipulation aids (i.e. mouse or keyboard).

On the contrary, for the visualization experience feedback was mixed. In particular, for shading and environmental mapping most students preferred other multimedia technologies (i.e. videos, online tutorials) and they found that AR could be distracting to use. In the case of shadows and transparency, they all agreed that this is definitely an excellent

visualization medium. One particular student pointed out that the use of AR technology is the best means of teaching computer graphics principles since it makes it easier to understand the underlying theories and concepts for three-dimensions.

## V. CONCLUSIONS

In this paper a low-cost AR educational and interactive environment for assisting teaching in higher education was presented. The main novelty of the system is that it can provide students with an interactive augmentation of teaching material focused on computer graphics principles in a compelling and engaging way. Three-dimensional objects illustrating some basic concepts of computer graphics and computer games were presented to both lectures and laboratory sessions.

The AR application was presented to fifteen second year undergraduate students, studying the "Games Technology" degree at Coventry University and initial evaluation results indicated that it is very useful to be able to 'see' and 'interact' with related computer graphics in three dimensions in some cases but not in all principles of computer graphics. Although some students were skeptical about the technology, the majority mentioned that this is a very promising technology for the future.

In the future, more computer graphics scenarios will be implemented and another study will be performed. In addition, the AR interface will be piloted for more computer games modules such as artificial intelligence and physics for computer graphics. Finally, the AR interface will be ported in mobile devices allowing students to enjoy the interactive AR presentation in alternative locations (i.e. their homes).

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