1 Introduction

There are various definitions of virtual reality. It is generally acceptable that by virtual reality we mean, on the most part, the computer-based three-dimensional environments. Often called worlds, they represent real-world or conceptual environments that can be navigated through, interacted with and updated in real-time.

Virtual reality can be accomplished through the use of a variety of methods. The environment may be projected inside a space within which users can move around. Headgear and gloves may be worn so that users feel like they are in a virtual world in which they can move around and touch. The most common form of virtual reality, though, is desktop virtual reality. In these systems virtual reality worlds run on users' PCs. They are displayed on the computer monitor and interactions take place through the use of a mouse or keyboard.

Desktop virtual reality systems can be distributed easily through the use of the internet or on CD and users don't need to be experienced to install or use them. Generally all that is necessary for this type of virtual reality to run on a PC is a single piece of software in the form of a viewer. Desktop virtual reality is both easily accessible from the average user and widely used.

2 Applications of Virtual Reality

The main applications of virtual reality are the following. Training, education, simulation, visualisation, conceptual navigation, design and entertainment but there is much overlap between these categories:

- Training applications include mainly simulations, which allow trainees to practise on their arena repeatedly in a no-risk environment. For example, users might fly with a fighting plane and make virtual battles without the risk of actually being killed.
- Educational applications include virtual visits and simulations. An example may be, a virtual visit to a museum that is too far away to visit or does not exist in the real world. Another example may be the simulation and analysis of historic battles.
- Visualisation examples include an architect's design for a building or the reconstruction of ancient buildings from archaeological evidence. Another use may be the visualisation of the structure of molecules, which are too small to see or, the other extreme, of a galaxy, which is too large.
- Applications of virtual reality for conceptual navigation enable, for example, users of a library or archive to find the information they need at a logical or physical level.
- Virtual reality allows designs to be visualised and tested. For example, a design application might allow film directors to see their scenes in action before actually being shot.
- Entertainment applications include virtual art galleries and games.
- Collaborative Virtual Environments (CVE) allows users to interact with each other in a virtual world. This allows the development of virtual communities, which add a new dimension to virtual reality.

3 Virtual Reality Defined

Generally, virtual reality (VR) is the label given to a number of computer-based approaches for the visualising concepts, objects or spaces in (usually) three dimensions. These approaches differ from other three-dimensional visualisations, such as Computer Aided Design (CAD) packages and Geographic Information Systems, in the fact that the resulting systems are interactive, although now this distinction is starting to become more vague. The user of VR is able to move inside the three-dimensional space and is usually able to interact with objects found there.

There are many ways of interpreting the term virtual reality. We can say that it is a technology that enables interaction with three-dimensional databases or a way of integrating man with information (Stone 1998; Warwick et al. 1993). The idea that information is at the core of VR is supported by those who see VR as a method of transferring knowledge or of turning information into knowledge. The most common description of VR is perhaps the military application of synthetic environments.

Nowadays, most of the people have unrealistic expectations from virtual reality. The media-promoted image of VR is as surreal, artificial worlds into which participants are immersed via various futuristic gadgets. Putting this image aside, VR is rapidly developing into a practical and powerful imaging tool for a wide variety of applications. So, when developing VR projects it may be wise to avoid definitions and concentrate on what it is that the technology can do.

4 Origins of virtual reality

VR's three-dimensional computer graphics capabilities give the developer the ability to create pictorial representations, abstract or realistic, and display them, with the sense of depth, on a computer screen. A VR world can simulate the real conditions of a hospital operating room, an airplane landing etc and it was in just these kinds of simulator scenarios that the earliest VR technologies began to develop.

The earliest simulators before VR were designed to train personnel in circumstances where real-world training was difficult, expensive or even fatal. Before the development of video or computer graphics, simulators were constructed through a combination of mechanical parts and flat illustrations or photographs. The use of video, as it became available, obviously increased the functionality of such systems, enabling alternative environments (like different airports in a commercial flight simulator) to be installed fairly easily. However, computer graphics had two fundamental advantages over this approach: flexibility and interactivity.

