7
AUGMENTED REALITY THEORY AND APPLICATIONS

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INTRODUCTION

The chapter covers the state-of-the-art in the field of Augmented Reality (AR), in which 3D virtual objects are integrated into a 3D real environment in real-time. It describes the theory of Augmented Reality and explores AR that can be applied in medical, manufacturing, visualization, path planning, entertainment, military and so on. This chapter will provide a starting point for anyone that is interested in doing research or using Augmented Reality.

This chapter will discuss about the theory of AR. Azuma (1997) mentioned three criteria that have to be fulfilled for a system to be classified as an AR system: they combine the real and the virtual, they are supposed should interactive in real-time in other meaning that the user can interact with the system and get response from it without delay, and they are registered and aligned in three dimensions. This section also will discuss about technologies in AR in order to develop AR system.

In the next section, we will describe about AR applications. AR applications can be found in diverse domains such as medical, education, military applications, entertainment and infotainment, technical support and industry applications and so on. However, this chapter is focusing on description of AR applications in medical, annotation and visualization, education, manufacturing and repair, robot path planning, entertainment and games.

AUGMENTED REALITY'S THEORY

Definition

AR is an environment that supported by real and virtual objects in real time representation. Azuma (1997) defined AR as "an environment that includes both virtual reality and real-world elements. For instance, an AR user might wear translucent goggles; through these, he could see the real world, as well as computer generated images projected on top of that world".

The goal of AR system is to add information and improve the user's view to a real environment. This definition of AR system is not limited to display technologies only for instance Head Mounted Display (HMD) but it can be potentially applied to the visual common sense including hearing, smell and touch.

Milgram and Kishino (1994) elaborated the virtuality continuum of real environment to virtual reality in which AR is one part of Mixed Reality. The environment of Augmented Virtuality and Virtual Environment are virtual whereas the environment of AR is real.

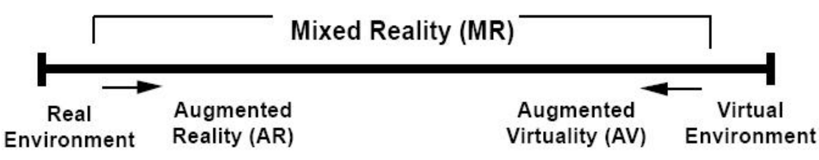

Figure 7.1 Virtuality Continuum (Azuma et al. 2001)

The differences between VE and AR are based on immersion level. AR can give user an immersive experience however user still can see and feel the presence of real world. Some researchers describe AR with several features; i) combines real and virtual, ii) interactive in real-time and iii) registered in 3D. Registration is an accurate alignment of real and virtual object. The illusion between the virtual and real objects exist in the real space is severely compromising without accurate registration. The application of AR can be applied in medical, manufacturing, visualization, path planning, entertainment, education and others.

Technology of AR

To develop AR system, several displays technology is required to accomplish the combination of real and virtual environment. These technologies include optical see-through, video see-through, Virtual Retinal Systems and Monitor based AR.

Optical See-Through HMD

One of the devices used to merge real and virtual environment is an Optical See-Through HMD. It allows the user to interact with real world using optical technologies to superimpose virtual objects on the real world. The optical see-through is used transparent HMD to produce the virtual environment directly to the real world. Optical see-through HMDs' function is placing optical combiners in front of the user's eyes. These combiners are partially transmissive to allow users look directly through them to see the real world and partially reflective to see virtual images bounced off the combiners from head mounted monitors. However, these combines will reduce the amount of light that the user sees from the real world. Figure 7.2 shows a conceptual diagram of an optical see through HMD. Figure 7.3 shows two optical see-through HMDs made by Hughes Electronics.

