Exploring Augmented Reality

By Matt Scheinerman
Advisor: John Dougherty
Haverford College Computer Science
4/24/09

Table of Contents

Abstract

This paper illustrates a general overview of augmented reality, a type of technology that incorporates virtual reality and video images into one image. A subset of computer graphics, augmented reality is becoming more useful outside of research, inspiring new methods of human-computer interaction and interface design. This paper describes the history of augmented reality, including its origins in virtual reality, the various technologies required with its use, and its current and future applications.

Introduction

Augmented reality is an innovative use of computer graphics in combination with real world data to create a new kind of video image. This area of computer science has appeared fairly recently and is the subject of considerable research and innovation. What is new about this technology is that it seamlessly integrates technology with the real world, allowing for a naturally enhanced computing experience.

In this thesis, we will first develop an understanding of AR by exploring its origins in virtual reality (VR). Then we will examine the first innovations of AR and the people who created them. We will learn how AR works on the technical level and the kinds of technology that are used in AR applications. Then we will examine some examples of AR applications used in today's industries, and speculate on the future possibilities for AR. AR is a new and exciting technology and in order to understand its potential, all of these different aspects of it must be investigated.

1. History of Virtual Reality

Augmented reality is an extension of virtual reality. In order to fully understand augmented reality, its uses and its limitations, it is important to first develop a foundation in virtual reality.

i. What is Virtual Reality?

A virtual reality, also called VR, experience is one "in which the user is effectively immersed in a responsive virtual world."[1] This definition has several important parts. Firstly: that the user is in a virtual world. This part means the world is not real; it is instead created by a computer. It is separate from the real world and completely artificial.

Secondly, the user is effectively immersed in such a world. This part implies there is a certain level of depth in the experience, and the user can be led to believe that the virtual world he or she is in is close to an actual world.

Lastly, the virtual world must be responsive. When in a VR experience, the virtual world has to react in some way to the user's movements and commands. Otherwise, it is no different than watching a computer-generated movie. In order to understand the full range and possibilities of virtual reality, it is valuable to study the origins of this technology. There are many innovative technologies that have contributed to the development of VR, so we will investigate those considered to be the most important.

ii. History of VR

a. Sensorama

In 1962, Morton Heilig released his brainchild of a machine: the Sensorama. During the 1950s, he had been thinking about the concept of a “reality machine” which would provide the illusion of an experience to a customer. Expanding beyond traditional cinema and the fad of 3D movies, Heilig imagined a new form of entertainment which incorporated all five senses, instead of only sight and sound. The Sensorama looked like an arcade machine with the customer seated in front of it (see figure 1).

Figure 1: the Sensorama

The machine replicated a motorcycle ride through Brooklyn. It is important to note that the Sensorama, while illustrating the basic concept of virtual reality, was purely mechanical and did not use computer-generated graphics. The Sensorama, while innovative and ahead of its time, was not a success commercially.[2]

b. Heilig’s Head-Mounted Display

Also released in the 1960s was Morton Heilig’s “Telesphere Mask,” which was the forbearer of the modern Head-Mounted Display or HMD. It actually was developed before the Sensorama, and performed essentially the same function, except it was worn on the head. The device blew air currents, provided sounds and was “the first patented head-mounted apparatus designed to convey virtual views to the user.” The Telesphere Mask was the second great innovation in virtual reality technology to be developed by Morton Heilig.[3]


[4]

Figure 2: The Telesphere Mask

c. Philco Headsight

Around the same time as Heilig's innovations, two employees of the Philco Corporation, Comeau and Bryan, were developing another VR landmark device. The system they developed, dubbed Headsight, was an HMD, linked to a closed-circuit security system. It was designed to remotely view dangerous situations. This technology was based on mechanical film rather than computer generated graphics. Still, Headsight is significant because it demonstrated that virtual reality technology could be used for more than just entertainment purposes.[5]

d. UNC Haptics

In the late sixties, the University of North Carolina (UNC) developed haptic systems to be used with computers. Haptic technology means technology that creates the sensation of touch. The UNC team progressed from simple fields and particles, to children's building blocks, to eventual remote operation of a device. This work continued from 1967 to the early 1980s, and is still an innovative area of research in virtual reality. Haptic technology is remarkable because it is a truly virtual way of replicating the sense of touch, which had not been done before.

e. Videoplace

This technology, created at the University of Connecticut in the late 1970s to early 1980s, combines a person's video image with a computer-generated environment. It also "coordinates the behavior of graphic objects and creatures so that they appear to react to the movements of the participant's image in real-time."[6] The developers of this technology sought to create a "Responsive Environment" which would allow the user to affect virtual objects without the use of keyboard and mouse. Using a camera and a projection screen, such an environment was created.

f. Super Cockpit

Numerous other technological breakthroughs took place in the 1980s, but the culmination came about in the US Air Force's Super Cockpit. The cockpit seeks to replicate an actual airplane cockpit in flight, using visual, auditory, and tactile means to convey the sensation of flight. The user can also interact with the interface using eye movements, head and hand movements, and speech. Again, virtual reality technology used in a way that is real-world applicable helped cement it as a valuable research area to be explored further.[7]

As we can see from all of these examples, virtual reality has grown from a form of sideshow entertainment to a valuable technology useful in industry, gaming, and government training. VR is now a common part of everyday life in many ways, and it is the direct predecessor to augmented reality, which we will now discuss at some length.

