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Web3D and augmented reality to support engineering education

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ABSTRACT: In the article, the authors present an educational application that allows users to interact with 3D Web content (Web3D) using virtual and augmented reality (AR). This enables an exploration of the potential benefits of Web3D and AR technologies in engineering education and learning. A lecturer's traditional delivery can be enriched by viewing multimedia content locally or over the Internet, as well as in a tabletop AR environment. The implemented framework is composed in an XML data repository, an XML-based communications server, and an XML-based client visualisation application. In this article, the authors illustrate the architecture by configuring it to deliver multimedia content related to the teaching of mechanical engineering. Four mechanical engineering themes (machines, vehicles, platonic solids and tools) are illustrated here to demonstrate the use of the system to support learning through Web3D.

INTRODUCTION

Traditional methods of educating students have well-proven advantages, but some deficiencies have also been detected. A typical problem has been how to engage students with appropriate information and communication technologies (ICT) during the learning process. In order to implement innovative interactive communication and learning paradigms with students, teachers should make innovative use of new ICT [1]. Although multimedia material is provided in a number of formats, including textual, images, video animations and aural, educational systems are not designed according to current teaching and learning requirements. That requirement is to efficiently integrate these formats in well-proven means, eg through the Web. The system described here does this by introducing Web3D, virtual and augmented reality (AR) in the same Web-based learning support application.

Research into educational systems associated with the use of Web3D technologies is very limited. Web3D has the potential for a number of different applications ranging from 2D to 3D visualisation [2]. One of the most appropriate means of presenting 2D information is through the WWW Consortium [3]. On the other hand, a promising and effective way of 3D visualisation is AR, which combines computer-generated information with the real world, and it can be used successfully to provide assistance to the user necessary to carry out difficult procedures or understand complex problems [4].

An overview of existing AR systems in education and learning has been presented elsewhere [5]. A more recent educational application is an experimental system that demonstrates how to aid teaching undergraduate geography students using AR technologies [6]. An educational approach for collaborative teaching targeted at teachers and trainees that makes use of AR and the Internet has been illustrated by Wichert [7].

An educational system is presented here for improving the understanding of the students through the use of Web3D and AR presentation scenarios. An engineering and design application has been experimentally designed to support the teaching of mechanical engineering concepts such as machines, vehicles, platonic solids and tools. It should be noted that more emphasis has been given to the visualisation of 3D objects because 3D immediately enhances the process of learning. For example, a teacher can explain what a camshaft is using diagrams, pictures and text, etc. However, it still may be difficult for a student to understand what a camshaft does. In the current system's Web3D pictures, text and 3D model (which can be animated) are visualised so that the student can manipulate and interact with the camshaft, and also see other related components such as the tappets, follower, etc, arranged as they might be with an engine.

In this article, the authors present four example themes to support the teaching of engineering design. These four themes may represent different courses or different teaching sessions as part of the same course. The remainder of this article describes the requirements for augmented learning, provides a brief discussion of the presented system's architecture, and illustrates how the system might be used to support teaching processes using Web3D and AR technologies. Finally, conclusions are made and future work suggested.

THE REQUIREMENTS OF AUGMENTED LEARNING

The requirements for virtual learning environments have been already well defined [8]. However, in AR learning environments, they have not been systematically studied. In general, any educational application requires technological, pedagogical and psychological aspects to be carefully investigated before their implementation [9]. Especially when introducing new technologies, such as Web3D and AR into the education process, many aspects need to be considered. The authors have classified some of the most important issues that are involved in AR learning scenarios.

To begin with, the educational system must be simple and robust and provide users with clear and concise information. This will increase the level of students' understanding and their skills. Moreover, the system must provide easy and efficient interaction between the lecturer, students and the teaching material. Apart from these issues, the digitisation of the teaching material must be carried out carefully so that all of the information is accurately and clearly presented to users. This digitisation or *content preparation* is usually an offline process and consists of many different operations, depending on the target application.

The authors believe that a combination of Web3D and AR technologies can help students explore the multidimensional augmentation of teaching materials in various levels of detail. Students can navigate through the augmented information and, therefore, concentrate and study in detail any part of the teaching material in different presentation formats, thus enhancing understanding. With Web3D environments traditional teaching materials may be augmented by high quality images, 3D models, single- or multi-part models, as well as textual metadata information. An image could be a complex diagram, a picture or even a *QuickTime* movie. The 3D model allows the student to understand aspects of the teaching material that is not evident in the pictures, because they are hidden. Finally, metadata can provide descriptive information about the teaching material that cannot be provided by the picture and the 3D model.

SYSTEM ARCHITECTURE

The system presented here can be used to create and deliver multimedia teaching material using Web3D and AR technologies. The authors have already demonstrated this in other application domains, such as virtual museum exhibitions [10]. The architecture of this system is based on an improvement of the researchers' previously defined three-tier architecture [11]. The architecture, as shown in Figure 1, consists of content production, a server and visualisation clients.

