UNIT 1

INTRODUCTION OF VIRTUAL REALITY 9 Hrs. Fundamental Concept and Components of Virtual Reality- Primary Features and Present Development on Virtual Reality - VR systems - VR as a discipline-Basic features of VR systems-Architecture of VR systems-VR hardware -VR input hardware: tracking systems, motion capture systems, data gloves-VR output hardware: visual displays.

AUGMENTED AND VIRTUAL REALITY

AUGMENTED AND VIRTUAL REALITY

Definition of VR: Inducing targeted behavior in an organism by using artificial sensory stimulation, while the organism has little or no awareness of the interference. Four key components appear in the definition:

1. Targeted behavior: The organism is having an "experience" that was designed by the creator. Examples include flying, walking, exploring, watching a movie, and socializing with other organisms.

2. Organism: This could be you, someone else, or even another life form such as a fruit fly, cockroach, fish, rodent, or monkey (scientists have used VR technology on all of these!)

3. Artificial sensory stimulation: Through the power of engineering, one or more senses of the organism become co-opted, at least partly, and their ordinary inputs are replaced or enhanced by artificial stimulation.

4. Awareness: While having the experience, the organism seems unaware of the interference, thereby being "fooled" into feeling present in a virtual world. This unawareness leads to a sense of presence in an altered or alternative world. It is accepted as being natural.

HISTORY OF VIRTUAL REALITY

The very first idea of VR was presented by Ivan Sutherland in 1965: "make that (virtual) world in the window look real, sound real, feel real, and respond realistically to the viewer's actions". It has been a long time since then, a lot of research has been done and status quo: "the Sutherland's challenge of the Promised Land has not been reached yet but we are at least in sight of it". Let us have a short glimpse at the last three decades of research in virtual reality and its highlights [1]:

• **Sensorama** – in years 1960-1962 Morton Heilig created a multi-sensory simulator. A prerecorded film in color and stereo was augmented by binaural sound, scent, wind and vibration experiences. This was the first approach to create a virtual reality system and it had all the features of such an environment, but it was not interactive. •

The Ultimate Display – in 1965 Ivan Sutherland proposed the ultimate solution of virtual reality: an artificial world construction concept that included interactive graphics, force-feedback, sound, smell and taste.

• **"The Sword of Damocles**" – the first virtual reality system realized in hardware, not in concept. Ivan Sutherland constructs a device considered as the first Head Mounted display (HMD), with appropriate head tracking.

• **GROPE** – the first prototype of a force-feedback system realized at the University of North Carolina (UNC) in 1971. • VIDEOPLACE – Artificial Reality created in 1975 by Myron Krueger – "a conceptual environment, with no existence". In this system the silhouettes of the users grabbed by the cameras were projected on a large screen. The participants were able to interact one with the other thanks to the image processing techniques that determined their positions in 2D screen's space.

• **VCASS** – Thomas Furness at the US Air Force's Armstrong Medical Research Laboratories developed in 1982 the Visually Coupled Airborne Systems Simulator – an advanced flight simulator. The fighter pilot wore a HMD that augmented the out-thewindow view by the graphics describing targeting or optimal flight path information.

• **VIVED** – VIrtual Visual Environment Display – constructed at the NASA Ames in 1984 with off-the-shelf

technology a stereoscopic monochrome

BASIC COMPONENTS OF VIRTUAL REALITY

VRrequires more resources than standard desktop systems do. **Additional input and output hardware devices and special drivers f**or them are needed for enhanced user interaction. But we have to keep in mind that extra hardware will not create an immersive VR system. Special considerations by making a project of such systems and special software are also required . Fig. 1 depicts the most important parts of human-computer-human interaction loop fundamental to every immersive system. The user is equipped with a head mounted display, tracker and optionally a manipulation device (e.g., three-dimensional mouse, data glove etc.). As the human performs actions like walking, head rotating (i.e. changing the point of view), data describing his/her behavior is fed to the computer from the input devices. The computer processes the information in real-time and generates appropriate feedback that is passed back to the user by means of output displays.

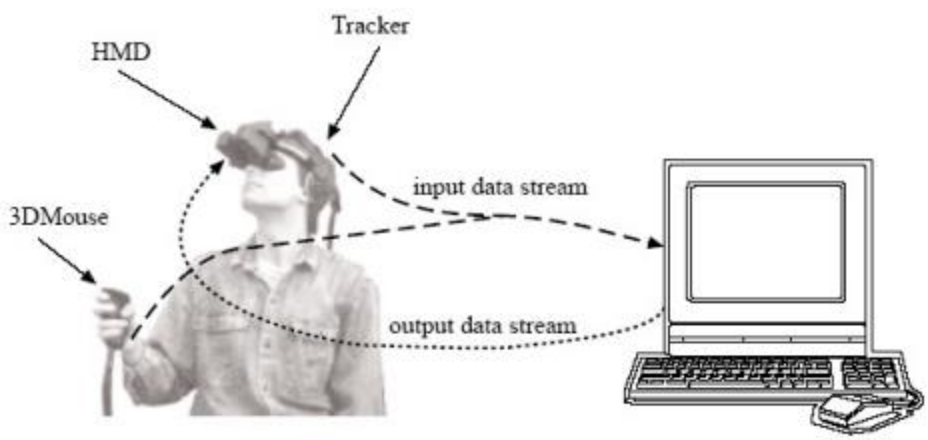


Fig. 1. Basic components of VR immersive application

In general: input devices are responsible for interaction, output devices for the feeling of immersion and software for a proper control and synchronization of the whole environment.

Input Devices

Input devices determine the way a user communicates with the computer. Ideally all these devices together, should make user's environment control as intuitive and natural as possible – they should be practically invisible. Unfortunately, the current state of technology is not advanced enough to support this, so naturalness may be reached in some very limited cases. In most of cases we still have to introduce some interaction metaphors that may become a difficulty for an unskilled user. The absolute minimum of information that immersive VR requires, is the position and orientation of the viewer's head, needed for the proper rendering of images. Additionally other parts of body may be tracked e.g., hands – to allow interaction, chest or legs – to allow the graphical user representation etc. Three dimensional objects have six degrees of freedom (DOF): position coordinates (x, y and z offsets) and orientation (yaw, pitch and roll angles for example). Each tracker must support this data or a subset of it. In general there are two kinds of trackers: those that deliver absolute data (total position/orientation values) and those that deliver relative data (i.e. a change of data from the last state).

The most important properties of 6 DOF trackers, to be considered for choosing the right device for the given application are:

• update rate – defines how many measurements per second (measured inHz) are made. Higher update rate values support smoother tracking of movements, but require more processing.

• latency – the amount of time (usually measured in ms) between the user's real (physical) action and the beginning of transmission of the report that represents this action. Lower values contribute to better performance.

• accuracy – the measure of error in the reported position and orientation. Defined generally in absolute values (e.g., in mm for position, or in degrees for orientation). Smaller values mean better accuracy.

• resolution – smallest change in position and orientation that can be detected by the tracker. Measured like accuracy in absolute values. Smaller values mean better performance.

• range – working volume, within which the tracker can measure position and orientation with its specified accuracy and resolution, and the angular coverage of the tracker. Beside these properties, some other aspects cannot be forgotten like the ease of use, size and weight etc. of the device. These characteristics will be further used to determine the quality and usefulness of different kinds of trackers.