2. History of Augmented Reality

In order to understand augmented reality or AR's uses today, it is worthwhile to explore its origins in graphics, interface design, and industry. This section will trace AR's development from the 1960s, Sutherland innovation through the innovation of Boeing, the early scientific uses of AR, the creation of AR conferences and uses in sports in the late 90s, and up to the modern day labs and technologies.

i. Sutherland

In the 1960s, Ivan Sutherland wrote about his working prototype of what is now considered to be the first augmented reality system. He wrote that "our objective in this project is to surround the user with displayed three-dimensional information."[8] Using wire-frame graphics and a HMD that was incredibly heavy, Sutherland was able to build the first AR system. The fundamental difference between this system and the kind of computer graphics that had come before is that Sutherland wanted the graphics to change depending on where the user was standing. This objective required a new form of technology that had not been used before, the head sensor, which measured the position and angle of the user's head. The system would then change the virtual objects accordingly.

Like Alan Turing before him, Sutherland foresaw a wide-open future for the technology he had created. He knew the interface he had made was flawed, to say the least. He wrote another paper, "The Ultimate Display," in which he wrote,

> The ultimate display would, of course, be a room within which the computer can control the existence of matter. A chair displayed in such a room would be good enough to sit in. Handcuffs displayed in such a room would be confining, and a bullet displayed in such a room would be fatal. With appropriate programming such a display could literally be the Wonderland into which Alice walked.[9]

We still have yet to create such a room that Sutherland imagined, but AR interfaces have become much more flexible and mobile than the HMD of Sutherland.

ii. Boeing

In 1990, a paper was published written in part by two Boeing engineers, Tom Caudell and David Mizell. Their job at Boeing was to replace a current system of solving wiring problems. Boeing employees at the time used a large plywood board with nails stuck to it, which held up strings representing wires. These string representations could get very large and complex, and it was a tiresome job to manually restring wires when there was a problem or change that had to be made. Caudell and Mizell replaced the plywood board with multipurpose boards. A HMD would be used in combination with these boards to display the plane's blueprints. The wiring would be done virtually and kept track of by a computer, which allowed it to be done quicker and more efficiently.

In their paper, Caudell and Mizell wrote that:

> This technology allows a computer-produced diagram to be superimposed and stabilized on a specific position on a real-world object. Successful development of the HUDset technology will enable cost reductions and efficiency, improvements in many of the human-involved operations in aircraft manufacturing, by eliminating templates, formboard diagrams, and other masking devices[10]

This use of AR in industry is unique because it is the first time AR was used in such a manner. It is also historic because Caudell is considered to be the person who coined the term "augmented reality."

iii. Azuma

The next innovation in the evolution of AR came from the laboratory. In 1994, Robert Azuma and company working in HRL Laboratories in Malibu published a paper describing their latest work in AR. Their objective was to find the "holy grail" of AR technology outside, accurate operation both indoors and outdoors. Azuma writes in the abstract:

> Almost all previous augmented reality (AR) systems work indoors. Outdoor AR systems offer the potential for new application areas…We demonstrate a hybrid tracker that stabilizes an outdoor AR display with respect to user motion, achieving more accurate registration than previously shown in an outdoor AR system.[11]

In other words, Azuma and his team had found technology that allows for AR applications to be used *outside*. The way they did this was by compensating for user motion. In previous uses of AR, the user had remained in essentially the same place (a room or enclosed area), but Azuma wanted to allow for more freedom of movement. His team added to AR technology a hybrid tracker, which kept track of where a user is in space using rate gyros, a compass, and a tilt orientation sensor.

The application of Azuma’s technology was to display virtual text labels over distant landmarks, and while he admits the system, “still has apparent registration errors and limitations on where it can operate outdoors,”[12] it was a huge step forward in creating AR technology that had real world usage.

iv. Hybrid Tracking

The next new development came from UNC, where research into tracking methods had been taking place. At this point in AR research, there were two methods for tracking a user. There were magnetic trackers, which suffered from a large amount of jittering and skipping due to metal in the environment, but had the advantage of being robust and allowing for more unrestricted user movement. There were also vision-based trackers, which were very accurate but sometimes had trouble dealing with movement. Tracking systems are one of the most important components to any AR system, and will be discussed in more detail in section 5.

