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A Survey of Some Virtual Reality Tools and Resources

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1. Introduction

Virtual Reality (VR) technology enables users to interact with three-dimensional data, providing a potentially powerful interface to both static and dynamic information (Ausburn & Ausburn, 2003; Ausburn & Ausburn, 2004; Baieier, 1993; Onyesolu, 2011; Onyesolu & Eze, 2011). VR has existed in various forms since its inception. It has been known by names such as synthetic environment, cyberspace, artificial reality, simulator technology and so on and so forth before VR was eventually adopted (Onyesolu, 2006; Onyesolu & Eze, 2011). Though VR has existed from the late 1960s, its latest manifestation, desktop screen-based semi-immersive type which made its first appearance in entertainment industry, has made it come within the realm of possibility for general creation and use. As a result of proliferation of desktop VR, the technology has continued to develop applications that are less than fully immersive. These non-immersive VR applications are far less expensive and technically daunting and have made inroads into industry training and development.

There have been a lot of advances in VR and VR is being applied in all areas of human endeavor (Onyesolu, 2009a; Onyesolu, 2009b; Onyesolu & Eze, 2011; Onyesolu, 2006). Many VR applications have been developed for manufacturing, training in a variety of areas (military, medical, equipment operation, etc.), education, simulation, design evaluation, architectural walk-through, ergonomic studies, simulation of assembly sequences and maintenance tasks, assistance for the handicapped, study and treatment of phobias, entertainment, rapid prototyping and much more (Onyesolu & Akpado, 2009). VR has had impact in heritage and archeology, mass-media, fiction books, television, motion pictures, music videos, games, fine art, marketing, health care, real estate etc. Today, VR is being used as powerful tool in education to simulate learning environments. Such VR environments have been very valuable instructional and practice alternative (Onyesolu & Eze, 2011).

The question is what are the available tools and resources needed for building VR systems be it non-immersive VR systems, semi-immersive VR systems or immersive VR systems. There are a lot of companies that offer services in the field of VR and related areas. While some companies specialize in VR hardware, some specialize in VR software, be it 3D tools, 2D tools, or VR simulation tools. Some of these companies and software tools are provided in section 3 and section 5.

2. Virtual reality technology

VR technology enables users to immerse themselves in an artificial environment simulated by a computer, with the ability to navigate through the environment and interact with objects in it. Two keywords in the field of VR are presence and immersion. VR immerses the user in a simulation so that the user has a sense of being present in the virtual environment. The degree of immersion depends primarily on the computer hardware used whereas presence is achieved if the virtual environment causes the user to suspend disbelief and accept the computer-generated experience as real.

A computer system that generates an artificial world that tricks the user into feeling part of it would not be a complete definition of VR because it lacks the vital component of interactivity (Louka & Balducelli, 2001). VR is a highly interactive, computer-based multimedia environment in which the user becomes the participant in a computer-generated world (Kim et al., 2000; Onyesolu, 2009a; Onyesolu & Akpado, 2009). It is the simulation of a real or imagined environment that can be experienced visually in the three dimensions of width, height, and depth and that may additionally provide an interactive experience visually in full real-time motion with sound and possibly with tactile and other forms of feedback. VR is a way for humans to visualize, manipulate and interact with computers and extremely complex data (Isdale, 1998). It is an artificial environment created with computer hardware and software and presented to the user in such a way that it appears and feels like a real environment (Baieier, 1993). VR is a computer-synthesized, three-dimensional environment in which a plurality of human participants, appropriately interfaced, may engage and manipulate simulated physical elements in the environment and, in some forms, may engage and interact with representations of other humans, past, present or fictional, or with invented creatures. It is a computer-based technology for simulating visual auditory and other sensory aspects of complex environments (Onyesolu, 2009b). VR incorporates 3D technologies that give a real-life illusion. VR creates a simulation of real-life situation (Haag et al., 1998). VR is a three-dimensional user interface in which the user can perform actions and experience their consequences. It is a multidimensional real-time simulation rather than a linear animation with predefined camera movement.

This is what distinguishes VR from recorded, computer generated, images used in films and on television and from real-time computer animation where the user is a passive viewer (Louka & Balducelli, 2001). Unlike pre-rendered images of a 3D environment, the user of a VR system can usually move around freely in a virtual environment. The manner in which a user interacts with a virtual environment depends on the hardware and software used (Louka & Balducelli, 2001). In most cases, an off-the-shelf desktop computer with a 3D graphics acceleration and appropriate software are all that is necessary. This form of VR is often called desktop or fishtank VR (Louka & Balducelli, 2001, Onyeslu & Eze, 2011). In a desktop VR configuration, a 2D pointing device such as a mouse is typically used to select and manipulate objects, choose menu option, etc. Desktop VR is an effective, relatively cheap, option. The desktop VR experience can be taken a step further by using a projector and a large screen to display the virtual environment so that several users can work together in a meeting room or control centre, with one user controlling the computer. The 2D pointing device can also be replaced by a 3D input-device, which may improve usability.

Some 3D graphics cards and software support stereoscopic display, enabling users to view the virtual environment with an enhanced sense of depth using either a desktop display or a suitable projector. Stereoscopic displays typically require that users wear special glasses.

Some users find that stereoscopic viewing enhances their spatial understanding, however such display systems should only be used for brief viewing sessions (e.g. up to half an hour) to avoid simulator sickness (Louka & Balducelli, 2001).

For a greater sense of immersion, multi-screen projection systems or head-mounted displays can be used to place the viewer inside the model. While the hardware required to do this efficiently, with motion tracking and 3D input devices such as gloves, is relatively costly, immersive VR is particularly useful if a realistic view of a virtual environment is required. The user experiences the environment within the model as opposed to looking into it from the outside. VR systems based on immersive technology are relatively expensive, but can be justified when the benefits outweigh the cost (Louka & Balducelli, 2001).