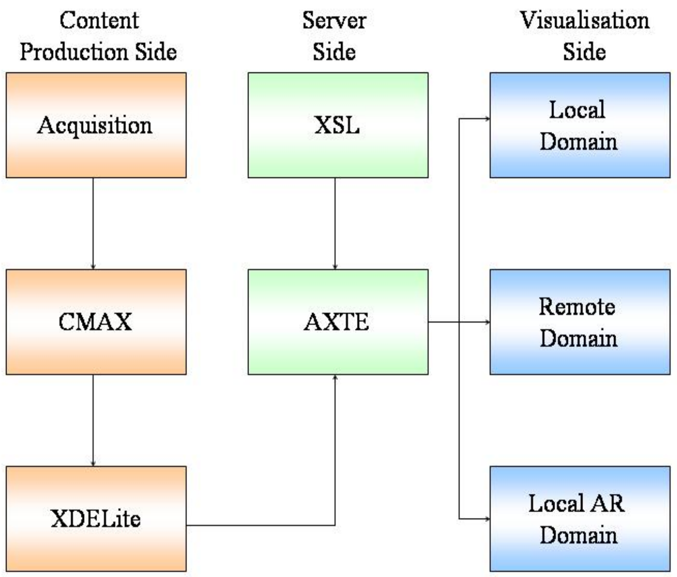

Figure 1: The three-tier architecture.

The first tier is the content production side, which consists of the content acquisition process – content can consist of 3D models, static images, textual information, animations and sounds – and a content management application for XML (CMAX) that gathers content from the file system and packages this content into an XML repository called XDELite. In the example illustrated in this article, most of the 3D models utilised were downloaded from the Internet [12]. This is quite important, because teachers should make best use of freely available content because generating 3D content can be expensive and time consuming.

The server side tier is based on XML and Java-Servlet technologies. The Apache Tomcat server was used and was configured with a Java Servlet, named the *ARCOLite* XML Transformation Engine (AXTE) [10]. The purpose of this server is to respond to user requests for data, stored in the XDELite repository, and dynamically deliver this content to the visualisation tier. XSL stylesheets are then utilised to render the content to the visualisation clients.

The client visualisation tier consists of three different visualisation domains, namely: the *local*, the *remote* and the *AR* domains. The local domain is used for delivering supporting teaching material over a Local Area Network (LAN), while the *remote domain* may be used to deliver the same presentations over the Internet, both utilising standard Web browsers.

The *AR domain* allows the presentation of the same content in a tabletop AR environment [10]. The authors have developed an application called *ARIFLite* that consists of a standard Web browser and an AR interface integrated inside a user friendly visualisation client built from Microsoft Foundation Class (MFC) libraries. The software architecture of *ARIFLite* is implemented in C++ using an Object-Oriented (OO) style. *ARIFLite* uses technologies, such as *ARToolKit's* tracking and vision libraries [13] and computer graphics algorithms based in the OpenGL API [14]. The only restriction of the AR system is that the marker cards and the camera are always in line of sight of the camera.

USER OPERATION

The user, eg a student, accesses this system simply by typing a URL into a Web browser that addresses the index page of the presentation or launches the presentation from a desktop icon. In this case, the student will be accessing a Web3D presentation with 3D, but no AR view (see Figure 2), which illustrates the Web browser embedded in *ARIFLite*. This is the mode of operation for the Internet.

For local Web and AR use, eg in a university laboratory environment or a seminar room, the student would launch *ARIFLite* from an icon on the PC desktop. By using *ARIFLite*, the student can browse multimedia content as usual, but also extend the 3D models into the AR view. Switching to AR view causes the Web browser to be replaced with a video window in which the 3D model appears. The user can then interact with the 3D model and can compare it to real objects in a natural way, as illustrated in Figure 5.

WEB3D PRESENTATION

Demonstration in seminars and lecture rooms is one of the most effective means of transferring knowledge to groups of people. One of the capabilities of the presented system is to increase the level of understanding of students through interactive Web3D and AR presentation scenarios. The lecturer can control the sequence of the demonstration using the visualisation client [10]. One can imagine a group of students and the lecturer gathered around a table on which there is a computer and large screen display. The virtual demonstration starts by launching a Web browser (ie *Internet Explorer*) or *ARIFlite*. Figure 2 actually illustrates the Web browser embedded in *ARIFLite*.

Figure 2: Web browser embedded in *ARIFLite* showing the presentation's homepage.