To solve this problem, the researchers at UNC created a hybrid tracking system, which uses the accuracy of vision based systems and the robustness of magnetic systems. This system uses the markers that many AR systems today are based one. This new tracking system was a much better system than either of its two parts and became a standard part of most AR applications.

v. 90s-00s

In the period of the late 1990s to early 2000s, augmented reality made several steps towards becoming a widely acceptable branch of computer science. In 1998, conferences dedicated to the study of AR started, namely, the International Symposium on Mixed and Augmented Reality and also the International Symposium on Augmented and Virtual Reality.

Also, in the late 1990s, the most widely used application of AR was developed: the placement of virtual lines and markers during sports broadcasts. Dedicated research places such as the Mixed Reality Systems Lab in Singapore and Project Arvika in Germany devoted themselves full time to the study of VR and AR applications.[13] All of these developments have led to AR’s current position as an important emerging technology.

vi. Augmented Reality vs. Virtual Reality

After AR arose, it became apparent that AR fell into a range of views between the real world, which contains no computer-generated images, and the virtual world, which contains entirely computer-generated images and no real ones. This caused Milgram to create his "Reality-Virtuality continuum," shown in Figure 3.

[14]

Figure 3: The Reality-Virtuality Continuum

AR is the closest to the real environment because it consists mostly of real world images, with a minority of the images being computer-generated. Augmented virtuality is a term for applications that create a mostly virtual world, but which includes a few images from the real world. All of these different realities are part of the continuum that Milgram describes. [15]

3. How Augmented Reality Works

AR systems come in a variety of shapes and sizes, but in order to gain an understanding of how AR works in general, it is valuable to examine a typical system. All AR systems have some common elements, and we will investigate them to show how AR works at a fairly high level.

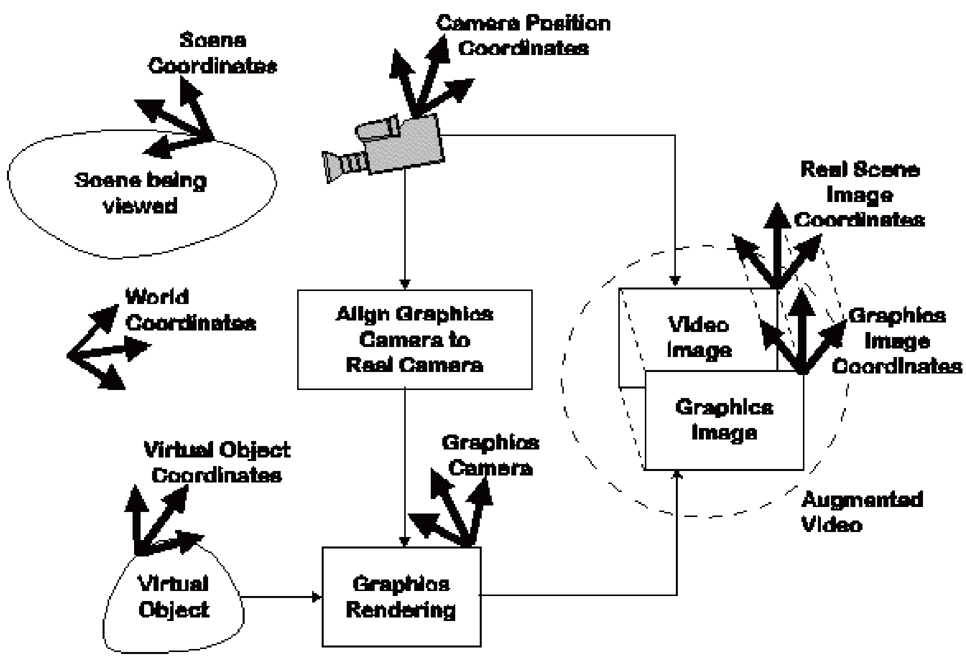


Figure 4: General Outline of AR

The video camera works in combination with a computer to create the augmented scene. The scene is captured by the camera, as seen at the top of Figure 4. The computer can keep track of the camera's position through a coordinate system. The video image is sent on to be used later. This video image is the “unaugmented” video, which will be combined with the virtual objects to create the final image.

The real camera also needs to be aligned with the graphics camera in order for the real images and the virtual images to be aligned. This step takes place in the box labeled “Align Graphics Camera to Real Camera” in Figure 4. The virtual camera view is combined with where the virtual objects should be placed in the scene in the Graphics Rendering step. How the computer knows where to place the virtual objects will be discussed in later sections. Once the graphics are completed, they are sent on to the last step.
In the last step, the video image and the graphics image are overlaid to create the augmented video. It is crucial to the accurate representation of the scene that the real world coordinate system correctly aligns with the graphics coordinate system. If the correct alignment takes place, the virtual objects will appear correctly in the scene, creating an accurate augmented video.

As we see from the picture above, the trickiest part of creating an augmented scene is making sure that all of the different elements have compatible coordinate systems. The actual video camera, the graphics camera, the virtual objects, the actual scene being viewed, and the graphical world viewed by the graphics camera each have their own coordinate systems. If any one of these do not match up with the rest, the scene will not appear correctly.