In order to create usable virtual reality systems at a reasonable cost and with an appropriate level of performance, the application designer's understanding of the advantages and limitations of combinations of VR hardware and software is crucial (Louka & Balducelli, 2001).

3. Some VR technology resource companies

Some of the companies offering services in the field of VR and related areas are provided below (http://vresources.org/company_link_list).

3.1 3D Ace Studio

3D Ace Studio is a subsidiary of Program Ace LLC. 3D Ace studio delivers high quality graphics and programming services for high-end games, movies, etc. 3D Ace Studio's area of expertise includes creation of 2D concept art and design, GUI design, high-poly models for movies and games, 3D environments, low-poly and budget models, characters and creatures, animated next gen 3D movies, 3D SFX for feature and TV films, in-game cut scenes and intro reels, custom entire game development, CG, AI, tools and network programming (http://www.3dace.com).

3.2 3D Web (3DW) technologies

3DW technologies (3DW) provide a range of services based on interactive 3D computer graphics. 3DW Virtual Reality (VR) and Multimedia solutions provide innovative, dynamic and engaging solutions that improve communication and increase understanding. 3DW have spent so many years providing software and developing solutions in the fields of energy, regeneration and sport. 3DW technologies apply innovative, interactive graphics and software solutions to engage, communicate and entertain (http://www.3dwebtech.co.uk).

3.3 Virtual Heroes Inc. (VHI)

This is an "Advanced Learning Technology Company" that creates collaborative interactive learning solutions for Federal Systems, Healthcare and Corporate Training markets (http://www.virtualheroes.com/about.asp). VHI applications facilitate highly interactive, self-paced learning and instructor-led, distributed team training on its Advanced Learning Technology (ALT) platform. Major components of this platform include the Unreal® Engine 3 by Epic Games, and Dynamic Virtual Human Technology (DVHT). ALT leverages simulation learning and digital game-based learning paradigms to accelerate learning,

increase proficiency and reduce costs. DVHT combines best-in-class electronic computer game technology with a digital human physiology engine, digital pharmacokinetic drug models, accurate biomechanical parameters and artificial intelligence subroutines for the most realistic virtual humans available anywhere.

3.4 5DT (Fifth Dimension Technologies)

5DT is a high technology company specializing in Virtual Reality (VR). 5DT develops, produces and distributes VR hardware, software and systems. 5DT's main focus is VR Training Simulators and VR Peripherals. 5DT products include VR hardware, Animation Software, Systems and Application Software (http://www.5dt.com).

3.5 Adacel Technologies Limited

Adacel Technologies Limited is a leading developer of advanced simulation and software applications and services for market segments such as aviation, defence, telecommunications, corporate and government (http://www.adacel.com).

3.6 CAE Electronic

CAE Electronic is a world leader in commercial flight simulation. CAE Electronic provides a wide range of flight simulation platforms for many commercial aircraft models (http://www.cae.ca/).

3.7 CMLabs Simulations, Inc.

CMLabs' Vortex team provides physics-based behaviour modeling solutions and services to companies and institutions throughout the real-time visual-simulation world. With a long history in the visual-simulation and gaming industries, the Vortex team produces feature-rich simulation tools that set the industry standard for interactive 3D dynamics and simulating mechanical equipment behaviour. Vortex expertise and technology put high-fidelity behaviour in motion in applications for training simulators, mission rehearsal, serious games, virtual prototyping and testing. Vortex customers include Honda, John Deere, L-3, Lockheed Martin, NASA, Carnegie Mellon University, and over 100 other leading companies and academic institutions (http://www.vxsim.com)

3.8 Digimation Defense

Digimation has developed the largest library of military and associated 3D models for use in simulations and training. Digimation currently has more than 1,500 models in industry standard OpenFlight format and more than 30,000 3D models in a wide range of 3D formats which can be used in anything from realtime applications to high-end product demonstrations. Some of Digimation military models at work in movies are seen in Black Hawk Down, The Rock, Independence Day, Lord of War and Air Force One among others (http://defense.digimation.com/).

3.9 EdgedSign Inc.

EdgedSign was founded in 2008 to provide professional 3D modeling services for the simulation, training and entertainment markets. Since its inception, EdgedSign unites the

best human resources to provide highest quality of visual content. The leaders of the simulation industry trust EdgedSign to make their graphics (http://www.edgedsign.com)

3.10 On-Line Interactive Virtual Environment (OLIVE)

This is a product of Forterra Systems Inc. Forterra Systems Inc. builds distributed virtual world technology and turnkey applications for defense, homeland security, medical, corporate training, and entertainment industries (http://company.mmosite.com/forterra /index.shtml). Using the On-Line Interactive Virtual Environment (OLIVE) technology platform, customers can rapidly generate realistic three-dimensional virtual environments that easily scale from single user applications to large scale simulated environments supporting many thousands of concurrent users. Forterra's technology and services enable organizations to train, plan, rehearse, and collaborate in ways previously considered impossible or impractical.

OLIVE combines multimedia, scalable computing and network enabled connectivity to provide a complete IT-ready platform for developing and supporting truly collaborative, multiplayer interactive virtual environments. It is a 3D client-server virtual world platform using PC clients connected to a central server via a network. The architecture scales from a Windows based development environment to large scale Linux clusters. This architecture supports many thousands of concurrent, geographically distributed users (http://www.webbuyersguide.com/product/brief.aspx?src=rss&kc=rss&id=52841)

3.11 Icarus Studios Inc.

The company offers tools and products for creating massively multi-player online (MMO) environments, virtual worlds, and serious games for major entertainment, corporate, and government clients (Mousa, n.d). Icarus provides next generation technology, tools and production services enabling publishers and marketers to develop immersive environments to create new revenue streams and branding opportunities (http://www.icarusstudios.com/). Icarus Studios products include compatibility with industry standard tools such as 3D Max, Collada, and other 3D applications with simple editors.