5 Interaction with the Virtual Environment

Video or paintings can be used to represent limited conditions. On the other hand, a computer-based model is theoretically unbounded. For example, the model of an airport can be viewed under a variety of programmed conditions (bad weather, night-time etc.). The capability for designing worlds, and the objects within them, is limitless, because real-world constraints, such as gravity, dimension or even common sense, do not have to apply.

VR has the capability of presenting realistic scenarios, but it can also be used to construct scenarios that would otherwise be impossible to experience. A VR developer could “construct” a rocket for travel to distant galaxies, or reconstruct the streets of an ancient city. In theory, such boundless opportunity is available to any graphics medium and it depends only on the skill and imagination of the illustrator. The extra value of VR is that it can take the created world, real or fantastic, and allow the user to interact with it. The ability to interact is one of the core elements of VR and separates it from other two and three-dimensional graphical environments. VR allows one or many people to interact with computer-generated objects and worlds in the way that they would interact with such objects in real life. Users can fly to distant galaxies or, if they so wish, stand on the streets of long lost ancient cities.

The degree of interaction that users have in a VR world depends on engineering within this world and the hardware that they use to interact with it. A VR world is essentially an interface that gives users the feeling of existence within an artificial world created by computer graphics. Inside the virtual world, users may be represented in a variety of ways: as a complete virtual body (an avatar), as a part of a body such as a hand or as a controllable viewpoint. The world can be engineered to give users control of elements within it, for example a vehicle, and navigation can be enhanced by elements like instruments or buttons. It is also possible to add text or other two-dimensional graphic aids to a VR world to assist users in their tasks.

A variety of visualisation systems and external hardware devices are used to enable interactions with VR worlds. The level of immersion within a world depends on the devices that are used, and the sort of interactivity that is designed into the world. The most common systems for viewing VR worlds are the following:

- Projected. Screens displaying a projected virtual world effectively fill the user’s field of vision. Projection may be onto large concave screens in front of the user or within closed spaces where users walk into. The latter can fill a 360-degree field of vision.
- Headsets. Users wear stereoscopic glasses or head-mounted displays (HMD), which place small screens right in front of their eyes. HMD enhance users' feeling of immersion/interaction within a world by excluding any glimpse of the real world and by revising the view of the virtual world as the user moves their head to look around.
- Desktop. The virtual world is projected on a standard computer monitor. This approach relies on interactive features built into the world to provide a degree of immersion for users.
- Tabletop. The virtual world is projected onto a horizontal tabletop screen, and is otherwise similar to the desktop display. It allows interaction in circumstances where a horizontal format is more appropriate than a normal monitor. A mechanic, for example, could learn how to fix a virtual machine on a tabletop in a way that simulates working on a real machine.

Specialist hardware devices are available that can give users a greater sense of immersion within the world. These devices include the HMD (Barfield et al. 1997) and sensor or data-gloves, which are designed to allow natural movements of the head or the hands in the real world to control movements in a virtual world. However, the standard computer keyboard, mouse and joystick can enable a user to control a vehicle, avatar, tool or viewpoint and offer a level of immersion within a virtual world. The different levels of immersion within a virtual world are the following:

- Fully immersive. An array of VR specific hardware is used to translate a user's natural movements into virtual activity. Devices include the HMD (described above), sensor or data-gloves and sensors attached to a user's body that detect, and translate, real movement into virtual activity (Cress et al. 1997). Devices can also be designed to give users feedback from the virtual world, for example sensations can be stimulated on the skin (e.g. heat or cold) or gloves can physically resist movement when a virtual object is encountered (Luecke and Chai 1997).
- Partially immersive. The hardware that is used in these systems allows users to remain aware of their real-world surroundings rather than being fully immersed in the virtual world. For example, a partially immersive system may include a sensor-glove and a virtual hand but use a desktop screen for visualisation. In this case, users are fully aware of their surroundings but can interact with the world with natural movements using the glove. Desktop systems, which allow users to control movements using a standard mouse, offer a lesser degree of immersion.
- Augmented. In augmented reality systems, users have access to a combination of VR and real-world attributes by superimposing graphical information over the real world (Kim et al. 1997). For example, a trainee surgeon could perform an operation on a virtual dummy using HMD or tabletop display and a real scalpel. Such a system enables users to develop appropriate motor skills without the risks inherent in the corresponding real situation.

