Virtual Reality: Opportunities and Challenges

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Abstract: *Virtual Reality systems have drawn much attention by researchers and companies in the last few years. Virtual Reality is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. Interactivity and its captivating power, contribute to the feeling of being the part of the action on the virtual safe environment, without any real danger. So, Virtual Reality has been a promising technology applicable in various domains of application such as training simulators, medical and health care, education, scientific visualization, and entertainment industry. Virtual reality can lead to state of the art technologies like Second Life, too. Like many advantageous technologies, beside opportunities of Virtual Reality and Second Life, inevitable challenges appear, too. This paper is a technical brief on Virtual Reality technology and its opportunities and challenges in different areas.*

Keywords: *Virtual Reality, Virtual environment, training simulators, Second Life*

I. INTRODUCTION

Virtual Reality is described in various and sometimes inconsistent ways in some publications and conferences because this technology is new and writers attempt to define it based on different perspectives such as the tools it uses, its functions, etc [1]. If we consider the perspective based on functionality, Virtual reality (VR) is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. In other word, virtual Reality is a simulation in which computer graphics is used to create a realistic looking world. Moreover the synthesized world is dynamic and responds to user inputs such as gestures and verbal commands.

Virtual Reality is a real-time and interactive technology. It means that the computer is able to detect user inputs and modify the virtual world instantaneously. Interactivity and its captivating power contribute to the feeling of being the part of the action on the environment that the user experience. All human sensorial channels can be used to have a high level interaction. Most current virtual reality environments are primarily visual experiences, displayed either on a computer screen, but some simulations include additional sensory information, such as sound through speakers or headphones. Some advanced simulators, use haptic systems which include tactile information, generally known as force feedback. So, we can summarize the above ideas of Virtual Reality in one definition [1]: Virtual Reality is a high-end user interface that involves real time simulation and interaction through multiple sensorial channels like visual, auditory or tactile. Samples of Virtual Reality interaction are illustrated in Figure 1.

In1962, inspired by holographic movies, Morton Heilig patented the design called “sensorama”. The patent is the first video device of virtual reality by which a user can feel the vibration, sound, smell, and wind recorded in advance. The head-mounted video is similar to the head mounted display seen in the early 1990s. In1965, the founder of computer graphics, Sutherland [2] inherited and developed the design of Heilig. Sutherland presented the basic concept of a virtual reality system which had multi-senses, immersion, and interaction. In1966, funded by the navy scientic research office, American MIT Lincoln Laboratory developed the first head-mounted display (HMD) and applied the feedback devices which simulate the force and tactile in the system later. In1967, inspired by the conception of Sutherland’s system, the University of North Carolina launched the GROPE project which researched and developed force feedback devices that made users feel computer simulated force. In 1968, organized by Harvard University, Sutherland designed the helmet mounted display and later a virtual system which was considered as the first virtual reality system. In 1970, American MIT Lincoln Laboratory developed a full-fledged HMD system. In1973, Krurger [3] presented the term “artificial reality”, which was the early term of virtual reality.

In 1987, Foley [4] published a paper entitled “Interfaces for Advanced Computing” in the journal “Scientifc American”. Another paper [5] about data gloves was also published in this journal. These published papers about virtual reality attracted people greatly. In 1989, American Jarn Lanier formally presented the term “virtual reality”. In 1994, Burdea and Coiffet [6] published a book about virtual reality in which they summarized the basic characters of VR as 3I (imagination, interaction and immersion).

From 1995 up to now, by development of computer graphic science, “Virtual Reality” has become one of state of the art topics and researchers attempt to create more realistic environment and more active interfaces for high quality interaction in this field.

Figure. 1. Samples of Virtual Reality interaction

Virtual Reality technology has been a promising technology applicable in various domains of application such as training simulators [7], medical and health care, rehabilitation [8], education [9-10], engineering [11], scientific visualization [12], and entertainment industry. In addition, Virtual reality can lead to state of the art technologies like Second Life, too [13-14]. Like many advantageous technologies, beside opportunities of Virtual Reality and Second Life, inevitable challenges appear, too.