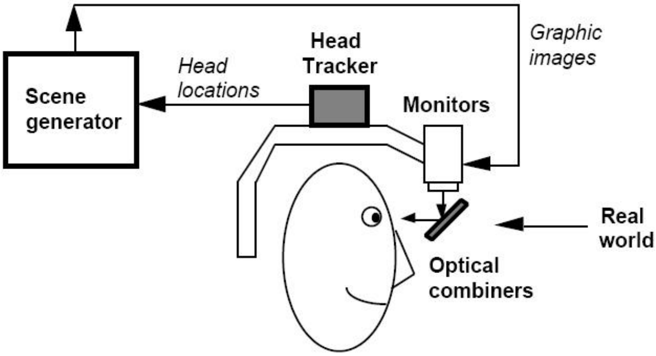

Figure 7.2 Conceptual diagram of an optical see through HMD (Azuma 1997)

Figure 7.3 Optical see-through HMDs made by Hughes Electronics (Azuma 1997)

Video See Through

Video see-through HMDs are able to give user a real world sight by combining a closed-view HMD with one or two head-mounted video cameras, due to this mixture give user a view of real world and virtual world in real-time through the monitors in front of the user's eyes in the closed-view HMD. Figure 7.4 shows a conceptual diagram of a video see-through HMD. Figure 7.5 shows a video see-through HMD. Video composition can be done using chroma-key or depth mapping (Silva, Oliveira & Giraldi 2003).

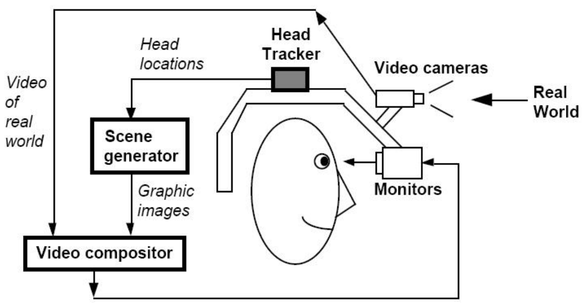

Figure 7.4 A conceptual diagram of a video see-through HMD (Azuma 1997)

Figure 7.5 Video see-through HMD (Silva, Oliveira & Giraldi 2003)

Virtual Retinal Systems

Virtual Retinal Systems aim to produce a full color, wide field-of-view, high resolution, high brightness and low cost virtual display. This technology can be used in wide range of applications from head-mounted displays for military or aerospace applications to medical purposes.

The Virtual Retinal Display (VRD) uses a modulated beam of light (from an electronic source) directly onto the retina to produce a rasterized image. If the viewer stands to feet away in front of 14 inch monitor, the viewer can see the illusion of source image. In real world, the image is on the retina of its eye and not on a screen. The quality of the image that user sees is really superb with stereo view, full color, wide field of view and no flickering characteristics. Figure 7.6 shows the Virtual Retinal System HMD.

Figure 7.6 Virtual Retinal System HMD (Silva, Oliveira & Giraldi 2003)

Monitor Based AR

Monitor based AR uses one or two video cameras to view the environment where the cameras may be static or mobile. The video was produced by combining the video of the real world and graphic image generated by a scene generator and the product was shown to user by using monitor device. The display devices are not wearing by the user but when the images are presenting in the stereo on the monitor, it requires user to wear the display devices such as stereo glasses. Figure 7.7 shows the build of Monitor-based system and Figure 7.8 shows an external view of the ARGOS system, which uses a monitor-based configuration.

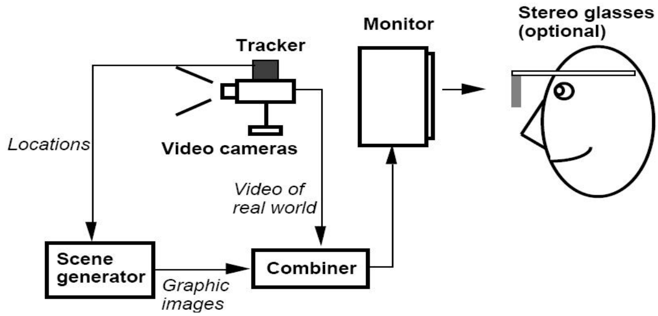

Figure 7.7 Build of Monitor-based system (Azuma 1997)