4. The history of hardware components for VR application development

Hardware components for VR have evolved since the inception of VR. Hardware components for VR application development are computer workstation, sensory displays, process acceleration cards, tracking system and input devices. Other specialized types of hardware that have been developed or used for VR applications are navigation devices, interaction devices and tactile and force feedback among others (Isdale, 1998; Perry, Smith, & Yang, 2004).

4.1 Computer workstation

Computer workstation is used to control several sensory display devices to immerse you in 3D virtual environment (Onyesolu & Eze, 2011). A computer workstation is a microcomputer designed for technical or scientific applications. Intended primarily to be used by one person at a time, they are commonly connected to a local area network and run multi-user operating systems. The term workstation has also been used to refer to a

mainframe computer terminal or a personal computer (PC) connected to a network. Workstations had offered higher performance than personal computers, especially with respect to CPU and graphics, memory capacity and multitasking capability. They are optimized for the visualization and manipulation of different types of complex data such as 3D mechanical design, engineering simulation animation and rendering of images, and mathematical plots. Workstations are the first segment of the computer market to present advanced accessories and collaboration tools. Presently, the workstation market is highly commoditized and is dominated by large PC vendors, such as Dell and HP, selling Microsoft Windows/Linux running on Intel Xeon/AMD Opteron. Alternative UNIX based platforms are provided by Apple Inc., Sun Microsystems, and Silicon Graphics International (SGI) (http://en.wikipedia.org/wiki/Workstation).

4.2 Sensory displays

Sensory displays are used to display the simulated virtual worlds to the user. The most common sensory displays are the computer visual display unit, the head-mounted display (HMD) for 3D visual and headphones for 3D audio.

4.2.1 Head mounted displays

Head mounted displays place a screen in front of each of the viewer's eyes at all times. The view, the segment of the virtual environment generated and displayed, is controlled by orientation sensors mounted on the “helmet”. Head movement is recognized by the computer, and a new perspective of the scene is generated. In most cases, a set of optical lens and mirrors are used to enlarge the view to fill the field of view and to direct the scene to the eyes (Lane, 1993). Four types of Head Mounted Displays (HMDs) are: (a) Liquid Crystal Display (LCD) head mounted display; (b) Projected head mounted display; (c) Small CRT head mounted display; and (d) Single Column LED head mounted display.

LCD head mounted display uses LCD technology to display a scene. When a liquid crystal pixel is activated, it blocks the passage of light through it. Thousands of these pixels are arranged in a two dimensional matrix for each display. Since liquid crystals block the passage of light, to display a scene a light must be shone from behind the LCD matrix toward the eye to provide brightness for the scene (Aukstakalnis & Blatner, 1992). LCD head mounted display is lighter than most HMDs. As with most HMDs, it does provide an immersive effect, but the resolution and the contrast are low. The problem associated with low resolution is inability to identify objects and inability to locate the exact position of objects. Since the crystals are polarized to control the color of a pixel, the actual polarizing of the crystal creates a small delay while forming the image on the screen. Such a delay may cause the viewer to misjudge the position of objects (Bolas, 1994).

Projected head mounted display uses fiber optic cables to transmit a scene to the screen. The screen is similar to a cathode ray tube (CRT) except the phosphor is illuminated by the light transmitted through fiber optic cables. Ideally, each fiber would control one pixel. But due to the limitation in cost and manufacturing, each fiber controls a honeycomb section of pixels (Lane, 1993). Projected head mounted display provides better resolution and contrast than LCD displays. This HMD is also light weight. Higher resolution and contrast means that the viewer is able to see an image with greater detail. The downside of this type of HMD is that it is expensive and difficult to manufacture (Bolas, 1994).



Fig. 1. Visette 45 SXGA head mounted display (HMD)

Small CRT head mounted display uses two CRTs that are positioned on the side of the HMD. Mirrors are used to direct the scene to the viewers' eye. Unlike the projected HMD where the phosphor is illuminated by fiber optic cables, here the phosphor is illuminated by an electron gun as usual (Lane, 1993). CRT head mounted display is in many ways similar to the projected HMD. This type of HMD is heavier than most other types because of added electronic components (which also generate large amounts of heat). The user wearing this type of HMD may feel discomfort due to the heat and the weight of the HMD (Bolas, 1994).

Single Column LED head mounted display uses one column of 280 LEDs. A mirror rapidly oscillates opposite from the LEDs, reflecting the image to the user's eye. The LEDs are updated 720 times per oscillation of the mirror. As the LED column updates for each column of the virtual screen, the mirror redirects the light to the viewers' eye, one column at a time, to form the image of the entire virtual screen (Aukstakalnis & Blatner, 1992). Single Column LED HMDs allow the user to interact with a virtual world and the real world simultaneously. This type of display can be used to create a virtual screen that seems to float in the real world.

One of the common problems of HMDs is that the cable connecting the HMD and a computer restricts the mobility of the user. The user can only move as far as the cable allows. If the cable is not properly managed, the user could trip over it or become entangled in it. In addition, switching frequently between a virtual world and the real world is tedious and tiresome.

4.2.2 Binocular Omni-Orientation Monitor (BOOM)

The BOOM is mounted on a jointed mechanical arm with tracking sensors located at the joints. A counterbalance is used to stabilize the monitor, so that when the user releases the monitor, it remains in place. To view the virtual environment, the user must take hold of the monitor and put her face up to it. The computer will generate an appropriate scene based on the position and orientation of the joints on the mechanical arm (Aukstakalnis & Blatner, 1992).