This paper is a technical brief on Virtual Reality technology and its opportunities and challenges in different areas. After this introduction, in section 2, virtual reality types and structural elements of a virtual reality system are described. Then sections 3 & 4 explain two main of these elements: Virtual Environment and Virtual Reality Interfaces, consequently. Section 5 presents applications of virtual reality that providing opportunities for humanity in various domains. Section 6 describes challenges of applying virtual reality technology and at last, conclusion appears in section 7.

II. VIRTUAL REALITY TYPES

We can categorize Virtual Reality systems into three groups depending on the degree of immersion and interactivity. These three groups are immersive systems, non-immersive systems and hybrid VR systems. Immersive systems replace our view of the real world with the computer-generated images that interact to the position and orientation of the user's head. A non-immersive system on the other hand, leaves the user visually aware of the real world but able to observe the virtual world through some display device such as graphics workstation. A hybrid VR system permits the user to view the real world with virtual images superimposed over this view. Such systems are also known as "Augmented Reality" systems. A practical example is found in the HMDs used by fighter pilot, which allow the pilot to view their outside world simultaneously with overlaid synthetic graphics. [15]

A generic immersive VR system consists of three system elements interacting with each other to make the whole functioning system. These three elements are the Virtual Environment, the computer environment and VR Interfaces. VE covers ideas such as model building, introducing dynamic features and physical constraints. The computer environment includes the processor configuration, the I/O channels the VE database and the real-time operating system and VR Interfaces encompass the hardware used for tracking head, recognizing hand gestures, detecting sound or haptic, 3D interfaces and multi-participant systems. The connectivity between the system elements is depicted in Figure 2 [15].

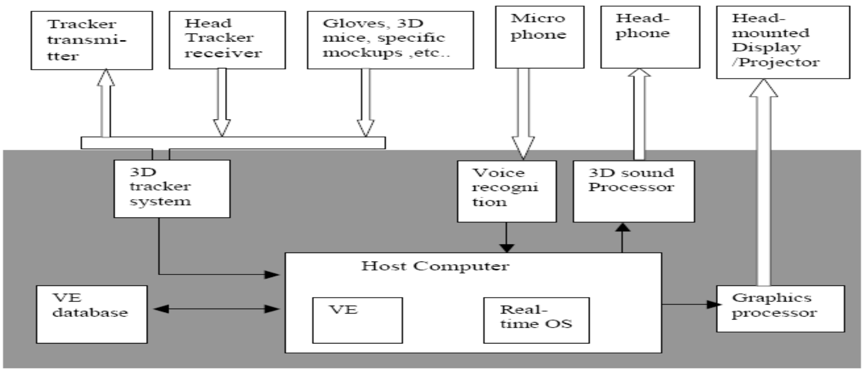

Figure. 2. Connectivity between elements of a Virtual Reality system

The core of our research in this paper is Virtual reality systems with realistic environment and active interfaces, so discussion about computer environment is out of this research framework. We describe virtual environment and VR interfaces in the following sections.

III. VIRTUAL ENVIRONMENT

Virtual Environment as its name implies is a virtual representation of an existing or non existing physical environment or an abstract information which offers end users real time interactivity and make them feel as if they are part of it. Due to the interactive and behaviors that occur in real, immersive nature of Virtual Environment have resemblance with behaviors that occur in real environments.

The VE can take many forms; for example it could be realistic representation of some physical environment such as the interior of a building, a kitchen or even an object such as a car. It could be that the VE does not have any physical basis at all. For instance, it might be a 3D database of a geographical, hierarchical network describing a multinational company or a multidimensional data set associated with stock transactions. Whatever the nature of the underlying data, a geometric model is required to represent atomic entities and their relationships with one another. Based on this geometric model a geometric database must be built to represent the environment and stored such that it can be retrieved and rendered in real time when required. The database storing VE includes 3D geometry, color and texture, dynamic characteristics, physical constraints and acoustic attributes [15].