6 Applications

Virtual reality has been described as a 'multidisciplinary effort covering everything from mechanical engineering to psychophysiology' (Rosenblum et al. 1994). Just a brief examination into the applications of VR is enough to support this idea. The potential uses of the technology are unlimited, but there are two approaches to current VR development: modelling the real world and abstract visualisation.

- Modelling the real world. Probably the most obvious applications of VR are those where a computer permits simulations of the real world in a safe, controlled and economical environment. Examples of such applications are fire fighting training, medical examinations, driving instruction, vehicle crash testing or wind tunnel experiments. This approach makes the modelling of reality possible in ways that would be impossible in the real world; Examples are space and deep-sea travel. It also permits the sort of model that we frequently see in TV archaeology broadcasts, where long-since destroyed buildings are virtually rebuilt and presented in a synthetic environment.

- Abstract visualisation. Another very common approach to VR application is in those cases where large amounts of abstract data have to be manipulated, examined or accessed. Such visualisations range from common applications such as maps, to structures such as molecular architecture or social networks. By combining VR with Geographical Information Systems (GIS), geographical information can be explored in three dimensions or the data contained within a computer database can be visualised and manipulated as a tangible entity.

  Almost any situation that requires interaction with information (even mathematical algorithms) can benefit from VR visualisation. Users are able to visualise and interact with information through multi-dimensional graphical representations. Such representations increase users' ability to analyse the underlying data because the need for them to construct a mental image of the data structure is not present anymore.

- Distribution. The growth in network computer systems is increasing the variety of VR applications, although the advantages of accessing applications from more than one machine are still being explored. Two areas can already be identified: those where groups of people can interact within a single simulation (see Section 4), and those where information can be distributed to wider numbers of people. It is already possible for multiple users to take part in game playing. As technology progresses even more complex applications will become possible. Distributing information to ever increasing audiences is useful in almost every field. Communicating scientific findings and access to public information have already been enhanced through the use of distributed systems.

  As the World Wide Web and its associated technologies develop, there will doubtless be an increase in the applicability of presentation mediums such as VR. There will also be a corresponding growth in the number of corresponding applications.

7 Virtual reality formats

For developing VR applications, VR-type software is necessary. Each format has differing approaches to three-dimensionality, immersion and interaction. Whatever the format, as a result of the need to provide clear and flowing imaging that constantly changes as users move within the world, VR requires substantial processing power. Until relatively recently, VR systems were restricted to very expensive graphics workstations. Increasingly though, VR is used on personal computer (PC) platforms as a result of their increasing processing power and improvements in graphics delivery hardware (graphics cards) and developments in PC-based VR software packages and formats.

The benefits of these developments can be seen on the Internet where they enable increased activity in three-dimensionality and interactive graphics development. The Virtual Reality Modeling Language (VRML) standard currently has a dominant VR presence on the Internet. This language has been developed to provide a multi-platform, universal language for interactive three-dimensional graphics across the web. There are already many applications, which utilise the benefits of VR in the VRML format, but the format has not grown, or become acceptable, as quickly as originally thought. This is due to the limiting factors of cross-platform, cross-browser compatibility, and also to less-than-perfect technical and political development. Various companies have attempted to develop VRML standards, including Microsoft, Sun Microsystems and Apple, but all were rejected in favour of VRML 2, which has since progressed to VRML 97.

VRML is not the only PC-based web-compatible VR format. Superscape, for example, created its own format (SVR), which runs efficiently, through either Netscape or Internet Explorer, via its own viewer. A number of SVR models can be found on the Web covering a variety of applications (including entertainment, marketing, training, and data visualisation).

The withdrawal of VR products by manufacturers, combined with the apparent slow acceptance of VRML as a securely established medium, should perhaps provide something of a warning to all developers of VR models or applications.

8 Two Important VR Development Languages

8.1 VRML

8.1.1 What is VRML

Virtual Reality Modelling Language (VRML) was developed by the Web3D Consortium and was designed for use on the Internet. VRML is both a scene description language and a file format for virtual worlds. The language is used to describe the geometry and behaviour of three-dimensional scenes. VRML is a popular 3-D format for the web because of its relative ease of use, standardisation and the comparatively small file sizes that it produces.