Output Devices

Output devices are responsible for the presentation of the virtual environment and its phenomena to the user – they contribute to the generation of an immersive feeling at most. These include visual, auditory or haptic displays. As it is the case with input, the output devices are also underdeveloped. The current state of technology does not allow to stimulate human senses in a perfect manner, because VR output devices are far from ideal: they are heavy, lowquality and low-resolution. In fact most systems support visual feedback, and only some of them enhance it by audio or haptic information. Different type of VR systems – from desktop to full immersion – use different output visual displays. They can vary from a standard computer monitor to a sophisticated HMDs. The following section will present an overview of most often used displays in VR. a) 3D glasses The simplest VR systems use only a monitor to present the scene to the user. However, the "window onto a world" paradigm can be enhanced by adding a stereo view by use of LCD shutter glasses. LCD shutter glasses support a three-dimensional view using sequential stereo: with high frequency they close and open eye views in turn, when the proper images are presented on the monitor (Fig. 2). An alternative solution uses a projection screen instead of a CRT monitor. In this case polarization of light is possible and cheap polarization glasses can be used to extract proper images for each of the eyes. A head movement tracking can be added to support the user with motion parallax depth cue and increase the realism of the presented images.

Fig. 2 *Crystal Eyes LCD shutter glasses*

Fig. 3 *Surround display diagram: CAVE*

b) Surround displays An alternative to standard desktop monitors are large projection screens. They offer not only better image quality but also a wider field of view, which makes them very attractive for VR applications. The total immersion demand may be fulfilled by a CAVE-like displays (Fig. 3), where the user is surrounded by multiple flat screens or one domed screen. Ideally it would support full 360° field of view. The disadvantage of such projection systems is that they are big, expensive, fragile and require precise hardware setup.

c) Binocular Omni Oriented Monitors (BOOM) Developed and commercialized by Fake Space Labs BOOMs are complex devices supporting both mechanical tracking and stereoscopic displaying technology. Two visual displays (for stereo view) are placed in a box mounted to a mechanical arm. The box can be grabbed by the user and the monitors can be watched through two holes. As the mechanical construction supports usually counter-balance, the displays used in the BOOMs need to be neither small nor lightweight. Therefore CRT technology can be used for better resolution and image quality.

d) HMDs can be divided in two principle groups: opaque and see-through. Opaque HMDs totally replace the user's view with images of the virtual world and can

Head Mounted (Coupled) Displays (HMD) HMDs are headsets incorporating two small CRT or LCD monitors placed in front of the user's eyes. The images are presented to the user based on his/her current position and orientation measured by a tracker. Since the HMD is mounted to the user's head it must fulfill strict ergonomic requirements: it should be relatively light, comfortable and easy to put on and off. As any visual display it should also have possibly the best quality. These demands force engineers to make hard trade-offs. Consequently, the prices and quality of HMDs vary dramatically: from about 800 dollars for a low-cost, low-quality device to about one million dollars for hi-tech military HMDs. be used in applications that create their own world like architectural walkthroughs, scientific visualization, games etc.

Software

Beyond input and output hardware, the underlying software plays a very important role. It is responsible for the managing of I/O devices, analyzing incoming data and generating proper feedback. The difference to conventional systems is that VR devices are much more complicated than these used at the desktop – they require extremely precise handling and send large quantities of data to the system. Moreover, the whole application is time-critical and software must manage it: input data must be handled timely and the system response that is sent to the output displays must be prompt in order not to destroy the feeling of immersion. Human Factors As virtual environments are supposed to simulate the real world, by constructing them we must have knowledge how to "fool the user's senses". This problem is not a trivial task and the sufficiently good solution has not yet been found: on the one hand we must give the user a good feeling of being immersed, and on the other hand this solution must be feasible [13]. Which senses are most significant, what are the most important stimuli and of what quality do they have to be in order to be accepted by the user? Let us start by examining the contribution of each of the five human senses:

- sight .... 70 %
- hearing .... 20 %
- smell .... 5 %
- touch .... 4 %
- taste .... 1 %

This chart shows clearly that human vision provides the most of information passed to our brain and captures most of our attention. Therefore the stimulation of the visual system plays a principal role in "fooling the senses" and has become the focus of research. The second most important sense is hearing, which is also quite often taken into consideration. Touch in general, does not play a significant role, except for precise manipulation tasks, when it becomes really essential. Smell and taste are not yet considered in most VR systems, because of their marginal role and difficulty in implementation. The other aspects cannot be forgotten too: system synchronization (i.e. synchronization of all stimuli with user's actions), which contributes mainly to simulator sickness and finally the design issues (i.e. taking into account psychological aspects) responsible for the depth of presence in virtual environments.

FOUR KEY ELEMENTS OF VIRTUAL REALITY EXPERIENCE

Key Element 1:Virtual Wor|d

A virtual world is the content of a given medium. It may exist solely in the mind of its originator or be broadcast in such a way that it can be shared with others. A virtual world can exist without being displayed in a virtual reality system (i.e., an integrated collection of hardware, software, and content assembled for producing virtual reality experiences) - much like play or film scripts exist independently of specific instances of their performance. Such scripts do in fact describe virtual worlds. Let's carry the analogy further. We can refer to the script of a play as merely the description of a play. When that description is brought to life via actors, stagesets, and music, we are experiencing the play's virtual world. Similarly, a computerbased virtual world is the description of objects within a simulation. When we view that world via a system that brings those objects and interactions to us in a physically immersive, interactive presentation, we are experiencing it via virtual reality.

virtual world 1. an imaginary space often manifested through a medium. 2. a description of a collection of objects in a space and the rules and relationships governing those objects.

Key Element 2: Immersion

Considering the user must be immersed within some other, alternate reality, an admittedly simplistic definition of VR might be Immersion into an alternate reality or point of view. But what does this mean? Where do you go to get immersed into an alternate reality or point of view? What in fact is an alternate reality or point of view? According to our simple definition, a medium qualifies if its participants are able to perceive something other than they would have without an external influence. This definition acknowledges the possibility of perceiving something besides the world you are currently living in in two ways: you can either perceive an alternate world or the normal world from another point of view. An alternate world might be a representation of an actual space that exists elsewhere, or it could be a purely imaginary environment. Alternate worlds are often created in the minds of novelists, composers, and other artists and creative individuals. Imagine for a moment that you are empowered with the magical ability to live in a world other than the one you currently inhabit. You are given new powers, objects have different properties, perhaps there is no gravity. Other human and nonhuman beings inhabit this space. Space may or may not exist in the same way it does in our universe. Perhaps the shortest distance between two points is not a straight line. Is such a scenario possible?

Physical and Mental Immersion We have already indicated that the term immersion can be used in two ways: mental immersion and physical (or sensory) immersion. In discussions of most media, "being immersed" generally refers to an emotional or mental state-a feeling of being involved in the experience. In the medium of VR, however, we also refer to physical immersion as the property of a VR system that replaces or augments the stimulus to the participant's senses. The state of being mentally immersed is often referred to as having "a sense of presence" within an environment. Unfortunately, there is not yet a common understanding of precisely what each of these terms mean, how they relate to one another, or how to differentiate between them. (We have found one book in which chapters written by different authors give exactly the opposite definitions for immersion and presence.) Let's define what we mean by these three terms and how they are used in this book.

immersion sensation of being in an environment; can be a purely mental state or can be accomplished through physical means: physical immersion is a defining characteristic of virtual reality; mental immersion is probably the goal of most media creators.

mental immersion state of being deeply engaged; suspension of disbelief; involvement.

physical immersion bodily entering into a medium; synthetic stimulus of the body's senses via the use of technology; this does not imply all senses or that the entire body is immersed/engulfed.