HMD, BOOM, CAVE are common virtual environments now and virtual globe is an upcoming technology in virtual environments; in the follow sections, we describe about these VEs, separately.

a. HMD

Head mounted device was the first device to create, and provide its wearer with unseen world of virtual reality. In 1965, Evans and Sutherland first introduced head mounted display. But unfortunately, it was commercially available only after 20 years by the name "Eye phone" system. HMD device consist of two miniature display screens and an optical system. These two components channel the images from the screens to the eyes, presenting a stereoscopic imaging. Others use a single larger display to provide higher resolution, but without the stereoscopic vision. We can see HMD in Figure 3.

HMD provides virtual images by continuously tracking the position and orientation of the user`s head. This allows viewer to look around and walk through the surrounding virtual environment. However, HMDs have cables which restrict our movement.

Figure. 3. HMD (Head mounted device)

b. BOOM

The Binocular Omni-Orientation Monitor (BOOM) from fake space is a high-resolution stereoscopic viewing device. Screens and optical system are housed in a box that is attached to a multi-link arm. The user looks into the box through two holes, sees the virtual world, and can guide the box to any position within the operational volume of the device. Head tracking is accomplished via sensors in the links of the arm that holds the box. The main advantage of BOOM is that it has the ability to generate better images compared to HMD. When a user releases the BOOM, another person can view the same images from the same perspective, which is another advantage over HMDs. We can see BOOM in Figure 4.

Figure. 4. BOOM (Binocular Omni-Orientation Monitor)

c. CAVE

The Cave Automatic Virtual Environment (CAVE) is an immersive virtual reality facility designed for the exploration of and interaction with spatially engaging environments. Basically, the CAVE's comprises of four projection surfaces on which images are projected with uniquely immersive design. In addition, including projection on the ceiling gives a fuller sense of being enclosed in the virtual world. Furthermore, projection on all six surfaces of a room allows users to turn around and look in all directions. This allows user to interact with virtual environment in ways with better sense of full immersion. CAVE is shown in Figure 5.

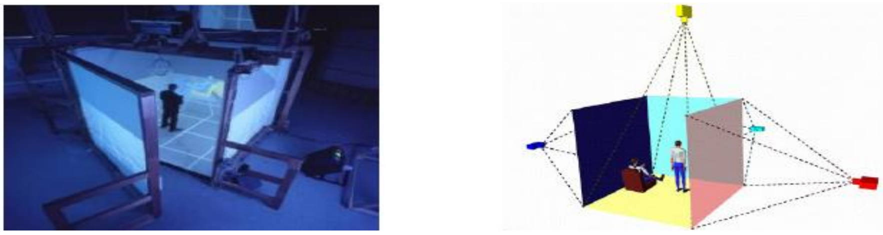

Figure. 5. CAVE(Cave Automatic Virtual Environment)

d. Virtual Globe

Virtual globe is a 3D software model or representation of the Earth or another world. Now, Virtual globes are rapidly becoming an easy and accessible way of finding, distributing and visualizing all sorts of data in a geographical context. In fact, a virtual globe provides the user with the ability to freely move around in the virtual environment by changing the viewing angle and position. So it may be used instead of the CAVE with up to six surfaces, in future and will provide full sense of immersion for users.

IV. VIRTUAL REALITY INTERFACES

One of the key features of Virtual Reality is interactivity. So HCI (Human-Computer Interaction) is one of domination factors in VR researches. In order to allow human-computer interaction it is necessary to use special tools designed both to allow input to the computer and to provide feedback to the users. Today's VR interfaces are varied in functionality and purpose as they address several human sensorial channels [1]. In this paper, we only describe those VR interfaces, which are popular and most used.

To generate the VE's images according to the movements of the user's body, it is fundamental to rapidly acquire data about the different body positions in the 3D space, and transmit them to the computer in order to elaborate the environment's modifications to be issued in response to the user's actions. This can be done by dedicated devices named 3D trackers. The technologies used predominantly in 3D tracking are four: mechanically based, optically based, magnetically based and acoustically based.