Some of the problems associated with HMDs can be solved by using a BOOM display. The user does not have to wear a BOOM display as in the case of an HMD. This means that crossing the boundary between a virtual world and the real world is simply a matter of moving your eyes away from the BOOM.



Fig. 2. A binocular omni-orientation monitor (BOOM)

4.2.3 Visual Display Unit (VDU) or monitors

There are two types of computer visual display unit. The CRT monitors and the LCD monitors. The distinguishing characteristics of the two types are beyond the scope of this piece.

4.3 Process acceleration cards

Process acceleration card is an expansion card whose function is to generate output images to a display. Most video cards offer added functions, such as accelerated rendering of 3D scenes and 2D graphics, video capture, TV-tuner adapter, MPEG-2/MPEG-4 decoding, FireWire, light pen, TV output, or the ability to connect multiple monitors (multi-monitor). These cards help to update the display with new sensory information. Examples are 3D graphic cards and 3D sound cards. Other modern high performance video cards are used for more graphically demanding purposes, such as PC games (http://en.wikipedia.org/wiki/Video_card). Examples are 3D Nvidia Video Card and 3D ATI Video Card

4.4 Tracking system

This system tracks the position and orientation of a user in the virtual environment. The purpose of a tracking device is to determine the x, y, and z position, and the orientation (yaw, pitch, and roll) of some part of the user's body in reference to a fixed point. Most types of virtual reality interaction devices have a tracker on them. HMDs need a tracker so that the view can be updated for the current orientation of the user's head. Datagloves and flying joysticks usually have trackers so that the virtual "hand" icon will follow the position and orientation changes of the user's real hand. Full body datasuits will have several trackers on them so that virtual feet, waist, hands, and head are all slaved to the human user. This system is divided into: mechanical, electromagnetic, ultrasonic, infrared and inertial trackers.



Fig. 3. Patriot wireless electromagnetic tracker



Fig. 4. A.R.T. optical tracking system

A mechanical tracker is similar to a robot arm and consists of a jointed structure with rigid links, a supporting base, and an "active end" which is attached to the body part being tracked (Sowizral, 1995) often the hand. This type of tracker is fast, accurate, and is not susceptible to jitter. However, it also tends to encumber the movement of the user, has a restricted area of operation, and the technical problem of tracking the head and two hands at the same time is still difficult.

An electromagnetic tracker (EMT) allows several body parts to be tracked simultaneously and will function correctly if objects come between the source and the detector. In this type of tracker, the source produces three electromagnetic fields each of which is perpendicular to the others. The detector on the user's body then measures field attenuation (the strength and direction of the electromagnetic field) and sends this information back to a computer. The computer triangulates the distance and orientation of the three perpendicular axes in the detector relative to the three electromagnetic fields produced by the source (Baratoff & Blanksteen, 1993). Electromagnetic trackers are popular, but they are inaccurate. They suffer from latency problems, distortion of data, and they can be thrown off by large amounts of metal in the surrounding work area or by other electromagnetic fields, such as those from

other pieces of large computer equipment. In addition, the detector must be within a restricted range from the source or it will not be able to send back accurate information (Sowizral, 1995), so the user has a limited working volume.

Ultrasonic tracking devices consist of three high frequency sound wave emitters in a rigid formation that form the source for three receivers that are also in a rigid arrangement on the user. There are two ways to calculate position and orientation using acoustic trackers. The first is called "phase coherence". Position and orientation is detected by computing the difference in the phases of the sound waves that reach the receivers from the emitters as compared to sound waves produced by the receiver. The second method is "time-of-flight", which measures the time for sound, emitted by the transmitters at known moments, to reach the sensors. Only one transmitter is needed to calculate position, but the calculation of orientation requires finding the differences between three sensors (Baratoff & Blanksteen, 1993). Unlike electromagnetic trackers that are affected by large amounts of metal, ultrasonic trackers do not suffer from this problem. However, ultrasonic trackers also have a restricted workspace volume and, worse, must have a direct line-of-sight from the emitter to the detector. Time-of-flight trackers usually have a low update rate, and phase-coherence trackers are subject to error accumulation over time (Baratoff & Blanksteen, 1993). Additionally, both types are affected by temperature and pressure changes (Sowizral, 1995), and the humidity level of the work environment (Baratoff & Blanksteen, 1993).

Infrared (optical) trackers utilize several emitters fixed in a rigid arrangement while cameras or "quad cells" receive the IR light. To fix the position of the tracker, a computer must triangulate a position based on the data from the cameras. This type of tracker is not affected by large amounts of metal, has a high update rate, and low latency (Baratoff & Blanksteen, 1993). However, the emitters must be directly in the line-of-sight of the cameras or quad cells. In addition, any other sources of infrared light, high-intensity light, or other glare will affect the correctness of the measurement (Sowizral, 1995).

Inertial trackers apply the principle of conservation of angular momentum (Baratoff & Blanksteen, 1993). Inertial trackers allow the user to move about in a comparatively large working space where there is no hardware or cabling between a computer and the tracker. Miniature gyroscopes can be attached to HMDs, but they tend to drift (up to 10 degrees per minute) and to be sensitive to vibration. Yaw, pitch, and roll are calculated by measuring the resistance of the gyroscope to a change in orientation. If tracking of position is desired, an additional type of tracker must be used (Baratoff & Blanksteen, 1993). Accelerometers are another option, but they also drift and their output is distorted by the gravity field (Sowizral, 1995).

4.5 Input (interaction) devices

They are used to interact with the virtual environment and objects within the virtual environment. Examples are joystick (wand), instrumented glove, keyboard, voice recognition etc.

For interaction with small objects in a virtual world, the user can use one of several gloves designed to give feedback on the characteristics of the object. This can be done with pneumatic pistons, which are mounted on the palm of the glove, as in the Rutgers Master II (Gomez, Burdea, & Langrana, 1995). Gloves are used for sensing the flexion of the fingers.