Figure 7.8 An external view of the ARGOS system, which uses a monitor-based configuration (Azuma 1997)

AUGMENTED REALITY APPLICATIONS

Medical

In medical applications, computer will generate 3D data. These data will be superimposed onto the surgeon's view of the patient. Then, it provides a spatial data of the organ which belongs to the patient's body or simply "X-ray" vision. Doctors have been implementing AR in surgery as a visualization and training aid. Non-invasive sensors such as Magnetic Resonance Imaging (MRI), Computed Tomography scan (CT), or ultrasound imaging has been used for the purpose of colleting 3D data of the patient. Those data are being rendered and combined with a view of the real patient in real-time. In context of AR system, those 3D data are combined with the view of real patient when the virtual view of 3D data is rendered in real-time. Therefore, doctors can easily interact with the AR system and get response without delay. As a result, this would give a doctor "X-ray vision" inside the patient. This is an efficient way to reduce high risks of operation during minimally-invasive surgery. A problem with minimally-invasive techniques is doctor has a lack of ability to see inside the patient, so it is making surgery more complicated. Thereby with AR technology, it might provide an internal view without the need for larger incisions.

AR is also helpful for general medical visualization tasks in the surgical room. Surgeons can differentiate certain features with the naked eye which is cannot be seen in MRI or CT scans. However, with AR, surgeons will be given the ability to access simultaneously types of data. This also leads precision tasks, such as display where to bore a hole into the skull for brain surgery or where to make a needle biopsy of a tiny tumor. The information from the non-invasive sensors would be directly displayed on the patient and presented where the accurate part to perform the operation.

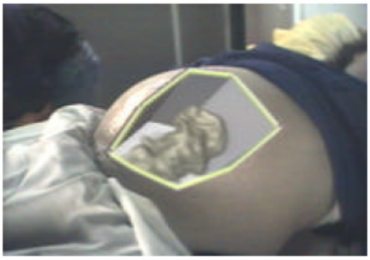

Figure 7.9 Virtual pregnant patient (State et al. 1996)

AR is very helpful to propose virtual instructions that could help a novice surgeon on the required steps without using the manual as instruction to guide them. As initiated by Kancherla (1995), AR is also useful for training purposes which involve virtual objects. Agreed by Durlach (1995), virtual objects could identify the organ and specific locations to avoid disturbing. Figure 7.9 presents a runs of scanning the womb of a pregnant woman with an ultrasound sensor, a 3D representation of the fetus inside the womb generated and displayed to see through HMD according to State (1996).

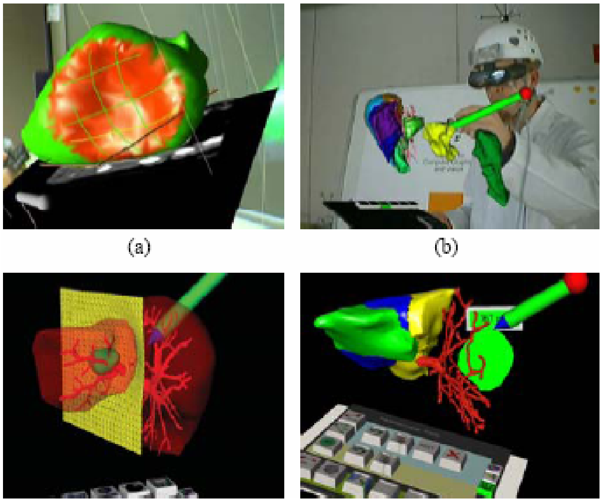

Figure 7.10 These images show Liver-Surgery planning using AR. (a) Process 3D refinement that allows changing of an incorrectly segmented liver. (b) Input and output devices tracking process. (c) Simulation of non-standard tumor resection process. (d) Simulated calculation for quantitative analysis (Bornik et al. 2003)