That is the essence of AR systems. The variety between different kinds of AR systems lies in the various ways of how the video images are displayed, how to know where to place the virtual objects, and the best ways to render the images quickly enough. [16]

4. Technology of Augmented Reality

AR applications are diverse, but they all have the same basic components. There are three important different pieces of technology required for most AR applications, all of which will be discussed in this section. These different parts all work together to create the result of a working AR application.

i. The Interface

Depending on the AR application, there needs to be different ways of viewing the computer screen with the virtual objects. These different user interface designs fall into two different categories, those for individual use and those designed for multiple users.

a. Head-Mounted Display

The Magic Lens is another term for the Head-Mounted Display (HMD). These devices are worn on the user’s head and cover the eyes. Most of these devices are not built specifically for AR applications; they are built for virtual reality applications and are easily adapted for AR.

HMDs are very good for a single user, as they provide an immersive experience. However, this experience is limited to one person at a time, so that is a design choice to be made when constructing an AR application. There are two kinds of HMDs; namely, *video see-through* and *optical see-through* displays.

Video see-through displays have small video cameras attached to the headset to record images. Once the video is recorded, it is sent through the computer and the graphics are superimposed into the video footage. This newly augmented video footage is transposed on the goggles part of the HMD, giving the illusion of looking through the headset into the real world, when in actuality the user is looking at a video recording of the real world. Video see-through displays are the most commonly used kind of HMD, because they are the easiest to make. The downside to them is they sometimes have lag, which can cause a delay in the video stream when the user moves his or her head.

Figure 5: An HMD

Optical see-through displays are not as popular, and as a result most of the companies that make them have gone out of business. However, one device based on this design is considered to “hold the most promise for an augmented-reality system.”[17] This device, the Virtual Retinal Display (VRD) by Microvision, works in an innovative way. In essence, the user wears an HMD over his or her head and eyes, but instead of recording a video and running it through the HMD, the HMD projects a beam of light directly into the retina of the user’s eye. The user believes he or she is viewing an image on a screen nearby, but in actuality the image is being placed into the user’s eye directly.

The advantage to using VRD technology is that the image is a much higher quality than usual, with no flickering or restricted field of vision. In addition, the display would be much lighter in weight, the images would be at a very high resolution, full color, and bright enough for outdoor use, and would have low power consumption. In the future, the Microvision system could be fitted into a pair of apparently normal sunglasses, as envisioned below. The problem with the Microvision system, and optical see-through systems in general, is that they are very expensive. The Microvision system in particular costs around $10,000, which is not conducive for the average consumer. If the price of such technology went down, optical see-through systems would undoubtedly become more popular. [18]

Figure 6: An HMD of the future

b. Video Screen Interface

There is another different kind of user interface, one that allows for multiple users to view the augmented video. This is usually achieved by connecting the video feed into a larger screen, such as a television or wall-mounted projector. It may be helpful to examine a few innovative examples of AR applications using this kind of interface
For the AR application that I have installed on my computer, I use my laptop's monitor to display the augmented video. This screen allows for multiple users to view the video, and the computer can also be connected to a projector to display the video in a presentational environment.

Cawood and Fiala cite an example in which a person stands in front of a camera and see an augmented version of him or herself projected onto a video screen behind the camera. This gives the illusion of looking into a mirror and seeing a reflection.[19]

A team of students at Iowa State University built a system using a webcam, mirror, and large-screen television. The television was placed at an angle above the table where the AR markers were. By pointing the webcam at the mirror and reflecting the image to show the top of the table, and running the video feed from the webcam into the television, the illusion of looking through the television at the table was conveyed. The large screen of the television allowed multiple users to view the augmented video very easily.[20]

These types of AR interfaces work very well for systems that are stationary and designed for presentational purposes. They have the disadvantage of not being very portable or mobile, and at the moment they are rarely found outside of the laboratory.

ii. AR Markers

In order for an AR application to correct place virtual objects into a scene, most applications require some signal as to where the virtual objects should go. As a result of this requirement, many AR applications require markers. Markers can be almost anything, “from light-emitting diodes (LEDs) to a person’s head.”[21] What has emerged as the most popular kind of marker, though, are black and white squares, each of which has a unique pattern on it. The AR camera is trained to recognize these markers and know that when that pattern is viewed to place a virtual object in the scene. Markers are very important for the correct placement of virtual objects because “the marker tags are used to determine the viewpoint of the real camera so that the virtual [object] can be rendered appropriately.”[22] Not all AR applications use these markers, but many do.

iii. Software

There are many different kinds of AR software, so we will examine two examples.
For the application that I have on my computer, the software used is called ARTag, and it was developed by Mark Fiala, a researcher at the National Research Council of Canada. ARTag uses the markers described above to insert virtual objects into a webcam feed. It is possible to code virtual objects in ARTag, as in, create your own applications.[23] At Iowa State, the team there used ARToolkit, another AR software package that served essentially the same purpose.[24]