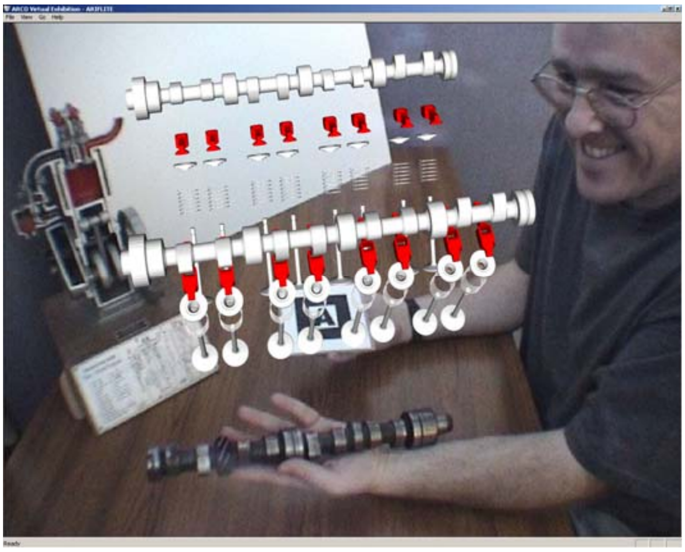

Figure 5: AR visualisation of a piston.

On the homepage, the user has the option to choose between four different supporting material themes, namely: platonic solids, tools, machines and vehicles. Each module contains a list of thumbnails representing links to relevant sub-categories, as shown in Figure 3.

Next, the user can access more specific information about any of the existing sub-categories. For example, in Figure 4, the user has clicked on the camshaft, which accesses a new Web page showing a thumbnail (that could access a larger picture or a *QuickTime* movie), description of the camshaft and an interactive 3D model displayed in an embedded VRML browser. At this stage, the lecturer can describe the underlying theory of a camshaft while interacting with the 3D model, eg rotating, translating or scaling the model.

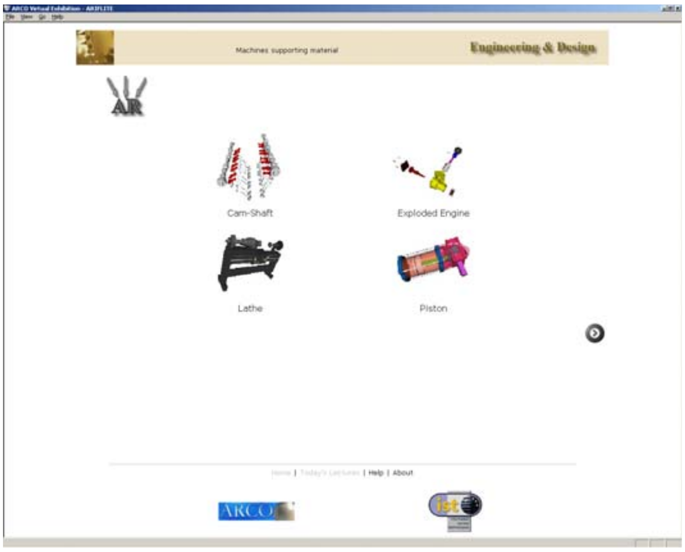

Figure3: Selection of machines.

Figure 4: Web3D visualisation.

Augmenting a Web-based presentation with 3D information (as shown in Figure 4) can enhance student understanding and allow the lecturer to present material in a more efficient manner.

AUGMENTED REALITY PRESENTATION

By using *ARIFLite*, the authors could now extend the Web3D presentation into a tabletop AR environment. AR can be extremely effective in providing information to a user dealing with multiple tasks at the same time [15]. With *ARIFLite*, users can easily perceive visual information in a new and exciting way. In order to increase the level of understanding of the teaching material, 3D information is presented on the tabletop in conjunction with real objects. Figure 5 shows an AR view of a user examining a virtual 3D model of camshaft arrangement in conjunction with a set of real engine components.

Similarly with the system demonstrated by Kato et al, users can physically manipulate the marker cards in the environment by just picking the markers and moving them into the real world [16]. In this way, students are able to visualise how a camshaft is arranged in relation to other engine components and examine the real components at the same time. Users can interact with the 3D model using standard I/O devices, such as the keyboard and the mouse.

In order to manipulate better the 3D model, haptic interfaces, such as 3D mouse (ie SpaceMouse XT Plus), are integrated within the system. The SpaceMouse provides an 11-button menu and a puck allowing six degrees of freedom, which gives a more efficient interface than the keyboard [17]. The user can zoom, pan and rotate virtual information as naturally as if they were objects in the real world.

CONCLUSION AND FUTURE WORK

In this article, a simple and powerful system for supporting learning based on Web3D and AR technologies is presented. Students can explore a 3D visualisation of the teaching material, thus enabling them to understand more effectively through interactivity with multimedia content. It is believed that the presented experimental scenarios can provide a rewarding learning experience that would be otherwise difficult to obtain.

In the future, the authors plan to create more educational templates and add further multimedia content for the XML repository so as to apply the system in practice. In order to optimise the system's rendering capabilities, greater realism will be added into the augmented environment using augmented shadows. Finally, more work needs to be conducted in improving human-computer interactions by adding haptic interfaces so that the system will have a more collaborative flavour.

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