Overview of Virtual Reality Technologies

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ABSTRACT

The promise of being able to be inside another world might be resolved by Virtual Reality. It wouldn't be naïve to assume that we will be able to enter and completely feel another world at some point in the future; be able to interact with knowledge and entertainment in a totally immersive state.

Advancements are becoming more frequent, and with the recent popularity of technology in this generation, a lot of investment is being made. Prototypes of head displays that completely cover the user's view and movement recognition which doesn't need an intermediate device for input of data are already Virtual Reality devices available to developers and even to the public. From time to time, the way we interact with computers change, and virtual reality promises to make this interaction as real as possible. Although scenes like flying a jet or tank, are already tangible, another scenes, such as being able to feel the dry air of the Sahara in geography classes or feel the hard, cold scales of a dragon in a computer game seem to be in a long way from now. However, technologic advancements and increase in the popularity of these technologies point to the possibility of such amazing scenes coming true.

Keywords

Virtual Reality, Simulation, Immersion, Human-Computer Interaction, Head-Mounted Display, Wired Gloves, Computer Vision, Motion Control.

1. INTRODUCTION

Virtual Reality has been pursued for some time now, as it is known by many to be, perhaps, the ultimate computational experience. One would feel complete immersion through it, unable to differ the computer generated data from reality [1]. That goal, however, is still far away, but advancements are made everyday. Virtual Reality embraces a diverse amount of field applications, such as the military, educational, medical, entertainment fields, among others.

This paper will focus on giving the reader an overview about virtual reality devices, briefly passing through the history and evolution of the field and giving special attention to technical information regarding currently available technology. In this section, definitions some terms commonly used are given. Section 2 includes information about the history of Virtual Reality. Section 3 shows the common technologies related to it. Section 4 contains applications and conclusion comes in Section 5.

1.1 Definitions

Virtual Reality stands for the field of computing which has the objective of creating a virtual world, having one immerse into it and giving one the capability of interacting with this world, while using specific devices to simulate an environment and stimulate one by feedback in order to make the experience as real as possible.

1.1.1 Immersion

When someone reads a book and get so captivated by it, the person feels completely absorbed by the words. Immersion is the suspension of disbelief possibly being given by any media.

There are three types[2] of systems in Virtual Reality:

. Non Immersive Systems, such as Desktops, which are not very sophisticated devices for Virtual Reality applications, as they are cheap and don't require great performance,

. Fully Immersive Systems, which give the user the closest experience to reality through high quality graphics and performance as well as complete or major absence of unrelated stimuli.

. Semi-Immersive Systems are between the above two. Flight simulators are a good example. These systems combine high performance software with stereoscopic vision, increased field of view, haptic feedback, among other Virtual Reality inducing technologies, to deliver a more immersive experience.

1.1.2 Perception

Perception is the awareness of the surroundings through physical senses. So, in order to give one the perception of something, sensorial stimuli must be used. Two approaches [3] are usually seen:

. The data-oriented approach, which aims immersion through quality of data, meaning the more the data seems like reality, more immersive the experience will be. That can be seen as experiences with higher definition medias provoke more immersion to the user.

. And the constructivist approach, which, on the other hand, uses the human capability of building a reality, thus being capable of immersing one with not so high quality technologies. Evidence for this can also be found, as there's not one human being which haven't being amazed by a book.

1.1.3 Telepresence

Virtual Reality also uses the concept of Telepresence, which is the characteristic of being able to feel present somewhere different of your real location, a remote presence. It was created by Marvin Minsky in 1980 [4] and is a term widely used by the virtual reality community for it is highly connected with the concept of immersion.

2. HISTORY

A classic virtual reality novelty is Morton Heilig's Sensorama.

Figure 1: The Sensorama.

Designed in the 50s and with a mechanical prototype in 1962 which used 3D visual, audio, haptic, olfactory stimuli and even wind to provide an immersive experience [1]. It is regarded as one of the first examples of virtual reality. The Sensorama displayed a movie of a motorcycle running through Brooklyn, giving a high amount of feedback to make the user feel like he is actually there. However, there was no interaction with the movies. Heilig was not able to find financial support of production, so the project was abandoned.

On 1961, Philco developed the first Head-mounted Display (HMD): the Headsight. It was a helmet with cathode ray tube display and a tracking system that made possible to identify the position of the head.

One of the most famous HMD, or better: BOOM (Binocular Omni Orientation Monitor), is the "Sword of Damocles", invented by Ivan Sutherland in 1968 [5]. It had to be hanged to the ceiling because is was too bulky to head-mount (characteristic of BOOMs) as seen in Figure 2. Hence, it received the name from the Greek story of Damocles, which a sword was suspended over the king's throne by a hair.

Figure 2: Ivan Sutherland and the Sword of Damocles.

The Sword of Damocles was capable of tracking both the position of the user and his eyes and update the image of its stereoscopic view according to user's position.