Key Element 3: Sensory Feedback

Unlike more traditional media, VR allows participants to select their vantage point by positioning their body and to affect events in the virtual world. These features help to make the reality more compelling than a media experience without these options. Without getting into that philosophical discussion of what reality is, we will consider that there can be more than the reality we experience firsthand with our unaided senses. We refer to the latter as physical reality. Imagined reality refers to the experiences we have in our thoughts and dreams or that we experience secondhand in novels, films, radio, and so on. In imagined reality, we imagine ourselves within the world presented through the medium-also known as the diegesis. The diegesis of a world presented through a medium includes places and events that are not directly presented but are implied to exist or to have occurred. Virtual reality is the medium through which we can experience an imagined reality with many of our physical senses; that is, we use less of our imagination during the experience and rely more on the imagination of the content creator. In other words, virtual reality is a medium that allows us to have a simulated experience approaching that of physical reality. VR also allows us to purposefully reduce the danger of physical reality and to create scenarios not possible in the real world. Sensory feedback is an ingredient essential to virtual reality. The VR system provides direct sensory feedback to the participants based on their physical position. In most cases, it is the visual sense that receives feedback, although virtual reality environments do exist that display exclusively haptic (touch) experiences. Achieving immediate interactive feedback requires the use of a high-speed computer as a mediating device.

Key Element 4: Interactivity

For virtual reality to seem authentic, it should respond to user actions, namely, be interactive. Thus, another necessary component in the full definition of virtual reality is interactivity. Interactivity comes more readily with the addition of the computer to the equation. Alternate realities supported by computers include games, computer simulations of natural and unnatural phenomena, and flight simulation. It should be noted that computer graphics are not required for any of these alternate realities. The classic computer games The Oregon Trail, Adventure, and Zork (originally called Dungeon; see FIGURE 1-4) render their worlds via text description. Each world responds to commands typed by the player, giving the player the sense of being involved with these worlds. The player interacts with objects, characters, and places in these imaginary worlds. The medium of authored, text-based interactive worlds is now often referred to as interactive fiction (IF).

Collaborative Environment

The collaborative environment is an extension of the interactive element and refers to multiple users interacting within the same virtual space or simulation. Users can perceive others within the simulation, allowing for mutual interaction. The users' representations are referred to as their avatars. collaborative environment multiple users interacting within a virtual world that enables interaction among participants; not necessarily manifested in virtual reality; a collaborative VR environment can be referred to as multipresence or multiparticipant. Of course, this is a very important feature for many VR applications, including those in combat simulation/practice and the VRteam play and human opponents. By being unpredictable, other participants make an environment more challenging. It is important for other uses of VR as well. In virtual prototyping, designers at different locations can interact with one another across large distances.

In telepresence surgery, multiple surgeons can watch an operation from the same vantage point, and perhaps hand off control to another participating surgeon in a particular situation. (In Appendix D, we discuss the Placeholder application as an example of a collaborative virtual reality application.) When experiencing a space with other human participants, it is often important to be able to sense their presence in the world-where they are located, which way they are looking/pointing, and what they are saying. The Hindi word avatar (which means the worldly incarnation of a deity) is used to denote the concept of representing users in a virtual world. Sometimes a live video image of the person is used as part or the whole of an avatar representation.

Artificial Reality

Artificial reality is another term used to describe synthetic environments in which a user may interactively participate. Myron Krueger coined the term to describe his research, giving a definition of artificial reality that coincides with what is now generally referred to as virtual reality. In his book Artificial Reality II [Krueger 1991], he discusses many issues of how artificial reality relates to art and technology and indeed brings the two closer together. In his glossary, Krueger defines artificial reality in the following way (and we quote):

artificial reality an artificial reality perceives a participant's action in terms of the body's relationship to a graphic world and generates responses that maintain the illusion that his or her actions are taking place within that world.

Virtual

Because of the hype that has come to be associated with virtual reality, the word virtual is often co-opted to imply that VR technology is involved. However, calling something virtual does not necessarily mean it falls within the scholarly definition of virtual reality. We have mentioned that virtual can be added to the name of a computing system to indicate that some component of the system is an extension of the hardware, emulating the real thing through another source. Another use is in simulated virtual worlds where objects exist virtually in that world. Because these objects are merely images of the physical objects they represent, the word virtual can be appended to the name of each object to indicate this. We can describe a virtual table in a virtual kitchen, both existing in a virtual world. In a related usage, the domain of optics employs the phrase virtual image to refer to objects that appear to exist through a lens or mirror, a use very similar to its meaning in virtual reality.

Virtual World

Virtual worlds and virtual environments are a couple of other terms that are often used and confused. How does the term virtual reality relate to virtual world and virtual environment? The term virtual environment is often used as a synonym for both virtual reality and virtual world. However, use of the term virtual environment actually predates the phrase virtual reality. Virtual environment is ambiguous in that it can be defined as a virtual world or as a world presented in a particular virtual reality hardware configuration. In the mid-198os, researchers at NASA's Ames Research Lab frequently used virtual environment to describe their work in creating an interface that allowed a person to experience a computer-generated scene from a first person point of view (POV)-describing what we would now call their VR systems.

Cyberspace Cyberspace is another concept that is related to these terms and which is important to understand. Historically, technology (such as the telephone) has provided a means for people to communicate as if they were in the same location. In the process, a new virtual location was created: cyberspace. The term cyberspace was popularized in 1984 by William Gibson, in his novel Neuromancer; it described the vast space existing in the computer network of the future that allowed the denizens of this space to locate, retrieve, and communicate information. Cyberspace is not the same as virtual reality. While we can certainly use virtual reality techniques to interact in cyberspace, such an interface is not required. There are many examples where simple text, voice, or video creates cyberspace. The Internet provides many additional examples of locations that exist only in cyberspace, such as live chat forums, MUDs (multiuser dimensions/dungeons), newsgroups, and the like. Some non-lnternet examples include the telephone, CB radio, and video conferencing. **cyberspace a location that exists only in the minds of the participants, often as a result of technology that enables geographically distant people to interactively communicate.** An interesting aspect of this new space is that it is often treated much like a physical location. This is particularly noticeable in people's use of the words here and there. For example, in a live chat forum, when asking if a particular person is participating, the question asked is "Is Beaker here?"-here being the space created by the forum. This same phenomenon can be witnessed in television interviews, when the host will say something like, "Here with us now is an expert in the field of virtual reality, Dr. Honeydew." Yet, often that person is not physically in their studio but at another location and displayed on a large television monitor

ARCHITECTURE OF VR

The first step to understanding how VR works is to consider what constitutes the entire VR system. It is tempting to think of it as being merely the hardware components, such as computers, headsets, and controllers. This would be woefully incomplete. it is equally important to account for the organism, which in this chapter will exclusively refer to a human user. The hardware produces stimuli that override the senses of the user.