Mechanical tracking makes use of a mechanical armature with one side connected to the top of a helmet and the other end connected to an encoding device on the ceiling. As the user changes head position, the helmet moves the upper device like a mechanical arm, and data related on that movement is relayed to the computer. While mechanical position/orientation tracking is the most precise method of tracking, it has the disadvantage of being the most limiting.

Optical tracking can be implemented by sensor or by camera. Sensor-based tracking makes use of small markers - for example flashing infrared LED's- on the body. Sensors surround the subject and pick out the markers in their field. Software correlates the marker positions in the multiple viewpoints and calculates a 3D coordinate for each marker. Data glove is sensor-based tool in the optical trackers. Figure 6 shows a Data glove interfacing tool. Data glove reports position and pose information of the participant's hand to the VR system. They can also report pinching gestures (Fakespace Pinchglove), button presses (buttons built into the glove) and finger bends (Immersion CyberTouch). These glove actions are associated with virtual actions such as grasping, selecting, translation, and rotation. Data glove disadvantages include sizing problems (most are a one size fits all) and hygiene complications with multiple users. Gesture commands are limited by the number of finger positions that can be defined as unique, mutually exclusive, and comfortable. Gestures can require a degree of manual dexterity that many people do not have.

Figure. 6. Data glove

Generally, implementing sensor-based tracking often leads to three problems:

1. Sensor outputs need some filter stages to eliminate temperature, pressure and other noise effects.
2. Processing time needed to analyze several sensor information and determine each marker's 3D position slows down the system real-time interactions.
3. Using of sensors may be annoying the users.

Camera-based tracking makes use of several images captured from one or two cameras around the subject. Then by applying image processing and machine vision technologies on the camera's images, positions and movements can be tracked and gestures can be recognized for interaction of users with computer [16].

Magnetic tracking uses a source element radiating a magnetic field and a small sensor that reports its position and orientation with respect to the source. Magnetic systems do not rely on line-of-sight observation, as do optical and acoustic systems, but metallic objects in the environment will distort the magnetic field, giving erroneous readings.

Acoustic trackers use high-frequency sound to triangulate a source within the work area. Most systems like those from Logitech and the one used in the Mattel Pow pings from the source received by microphones in the environment [17].

Human vision is the most powerful sensorial channel and has an extremely large processing bandwidth. It is therefore not surprising that there is a multitude of Optical tracking tools. Human use their hands for many interaction tasks. So tracking and obtaining inputs from users hands images in camera-based technology are a natural evolution for VR interfaces, now [18-19].

V. VIRTUAL REALITY APPLICATIONS

The virtual domain offers reliability, speed, ease of access, compactness and security, and is easily transmitted to other virtual domains for example computers located in distant parts of the world [15]. Due to these facts, VR technology has been a promising technology applicable in various domains of application.

These most popular domains of application are training simulators, medical and health care, education, defense, engineering, ergonomics and human factors research, database and scientific visualization, and entertainment industry.

Training simulators are used for planes, submarines, power plants, surgery, endoscopes and air traffic control. Such simulation uses a replica of the real operational environment and real time computer to model its dynamics. Training through simulation provides significant benefits over other methods. Hazardous environment, such as a nuclear power station [20], or an aircraft landing in a fog can be accurately simulated without any danger to the trainee. Other benefit is the ability of computer software in providing flexibility to structure training programs and even monitor and measure the progress of a training session. Many simulators employ image processing and machine vision techniques to feel more real images in the virtual environments.