Dataglove is a neoprene fabric glove with two fiber optic loops on each finger. Each loop is dedicated to one knuckle and this can be a problem. If a user has extra large or small hands, the loops will not correspond very well to the actual knuckle position and the user will not be able to produce very accurate gestures. At one end of each loop is an LED and at the other end is a photosensor. The fiber optic cable has small cuts along its length. When the user bends a finger, light escapes from the fiber optic cable through these cuts. The amount of light reaching the photosensor is measured and converted into a measure of how much the finger is bent (Aukstakalnis & Blatner, 1992). Dataglove requires recalibration for each user (Hsu, 1993). Fatigue effects and recalibration during a session are problems associated with long term use of Dataglove (Wilson & Conway, 1991).



Fig. 5. An instrumented glove (Nintendo power glove)

Powerglove uses strain gauges to measure the flexion of each finger. A small strip of mylar plastic is coated with an electrically conductive ink and placed along the length of each finger. When the fingers are kept straight, a small electrical current passing through the ink remains stable. When a finger is bent, the computer can measure the change in the ink's electrical resistance (Aukstakalnis & Blatner, 1992). Powerglove is less accurate than the Dataglove, and also needs recalibration for each user, but is more rugged than the Dataglove.

The dexterous hand master (DHM) is not exactly a glove but an exoskeleton that attaches to the fingers with velcro straps. A mechanical sensor measures the flexion of the finger. Unlike the Dataglove and Powerglove, the DHM is able to detect and measure the side-to-side movement of a finger. The other gloves only measure finger flexion. The DHM is more accurate than either of the gloves and less sensitive to the user's hand size, but can be awkward to work with (Hsu, 1993).

The main strength of the various types of gloves is that they provide a more intuitive interaction device than a mouse or a joystick. This is because the gloves allow the computer to read and represent hand gestures. Objects in the environment can therefore be “grasped” and manipulated, the user can point in the direction of desired movement, windows can be dismissed, etc (Wilson & Conway, 1991). Wilson and Conway (1991) opined that more work is needed to expand glove’s set of command gestures beyond the current simple mapping. Another area of improvement is feedback for the user to aid hand-eye coordination and proprioceptive feedback to let a user know when an object has been successfully grasped (Wilson & Conway, 1991).

The final category of interaction device is the wand or floating joystick. Basically, this device works exactly the same as a conventional joystick, but it is not attached to a base that sits on a tabletop. Instead, the joystick is equipped with an orientation tracker so the user simply holds it in their hand and tilts it. Most flying joysticks also have some buttons on the stick for "clicking" or selecting, similar to a mouse (Hsu, 1993).

4.6 Cave Automatic Virtual Environment

Cave Automatic Virtual Environment (CAVE) is an immersive virtual reality environment where projectors are directed to three, four, five or six of the walls of a room-sized cube (Fisher, 2003; http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

4.6.1 General characteristics of the cave

The CAVE is a large theatre that sits in a larger room measured of a varied size. The walls of the CAVE are made up of rear-projection screens, and the floor is made of a down-projection screen. High-resolution projectors display images on each of the screens by projecting the images onto mirrors which reflect the images onto the projection screens. The user will go inside of the CAVE wearing special glasses to allow for the 3D graphics that are generated by the CAVE to be seen. With these glasses, people using the CAVE can actually see objects floating in the air, and can walk around them, getting a proper view of what the object would look like when they walk around it. This is made possible with electromagnetic sensors. The frame of the CAVE is made out of non-magnetic stainless steel in order to interfere as little as possible with the electromagnetic sensors. When a person walks around in the CAVE, the person's movements are tracked with these sensors and the video adjusts accordingly. Computers control this aspect of the CAVE as well as the audio aspects. There are multiple speakers placed from multiple angles in the CAVE that give the user 3D audio (http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

4.6.2 The first CAVE

The first CAVE was developed in the Electronic Visualization Laboratory at the University of Illinois at Chicago. This was announced and demonstrated at the 1992 SIGGRAPH (Fisher, 2003). The CAVE was developed in response to a challenge from the SIGGRAPH 92 Showcase effort for scientists to create and show off a one-to-many visualization tool that utilized large projection screens. The CAVE answered that challenge, and became the third major physical form of immersive VR (after goggles 'n' gloves and vehicle simulators). Carolina Cruz-Neira, Thomas A. DeFanti and Daniel J. Sandin are credited with its invention. It has been used and developed in cooperation with the National Centre for Supercomputing Applications (NCSA), to conduct research in various virtual reality and scientific visualization fields. CAVE is a registered trademark of the University of Illinois Board of Regents (http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

4.6.3 How the CAVE works

A lifelike visual display is created by projectors positioned outside the CAVE and controlled by physical movements from a user inside the CAVE. Stereoscopic LCD shutter glasses convey a 3D image. The computers rapidly generate a pair of images, one for each of the

user's eyes. The glasses are synchronized with the projectors so that each eye only sees the correct image. Since the projectors are positioned outside of the cube, mirrors often reduce the distance required from the projectors to the screens. One or more computers, often SGI workstations, drive the projectors. Clusters of desktop PCs are popular to run CAVEs, because they cost less and run faster (http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

4.6.4 Developments in CAVE research

The biggest issue that researchers are faced with when it comes to the CAVE is size and cost. Researchers have realized this and have come up with a derivative of the CAVE system, called ImmersaDesk. With the ImmersaDesk, the user looks at one projection screen instead of being completely blocked out from the outside world, as is the case with the original CAVE. The idea behind the ImmersaDesk is that it is a single screen placed on a 45-degree angle so that the person using the machine has the opportunity to look forward and downward. The screen is 4' X 5', so it is wide enough to give the user the width that they need to obtain the proper 3D experience. The 3D images come out by using the same glasses as were used in the CAVE. This system uses sonic hand tracking and head tracking, so the system still uses a computer to process the users' movements (http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