The VR hardware accomplishes this by using its own sensors, thereby tracking motions of the user. Head tracking is the most important, but tracking also may include button presses, controller movements, eye movements, or the movements of any other body parts. Finally, it is also important to consider the surrounding physical world as part of the VR system. In spite of stimulation provided by the VR hardware, the user will always have other senses that respond to stimuli from the real world. She also has the ability to change her environment through body motions. The VR hardware might also track objects other than the user, especially if interaction with them is part of the VR experience. Through a robotic interface, the VR hardware might also change the real world.

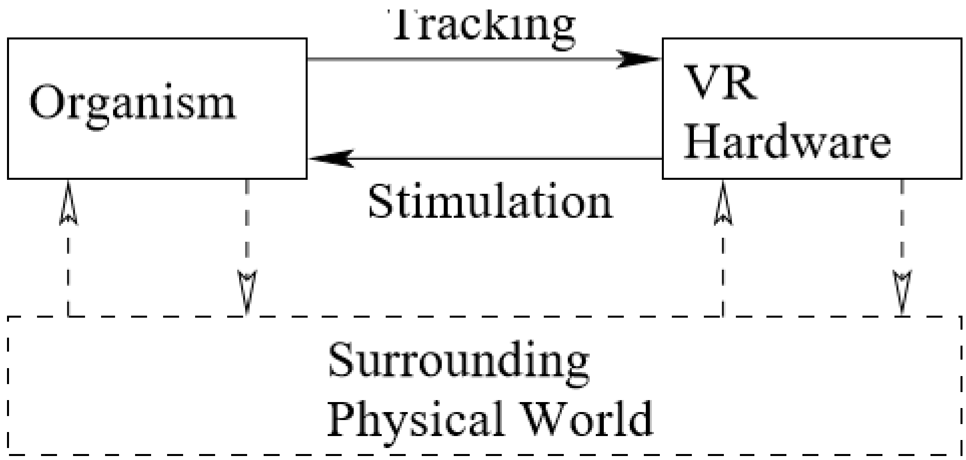


Fig Architecture of VR

A third-person perspective of a VR system. It is wrong to assume that the engineered hardware and software are the complete VR system: The organism and its interaction with the hardware are equally important. Furthermore, interactions with the surrounding physical world continue to occur during a VR experience.

Sensors and sense organs How is information extracted from the physical world? Clearly this is crucial to a VR system. In engineering, a transducer refers to a device that converts energy from one form to another. A sensor is a special transducer that converts the energy it receives into a signal for an electrical circuit. This may be an analog or digital signal, depending on the circuit type. A sensor typically has a receptor that collects the energy for conversion. Organisms work in a similar way. The “sensor” is called a sense organ, with common examples being eyes and ears. Because our “circuits” are formed from interconnected neurons, the sense organs convert energy into neural impulses. As you progress through this book, keep in mind the similarities between engineered sensors and natural sense organs. They are measuring the same things and sometimes even function in a similar manner. This should not be surprising because we and our engineered devices share the same physical world: The laws of physics and chemistry remain the same.

Configuration space of sense organs As the user moves through the physical world, his sense organs move along with him. Furthermore, some sense organs move relative to the body skeleton, such as our eyes rotating within their sockets. Each sense organ has a configuration space, which corresponds to all possible ways it can be transformed or configured. The most important aspect of this is the number of degrees of freedom or DOFs of the sense organ. Chapter 3 will cover this thoroughly, but for now note that a rigid object that moves through ordinary space has six DOFs. Three DOFs correspond to its changing position in space: 1) side-to-side motion, 2) vertical motion, and 3) closer-further motion. The other three DOFs correspond to possible ways the object could be rotated; in other words, exactly three independent parameters are needed to specify how the object is oriented. These are called yaw, pitch, and roll,

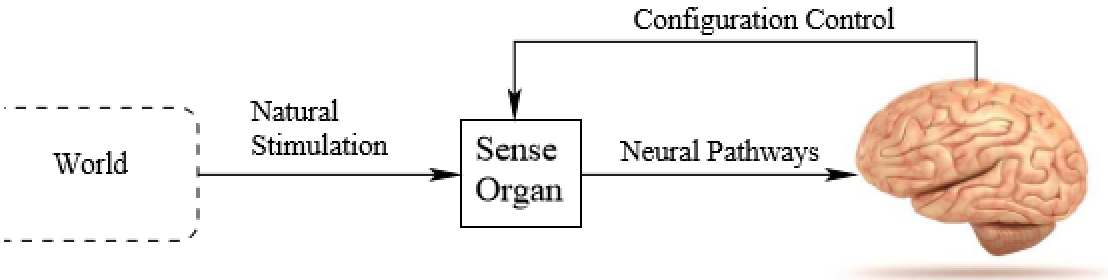


Figure 2.2: Under normal conditions, the brain (and body parts) control the configuration of sense organs (eyes, ears, fingertips) as they receive natural stimulation from the surrounding, physical world.

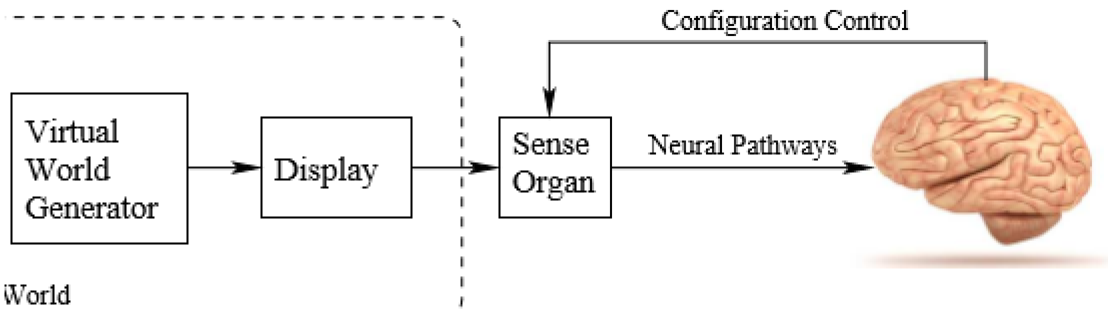


Figure 2.3: In comparison to Figure 2.2, a VR system "hijacks" each sense by replacing the natural stimulation with artificial stimulation that is provided by hardware called a display. Using a computer, a virtual world generator maintains a coherent, virtual world. Appropriate "views" of this virtual world are rendered to the display.

three DOFs correspond to possible ways the object could be rotated; in other words, exactly three independent parameters are needed to specify how the object is oriented. These are called yaw, pitch, and roll, and are covered in Section 3.2. As an example, consider your left ear. As you rotate your head or move your body through space, the position of the ear changes, as well as its orientation. This yields six DOFs. The same is true for your right eye, but it also capable of rotating independently of the head. Keep in mind that our bodies have many more degrees of freedom, which affect the configuration of our sense organs. A tracking system may be necessary to determine the position and orientation of each sense organ that receives artificial stimuli, which will be explained shortly.