Three specifications for VRML have been developed. The Web3D Consortium defined VRML 1.0 as a minimum specification to put VRML in use quickly and then continued development work. Features and higher levels of interactivity were added and VRML 2.0 was released as an International Organisation for Standardization (ISO) Committee Draft in 1996. VRML 2.0 has now been replaced by VRML 97, which has been approved by the ISO and published as International Standard ISO/IEC 14772-1:1997.

VRML allows for the description of hierarchies of simple shapes such as cubes, cylinders and spheres. More complex shapes can also be defined, as can surface materials, texturing of facets and level of detail (LOD) data. Objects can be linked to other URLs via hotspots. Other features include transformation (the reuse of objects more than once), viewpoint setting (which allows users to look at pre-defined views of the world), the definition of lighting within the world and shape hints, which define how particular objects and object types will be rendered. VRML also works with other standard file formats in use on the Internet. Sounds, textures and animations can be linked to objects described in a VRML file by referring to image files, sound clips and program scripts in standard formats.

Features that were first introduced in VRML 2.0 were made easier to implement in VRML 97. The most important of these features are the sensors, which perform collision and proximity detection. Checks can be built into the world to test the visibility of an object from a given viewpoint. User interactions such as clicking and dragging are allowed and time can be measured and expressed. Importantly, there is the ability to incorporate scripts which define behaviours in the virtual worlds.

8.1.2 How to view VRML worlds

VRML viewers are needed to allow users to navigate their way through and interact with VRML worlds. Most web-browsers now include a VRML viewer. However, some browsers do not and users must download a plug-in or viewer from the World Wide Web. A number of different viewers are available for download and many are free. They differ in the style of navigation and performance that they can offer users. VRML developers often point users to a particular viewer, but users may select a different viewer because they are familiar with its style of navigation.

The Cosmo Player is one of the most popular viewers because it offers a wide range of movements. The Cosmo Player runs on a wide range of operating systems. VRML browsers that support multi-user shared worlds are also available, for example Blaxxun Contact 4.0.

8.1.3 What is needed to develop VRML worlds

VRML can be written using a text editor and viewed through a web browser. It is cheap because it requires no expenses other than the time taken to learn how to write VRML. However, hand coding is time consuming, can be tedious and it can be difficult to spot problems and debug the resulting code.

Another option is to use a VRML world-building tool (modeller). These packages allow developers to define worlds graphically and save them as VRML script. This process is much faster and easier than hand coding but is more expensive. Textures, sound, interactivity and behaviours are then added to the VRML using a text editor. There are dozens of world builders available, varying in price and quality, with new systems emerging all the time. The VRML repository includes a list of world builders along with syntax checkers and optimisation tools. When selecting world builders, developers are recommended to select those, which will produce VRML that complies with the ISO standard.

Once worlds have been created, a syntax checker can be used to check that the VRML code is correct. Optimisation programs can also be used to improve the performance of the world by removing redundant shapes from the code.

Large libraries of VRML objects, textures and sounds are available on the World Wide Web. When selecting objects it is important to check the units of measurement that have been used and whether they have been optimised so that they are drawn quickly on screen.

8.1.4 Problems with VRML

Although VRML is the most popular format available for delivery of 3-D models on the Internet, there are some problems associated with it. VRML is not the best virtual reality system. It is rather too general-purpose, providing many basic functions, which are designed to run on all platforms. It can never replace more sophisticated and specialised VR systems made for specific tasks or configured to run on specialised hardware. Although standardisation helps developers to make sure that VRML files will be delivered consistently on different browsers and plug-ins there are differences, particularly in their handling of lighting and colour. However, the browser manufacturers are co-operating to improve conformance.

At the present time, VRML is the best standard that exists for publishing, constructing and viewing virtual worlds on desk-top computers. VRML is currently the best standard for archiving and reuse of virtual reality, although the Web3D consortium, are working on developing X3D as the successor to VRML.

8.2 Java 3D

8.2.1 What is Java 3D

Java 3D is an extension to the Java programming language that creates a connection between the JRE and a computer's 3-D graphics support.

