Ewan McIntyre

Multimedia Technology 2 – Virtual Reality

FAO Iain Stewart

Ewan McIntyre
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Introduction

Virtual Reality can be defined as an environment which is simulated by a computer system. The environment can mimic the “real” world, or it can be a simulation of a completely imaginary world. The term Virtual (or Artificial) Reality is attributed to Myron Krueger, an American computer artist [1] in the 1970s. It has been recorded as far back as 1938 however, by the French artist Antonin Arnaud, who coined the phrase while discussing his theatre shows [2].

The first virtual reality equipment, which attempted to physically realise the concept was developed by Morton Heilig [3] in the 1950s. He created the Sensorama machine, which contained a moving seat, along with 3-D moving images, smell, sound, and even wind. This is demonstrated in the image below.

Fig 1: Morton Heiligs Sensorama Machine

In the 1960s, further work in the field was done by Ivan Sutherland. In 1968, he developed a headset which allowed the wearer to “interact” with virtual objects, using wire frame graphics [4]. Virtual Reality entered the public consciousness in the 1980s and 90s. It was featured in popular

culture, including films such as Tron, The Lawnmower Man, The Matrix, and the Holodeck in Star Trek, The Next Generation. The Holodeck is a fictional example of True Immersive Virtual Reality, which is one of the levels or methods of Virtual Reality.

Levels of Virtual Reality

There are five levels, or methods of Virtual Reality [5].

Simulation Based:

This level is typically used for training purposes. If the equipment is available, almost any scenario can be simulated, which eliminates any inherent dangers. Learner drivers will be able to experience any type of driving conditions without having to be near a car or a road. Flight simulators can allow pilots to experience and prepare for situations that cannot be implemented in real world training. Medical training can allow trainee surgeons to simulate operations without fear of mistakes.

Avatar Based:

This allows the user to control a visual representation of himself within the virtual environment, in this instance a virtual world such as Second Life [6].

Projector Based:

This method takes real life images, and projects them to mimic the environment. CAVE (CAVE Automatic Virtual Environment) is an example of this [7]. In a CAVE, the user is surrounded by projected images within a 10’x10’x9’ cube, which provides the illusion of immersion.

Desktop Based:

This method is found on a desktop computer, where the virtual environment is generated without any special hardware or other processes. The illusion of immersion is provided by responsive computer generated characters and actions that can be taken by the user.

True Immersive Virtual Reality:

This is purely hypothetical at this time. As mentioned earlier, this is represented in films such as The Matrix, where the human brain is directly linked to a computer generated simulation, or the Holodeck from Star Trek, where the user can select a scenario they would like to interact with.

Current Uses

Virtual Reality is currently in use in a wide variety of different forms. This report will look at some of these forms.

Medical Training

Historically, medical training and specifically surgery training has been accomplished by students learning by watching more experienced surgeons perform. This approach is a satisfactory one, but does have its own inherent problems; the sporadic nature of having a patient to operate on, the quality of the surgeons teaching skills. [8].

One of the main ways that virtual reality is used in this context is that of training for laparoscopy surgery, also known as keyhole surgery. This technique employs a camera on the end of a rod, which is used to view the surgery on a magnified view screen. This makes the incision smaller, which has obvious benefits for the patient. This process lends itself well to simulated training, as the operation already uses a display screen for the surgeon to view the magnified procedure they are carrying out. The simulation involves the trainee surgeon using surgical instruments as normal, and the operation being simulated onscreen. According to Sophie Leisby, a trainee surgeon [9], the simulation is very real, the instruments act as they would in a real life situation, and when a vessel is accidentally cut in the simulation, it bleeds, and in the example shown, the surgeon failed the situation. This illustrates the benefits of virtual training; if the trainee surgeon had made this mistake in a real operation it is likely the patient would have experienced severe problems as a result. In the example given from Denmark, each trainee has to attain a certain score in the simulation before they will be considered for real life surgery.

Fig 2: Sophie Leisby using a Virtual Reality Simulator

http://www.bmj.com/cgi/content/abstract/338/may14_2/b1802 Link to video [9]

This is obviously a very useful tool in training surgeons. Previous methods, such as practising on cadavers offer valuable experience of interacting with a real human body. Interacting with a live patient is obviously a different matter however. Virtual Reality training offers trainees the opportunity to interact with material very close to what they would experience in a real operation. The use of such technologies as haptic feedback can only enhance their training further. Care needs to be taken though, to guard against complacency, and detachment from the dangers present in the operations that are being performed. This is an issue with Virtual Reality as a whole, not just with surgical training. There is a danger that the user will become desensitised to the consequences of mistakes. After all, if you die while playing a computer game, you simply respawn at your last save point. Using Virtual Reality to train people in anything runs the risk of this becoming a natural reaction.