The key components of medical and health care where Virtual Environment can be applied are diagnosis, therapy, education and training and medical records. Diagnosis using virtual endoscopy is one of the areas that can achieve clinical efficiency in the earliest time frame. Virtual environments can be used in computer assisted surgery, image guided surgery, tele-surgery, and treatment of phobias and other psychological disorders. The VR system offers a sense of realism in a safe environment. By gradually exposing the person to their fear - for example, fear of flying -with a Virtual Environment the patient becomes accustomed to the trigger of their problem to an extent that it no longer becomes an issue. One of the advantages of this technology is that it allows healthcare professionals to learn new skills as well as refreshing existing ones in a safe environment. Plus it allows this without causing any danger to the patients and can record improvement stages of the patient. Thus Technology can therefore be used in innovative ways to provide support for those with mental health problems and nowadays Virtual Reality Therapy (VRT) is one of the newest treatment technologies.

Education is another area which has adopted virtual reality for teaching and learning situations. Virtual Environments can be used for learning of the kind expected to occur in schools, colleges and universities, that is, the acquisition of general problem solving skills, mastery of facts and concepts, and improvement of the learning progress itself. The advantage of this is that it enables large groups of students to interact with each other as well as within a three dimensional environment. It is able to present complex data in an accessible way to students which is both fun and easy to learn. Plus these students can interact with the objects in that environment in order to discover more about them.

VI. VIRTUAL RELITY CHALLENGES

Virtual reality can lead to state of the art technologies like second life [13-14]. In fact, virtual reality program Second Life poses new challenges to its more than millions of users that include economic interactions, methods of communication and documentation. In other words, Second Life is a MUVE, or Multi-user Virtual Environment. Growth rate of using Second Life in the world is illustrated in Figure 7.

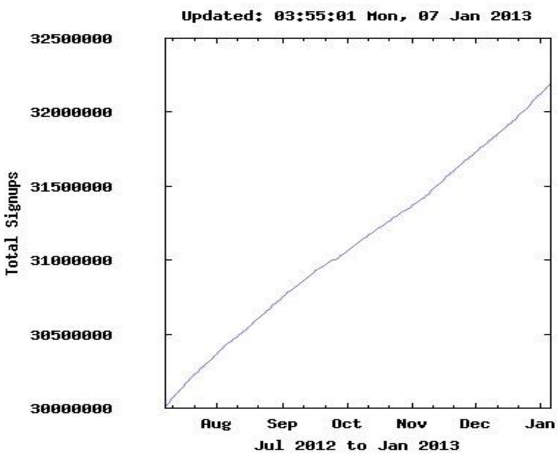

Figure. 7. Growth rate of using Second Life in the world [21]

Second Life is an online virtual world developed by an American company named Linden Lab. It was launched on June 23, 2003. A number of free client programs, or Viewers, enable Second Life users, called Residents, to interact with each other through avatars. Residents can explore the world (known as the grid), meet other residents, socialize, participate in individual and group activities, and create and trade virtual property and services with one another [22]. In the other hand, Second Life comprises the viewer (also known as the client) executing on the user's personal computer, and several thousand servers operated by Linden Lab. Second Life is intended for people aged 16 and over.

Now that worlds like Second Life have a stable and growing user base, various organizations and businesses are beginning to colonize, build and grow in these worlds [23]. Built into the software is a three-dimensional modeling tool based on simple geometric shapes that allows residents to build virtual objects. There is also a procedural scripting language, Linden Scripting Language, which can be used to add interactivity to objects. Sculpted prims (sculpties), mesh, textures for clothing or other objects, animations, and gestures can be created using external software and imported.

Like many advantageous technologies, beside opportunities of Virtual Reality and Second Life, unavoidable challenges appear, too. In fact, using Virtual Reality and Second Life offers both technical and cultural challenges. We can describe these challenges in two following sections.

a. TECHNICAL CHALLENGES

Second Life in Virtual Reality environments functions by streaming all data to the user live over the Internet with minimal local caching of frequently used data. The user is expected to have a minimum of 300kbit/s of Internet bandwidth for basic functionality, with 1Mbit/s providing better performance. Due to the proprietary communications protocols, it is not possible to use a network proxy/caching service to reduce network load when many people are all using the same location, such as when used for group activities in a school or business.