Another common Virtual Reality related device is the Wired Gloves. The first one created were the Sayre glove in 1977, by Tom DeFanti and Daniel J. Sandin, and worked by fiber-optics [6]. Thomas G. Zimmerman worked in the early 80s to develop the Dataglove, which heavily influenced other devices, such as the Power Glove. It was manufactured by Mattel for the Nintendo Entertainment System, available at a reasonable price[6], although is considered a commercial failure.

Figure 3: The Power Glove.

There were attempts to launch other Virtual Reality related products to the public after the Power Glove, but the reception of them were never more than lukewarm. Virtual Reality development were manly found in the military and academic research until technologies became more cost-effective.

3. TECHNOLOGY

There are many different specific devices throughout Virtual Reality (VR). In this section are found descriptions about the most common technologies, some of them being closely related to well-known commercial devices.

3.1 Head-Mounted Display

One of the classical images that comes to mind when thinking about VR is of someone with a device on the head, covering the eyes.

There are currently many Head-Mounted Displays (HMDs) in the market. Most of them have stereoscopic displays and tracking systems, enabling the user to see 3D images through a big field of vision and have the virtual camera move accordingly to the user's head position. As there are one display of each eye, stereoscopic images are made simply by including two virtual cameras on the software. Usually, Gyroscopes and accelerometers make position recognition possible[7].

Figure 4: the Oculus Rift prototype.

The Oculus Rift is a headset focused on gaming. It provides an extended field of view of 110 degrees, stereoscopic vision, and fast head tracking. It does that by processing data that comes through 3-axis gyroscope, accelerometer and magnetometer, giving the user a fast image update, meaning no delay should happen. It is still in development but a developer's kit is available, which include the Oculus Rift, access to the Oculus SDK and a copy of the game Doom 3, ready to be played. A consumer version is said to be in the market by 2013.

3.2 CAVE

Cave Automatic Virtual Environment is a virtual reality room. Projectors cover the walls of a room with stereoscopic image and the user need to use glasses which are synchronized with the alternating images the projectors (much like current 3D movies) and speakers are placed around the room to surround it with sounds [8].

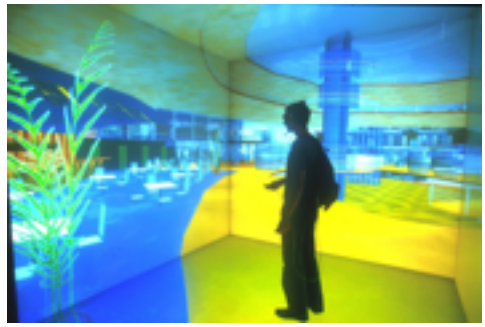

Figure 5: a CAVE environment.

Also, the ImmersaDesk is a device influenced by the CAVE. The ImmersaDesk is a screen which correspond as one wall of the CAVE. Equipped with the same stereoscopic vision and head tracking devices of the CAVE, but only use one screen, thus becoming semi-immersive.

3.3 Input Devices

The usual approach to data input in VR systems includes movement recognition. Having a device that reads and processes natural movements would change human-computer interaction to a more intuitive way. Here we see the most common types of data input related to VR.

3.3.1 Wired gloves

Wired gloves are capable of measuring joints angles, pressure, tracking and haptic feedback. There are three main technologies used in wired gloves: using light through fiber optics; using conductive ink to measure electrical resistance; and using mechanical sensors.

Gloves that used fiber optics measure finger flexion with the use of light and photo sensors. That means the amount of light received by each photocell is used to determine the angle of bending of the joints, the more the user bend his fingers, the less light is captured by the sensors, and vice-versa [6].

Figure 6: a fiber-optics wired glove.

Other gloves use a electric conductive ink and as the user makes movements, the electrical resistance changes and makes possible for a processor to identify movements[6]. This technology does not have a performance as good as the fiber-optics gloves, but are cheaper. This led a lot of VR enthusiasts to get a Power Glove, which uses this technology, to make their own software.

Another approach is the use of an Dexterous Hand Machine, which is more similar to an exoskeleton than to a glove, as mechanical sensors need to be fixated at the hand's joints [6], as seen in Figure 7.

Figure 7: a Dexterous Hand Machine.

These are more precise than the other two technologies, at the price of being rather bulky to wear.

3.3.2 Wands

The Nintendo Wii was the first console to bring motion-sensor controllers in popularity. The Wii remote controller possess a infrared sensor to identify the IR light emitted by a sensor bar placed at the top or bottom of the television, provided with five IR emitters in each side. The console, then, calculates the position of the controller by triangulation, based on the distance of a fixed point and the point the wii controller reads the infrared [9].

Figure 8: the Wii remote controller.

The controller is also equipped with a accelerometer which detect three axis movements and are sent to the console through bluetooth. A gyroscope determine the inclination by the calculation of the angle of such axis formed with the force of gravity. It also have speakers and a simple rumble pack to give the user feedback.