Another use of Virtual Reality in the medical world is that of treating phobias [10]. This article lists the types of phobia which can be treated using Virtual Reality. These include fear of spiders, flight, driving, and claustrophobia among others. This kind of treatment, known as

“exposure therapy”, [11] refers to the practise of exposing a patient to the very thing that they have a phobia of. Obviously Virtual Reality has the potential to play a significant role in this kind of treatment, as the patient can be exposed to the stimuli in a virtual manner, which means they are more likely to participate in the treatment. A lot depends on the individual patient however. The first article states that the study carried out was inconclusive; that certain patients responded well to the virtual treatment, but others did not. Another factor is how severe the phobia is, and how relevant the virtual nature of the treatment is to the patient. A lot would depend on the patient being able to suspend their knowledge of the virtual environment, simulated flight very different to the real thing, especially if one has a related phobia. The research carried out for this report could not locate many recent references to this practise, most dated from the 1990s. It can be assumed from this that this was not followed up on as being a viable treatment for phobias. Possibly as the technology improves and becomes more sophisticated it will be revisited in the future.

Other Training

Virtual reality can be used in many other disciplines as a safe alternative to in-the-field training. One such example is that of coal mine [12]. The example shown offers a variety of simulated coal mine environments, and users can take part in courses that will train them in the different situations that could arise in an environment such as this. Again this allows trainees to experience the real life dangers to both themselves, and expensive equipment without placing themselves in physical danger.

A very relevant point made by this company is that this is a “High impact experience for maximum learning and retention”. Learning is always most successful when the student has a memorable experience to look back on, and will learn and retain far more from actually *doing* the tasks they are learning than from reading about them. Virtual Reality offers students such as these the opportunity to experience firsthand the realities of the job they are training for, something that may not have been possible before the advent of this technology.

Conferencing

Another environment in which virtual reality is currently employed is in conferencing. There are areas where this approach has many benefits over its real life equivalent. The primary factor is that of attendance and travel, if great distances have to be travelled to attend a conference, this obviously costs time and money to achieve. Using Virtual conferencing, attendees can view and interact in proceedings without leaving their office or home. One of the main proponents of this facility is the virtual world Second Life, which offers businesses the facility to hold meetings, conferences. The idea is that each participant has an avatar, who sits at the virtual table (or similar), and contributes with the meeting through

text using audio technology to chat in real time with their colleagues. One interesting innovation mentioned [13] is the “Frustration Orb”. This allows attendees to click it anonymously if they are unhappy with the direction of the meeting. The more clicks it receives, the orb turns red, intimating that the group are unhappy. This illustrates features of Virtual Conferencing that would enhance the experience. The ideas used behind this can be expanded to cover a wide range of scenarios. Education is an example; distance learning, or programs such as the Open University would benefit hugely from having virtual lectures. [14] Such facilities already exist in various forms; the example referenced here is from the Twente University in The Netherlands.

This example has a lecturer giving his lecture in one University, and it is viewed in real time, with interactivity possible, at two further universities. It can be argued that this is not truly Virtual Reality, but it is certainly a step in that direction. It is certainly moving towards virtual classrooms, where each student will have a computer linked to the other students and the teacher. Distance becomes an irrelevance, and it will allow for specialised study, with like minded students and teachers able to work together while studying, which really helps to give the student an idea of the placement of their work in the larger scheme.

Military

Virtual Reality has been around for a long time in military training, before the term was coined. In the 1920s and 30s, primitive flight simulators were employed to train pilots [15]. Sawed off “coffins” were placed on a pedestal, with realistic instruments placed inside. The darkness inside, the movement and the instruments made this an effective method of training pilots to fly at night. Later on, more sophisticated flight simulators were used, not just for military training. Cockpits surrounded by projected images to simulate flight can train all pilots, not just military. For military purposes though, this approach offers a way to train for and develop tactical situations, without risking expensive equipment and personnel in the field. These techniques are used in military training apart from that of flight training. Increasingly, soldiers can be trained using laptops connected through a network to others, which allows “large numbers of personnel to interact in a simulated face-to-face environment with other distant military units through the Internet (or through the classified network known as SIPRNET), and with first-responder units, civilians, and even medical personnel units, providing a training experience that is increasingly effective, but at a much lower cost than would be required for assembling these personnel for a real-life face-to-face training exercise.” [16] This technique also allows virtually any scenario or environment to be played out for the purposes of training. The influence of this kind of technology can be seen in the current gaming world, the likes of Call of Duty: Modern Warfare is clearly inspired by these kinds of training simulations. The blending of these worlds is apparent as the US army have used XBOX controllers to control remote devices, including robots (some with guns), and spy planes.