AR technology is also being applied in liver surgery. Tumor resection is effective treatment for patients who are suffering from liver cancer. Information of liver shape, tumor location and the arrangement of the vascular structure are required. Therefore, it is necessary for doctors to prepare a systematic intervention plan. In usual routine, an intervention plan is defined using the information that has been retrieved from an imaging modality like X-ray computed tomography. However, manual intervention plan normally causes a few problems. In order to deal with these problems, the virtual liver surgery planning system, *LiverPlanner,* has been introduced by Bornik et al. (2003). Figure 7.11 shows the images of planning process for *LiverPlanner*. They use AR technology to manage clinical process of planning liver tumor resections so that it becomes more simple and easier.

Education

A potential and challenges of using collaborative AR within the context of immersive virtual learning environments becomes a high motivation to propose AR in education. For example, the experiences made during the development of a collaborative AR applications specifically designed for mathematics and geometry education called Construct3D, produced by Kaufmann (2000).

Roussos (1999) claimed that the most important purpose of educational environment is to encourage social interaction among users in the same environment. In collaborative AR, multiple users are able to share the same physical space and communicate with themselves for educational purposes. They perform natural means of communication and mixed successfully either with immersive virtual reality or remote collaboration. However, developers have to consider a few problems and issues when developing the AR learning environment. AR definitely cannot be an ideal way to realize all educational application needs but it is considering as optional. The technologies used always need to depend on the pedagogical goals, the needs of the educational application and the target audience.

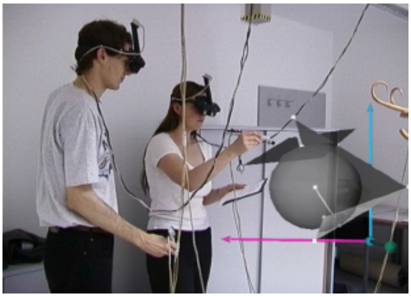

Figure 7.11 A tutor assists a student while working on constructing geometry model (Kaufmann 2000)

Figure 7.12 Collaborative works of students within the Augmented Reality application in constructing 3D object (Kaufmann 2000)

Annotation and Visualization

AR can be used for annotation and visualization tasks, which is efficient to annotate objects and environments with information either private or public. AR annotation system will draw the information given to view the virtual slide to users. Annotation that uses AR will combine the real and the virtual, the interactive annotation system AR in real-time means that the user can interact with the system and get response from it without delay. According to Fitzmaurice (1993), when the user walks around the library, the information of library shelves will be provided by a hand-held display.

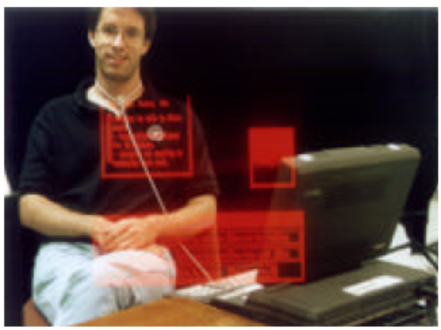

Figure 7.13 Annotation represented as reminders (Feiner 1993)

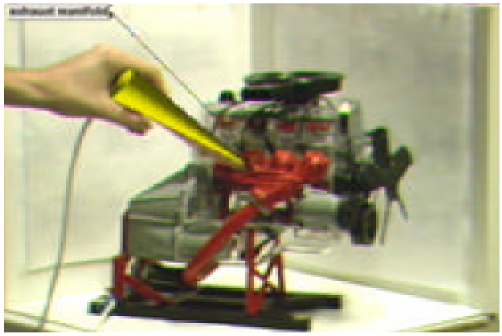

Figure 7.14 Annotation on engine model (Rose 1995)

According to Rose (1995), at the European Computer-Industry Research Centre (ECRC), when users point at parts of an engine model and AR system plays their role to display the name of the part once it is being pointed. Figure 7.14 shows where the user points at an engine model and the information appears as label of the part that being pointed.