Sony's response to the Wii was the combination of the Playstation Eye, which is an usual digital camera, and the Playstation Move, the proper motion controller.

Figure 9: the Playstation Eye and two Playstation Move controllers, respectively.

The first thing one see about the PS Move is the ball on the top of it. It is actually important to the motion detection, as the PS Eye identify the ball to recognize movements. It possess three LEDs (Red, blue and green), which make the orb change to a different color, thus easing the detection made by the PS Eye. Similar to the Wii controller, PS move is equipped with a three axis accelerometer and a gyroscope to determine its position. In addition, a magnetometer, which measure the Earth's magnetic field and is used to calibrate inertia sensors on the controller.
Its performance is better than the Wii remote, however it has not much software support to make it a huge commercial success yet.

3.3.3 Computer vision

Another way to enable movement interaction is using cameras to recognize models and identify motion.
The PS Eye was briefly mentioned previously, but the most famous device using such technology is the Microsoft Kinect. It has being greatly explored by the industry, universities and hobbyists since its launch through reverse engineering or later available SDK. Its main capabilities are using a RGB camera that allows face recognition; a depth sensor that enables it to scan the surroundings; built-in microphone to capture sound; and a microchip to track and recognize movements [10].

Figure 10: the kinect motion sensing device

Its depth sensor captures 3D videos with a infrared projector and a CMOS image sensor, which measures the distance between its pixels and the objects. These two sensors work together to identify the room and the user in 3D. The depth sensor perceives the nearer objects as more bright and the further ones in a darker tone. The generated image, by machine learning, is used to identify a human body, 48 joints per user. Then, the image is processed along with a library of pre-recorded positions in case the Kinect doesn't capture all the joints, to recognize movements and positions [10]. Plus, microphones enables it to capture sound commands.

4. APPLICATIONS

Basically, Virtual Reality may be applied to any area computers are involved.
Here are the most common fields that use VR:

4.1 Military

This field is one of the most important ones when it comes to VR investment and development. The most common use of VR in the military is that of training by simulation [11]. The use of vehicle simulators is well-known in the field, as it proves to be safer and, although expensive to install, more cost-effective than real training. Flight simulation is done by either providing the user sets of computer monitors to resemble a airplane view, or actually inserting the user in an simulation cockpit as shown in Figure 11.

Figure 11: a pilot in a military flight simulator.

Both of these approaches use high performance software, along with haptic feedback that greatly improves user's experience.
Ground and water vehicles simulation are also used by the military, although they are not as famous as their air counterpart. Heavy armored or tactical vehicles navigation, as well as tactical and communicational scenarios are simulated. Submarines simulation is an interesting area, as it don't need to use of visuals, but rather precise methods to simulate readings and underwater movement.
Military also uses VR in soldier training with the use of head-mounted displays and joysticks that resemble real firearms. The experience is much similar to computer games and partnerships between the military and computer games studios

are made to deliver a more immersive experience, from weapon simulation to strategy rehearsal.

4.2 Entertainment

The entertainment field has also being following VR evolution for some time[12]. Crudely speaking, any modern computer game has the basic aspects of virtual reality: simulation, immersion and interaction. The addition of VR devices are becoming more common throughout the years. The major video-gaming companies of today have already entered in the motion control market. Movie theaters and televisions have stereoscopic technologies as well. And smartphones are capable of giving haptic feedback to users. Evidently, technology is becoming more popular each day.

4.3 Educational

ScienceSpace is a well-known application focused on education [13], which contains three different applications: NewtonWorld, MaxwellWorld and PaulingWorld. It uses mainly a HMD which displays stereoscopic images and a magnetic position tracking system for heads and hands.

NewtonWorld focus on teaching students physics, specially the Laws of Motion, by interacting with a virtual hand with balls that rebound from each others and walls, while experiencing different states, such as no gravity or no friction sections.

In MaxwellWorld, users can explore electrostatic forces and fields, understand concepts and learn about Gauss's Law. The user is capable of placing charges into the virtual space, creating electric fields of different intensities and polarities at will, while being able to test the behavior of other charges affected by the created electric fields.

And PaulingWorld enables the user do visualize molecules, through different representations, and seeing details about its structure and its atoms. Interaction is a future plan from PaulingWorld, in which the user would be able to remove or substitute atoms and observe the consequences.

5. CONCLUSION

Virtual reality may affect every field in which computers are involved. It can change the way interaction with computers are made and it has the potential of being the most powerful experience delivering media, as it is connected with the concept of reality.

Also, the current generation Z cannot remember a time where computers were not involved in their life, therefore it is important to notice that virtual reality popularity is increasing as a result, as it can be seen through the recent success of emerging technologies and products throughout the decades.

Perhaps it will take long before humans can fully experience another "reality", not being able to tell difference between real and virtual. But everything is leading to the conclusion: it is possible.

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