 Fig 3 – US Army uses XBOX Controllers

As stated, the rise in the use of Virtual Reality in training situations like this is down to the fact that it is very cost effective; the cost of setting up simulations is a lot more affordable now than it has been previously. The benefits in a military setting are obvious. Safety of equipment and personnel are paramount, and the process of developing new tools and weapons is rendered simpler, through the use of prototyping in a virtual environment, many design issues can be caught and eliminated without the need for in the field testing. It can all be done in a virtual field.

Augmented Reality

When looking at Virtual Reality, Augmented Reality must be discussed at least briefly. This refers to the combining of the real and virtual worlds. Common examples of this that are seen are in televised sports, such as the puck in ice hockey being augmented to allow viewers to follow it onscreen, or advertising in cricket and football, where logos are displayed on the field of play when viewed on a television. Augmented reality was defined in 1997 by Ronald Azuma [17]; he says that Augmented Reality allows the user to see the real world with virtual components superimposed on top of it, supplementing reality rather than replacing it. This is of course very different in scope to Virtual Reality, but it can be seen as a stage in the development of the concept, and its acceptance in the wider world. The step up from real world images supplemented by augmented reality, to fully immersive virtual reality is a large one, but it can be seen as a step in that direction.

Hardware

There are a large number of virtual reality technologies available to buy for both personal and professional uses. The professional equipment is likely to be for the scenarios discussed earlier, training simulations and large scale conferencing among others. There is a wide range of more personal equipment however. Head Mounted Displays (HMD) are the modern Virtual Reality glasses. There are a wide variety of these, [18] which claim to offer a fully immersive virtual experience. They are typically compatible with modern games consoles and media player systems, allowing the user to be completely surrounded by a virtual environment in a game, or watching a film. These devices are also used in a professional capacity, having been integrated into helicopter cockpits, and used by the military and fire services to provide essential data to personnel. One interesting feature is the ability to merge this with Head Tracking Technology. This allows the virtual environment to be modified by the user moving their head, which allows a virtual world to seem very realistic, the user can turn their head for instance, and the environment will react to this and display what is *behind* the user in the virtual world. This greatly enhances the realism and effectiveness of the technology [19].

The obvious extension of this technique is that of full motion tracking. This is a technique already employed in the making of special effect filled Hollywood blockbuster movies. The Lord of the Rings trilogy made use of this, the character Gollum was created using an actor who was motion captured, and then this was used to create a fully digital character. More recently, James Cameron's Avatar expanded on this technique. This has the potential for wider use however. As head tracking technology expands the realism of using Head Mounted Displays, obviously full body motion tracking allows the user to fully interact with a virtual world. This

idea goes back to the ideas and work of Ivan Sutherland in the 1950s, but it is only now being fully realised. Motion capture technology will enter homes in the near future, with the advent of Microsoft's Project Natal. [20] This is obviously linked to Microsoft's Gaming console, the XBOX 360, but if it is a success, the technology will doubtless be used in an increasing number of ways.

Another aspect of the virtual experience is that of physical feedback. If the user is fully immersed in a virtual world, with virtual 360 degree vision, and able to interact with virtual objects through motion tracking, the next step is for those virtual objects to react upon the user physically, with the user actually "feeling" them. To facilitate this, there are further technologies which can simulate feedback from a surgeon, or a bullet hitting a gamer, or the world of teledildonics, which are sex toys that can be controlled remotely through a network connection. These are all examples of haptic technology. Haptics refers to a technology that utilises the user's sense of touch by applying vibrations and force to simulate physical feedback. An animated explanation can be found at www.isfh.com [21], and a more detailed explanation of Haptic rendering, which generates the type and level of feedback that the user experiences is at

http://www.isfh.org/GR-Principles_Haptic_Percept_VE.pdf [22]