An abstract view Figure 2.2 illustrates the normal operation of one of our sense organs without interference from VR hardware. The brain controls its configuration, while the sense organ converts natural stimulation from the environment into neural impulses that are sent to the brain. Figure 2.3 shows how it appears in a VR system. The VR hardware contains several components

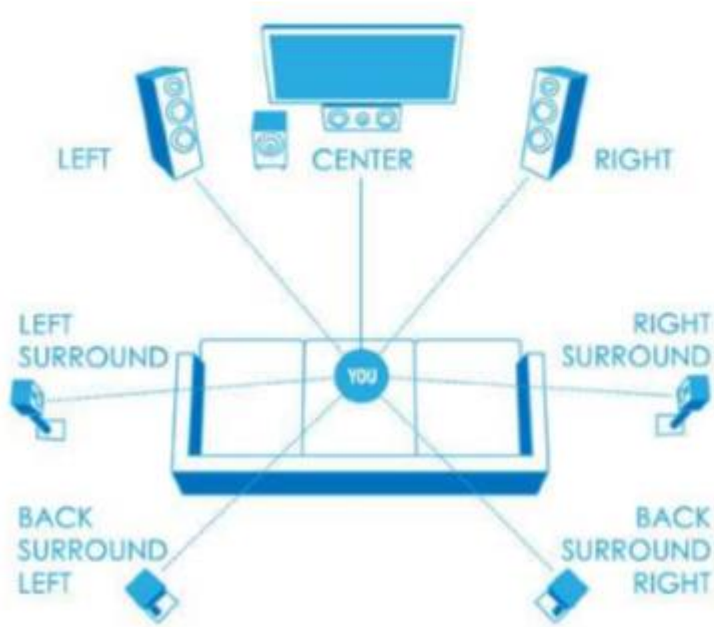


Figure 2.5: In a surround-sound system, the aural displays (speakers) are world-fixed while the user listens from the center.

Aural: world-fixed vs. user-fixed

the trend of having to go somewhere for an experience, to having it in the home, and then finally to having it be completely portable. To understand these choices for VR systems and their implications on technology, it will be helpful to compare a simpler case: Audio or aural systems. Figure 2.5 shows the speaker setup and listener location for a Dolby 7.1 Surround Sound theater system, which could be installed at a theater or a home family room. Seven speakers distributed around the room periphery generate most of the

Figure 2.6: Using headphones, the displays are user-fixed, unlike the case of a surround-sound system.

sound, while a subwoofer (the “1” of the “7.1”) delivers the lowest frequency components. The aural displays are therefore world-fixed. Compare this to a listener wearing headphones, as shown in Figure 2.6. In this case, the aural displays are user-fixed. Hopefully, you have already experienced settings similar to these many times.

What are the key differences? In addition to the obvious portability of headphones, the following quickly come to mind:

• In the surround-sound system, the generated sound (or stimulus) is far away from the ears, whereas it is quite close for the headphones.

• One implication of the difference in distance is that much less power is needed for the headphones to generate an equivalent perceived loudness level compared with distant speakers.

• Another implication based on distance is the degree of privacy allowed by the wearer of headphones. A surround-sound system at high volume levels could generate a visit by angry neighbors.

• Wearing electronics on your head could be uncomfortable over long periods of time, causing a preference for surround sound over headphones.

• Several people can enjoy the same experience in a surround-sound system (although they cannot all sit in the optimal location). Using headphones, they would need to split the audio source across their individual headphones simultaneously.

• They are likely to have different costs, depending on the manufacturing difficulty and available component technology. At present, headphones are favored by costing much less than a set of surround-sound speakers (although one can spend a large amount of money on either).

The hardware components of VR systems are conveniently classified as:

• **Displays** (output): Devices that each stimulate a sense organ.

• **Sensors** (input): Devices that extract information from the real world.

• **Computers**: Devices that process inputs and outputs sequentially.

Displays A display generates stimuli for a targeted sense organ. Vision is our dominant sense, and any display constructed for the eye must cause the desired image to be formed on the retina. Because of this importance, Chapters 4 and 5 will explain displays and their connection to the human vision system. For CAVE systems, some combination of digital projectors and mirrors is used. Due to the plummeting costs, an array of large-panel displays may alternatively be employed. For headsets, a smartphone display can be placed close to the eyes and brought into focus using one magnifying lens for each eye. Screen manufacturers are currently making custom displays for VR headsets by leveraging the latest LED display technology from the smartphone industry. Some are targeting one display per eye with frame rates above 90Hz and over two megapixels per eye.

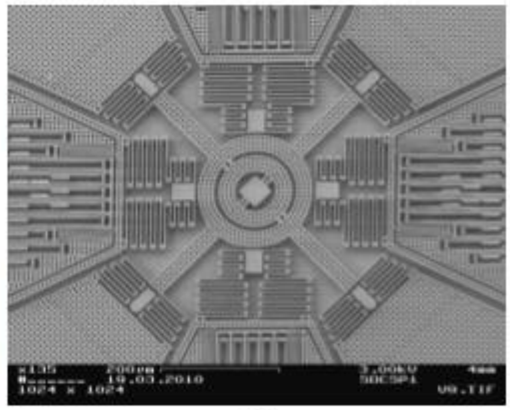
(a) (b)

Figure 2.8: Two examples of haptic feedback devices. (a) The Touch X system by 3D Systems allows the user to feel strong resistance when poking into a virtual object with a real stylus. A robot arm provides the appropriate forces. (b) Some game controllers occasionally vibrate.

Now imagine displays for other sense organs. Sound is displayed to the ears using classic speaker technology. Bone conduction methods may also be used, which vibrate the skull and propagate the waves to the inner ear; this method appeared Google Glass.

Sensors Consider the input side of the VR hardware. A brief overview is given here, covers sensors and tracking systems in detail. For visual and auditory body-mounted displays, the position and orientation of the sense organ must be tracked by sensors to appropriately adapt the stimulus. The orientation part is usually accomplished by an inertial measurement unit or IMU. The main component is a gyroscope, which measures its own rate of rotation; the rate is referred to as angular velocity and has three components. Measurements from the gyroscope are integrated over time to obtain an estimate of the cumulative change in orientation. The resulting error, called drift error, would gradually grow unless other sensors are used. To reduce drift error, IMUs also contain an accelerometer and possibly a magnetometer. Over the years, IMUs have gone from existing only

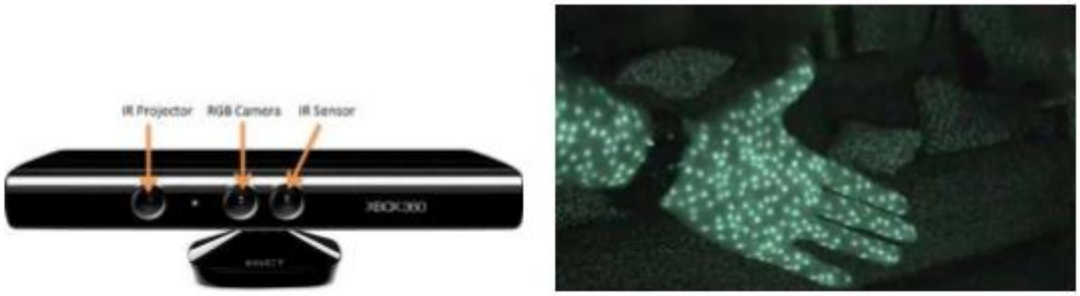
(a)



(b)

Figure 2.9: Inertial measurement units (IMUs) have gone from large, heavy mechanical systems to cheap, microscopic MEMS circuits. (a) The LN-3 Inertial Navigation System, developed in the 1960s by Litton Industries. (b) The internal structures of a MEMS gyroscope, for which the total width is less than 1mm.

as large mechanical systems in aircraft and missiles to being tiny devices inside of smartphones; see Figure 2.9. Due to their small size, weight, and cost, IMUs can be easily embedded in wearable devices. They are one of the most important enabling technologies for the current generation of VR headsets and are mainly used for tracking the user's head orientation. Digital cameras provide another critical source of information for tracking systems. Like IMUs, they have become increasingly cheap and portable due to the smartphone industry, while at the same time improving in image quality. Cameras enable tracking approaches that exploit line-of-sight visibility. The idea is to identify features or markers in the image that serve as reference points for an moving object or a stationary background. Such visibility constraints severely limit the possible object positions and orientations. Standard cameras passively form an image by focusing the light through an optical system, much like the human eye. Once the camera calibration parameters are known, an observed marker is known to lie along a ray in space. Cameras are commonly used to track eyes, heads, hands, entire human bodies, and any other objects in the physical world. One of the main challenges at present is to obtain reliable and accurate performance without placing special markers on the user or objects around the scene.