Both of these technologies used as their basis OpenGL. OpenGL is a computer graphics API (application programmer’s interface) which is designed to “[take] the specification of geometric objects and their properties and forming a picture of them with a virtual camera and lights.”[25] OpenGL is a popular choice among graphics programmers because it is platform independent, it has very stable, and it has a wide variety of functions. OpenGL is based off of the C++ programming language. In both ARToolkit and ARTag, OpenGL can be used to create the virtual objects used in the AR applications, as well as program possible animations into the objects.[26]

The team at Iowa State also used another kind of computer application to create virtual objects, the modeling software Maya and 3D Studio Max. Both of these applications are specifically designed to create very detailed virtual objects, much more detailed than any that could be made in OpenGL. Once created, the virtual objects could be imported into ARToolkit and placed into the scene. When creating AR applications, modeling software like Maya is very useful for making custom objects.[27]

5. Tracking

When creating an AR application, two of the most important requirements of such a system are where the camera is in relation to the virtual objects being displayed and where to display the virtual objects. Without this knowledge, virtual objects can appear misshapen, on the wrong plane, or simply fail to appear. This problem is called *location tracking* or simply *tracking*, because the computer needs to keep track of where the camera is, where the virtual objects, and how they relate to one another. There are numerous ways of solving these requirements, and each has its advantages and disadvantages.

i. Markers

Using black and white markers, as alluded to in the Technology section, is a popular choice for many AR applications. Once the camera is trained to detect the unique pattern on a marker, it can recognize it as the place where a virtual object must go. From there, it is a relatively simple matter for the computer to determine the distance and angle from the camera's point of view to the marker and display the virtual object accordingly.[28]

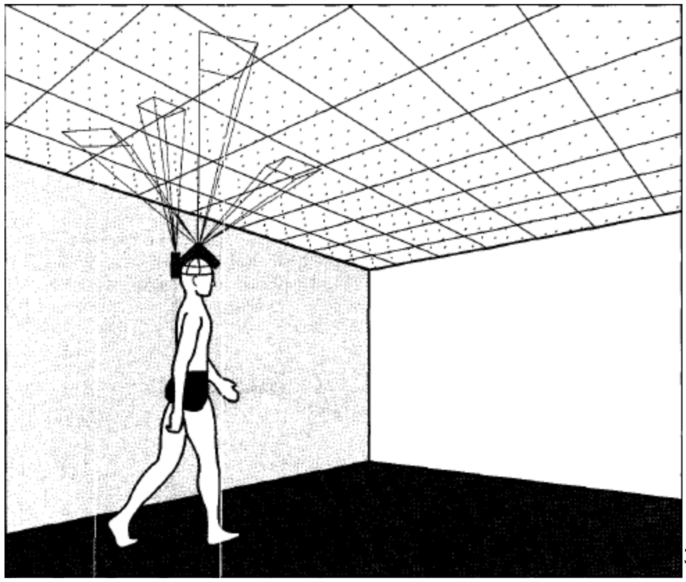
Markers are reliable and easy to train, but their disadvantage is an area must be covered with these markers in order for an AR application to work. There are some AR applications that use a marker system for tracking, but instead of black and white squares, natural landmarks are used. Still others compare the camera's footage to pre-recorded film and translate accordingly, although both of these methods of tracking are still in the experimental phase.[29]

ii. GPS

The approach of using the Global Positioning System (GPS) in conjunction with AR applications has been considered by a number of researchers. It works in the outdoors, unlike many other tracking methods, and it is accurate to several inches. Moreover, it works globally, giving an application that uses GPS the potential to be used anywhere. However, using GPS as a tracking system is not without its drawbacks. It requires a direct line of sight to multiple satellites and as a result is inconsistent indoors and in shaded areas.[30]

iii. Tethered Tracking Systems

Tethered tracking systems are designed to work exclusively inside and "require installation of large devices or dense arrays of beacons or sensors mounted in the covered area."[31] Tracking of these beacons work magnetically, ultrasonically, or optically. Such systems are highly accurate, down to the centimeter or millimeter range. The disadvantage to such systems, naturally, is that the room they are being used in requires a high amount of technology and preparation before an AR application can be used. As a result, they are not feasible on a large scale. Azuma imagined such a room in 1993, at that point he had yet to create one. See Figure for a conceptual drawing. In order to understand more precisely how exactly these tracking systems work, it is helpful to examine one particular example.



[32]

Figure 7: A conceptual drawing of a tracking system

The Hiball Tracking System out of UNC is such an example of a magnetic tracking system. According to the Hiball website, magnetic trackers are useful because, "They are small and unobtrusive, do not suffer from line-of-sight limitations, and recent models have both high update rates and low latency".[33] There are disadvantages, though, as the magnets have a limited range and can be adversely affected by metals and electromagnetic fields.