This system is much more affordable and practical than the original CAVE system for some obvious reasons. First, one does not need to create a "room inside of a room". That is to say that one does not need to place the ImmersaDesk inside of a pitch-black room that is large enough to accommodate it. One projector is needed instead of four and only one projection screen. One does not need a computer as expensive or with the same capabilities that are necessary with the original CAVE. Another thing that makes the ImmersaDesk attractive is the fact that since it was derived from the original CAVE, it is compatible with all of the CAVE's software packages and also with all of the CAVE's libraries and interfaces (http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

4.6.5 Applications of CAVE

The concept of the original CAVE has been reapplied and is currently being used in a variety of fields. Many universities own CAVE systems. CAVEs are used for many things. Many engineering companies use CAVEs to enhance product development. Prototypes of parts can be created and tested, interfaces can be developed, and factory layouts can be simulated, all before spending any money on physical parts. This gives engineers a better idea of how a part will behave in the entire product (http://en.wikipedia.org/wiki/Cave_Automatic_Virtual_Environment).

5. Software tools for VR application development

As interest in Virtual Reality technology has increased, so has the number of tools available to the developers of virtual worlds. Some of these are libraries and toolkits, while others are application frameworks, and still others are full development environments, integrating every aspect of the creation of a VR application – modeling, coding, and execution – into a single package (Bierbaum & Just, 1998). The software

components are divided into 3D modeling software, 2D graphics software, digital sound editing software and VR simulation software.

5.1 3D modeling software

3D modeling software refers to programs used to create 3D computer-generated imagery (http://en.wikipedia.org/wiki/3D_computer_graphics_software). 3D modeling software is used in constructing the geometry of the objects in a virtual world and specifies the visual properties of these objects. Some 3D modeling tools are presented below.

5.1.1 Autodesk 3d Max (3D Studio MAX)

Autodesk 3d Max was originally called 3D Studio MAX. It is a modeling, animation and rendering package developed by Autodesk Media and entertainment. It is a comprehensive and versatile 3D application used in film, television, video games and architecture for Windows and Apple Macintosh. It can be extended and customized through its SDK or scripting using a Maxscript. 3d Max is the third most widely-used off the shelf 3D animation program by content creation professionals. It is also used for movie effects and movie pre-visualization.

5.1.2 AC3D

This is a 3D modeling application that began in the 90's on the Amiga platform. AC3D is an easy-to-use, powerful and affordable 3D modeling package. It is perfectly suited to creating in-game objects and characters. It is used in a number of industries. AC3D does not feature its own renderer. It supports many output/input formats including Renderman RIB, Povray, Milkshape, Lightwave LWO, Collada, Alias triangle and Wavefront OBJ among others (http://www.thegamecreators.com/?m=view_products&id=2092).

5.1.3 Acron 3D Modeller

The Acron 3D Modeller application is a powerful integrated 3D modeling tool for real time graphics. This application has been specifically engineered for the Modelling, Simulation and Gaming (MS&G) industry with support for industry standard 3D formats and modelling formats used in the entertainment industry such as Microsoft Flight Simulator ™. With Acron 3D Modeller, it is easier than ever to share models across synthetic environments, or create new models from the tens of thousands of freeware and shareware models available on the internet. It's easy to learn environment enables artists and modellers to quickly produce stunning quality models and environments in less time (http://www.acroneng.com/3D%20Modeller.htm)

5.1.4 Alibre Design

This is another 3D design software. Alibre Design is a parametric 3D CAD suite that provides 3D model creation and documentation capabilities for a variety of downstream applications such as CAM, Rendering or 3D Printing. The software consists of several integrated modules that allow the creation of parts, unfoldable sheet metal parts, assemblies, and 2D drawings, photo realistic rendering and CAM (http://www.alibre.com).

5.1.5 Cinema 4D

This is a light (Prime) to full featured (Studio) 3D package by MAXON Computer GmbH. Cinema 4D is used for creating advanced 3D graphics quickly and easily. Although used in film usually for 2.5D work, Cinema's largest user base is in the television motion graphics and design/visualisation arenas. Originally developed for the Amiga, it is also available for Mac OS X and Windows (http://www.maxon.net/products/cinema-4d-studio/who-should-use-it.html).

5.1.6 GL Studio

GL Studio creates interactive 3D graphics, instrumentation and user interfaces for training, simulation, and virtual prototyping. It generates portable C++ and OpenGL source code that can run standalone or be easily integrated into existing programs (http://www.simulation.com/products/glstudio/glstudio.html).

5.1.7 Cobalt

Cobalt is a parametric-based computer-aided design (CAD) and 3D modeling software for both the Macintosh and Microsoft Windows. It integrates wireframe, freeform surfacing, feature-based solid modeling, photo-realistic rendering, and animation (http://www.ashlar.com/3d-modeling/3d-modeling-cobalt.html).

5.1.8 Electric Image Animation System (EIAS)

EIAS is an eminent 3D animation and rendering package available on both Mac OS X and Windows. Mostly known for its rendering quality and rendering speed it does not include a built-in modeler. EIAS is extensively used in Hollywood, and by professional studios all over the globe to create world-class animations. The popular film *Pirates of the Caribbean* and the television series *Lost* used the software (http://www.eias3d.com/products/eias-overview).

5.1.9 Houdini

This is used for visual effects and character animation. It was used in Disney's feature film *The Wild*. Houdini uses a non-standard interface that it refers to as a "NODE system". It has a hybrid micropolygon-raytracer renderer, Mantra, but it also has built-in support for commercial renderers like Pixar's Renderman and mental ray (http://www.sidefx.com).