(a) (b)

Figure 2.10: (a) The Microsoft Kinect sensor gathers both an ordinary RGB image and a depth map (the distance away from the sensor for each pixel). (b) The depth is determined by observing the locations of projected IR dots in an image obtained from an IR camera.

Computers A computer executes the virtual world generator (VWG). Where should this computer be? Although unimportant for world-fixed displays, the location is crucial for body-fixed displays. If a separate PC is needed to power the system, then fast, reliable communication must be provided between the headset and the PC. This connection is currently made by wires, leading to an awkward tether; current wireless speeds are not sufficient. As you have noticed, most of the needed sensors exist on a smartphone, as well as a moderately powerful computer. Therefore, a smartphone can be dropped into a case with lenses to provide a VR experience with little added costs (Figure 2.11). The limitation, though, is that the VWG must be simpler than in the case of a separate PC so that it runs on lesspowerful computing hardware. In the near future, we expect to see wireless, all-inone headsets that contain all of the essential parts of smartphones for delivering VR experiences. These will eliminate unnecessary components of smartphones (such as the additional case), and will instead have customized optics, microchips, and sensors for VR.

(a) (b)

Figure 2.11: Two headsets that create a VR experience by dropping a smartphone into a case. (a) Google Cardboard works with a wide variety of smartphones. (b) Samsung Gear VR is optimized for one particular smartphone (in this case, the Samsung S6).

THE TRACKING systems

The tracking systems are the main components for the VR systems. They interact with the system's processing unit. This relays to the system the orientation of the user's point of view. In systems which let a user to roam around within a physical space, the locality of the person can be detected with the help of trackers, along with his direction and speed.

The various types of systems used for tracking utilized in VR systems. These are a follows:-

- A six degree of freedom can be detected **(6-DOF)**
- Orientation consists of a yaw of an object, **roll** and **pitch**.
- These are nothing but the position of the objects within the x-y-z coordinates of a space, however, it is also the orientation of the object.

These however emphasizes that when a user wears a HMD then as the user looks up and down; left and right then the view also shifts. Whenever the user's head tilts, the angle of gaze changes. The trackers on the HMD describe to the CPU where you are staring while the right images are sent back to the screen of HMD.
All tracking system consists of a device that is capable of generating a signal and the signal is detected by the sensor. It also controls the unit, which is involved in the process of the signal and sends information to the CPU. Some systems ask you to add the component of the sensor to the user (or the equipment of the user's). If this takes place, then you have to put the signal emitters at certain levels in the nearby environment. Differences can be easily noticed in some systems; with the emitters being worn by the users and covered by sensors, which are attached to the environment. The signals emitted from emitters to different sensors can take various shapes, including electromagnetic signals, optical signals, mechanical signals and acoustic signals.

The Tracking devices have various merits and demerits:-

- **Electromagnetic tracking systems –** They calculate magnetic fields generated by bypassing an electric current simultaneously through 3 coiled wires. These wires are set up in a perpendicular manner to one another. These small turns to be an electromagnet. The system's sensors calculate how its magnetic field creates an impact on the other coils. The measurement shows the orientation and direction of the emitter. The responsiveness of an efficient electromagnetic tracking system is really good. They level of latency is quite low. The drawback is that whatever that can create a magnetic field, can come between the signals, which are sent to the sensors

- **Acoustic tracking systems –** This tracking system senses and produces ultrasonic sound waves to identify the orientation and position of a target. They calculate the time taken for the ultrasonic sound to travel to a sensor. The sensors are usually kept stable in the environment. The user puts on ultrasonic emitters. However, the calculation of the orientation as well as position of the target depending on the time on the time taken by the sound to hit the sensors is achieved by the system. Many faults are shown by the acoustic tracking system. Sound passes by quite slowly, so the update's rate on a target's position is naturally slow. The efficiency of the system can be affected by the environment as the sound's speed through air often changes depending on the humidity, temperature or the barometric pressure fousnd in the environment.

- **Optical tracking devices** – These devices use light to calculate a target's orientation along with position. The signal emitter typically includes a group of infrared LEDs. The sensors consist of nothing but only cameras. These cameras can understand the infrared light that has been emitted. The LEDs illuminates in a fashion known as sequential pulses. The pulsed signals are recorded by the camera and then the information is sent to the processing unit of the system. Data can be extrapolated by this unit. This will estimate the position as well as the orientation of the target. The upload rate of optical systems is quite fast which has in fact reduced the tenancy issue. The demerits of the system are that the line of sight between an LED and camera can be obscured, which interferes with the process of tracking. Infrared radiation or ambient light are also different ways that can make a system useless.

- **Mechanical tracking systems** – This tracking system is dependent on a physical link between a fixed reference point and the target. One of the many examples is that mechanical tracking system located in the VR field, which is indeed a BOOM display. A BOOM display, an HMD, is attached on the rear of a mechanical arm consisting 2 points of articulation. The detection of the orientation and position of the system is done through the arm. The rate of update is quite high with mechanical tracking systems, but the demerit is that they limit range of motion for a user.

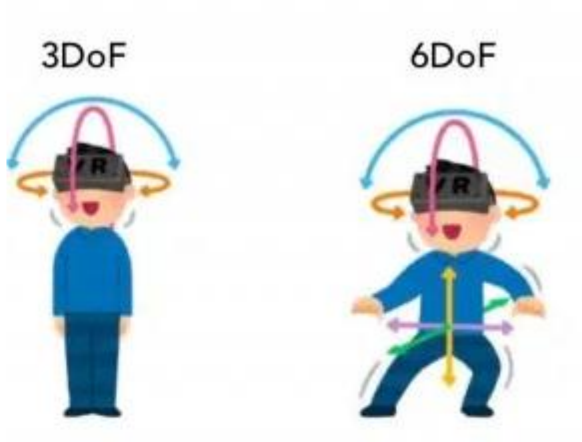
MOTION TRACKING

Motion Tracking, the process of digitising your movements for use in computer software, is a key component of VR systems. Without VR motion tracking systems, you would find yourself restricted in the virtual world, unable to look around, move, and explore.

Being able to engage and interact with the virtual world the moment you step into a VR CAVE or put on your VR headset – without being reminded of the real world – is crucial to the creation of a truly immersive experience.

HOW DOES MOTION TRACKING WORK?

To understand how an object is able to move in three-dimensional space, we need to look at the concept of **six degrees of freedom (6DoF)**, which refers to the freedom of movement of a rigid body in 3D space.