The tracking system has two parts; specifically, six sensors that are attached to the user, and a set of light-emitting diodes attached to the ceiling. The sensors attached to the user look upwards at the ceiling, and from that position and knowing the location of the user sensors compared to the location of the LEDs, it is possible to calculate the precise position of the user in the room and project the virtual objects accordingly. This magnetic tracking system uses magnetic fields, but it is a good example of tethered tracking systems in general because it showcases the accuracy and the limitations of such a system.[34]

6. Application of Augmented Reality: Medicine

One of the most useful applications of AR is in the field of medicine. By examining virtual representations of organs and tissues, doctors can gain a greater understanding of what is present in a patient's body without invasive surgery. An international conference, MIAR, or Medical Imaging and Augmented Reality, meets to explore the latest advances in this kind of technology. There are numerous examples of the use of AR in medical ways, a few of which should be examined.

i. Medical Training

Researchers in Europe have developed an AR system designed to simulate childbirth. This system is designed to train future doctors in how to deliver a child without having to experience an actual childbirth. The system is very advanced and provides important medical information to the student while in operation, such as, "values of blood pressure, heart rates, [and] pain and oxygen supplies."[35] The technology of the simulator consists of a haptic device in a body model, configured with software that keeps track of the biological information mentioned above. There is also a three-dimensional model of the simulated child, which is shown on a screen, and audio output is present as well. The simulator therefore showcases three of the most important parts of the experience of delivering a baby: the sights, sounds, and feelings. By incorporating augmented reality into the simulator, the user wears a HMD and is fully immersed in the experience, instead of having to look away at a screen to see the virtual objects.

According to the developers, the birth simulator is designed to be used in two parts. In the first part, students are simply to observe the interface in order to see what is happening inside a patient when childbirth is occurring, for the purposes of learning what to do. In the second part, a student is allowed to use the simulator to practice a delivery. The objective when such a delivery is taking place is to make it as realistic as possible, in order to best prepare the student for the future. Some elements of the simulator are not realistic, of course, for example the student can see "inside" the mother. In general, though, the developers believe they have developed an intuitive system. By creating this system, the developers have combined two important and innovative uses of AR technology, teaching and medicine.[36]

ii. Surgery

One of the most common uses of AR in medicine is as a help for surgeons. By using technology that scans a patient's body, such as an MRI or CT scan, multiple pictures of a part of anatomy that is of interest to a doctor. From these pictures, a three-dimensional model can be constructed, which is considerably easier to examine than a series of X-rays. Frederick describes an example, "in neurosurgery…a tumor seen in a volumetric MRI scan can be reconstructed into a three-dimensional model to allow the surgeon to visualize the entire tumor volume from any direction."[37] From this point, AR can be used in many different ways: to prep a surgeon for surgery, to train future surgeons about what to look for, and for doctors to get a better idea of what is happening inside a patient's body. The use of AR in surgery is one of the most commonly used and researched applications for AR and it will become a greater part of medicine in the future.
One innovative technological idea to come out of this use of AR is the idea of the "magic window". Such a window would be a display that a surgeon holds over a patient's body and illustrates an inner view of the body underneath the skin, virtually of course. However, this technology has not been incorporated into the medical profession because of some problems with it. A camera is needed to capture the image to be displayed in the window, and depending on the resolution of the camera, important details might not be displayed. Also, when the doctor moves the magic window, the view of the body must change as well. A tracking system would therefore be required, which could become very complicated.[38]

7. Application of Augmented Reality: Games

Video games are a very popular pastime. Millions of people play them, and as computing technology advances, so do the complexity and capabilities of video games. Frequently, video game developers attempt to make video games more immersive, in an effort to draw the player into the world of the game more fully. By incorporating augmented reality into a video game, the graphical elements of the game become part of the player's real world, blurring the line between reality and fiction. It serves to examine examples of AR video games, in order to understand what progress has been made and where the industry may go from here.

i. Space Station Construction

A group of students at Iowa State University created a game that gives the user the ability to construct a virtual space station out of component parts. The game uses a desktop display, where the user or users is seated at a desk and looks at a television screen. The screen shows the desk that the user is seated at, complete with markers and user's hands, as well as the virtual objects created by the computer. Through the use of a computer, a webcam, a flat-screen television, and a metal frame, a user interface is created for the purposes of playing this game.

The user is given three combinations of markers to use. One combination is a wand with two markers connected to it back to back (see figure 7). This wand can be used to "pick and drop" space station components wherever the user desires them.

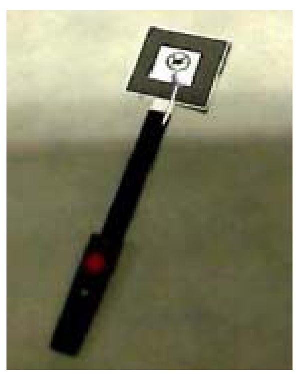


Figure 7: The wand used as an AR interface device

Another combination is three markers on a normal piece of paper. These markers allow for representation of the parts library of the space station. In other words, the user builds the space station out of these parts using the marker, and the parts library is where the parts come from.