5.1.10 LightWave 3D

This software was first developed for the Amiga. It was originally bundled as part of the Video Toaster package and entered the market as a low cost way for TV production companies to create quality CGI for their programming. It first gained public attention with its use in the TV series *Babylon 5* and it is used in several contemporary TV series. Lightwave is also used in a variety of modern film productions. It is available for both Windows and Mac OS X. LightWave's tools are designed for fast productivity and easy, intuitive use (http://www.newtek.com/lightwave.html).

5.1.11 MASSIVE

This is a 3D animation system for generating crowd-related visual effects, targeted for use in film and television. It was originally developed for controlling the large-scale CGI battles in *The Lord of the Rings*. Massive has become an industry standard for digital crowd control in high end animation and has been used on several other big-budget films. It is available for various Unix and Linux platforms as well as Windows (http://en.wikipedia.org/wiki/MASSIVE_(software)).

5.1.12 Maya

Autodesk Maya 3D animation software delivers an end-to-end creative workflow with comprehensive tools for animation, modeling, simulation, visual effects, rendering, match moving, and compositing on a highly extensible production platform. This software is currently used in the film, television, and gaming industry. Maya has developed over the years into an application platform in and of itself through extendibility via its MEL programming language. It is available for Windows, Linux and Mac OS X (http://usa.autodesk.com/maya)

5.1.13 Poser

Poser is a 3D CGI rendering and animation software program optimized for models that depict the human and animal figures in three-dimensional form. Poser has a basic library of human, animal, robotic, and cartoon figures. Poser software package also include poses, hair pieces, props, textures, hand gestures and facial expression (http://en.wikipedia.org/wiki/Poser).

5.2 2D graphics software

2D graphics software is used to manipulate texture to be applied to the objects which enhance their visual details. 2D graphics software (also known 2D graphics editor or drawing program) is an application-level software for the creation of images, diagrams and illustrations by direct manipulation (through the mouse, graphics tablet, or similar device) of 2D computer graphics primitives. These editors generally provide geometric primitives as well as digital images; and some even support procedural models. The illustration is usually represented internally as a layered model, often with a hierarchical structure to make editing more convenient. These editors generally output graphics files where the layers and primitives are separately preserved in their original form. MacDraw, introduced in 1984 with the Macintosh line of computers, was an early example of this class; recent examples are the commercial products Adobe Illustrator and CorelDRAW (http://en.wikipedia.org/wiki/CorelDRAW), and the free editors such as **xfig** or **Inkscape**. There are also many 2D graphics editors specialized for certain types of drawings such as electrical, electronic and VLSI diagrams, topographic maps, computer fonts, etc.

5.3 VR simulation software

Simulation software brings the components of VR together. It is used to program how these objects behave and set the rules that the virtual world follows. Some examples are presented:

5.3.1 WITNESS VR

This simulation software incorporates 3D displays and is designed to be used where first class presentation of a key proposal is required. This is an established general purpose simulation tool used by thousands of organizations to support continuous process improvement activities. WITNESS VR comes complete with a world building and editing package called mantra4D. This enables objects to be created from simple primitives (spheres, cylinders, boxes, etc) or to be imported from a variety of CAD and solid modeling packages (3DS, WRL formats included). Complex CAD models can be simplified using tools in mantra4D to render them suitable for real time fly-around VR. Backdrops can be created easily using simple surfaces and applied digital images which can be taken with any typical digital camera (http://www.laner.com/en/media/witness/vr.cmf).

5.3.2 Flexsim DS

Flexsim DS incorporates the latest advances in 3D simulation software-from realistic VR environments to network collaboration. Flexsim DS can create custom installations and build distributed modeling environment (http://www.flexsim.com/products/ds/).

5.3.3 OpenSimulator (OpenSim)

OpenSimulator is a 3D application server. It can be used to create a virtual environment (world) which can be accessed through a variety of clients, on multiple protocols (Mousa, n.d). OpenSimulator allows you to develop your environment using technologies you feel work best (Onyesolu & Eze, 2011). OpenSimulator has numerous advantages which among other things are:

a. OpenSimulator is released under BSD license, making it both open source, and commercially friendly to embed in products.
b. It has many tools for developers to build various applications (chat application, buildings, and avatars among others).
c. OpenSimulator can be extended via modules to build completely custom configuration.
d. It is a world building tools for creating content real time in the environment.
e. Supports many programming languages for application development such as Linden Scripting Language / OpenSimulator Scripting Language (LSL/OSSL), C#, and/or Jscript and VB.NET
f. It incorporates rich and handy documentations and tutorials.

5.3.4 Croquet

Croquet is an open source 3D graphical platform that is used by experienced software developers to create and deploy deeply collaborative multi-user online virtual world applications on and across multiple operating systems and devices (http://www.opencroquet.org/index.php/Main_Page). Croquet is a next generation virtual operating system (OS) written in Squeak. Squeak is a modern variant of Smalltalk. Squeak runs mathematically identical on all machines. Croquet system features a peer-based messaging protocol that dramatically reduces the need for server infrastructures to support virtual world deployment and makes it easy for software developers to create deeply