Essentially, the body is free to move forwards or backwards, up or down, and left to right – the three perpendicular axes, or 3DoF.
This is then combined with rotation around these axes – or 6DoF.
The virtual world must mimic the movements that we do in the real world, like using our hands, moving our heads, and moving around a room, but the degrees of immersion varies depending on the application:
For some applications, like digital prototyping for the automotive industry, VR motion tracking is necessary and will either make or break your state of immersion.
In some other cases, a Virtual Reality or Simulation experience might need a more fixed approached, e.g. a flight simulator where the person is sat in a cockpit using a joystick.
There are already different software and technologies to make the most of exploring a virtual environment, let's look at the main two types of VR motion trackers and at how they work.

WHICH TYPES OF MOTION TRACKING TECHNOLOGY EXIST TODAY?
There are two different types of applications that support the tracking of movement: optical and non-optical motion tracking.

OPTICAL TRACKING

Optical tracking is where an imaging device is used to track body motion of an individual. The person who is being tracked is required to hold handheld controllers or an HMD (Head Mounted Display) that has the trackers on them or to wear optical markers, which are placed on certain parts of the body. More advanced options can also use sound waves or magnetic fields.

To track movements of the user's point of view in a VR CAVE, we use a number of tracking cameras which send signals to adjust the images seen by the wearer as they move around the VR environment.

To maintain the immersion in the VR environment, the tracking of the VR glasses needs to be highly accurate. Leading manufacturers like ART or Vicon specialise in this, and ensure that the user's viewpoint in the 3D behaves in the same way as it would in the real world. Any delay or latency, caused by inaccurate tracking, would cause a disconnection between the two.

NON-OPTICAL TRACKING

Non-optical tracking makes use of microscopic electromechanical sensors that are installed in hardware or attached to the body to measure and track movements. These are typically gyroscopes, magnetometers, and accelerometers.

WHAT DOES THE FUTURE HOLD FOR MOTION TRACKING AND VR?

These optical and non-optical motion tracking methods are likely to be in VR motion tracking systems for the foreseeable future. But, what if in the next years you wouldn't need to move a muscle in the real world, but could freely move our virtual bodies using nothing but our minds?

Even today the development of direct brain-machine interfaces is fairly advanced. In neuroprosthetics, for example, it's already possible for quadriplegic individuals to operate robotic arms to accomplish complex tasks. Using targeted muscle reinnervation, the truncated nerve endings of amputees can be rerouted so that robotic prosthetic limbs can read signals from them and move the way natural limbs do.

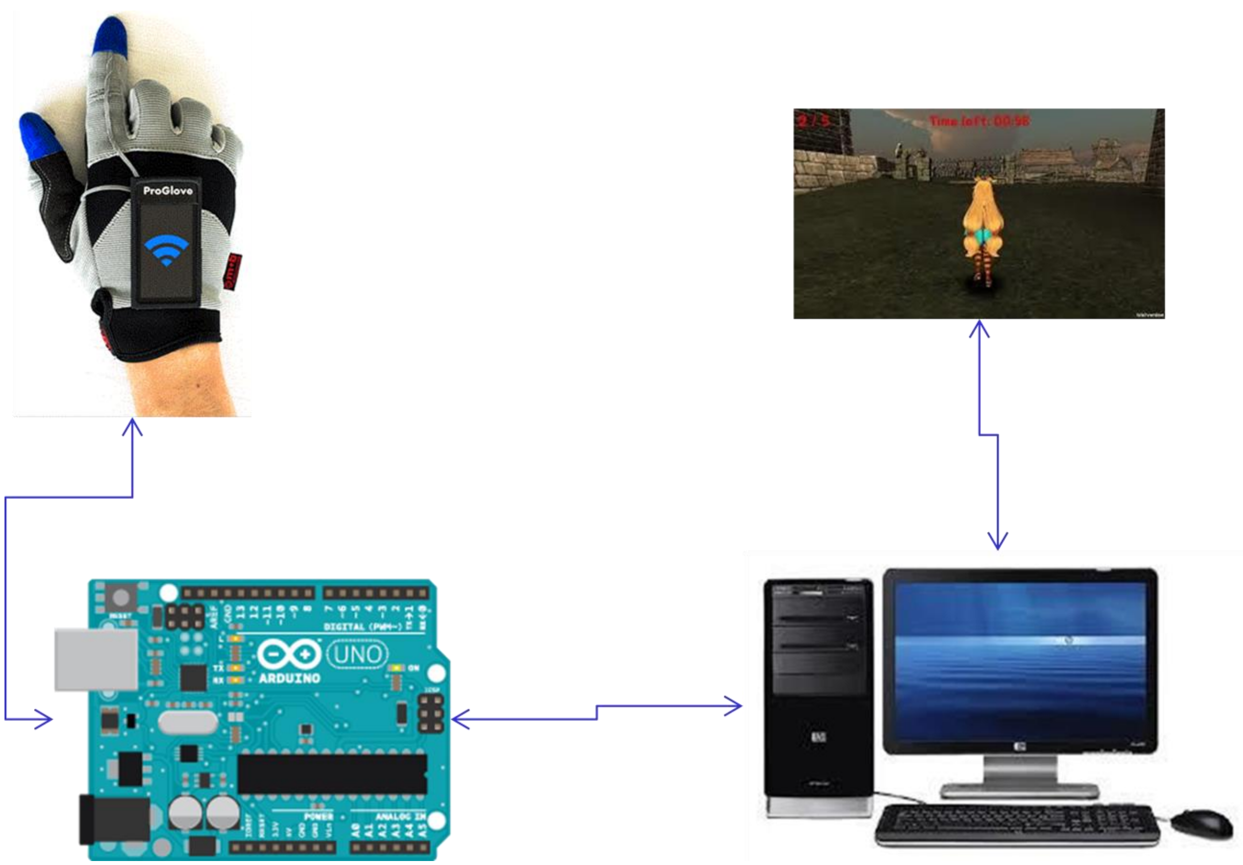
DATA GLOVE

A data glove is an interactive device, resembling a glove worn on the hand, which facilitates tactile sensing and fine-motion control in robotics and virtual reality. Data gloves are one of several types of electromechanical devices used in haptics applications.

Tactile sensing involves simulation of the sense of human touch and includes the ability to perceive pressure, linear force, torque, temperature, and surface texture. Fine-motion control involves the use of sensors to detect the movements of the user's hand and fingers, and the translation of these motions into signals that can be used by a virtual hand (for example, in gaming) or a robotic hand (for example, in remote-control surgery).