However, researcher at Columbia stated that AR applied for annotations are private notes attached to specific objects. As also stated in Feiner (1993), AR applications are demonstrated by attaching windows from a standard user interface onto specific locations in our real world, or could be represented as reminders. Figure 7.15 shows a window represented as a label upon a student.

Manufacturing and Repair

In industry, AR can be applied in various areas like repairing and maintenance of complex engines. For example, in the repairing and maintenance of complex engines, AR system can provide labels that aid mechanics in identifying engine components. Additional data such as maintenance reports, schematic manufacturer's specifications, and repair procedures might be retrieved and displayed next to the specified component which observed in the real environment.

AR applications in manufacturing and repairing could be found in diverse domains, such as the assembly, maintenance, and repair of multipart machines. Instructions might be easier to comprehend, compared to the manuals instructions that contain texts and pictures. It seems to be more difficult. But, AR produces a virtual instruction in 3D drawn, showing the task need to be done and how to be handled in easier way, perfect in step-by-step. These virtual instructions can be animated and thus, providing the directions even more clear

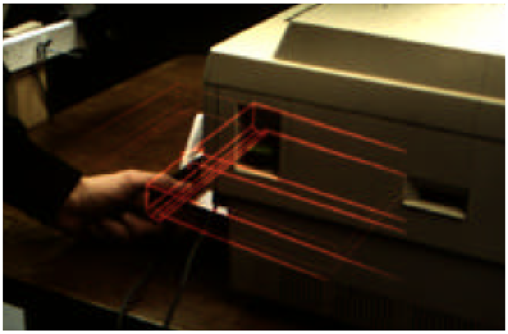

Figure 7.15 AR in laser printer maintenance (Feiner 1993)

Several research projects have confirmed prototypes in this area. As stated by Feiner (1993), they built a laser printer repairs application for printer maintenance. As shown in Figure 7.16, the user's view which the existing wireframe is guiding user on how to remove the paper tray. Almost applications also prove successful in Caudell (1992), Tuceryan (1995) and Sims (1994). Moreover, according to Tuceryan (1995), AR might be used for any complex machines such as automobile engines.

Robot Path Planning

The complex problem is the operation of a robot, especially with long delays in means of communication when the robot is moving far away. In effects, especially to conduct the robot directly without delay, it may be to instead run a virtual version of the robot. Manipulation of the local virtual version is needed in order to plan the robot's actions in real-time that are specified by users. The outputs are directly displayed on the real world. Then, user will inform the real robot to run the plan once the plan is tested and determined.

This avoids pilot-induced oscillations caused by the lengthy delays. AR technologies useful to predict the effects of manipulating the environment and serve as a tool on planning and previewing to aid the user in completing the task given. As stated in Drascic (1993) and agreed by Milgram (1993), the ARGOS system has demonstrated that stereoscopic AR is an easier and more precise way of doing robot path planning than traditional monoscopic interfaces. Figure 7.17 illustrates how a virtual outline can represent a future location of a robot arm.

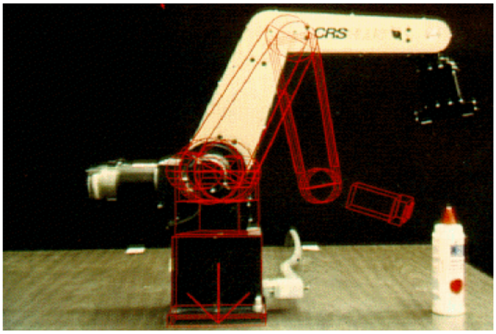

Figure 7.16 Virtual lines illustrate a designed motion of a robot arm (Milgram 1993)

Entertainments and Games

Interactive gaming becomes one of the dominant application areas for computer graphics. Playing game is also becoming the most interesting activities in means of entertainment. Collaborative gaming in AR is familiar with Mobile Augmented Reality (MAR). MAR is a variety of portable devices with flexible computing capabilities has emerged. Handheld computers, mobile phones and personal digital assistants have the potential to commence AR. Under this circumstance, AR can be widely applied for games. AR also can physically complement mobile computing on wearable devices by providing an intuitive interface to a 3D environment embedded within our real world.