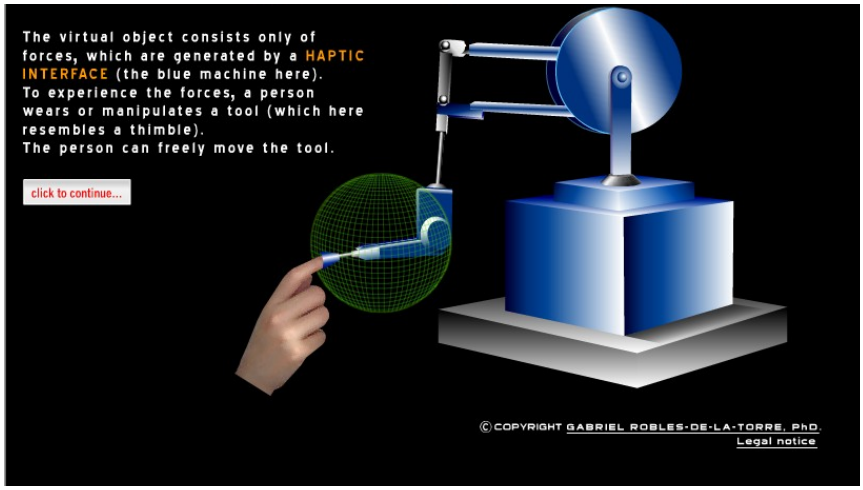

Fig 4 - Haptics

This is a swiftly emerging virtual reality technology, with some very interesting developments having been introduced in recent years. One such example is that of holograms that can be “touched”, with users having a virtual animal run about on their hand, or feeling virtual raindrops hit their hands [23] (with a demonstration video).

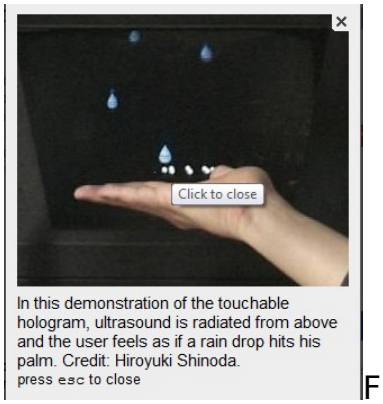

Fig 5- Virtual Raindrops
http://www.physorg.com/news168797748.html

This technology uses a technique called Airborne Ultrasound Tactile Display, which uses acoustic radiation pressure to simulate pressure on the user’s hand, which has an LED marker fixed on it. In this example Wii-motes (motion sensitive controllers used by the Nintendo Wii games console) pinpoint the position of the user’s hand and exerts feedback where appropriate in relation to the simulated hologram. If this technology can be expanded on, and perfected it would represent a huge advance, and a step towards truly virtual worlds being achievable. Another use of this technology expands on the virtual medical training discussed earlier, that of remote Haptic surgery. This is where a patient is prepared for surgery by local nurses and attendants, but is operated on via a remote link, by a surgeon who could be at any distance from the operation. This is known as telepresence, a type of virtual or augmented reality, where a person feels like they are present at a remote location. This is also present in video and virtual conferencing, as discussed earlier. Tactile feedback is generated by haptic technology. Early steps were taken using this technology in 2001 [24], when a surgeon in New York performed an operation on a patient in Strasbourg. This was known as Operation Lindbergh [25]. The main cause for concern was that of time

delay, anything above 150 milliseconds would have been dangerous. As it was, the time delay was 135 milliseconds, and the patient recovered well.

Fig 6 – Da Vinci surgical system

The technology and equipment has been developed further since then, Fig 6 shows a 3-D, HDTV system which can be used for remote surgery [26], which will increase the detail that the remote surgeon will be able to see and interact with.

The Future

As can be seen from the preceding report, the technology behind Virtual Reality continues to be developed, and, impressive as some of it is at this time, we are still some way off from having systems that will provide fully immersive virtual reality. It can be mimicked however.

Fig 7 – Homemade Virtual Reality Goggles

As this [27] video shows, easily accessible technology can be used and modified to create a form on immersive virtual reality. In this example, an HTC Android phone is attached to a homemade headset, which blocks out all other vision for the user. The phone has a digital compass application installed on it, which allows in this case the user to turn his head and body, and the viewpoint on the phone will dynamically react to this movement. It is not difficult to see how this concept could be improved on, to offer users fully immersive views of any location on the planet (and possibly off it) that is desired. Google's Street View project is a form of Virtual Reality that makes this sort of immersion possible. Google have taken panoramic photographs of large portions of the planet. It is not comprehensive in its locations yet, but over time this will increase, and users will be able to virtually visit anywhere they desire.