The last combination of markers is another piece of paper with three markers on it (see Figure 8). These markers combine to create the virtual space where the space station can be built. In order to have the virtual components remain where they are placed, they need to be represented by their own markers. These markers are for that purpose. All three of these physical pieces are required to allow for adequate gameplay.

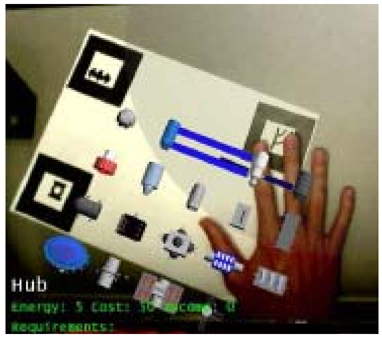


Figure 8: The three markers creating a virtual space

The gameplay consists of building a space station from component pieces. The pieces are divided into two categories, basic and advanced. Basic pieces are simple ones that are on space stations today: solar panels, living quarters, science labs, etc. Advanced pieces are space station components of the future: moon tours, space hotels, missile platforms. Every piece requires energy and materials. Energy is provided by solar panels and materials are provided by frequent space shuttle trips from Earth. If the player does not have enough materials or energy, he or she cannot add a piece. The player wins when he or she has built enough of the advanced components to make a certain kind of space station, either military or commercial.

This game is a good example of the innovative abilities of AR for video gaming. Building the space station allows the user to move the station using his or her own hands, not a gamepad or keyboard. In the future, it might possible to build a space station in a room, not only on a desk.[39]

ii. AR Quake

Another group of innovators out of the University of South Australia developed a different kind of game, a game based off of the "first person shooter" Quake. Unlike the video game developed at Iowa State, AR Quake is designed for a single user to move about the playing environment and interact with the virtual objects in a more immersive way.

The hardware needed for AR Quake is the usual equipment for a single user application. The user wears a head-mounted display (HMD) which allows for viewing both the real world as well as the computer-generated objects. A laptop is used to create the virtual objects, and is also carried around by the user. The Trimble Ag132 GPS is used to determine the user's position to an accuracy of 50 cm, and an Intersense IS-300 sensor to determine head orientation.

The gameplay of AR Quake is exactly the same as the original Quake game. The player moves around the environment and fights the monsters that inhabit it. The difference is that the environment that the player is in is the real world, not a virtual world; monsters appear to sit on top of real buildings.

Figure 9: The point of view of an ARQuake player

In order to achieve this effect, the developers had to map their university campus and build a virtual environment based on it. Then they trained the goggles to recognize where on campus the user was, based on the shape of the buildings and the user's GPS position. This is necessary because when the user moves, the environment must change in order to keep the quake world matched with the real world. The developers use "combinations of digital compasses, inclinometers, GPS (satellite) tracking and pattern recognition technologies just to work out exactly where [they] are in the real world."[40]

AR Quake is an extremely innovative and imaginative use of augmented reality in video games. It is foreseeable in the future that immersive video games such as this will be commonplace, and video games will no longer be played only in the home. The potential to physically move around an augmented environment is one that opens many doors for augmented reality applications.[41]

8. Future of Augmented Reality

The future of augmented reality is a bright one. As graphics engines become more powerful and HMDs become smaller, the possibilities for AR applications become endless.

For the personal computer, it might someday be possible to expand the desktop beyond the screen. A user could slip on a pair of glasses and view the icons in the air around the computer. The computer screen could be any size the user would like, limited only by the physical space the computer is placed in. Interacting with the desktop icons could be with the user's hands, not only with a mouse.

Virtual objects could appear in the home. Instead of purchasing a painting, a homeowner could simply place a marker on a wall, which when viewed through a HMD appears to be a painting. The result would be cheaper than buying an actual painting, and changing the picture would be effortless.

AR could be easily incorporated in a car as well, especially in combination with a GPS navigational system. Instead of the driver taking his or her eyes off the road to look at a screen, or trying to follow voice commands, a virtual arrow could appear on or above the road. This arrow would point the way for the driver to go, easily and safely. In the same way, important driving information such as speed, amount of gas, etc., could be displayed on the windshield instead of the dashboard. Technology like this is already being incorporated into many vehicles.

Perhaps even someday Ivan Sutherland's dream of a completely virtual room will finally come into reality (pun unavoidable). In this room, the user does not only see a virtually created environment, but can feel, hear and taste it as well. AR is the first step in creating such a room, and we still have a way to go before such a room could be made, but it is an intriguing possibility.

Conclusion

Augmented reality is an exciting emerging technology. By exploring its history, technology, technical specifications, current applications, and future, we have gained a greater understanding of exactly how exciting it is. This technology could revolutionize the way people use computers, work together, and even see and interact with their world. New innovations for AR are being developed all the time and soon AR will be a very common technology.

References

1. Brooks, Frederick Jr. "What's Real About Virtual Reality?" University of North Carolina at Chapel Hill. IEEE Computer Graphics and Applications.