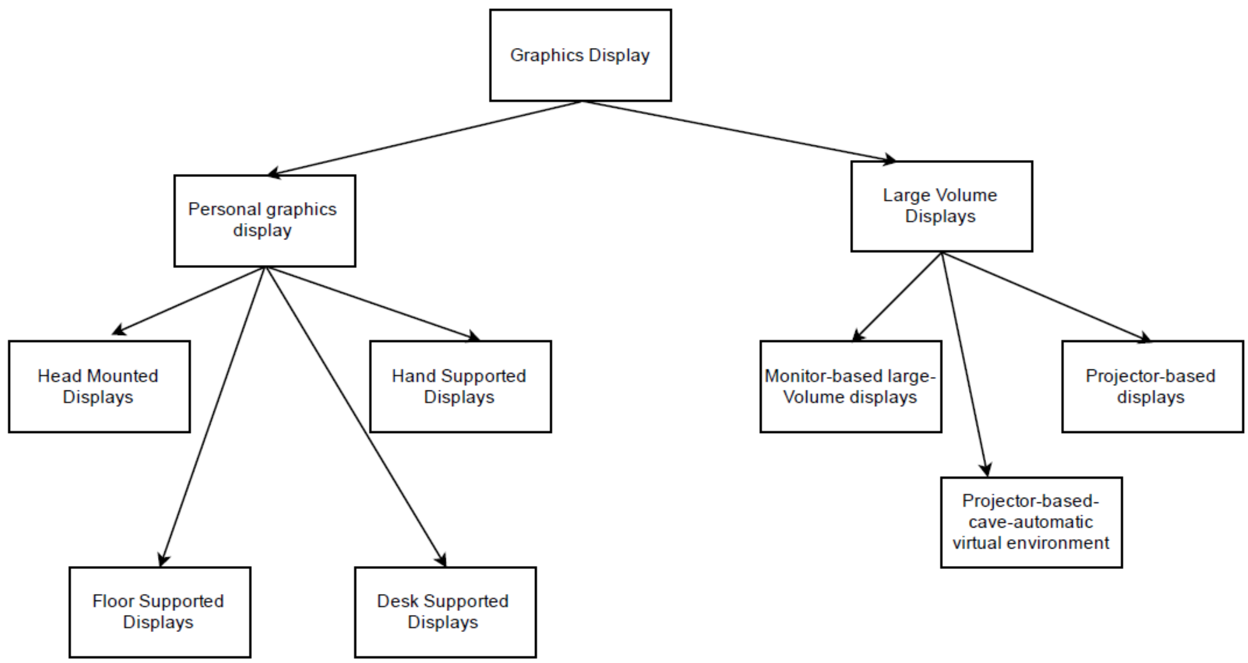
Within a virtual reality room or other VR environment, a data glove can allow you to interact normally with objects -- turning doorknobs, for example -- and receive haptic feedback to replicate grasping a doorknob and feeling the object in your hand rather than just making a

Architecture



gesture in air. Haptic feedback is essential to immersiveness, which enables user engagement in virtual environments, particularly for applications like VR gaming.

DISPLAY INTERFACES



Personal Graphics Display

- A graphics display that outputs a virtual scene destined to be viewed by a single user is called a ***personal graphics display.***
- Image produced may be :-
  - Monocular (for a single eye).
  - Binocular (displayed on both eye).

Head Mounted Display

- HMD can focus at short distances.
- It is a device worn on head or can be integrated as a part of the helmet ,with a small display optic in front of the eye.
- It can either be monocular or binocular.
- HMD’s are designed to ensure that no matter in what direction a user might look ,the monitor stays in front of the eyes.
- The HMD screen can be either LCD or CRT.
  - LCD-HMD’s: used for consumer grade devices ,

LCD-CRT: used in more expensive professional based devices for VR interaction.

H**AND *****S*****UPPORTED *****D*****ISPLAYS**

- Here ,the user can hold the device in one or both hands in order to periodically view a synthetic scene.
- This allows user to go in and out of the simulation environment as demanded by the application.
- HSD’s have additional feature namely push buttons that can be used to interact with

the virtual scene.

Floor Supported Displays

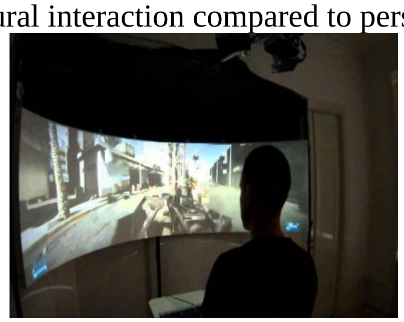
- These are alternatives to HMD’s and HSD’s in which an articulated mechanical arm is available to offload the weight of the graphics display from the user.
- Do not require use of special glass, can be viewed with unaided eye.
- Has 2 types:
  - Passive:
  - Active

Desk supported Displays

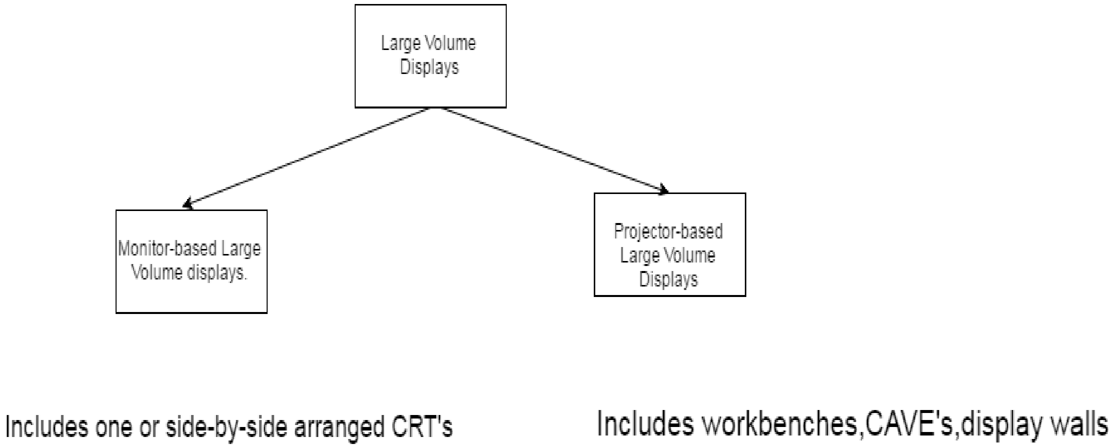
- It overcomes the problems faced by users due to the excessive display weights in HMD’s and HSD’s.
- Floor supported display also suffer from problem of oscillation due to excessive weight, Desk supported displays overcome these drawbacks.
- These are fixed and designed to be used for viewing with user in sitting position.
- Desk supported displays can be viewed with unaided eyes.

Large Volume Displays

- Large volume displays are used in VR environment that allow more than one user located in close proximity.
- These allow the user with larger work envelope ,thus improving upon user’s freedom of motion and ability of natural interaction compared to personal displays.



Large volume displays



Monitor-based Large Volume Display

- This display relies on use of active glasses coupled with stereo-ready monitor.
- The user of the system looks at the monitor through a set of shutter glasses.
- The stereo ready monitor are capable of refreshing the screen at double of the normal scan rate.
- The shutter glasses and the monitors are synchronized with each other.
- The active glasses are connected to an IR emitter located on top of the CRT display (connection is wireless).
- The IR controller controls and signals liquid crystal shutters to close and occlude the eyes alternately.
- The brain registers this rapid sequence of right and left eye images and fuses them to give the feeling of 3D.

PROJECTOR-BASED DISPLAYS

- Projector based displays have advantage of allowing group of closely located users to participate in a VR Simulation, on contrary to personal graphics displays.

***C*ave-*A*utomatic *V*irtual *E*nvironment(CAVE**

- A CAVE is a projection-based VR display that uses tracked stereo glasses to feel the environment.
- CAVE is basically a small room or cubicle where at least the 3 walls, sometimes the floor and the ceiling act as giant monitors.
- The display gives the users a wide field of view ,something that most HMD’s cannot do.
- User’s can also move around in the CAVE system.
- Wearing tracked stereo glasses is a must
- The sense of touch is also incorporated in the CAVE’s by using sensory gloves and other haptic devices. Some haptic devices also allow users to exert a touch or grasp or replace a virtual object.
- The sound interacts with the brain three dimensionally enhancing the realism of the virtual environment experience.