Name	Creator	Linux	Mac OS X	Unix	Windows	Free Software
Acoustica	Acon Digital Media	No	No	No	Yes	No
Amadeus Pro	HairerSoft	No	Yes	No	No	No
Ardour	Paul Davis	Yes	Yes	Yes	No	Yes
Audacity	Dominic Mazzoni	Yes	Yes	Yes	Yes	Yes
Audiobook Cutter Free Edition		No	No	No	Yes	Yes
Audio Dementia	Holladay Audio	No	No	No	Yes	No
Audition	Adobe Systems	No	yes (in beta)	No	Yes	No
BIAS Peak	BIAS	No	Yes	No	No	No
Creative Wavestudio	Creative Technology	No	No	No	Yes	No
Diamond Cut DC7	Enhancedaudio.com, Inc.	No	No	No	Yes	No
Ecasound	Kai Vehmanen	Yes	Yes	Yes	No	Yes
Eko	Peter Semiletov	Yes	Yes	Yes	No	Yes
Freecycle		Yes	No		No	Yes
Fast Edit	Minnetonka audio	No	No	No	Yes	No
Fission	Rogue Amoeba	No	Yes	No	No	No
FlexiMusic Wave Editor	FlexiMusic	No	No	No	Yes	No
Goldwave	Goldwave Inc.	No	No	No	Yes	No
Jokosher	Jokosher community	Yes	No	Yes	Yes	Yes
LMMS	Tobias Doerffel	Yes	Yes	Yes	Yes	Yes
Logic Pro	Apple	No	Yes	No	No	No
MAGIX Music Maker	MAGIX	No	No	No	Yes	No
Media Digitalizer	Digitope	No	No	No	Yes	No
mp3DirectCut		Yes (WINE)	No		Yes	Yes
MP3 Stream Editor	3delite	No	No	No	Yes	No
MusE		Yes	No		No	Yes
n-Track Studio	FAsoft	No	No	No	Yes	No
NU-Tech	Leaff Engineering	No	No	No	Yes	No
Pro Tools	Avid	No	Yes	No	Yes	No

Table 1. Some digital sound editing software and compatible operating systems. Source: http://en.wikipedia.org/wiki/Digital_audio_editor

collaborative applications. Croquet provides rich tutorials, resources and videos as educational materials for developers (Onyesolu & Eze, 2011).

5.3.5 Ogoglio

Ogoglio is an open source 3D graphical platform like Croquet. The main goal of the Ogoglio is to build an online urban style space for creative collaboration. Ogoglio platform is built from the languages and protocols of the web. Therefore, it's scripting language is javascript; it's main data transfer protocol is hypertext transfer protocol (HTTP), it's 2D layout is hypertext markup language (HTML) and cascading style sheet (CSS), and it has lightwave object geometry format for its 3D (http://foo.secondlifeherald.com/slh/2007/01/interview_with_.html). Ogoglio is very different from the other virtual reality world development platforms because it uses Windows, Linux, Solaris operating system platforms and runs on web browsers such as Internet Explorer, Firefox, and Safari.

5.3.6 Syzygy

This is a cross-platform, distributed operating system for PC-cluster-based VR. Syzygy is a programming toolkit for writing virtual reality or other graphical applications. Syzygy applications can run on a single computer, but Syzygy is especially designed for the creation of applications to run on clusters of networked computers. Programs or instances of the same program running on different computers in the cluster communicate with one another and share data. The cluster as a whole effectively becomes a single computer with multiple screens and input devices. The rendering of your virtual world is synchronized on all of the computers (to within a few milliseconds), so different screens in the cluster give you different simultaneous views on the virtual world. Included utilities handle communication with 6DOF trackers and other input devices. Spatially-localized sound is supported using the FMOD libraries and non-localized text-to-speech on Windows (http://www.isl.uiuc.edu/syzygy.htm).

5.4 Digital sound editing software

Digital sound editing software is used to mix and edit sounds that objects make within the virtual environment. There are so many digital sound editors. Some are presented in table 1.

6. Conclusion

There are so many VR resources and tools from industry providers. Some companies specialize in providing hardware components for use in VR system such as accelerator cards, pointing and manipulation devices, helmets, shutter glasses, motion platforms, projection system and spatial position and detection systems. There some others companies that specialize in software tools such as 2D software tools, 3D software tools and VR simulation tools. There are a quite handful of companies and institutions that specialize in providing VR applications for manufacturing, education, simulation, design evaluation (virtual prototyping), architectural walk-through, ergonomic studies, simulation of assembly sequences and maintenance tasks, assistance for the handicapped, study and treatment of phobias, entertainment, rapid prototyping and much more.

The exciting field of VR has the potential to change our lives in many ways. There are many applications of VR presently and there will be many more in the future. Many VR applications have been developed. VR technology is now widely recognized as a major breakthrough in the technological advance of science. In Japan today, with the help of VR technology, a customer can walk into a department store, done a VR helmet (HMD) and glove, and proceed to design his own kitchen. The customer can walk around inside the virtual kitchen, open and close drawers; turn on the water, etc. Once the customer is satisfied, the plans are produced and the kitchen is made to order. The Japanese are further developing this system to include various aspects of lighting, noises, humidity, and drafts.

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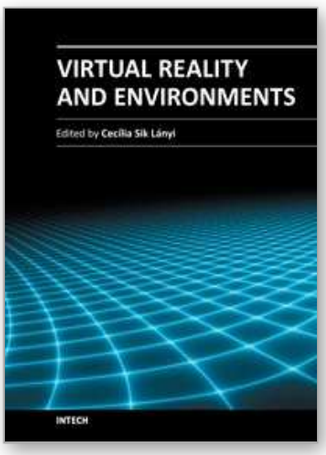
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Virtual Reality is clearly interdisciplinary research. It has, not only Information Technology importance but social, educational, economical importance too. It combines multiple disciplines for the development of virtual reality systems in which the user has the immersive feeling of being in the real world. Virtual reality has several applications in almost all fields of real life. The most typical fields for the application of virtual reality are health-care, engineering and game industry. This book may be a solid basis for the novice and advanced engineers who would like to develop user friendly Virtual Environments for education, rehabilitation and other applications of Virtual Reality. Our book provides a resource for wide variety of people including academicians, designers, developers, educators, engineers, practitioners, researchers, and graduate students.

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