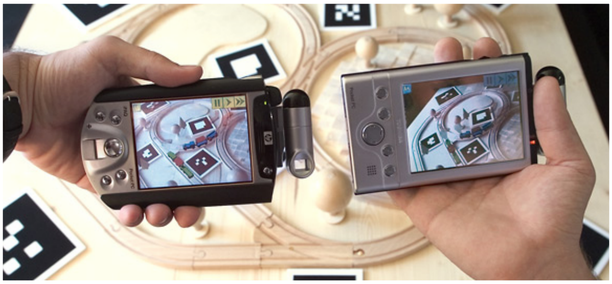

Figure 7.17 Invisible Train PDA Games (Wagner et al. 2005)

As introduced by Wagner et al. (2005) on their successful project delivery, The *Invisible Train*, which was the first real multi-user AR application for PDA devices. Figure 7.18 shows AR application for mobile games that can be played using PDA technologies. The *Invisible Train* is a mobile, collaborative multi-user AR game, in which players control virtual trains on a real wooden tiny rail track as shown in Figure 7.19. Virtual trains are only visible to players through their PDA's display as they actually do not exist in real world. According to Wagner et al. (2005), this type of user interface is usually called the "*magic lens metaphor*".

Figure 7.18 Mini platform shows *Invisible Train* rail track (Wagner et al. 2005)

The social communication aspect can be clearly observed with non-computer based multi-player board-games like *Mah-Jongg*, Trivial Pursuit, as stated in Gervautz et al. (1998), their research on collaborative gaming in AR. As shown in Figure 7.20, other collaborative AR applied in games, which multi-user interact each other to play the game in virtual mixed with real world.

Figure 7.19 Collaborative AR in *Mah-jong* game (Gervautz et al. 1998)

According to Thalmann et al. (1998) in their research work in the field of Networked Collaborative Virtual Environments thrives to incorporate such as natural communication in a virtual environment. These efforts are focusing on AR collaborative which is mostly based on the use of realistically modeled and animated virtual humans. There are many ways to use virtual human bodies for facial and gesture communication within a virtual environment.

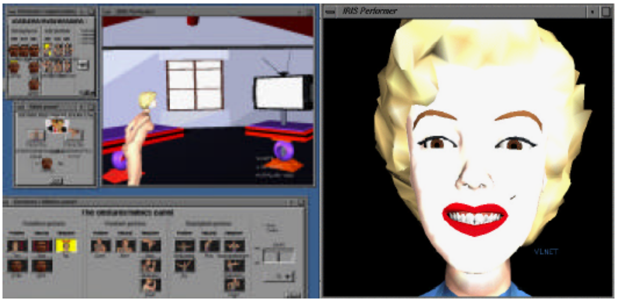

Figure 7.20 Nonverbal communication application (Thalmann et al. 1998)

CONCLUSION

AR is a field of computer research which deals with the combination of real-world and computer-generated data. AR research is evolved from the areas of virtual reality, wearable and ubiquitous computing and human computer interface. Human factors have been studied in order to know the information representation in such a way that the users are able to distinguish between what is real and what is virtual information. Recently, the field of AR is evolving as its own discipline, with strong ties to these related research areas.

This chapter discussed about the theory of AR. This chapter also consists of further discussion about the field of AR, which 3D virtual objects are integrated into a 3D real environment in real-time. It describes the AR technologies that are applied in medical, manufacturing, visualization, robot path planning, entertainment and education applications.

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