As discussed earlier, the hardware underpinning Virtual Reality is steadily moving forwards, with the military and medical professions two of the industries that are taking advantage of the ever more sophisticated equipment. In the home, progress has been slower, largely down to the cost of equipment, but this may change in the next few years, as Microsoft push their Project Natal, and their competitors will undoubtedly attempt to develop rival technologies. One recent innovation has come from the use of Nintendo's DSi gaming console. The remit of this report was specific in its "not gaming" direction, but this technology has wider implications for user interaction with 3D environments, and has been included. The technology uses the front facing camera present on the new model of Nintendo's DS console, the DSi. It employs face tracking software, which will analyse the position of the viewers face and eyes, and the images displayed on screen react in accordance to this. A 3D image is then given depth, and if the DSi is tilted, or the viewer moves his head back, the depth of the image changes, mimicking the real life perspective of the objects [28]. It is difficult to explain this properly, as it is a very visual effect. The link below at Fig 8 leads to a video demonstration.

Fig 8 (http://gizmodo.com/5481451/nintendo-dsi-uses-camera-face-tracking-to-create-3d-mirages)

These kinds of technologies, which are available to buy at relatively inexpensive prices, seem to be the future of Virtual Reality, for the average consumer anyway. Obviously large businesses will continue to make strides in fully immersive systems, such as CAVE, for training purposes. The portable nature of technology such as the DSi, and mobile

phones, is a lot more accessible and exciting for the average user. If the homemade Virtual Reality headset discussed earlier can be expanded upon, this could be as close to truly immersive Virtual Reality as anyone is likely to get, without spending vast amounts of money. Even combining this with proper HMDs (Head Mounted Devices) would seem to offer a relatively inexpensive way of immersing oneself in a Virtual World, albeit in the case of Street View, a virtual simulation of the real world. The DSi technology too, offers tantalising glimpse of what the future could hold. If this can be successfully transferred to large screen televisions, or similar devices, and utilise head tracking technology, real life depth and perspective can be used in a variety of applications. The real advances will come when these techniques are successfully combined with the various haptic technologies. As humans have five senses, for Virtual Reality to succeed, at least three of these should be stimulated (sight, hearing and touch). The other two are more difficult, and possibly less relevant, although it has been attempted, using smell at least, in Heiligs Sensorama machine.

Virtual Reality has then progressed since the term was first coined in the 1970s. While it was a buzz word of the 1980s, with fantastical promises of truly immersive systems that would be freely available to all, the reality is that this has been far more difficult to achieve than it was thought twenty or thirty years ago. Cost has been a hugely prohibitive factor; it is only fairly recently that technology capable of producing anything approximating the vision of immersive Virtual Reality has been available at prices near what the average consumer can afford. The basic pieces of equipment, such as Head Mounted Displays are a lot more affordable now than they have ever been. The fact remains that they are regarded as luxury items. The day may come when such items are commonplace in the average home, but this is still a long way off. The large scale virtual environments, like CAVE which were discussed earlier, are prohibitively expensive for the average company to use, let alone purchase for repeated use.

Another pitfall or possible danger inherent in the use of Virtual Reality in various scenarios is the effect it can have on the user. This report mentioned earlier the problem that medical students, among others can have with user detachment; becoming desensitised to the fact that their actions will have real life consequences, something that is not always readily reinforced in a virtual environment. A similar issue is that of the social problems that using a virtual world can cause. Anonymity is a factor, not just in virtual worlds, but in the use of the internet as a communication tool as a whole. A current issue in the news is that of social networking site Facebook installing a “panic button” for its users [29]. The issues this story raises are similar to those found in virtual worlds; how can the user know who they are dealing with? It is very easy to create a virtual character or avatar, which can bear little or no resemblance to the person who uses it. This leads to obvious safety concerns in the case of the news story referenced, but also to less sinister, but relevant issues of trust within a virtual world.

The world of Star Trek, with the Holodeck offering real life worlds of the users choosing still seem a long way off. This is possibly for the best however. It has been postulated that such an invention would mark the end of human civilisation. If everyone could live in a virtual world, who would be left to go to work, producing food and power to sustain the human race’s new virtual existence?

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