Java 3D applications have some similarities with VRML viewers. The main difference is that Java 3D applications are compiled programs. Unlike VRML, the source files which make up a Java 3D world (the three-dimensional objects, textures, sounds and interactions) are compiled together with the viewer into an application that users can run on their computers.

8.2.2 How to view Java 3D worlds

Users can run Java 3D applications either in their web-browser or directly on their computers if they:

- Install a compatible JRE plug-in.
- Install a Java 3D JRE plug-in that is compatible with the graphics capabilities of the computer
- Download a Java 3D application.

The process is complicated for users. Firstly, Java 3D applets will not work with Java-enabled browsers that do not have the version 1.2.1 JRE plus the Java 3D plug-in installed. Secondly, users must select and install versions of the JRE and the Java 3D plug-in that are compatible with each other. Finally, users are recommended to check the graphics capabilities of their computer before choosing between the Direct X or OpenGL versions of the Java 3D plug-in.

Java 3D applications can be run on Windows and Linux operating systems but cannot yet be run on Apple Macs.

8.2.3 What is needed to create Java 3D applications

To create Java 3D applications developers need:

- A Java development environment.
- A Java3D software developer's kit – which will incorporate both the JRE and the Java 3D plug-in.

Java and Java 3D can be written by hand using the Java and Java 3D Software Developer's Kits that are freely available from Sun. This takes no financial investment other than the time taken to learn how to write the programming language and access to a computer. However, learning to develop robust applications could take a novice from six months to two years. Writing programs by hand is also time consuming and the process of finding errors and debugging the code is extremely difficult.

Another option is to use a development environment, such as Borland's JBuilder, to ease the process of writing and debugging the program code. The three-dimensional objects that will make up the world are often created using a graphics package (such as AutoCAD, 3D Studio Max or Lightwave 3D), the objects are then converted into Java 3D code using a loader.

Java 3D developers may start by creating a world using VRML as a development environment and then converting it into Java 3D using a VRML loader. However, Java 3D does not support all of the features of VRML.

Java 3D applications are compiled programs, which means that Java 3D worlds are hard coded with the viewer. For developers this meant that Java 3D worlds could not be output to file edited and re-launched. As a result, the development process involved working with the 3-D models and other files that comprise the world in their original file format. With adequate documentation, worlds could be reloaded into Java 3D. Recently, Sun released Java 3D Fly Through helper classes, which will allow developers to output Java 3D models in j3f format files and should ease development. However, the best preservation strategy (see Section 6) is to maintain back-up copies of the original files with adequate documentation.

8.2.4 Java 3D Drawbacks

There are several limitations to Java 3D. Java 3D applications typically run more slowly than some other VR viewers. Large VR models may not work, as Java implementations may limit the amount of memory that can be used. The Java 3D plug-in is not available for Apple Macs, so will not run on all computers.

Perhaps the main drawback of Java 3D that makes it difficult to use, is that it is complicated to install. Two different plug-ins must be downloaded and, as the JRE and the Java 3D add-on are large files, this can take a long time for a user who is connected to the Internet via a 56k modem. Finally, having downloaded the files and installed the plug-ins, Java 3D does not offer the same degree of interactivity as other VR software programs.

8.2.5 Java 3D Advantages

Java 3D allows developers to create VR applications on a relatively low budget that can be delivered across a number of platforms. The development tools are inexpensive or free. Developers can also make use of Sun's Java Web Start application to provide software updates to their users through the Internet.

These factors may make Java 3D more suitable for in-house work rather than web-delivery. In-house work allows the developers to control the delivery platform, but delivery over the web means that developers are dependent on the end-user's willingness to install plug-ins.

9 Conclusion

Virtual Reality is a unique way for simulating reality as well as representing imaginary worlds or even abstract data. As technology is developing, the limitations that exist today (restricted processing power, hardware inadequacy etc) will be lifted and so it will most possibly become one of the dominant subjects in computing. As we saw, many benefits may be derived from such a progress. Humanity, though, should beware of such development because in a world of highly developed virtual reality, there is the tangible danger of people losing the sense of what is real and what is not and also forgetting the problems of the real world.

Note: A great deal of this assignment is based on the reference number 1.

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