Due to Virtual Reality's and Second Life's rapid growth rate, it has suffered from difficulties related to system instability. These include increased system latency, and intermittent client crashes. However, some faults are caused by the system's use of an "asset server" cluster, on which the actual data governing objects is stored separately from the areas of the world and the avatars that use those objects. The communication between the main servers and the asset cluster appears to constitute a bottleneck which frequently causes problems [22]. Typically, when asset server downtime is announced, users are advised not to build, manipulate objects, or engage in business, leaving them with little to do but chat and generally reducing confidence in all businesses on the grid.

Cost is another issue. In addition to appropriate internet band width and virtual reality environment and interfaces charges, establishing Second Life in virtual environments offers several membership plans, too. For example for virtual learning, a premium account is required to purchase land, which is necessary to create a sustained and safe learning environment for students. However, increasingly powerful computer systems are becoming more affordable each year, but commercial VR systems that are sophisticated enough to offer complex models and diverse functionality are still expensive relative to personal computers.

b. CULTURAL CHALLENGES

Liability issues are still at question in virtual worlds. In Second Life private land can be pur-chased. Private land can be restricted to only authorized users. However, users in public areas may be subjected to violence or disruptive players (LaChapelle, 2007). There are many unresolved legal issues surrounding virtual violence, virtual assault, and sexual harassment that take place in Second Life and in other Virtual Reality worlds. And unfortunately no one is liable in these events, now [24]. So, It would seem the virtual world and second life is facing criminal problems of real-world.

Nowadays, the concept of “Virtual Reality” is new to law enforcement agencies around the world. Yet every day, millions of people connect in these worlds to socialize, shop and learn. Unfortunately, lawbreakers have also joined these virtual worlds and the full range of criminal activities is now also present. Common crimes are occurring every day in virtual worlds, including money-laundering, theft of intellectual property, exchange of child abuse images and even suspected terrorist activities. For these reasons, new virtual worlds and communities pose a unique set of challenges for the criminal justice system. Moreover, the near total lack of requisite jurisprudence means that criminals are often free to act with impunity [25].

A more disturbing fact, believed to be caused by the same issue, is "inventory loss" in which items in a user's inventory, including those which have been paid for, can disappear without warning or permanently enter a state where they will fail to appear in-world when requested (giving an "object missing from database" error). Linden Lab offers no compensation for items that are lost in this way, although a policy change instituted in 2008 allows accounts to file support tickets when inventory loss occurs. Many in-world businesses will attempt to compensate for this or restore items, but they are under no obligation to do so and not all are able to do so. Although "inventory loss" is much less from past years but it does still exists.

Second life and most virtual Reality worlds do not have appropriate tools for system management. For instance virtual worlds and Second Life were not created for educational purposes, inherently. Nonetheless, they are being adapted by educators for teaching and learning. Faculty can integrate text information in the form of note cards and use Web sites, content slides, video, and audio in addition to creating 3-D objects. However, many of the features educators take for granted in Learning Management Systems do not exist in Virtual Reality and Second Life. Additionally, Second Life is a random access environment thus giving instructors very little control over lesson sequencing. Nowadays some of the Learning

Management features that are lacking in virtual worlds are beginning to be addressed and efforts are underway to facilitate the use of these systems, in future.

VII. CONCLUSION

Nowadays, VR technology has been applied in various domains such as training simulators, medical and health care, education, scientific visualization, and entertainment industry. Virtual reality can lead to state of the art technologies like Second Life, too. Virtual Reality (VR) is a term that applies to computer-simulated environments that can simulate physical presence in places in the real world, as well as in imaginary worlds. Like many advantageous technologies, beside opportunities of Virtual Reality and Second Life, unavoidable challenges appear, too. In this paper, Virtual reality types and structural elements of a virtual reality system are described. Two main of these elements: Virtual Environment and Virtual Reality Interfaces are explained further. Then applications of virtual reality that providing us opportunities in various domains are described and at last, challenges of applying virtual reality technology are presented. Of course, efforts are underway to overcome the challenges in future to use the advantages of this technology as more as possible.

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