2. Multimedia: From Wagner to Virtual Reality. Artmuseum.net. http://www.artmuseum.net/w2vr/timeline/Heilig.html.

3. "Morton Heilig, pioneer in virtual reality research." Theory and Research in HCI. http://comm6480rpi.blogspot.com/2008/09/morton-heilig-pioneer-in-virtual.html.

4. "Inventor in the Field of Virtual Reality: The Sensorama". The Father of Virtual Reality. http://www.mortonheilig.com/InventorVR.html.

5. "A Critical History of Computer Graphics and Animation. Section 17: Virtual Reality" Ohio State University. http://design.osu.edu/carlson/history/lesson17.html.

6. Krueger, Myron W., Gionfriddo, Thomas and Hinrichsen, Katrin. "Videoplace – An Artificial Reality". University of Connecticut, 1985.

7. Furness III, Thomas A. "The Super Cockpit and Human Factors Challenges" Human Interface Technology Lab, University of Washington. http://www.hitl.washington.edu/publications/m-86-1/.

8. Sutherland, Ivan E. "A Head-Mounted Three-Dimensional Display" Harvard University.

9. Azuma, Robert, Hoff, Bruce, Neely III, Howard, and Sarfaty, Robert. "A Motion-Stabilized Outdoor Augmented Reality System." HRL Laboratories, Malibu, CA. 1999.

10. Sutherland, Ivan E. "The Ultimate Display" Information Processing Techniques Office, ARPA, OSD. 1965.

11. Azuma, Robert. "Overview of Augmented Reality" SIGGRAPH 2004. (presentation slides)

12. Vallino, Jim. "Introduction to Augmented Reality". Rochester Institute of Technology. http://www.se.rit.edu/~jrv/research/ar/introduction.html. 1998

13. Bosner, Kevin. "How Augmented Reality Will Work". How Stuff Works.Com. http://computer.howstuffworks.com/augmented-reality2.htm.

14. Cawood, Stephen and Fiala, Mark. *Augmented Reality: A Practical Guide*. Pragmatic Bookshelf, Raleigh, North Carolina. 2007

15. Christian, Travis, Levine, Samantha and Scheinerman, Matthew. "Implemented Augmented Reality into the Gaming Industry on a Desktop Display Interface". Virtual Reality Applications Center at Iowa State University. 2008

16. Reitmayr, Gerhard and Schmalstieg, Dieter. "Location Based Applications for Mobile Augmented Reality". Vienna University of Technology.

17. UNC Tracker Research Group "UNC Hiball Tracker". University of North Carolina. http://www.cs.unc.edu/~tracker/media/html/hiball.html. Last Updated May 3, 2001.

18. Sielhorst, Tobias, Obst, Tobias, Burgkart, Rainer, Riener, Robert, and Navab, Nassir. "An Augmented Reality Delivery Simulator for Medical Training". AMI-ARCS 2004.

19. Morgan, Frederick. "Developing a New Medical Augmented Reality System" Carnegie Mellon University. May 1996.

20. "The ARQuake Project". Wearable Computing Lab, University of South Australia. http://wearables.unisa.edu.au/arquake/index.html. Last updated May 2002.

Endnotes

[1] Brooks, 1
[2] Multimedia: From Wagner to Virtual Reality
[3] "Morton Heilig, pioneer in Virtual Reality research."
[4] "Inventor in the Field of Virtual Reality: The Sensorama"
[5] "A Critical History of Computer Graphics and Animation"
[6] Krueger, Gionfriddo, and Hinrichsen, 1
[7] Furness
[8] Sutherland, "A Head-Mounted Three-Dimensional Display", 1
[9] Sutherland, "The Ultimate Display," 2-3
[10] Caudell and Mizell, "Augmented Reality: An Application of Heads-Up Display Technology to Manual Manufacturing Processes", System Sciences, 1992.
[11] Azuma, "A Motion-Stabilized Outdoor Augmented Reality System", 1
[12] Ibid., 2
[13] Azuma, "Overview of Augmented Reality"
[14] Vallino
[15] Ibid.
[16] Ibid.
[17] Bosner
[18] Ibid.
[19] Cawood and Fiala, 3
[20] Christian, Levine, and Scheinerman
[21] Cawood and Fiala, 4
[22] Ibid., 5
[23] Ibid., 6
[24] Christian, Levine, and Scheinerman
[25] Angel, 2
[26] Ibid., 2
[27] Christian, Levine, and Scheinerman, 3
[28] Cawood and Fiela, 3
[29] Reitmayr, 2
[30] Ibid.
[31] Ibid.
[32] Azuma, Robert. "Tracking Requirements for Augmented Reality". Communications for the ACM. July 1995.
[33] UNC Tracker Research Group
[34] Ibid.
[35] Sielhorst, 1
[36] Ibid.
[37] Morgan, 14
[38] Ibid.
[39] Christian, Levine and Scheinerman
[40] "The ARQuake Project"
[41] Ibid.