GUDLAVALLERU ENGINEERING COLLEGE

(An Autonomous Institute with Permanent Affiliation to JNTUK, Kakinada)

Seshadri Rao Knowledge Village, Gudlavalleru – 521 356.

Department of Computer Science and Engineering

HANDOUT

on

VIRTUAL and AUGMENTED REALITY

Vision of the Department

To be a Centre of Excellence in computer science and engineering education and training to meet the challenging needs of the industry and society

Mission of the Department

- To impart quality education through well-designed curriculum in tune with the growing software needs of the industry.
- To be a Centre of Excellence in computer science and engineering education and training to meet the challenging needs of the industry and society.
- To serve our students by inculcating in them problem solving, leadership, teamwork skills and the value of commitment to quality, ethical behavior & respect for others.
- To foster industry-academia relationship for mutual benefit and growth.

Program Educational Objectives

PEO1: Identify, analyze, formulate and solve Computer Science and Engineering problems both independently and in a team environment by using the appropriate modern tools.

PEO2: Manage software projects with significant technical, legal, ethical, social, environmental and economic considerations.

PEO3: Demonstrate commitment and progress in lifelong learning, professional development, leadership and Communicate effectively with professional clients and the public.

HANDOUT ON VIRTUAL AND AUGMENTED REALITY

Class & Sem.: III B.Tech – I Semester   Year : 2019-20
Branch : CSE   Credits : 3

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1. **Brief History and Scope of the Subject**

   "Virtual Reality (VR)"1 is a field of study that aims to create a system that provides a synthetic experience for its user(s). The experience is dubbed "synthetic," "illusory," or "virtual" because the sensory stimulation to the user is simulated and generated by the "system." For all practical purposes, the system usually consists of various types of displays2 for delivering the stimulation, sensors to detect user actions, and a computer that processes the user action and generates the display output. To simulate and generate virtual experiences, developers often build a computer model, also known as "virtual worlds" or "virtual environments (VE)" which are, for instance, spatially organized computational objects (aptly called the virtual objects), presented to the user through various sensory display systems such as the monitor, sound speakers, and force feedback devices. One important component of a successful VR system is the provision of interaction, to allow the user not just to feel a certain sensation, but also to change and affect the virtual world in some way.

   A New **scope** in today's world. **Virtual Reality** is something that allows everyone to experience the impossible. **Virtual Reality** is the term used to describe a three-dimensional, computer generated environment which can be explored and interacted by a person.

2. **Pre-Requisites**

   Basic knowledge on computer hardware and software components.

3. **Course Objectives:**

   - Learn a ton about virtual and augmented reality; get familiar with the latest technology and software,
   - Virtual reality in different object & applications
   - To understand key elements of virtual Reality with the components in VR systems.
   - To gain knowledge of various input and output devices required for interacting in virtual world along with rendering and modeling.

4. **Course Outcomes:**

CO1) Understand the components of the virtual reality system

CO2) Describe various input and output devices used for virtual reality

CO3) Apply the different modelling concepts to visual virtualization

CO4) Analyze the performance of given simple applications related to virtual reality

CO5) Understand the concepts of the augmented reality system

5. **Program Outcomes:**
Graduates of the Computer Science and Engineering Program will have

a. An ability to apply knowledge of computing, mathematics, science and engineering fundamentals to solve complex engineering problems.
b. An ability to formulate and analyze a problem, and define the computing requirements appropriate to its solution using basic principles of mathematics, science and computer engineering.
c. An ability to design, implement, and evaluate a computer based system, process, component, or software to meet the desired needs.
d. An ability to design and conduct experiments, perform analysis and interpretation of data and provide valid conclusions.
e. An ability to use current techniques, skills, and tools necessary for computing practice.
f. An ability to understand legal, health, security and social issues in Professional Engineering practice.
g. An ability to understand the impact of professional engineering solutions on environmental context and the need for sustainable development.
h. An ability to understand the professional and ethical responsibilities of an engineer.
i. An ability to function effectively as an individual, and as a team member/ leader in accomplishing a common goal.
j. An ability to communicate effectively, make effective presentations and write and comprehend technical reports and publications.
k. An ability to learn and adopt new technologies, and use them effectively towards continued professional development throughout the life.

l. An ability to understand engineering and management principles and their application to manage projects in the software industry.

6. Mapping of Course Outcomes with Program Outcomes:

	a	b	c	d	e	f	g	h	i	j	k	l
CO1		3	3				1				1	1
CO2	3			3							2	
CO3		3			2							
CO4				4								

7. Prescribed Text Books

1. Virtual Reality Systems, John Vince, Pearson Education.
2. Virtual Reality Technology, Second Edition, Gregory C. Burdea & Philippe Coiffet, John Wiley & Sons, Inc.,
3. Steve aukstakalnis, "Practical Augmented Reality: A Guide to the Technologies, Applications and Human Factorsfor AR and VR", Adision Wesley.

Reference Text Books

1. Understanding Virtual Reality, interface, Application and Design, William R.Sherman, Alan Craig, Elsevier (Morgan Kaufmann).

URLs and Other E-Learning Resources

a. Virtual Reality introduction : http://stanford.edu/class/ee267/
b. Standards: http://technav.ieee.org/tag/2188/virtual-reality

8. Digital Learning Materials:

9. Lecture Schedule / Lesson Plan

Topic	No. of Periods	
	Theory	**Tutorial**
UNIT –1: Introduction		
Virtual Reality Introduction	1	1
The three I's of virtual reality	1	
commercial VR technology	1	
five classic components of a VR system	1	
UNIT – 2: Input Devices		
Trackers	1	1
Navigation	1	
Gesture Interfaces	1	
Three-dimensional position trackers	1	
Navigation and manipulation	1	1
interfaces and gesture interfaces	1	
UNIT – 3: Output Devices		
Graphics displays	1	1
sound displays	1	
Haptic feedback	1	
UNIT – 4: Human Factors		
Methodology and terminology	2	1
user performance studies	2	
VR health and safety issues	2	
Medical applications	2	1
military applications	2	
robotics applications	2	
UNIT – 5: Augmented Reality		
Introduction – Head-up Displays	2	1
Helmet-mounted sights and displays	2	
Smart Glasses and augmenting displays	2	1
UNIT – 6: Understanding Virtual Space		
Visual and Object space	2	1
Defining position and orientation in 3 dimensions	2	
Total No.of Periods:	**35**	**9**

10. Seminar Topics

- openGL
- Types of Haptics
- Various Applications on virtual reality and augmented reality

UNIT-I

Objectives:

- Learn a ton about Virtual Reality; get familiar with the latest technology and software,

Syllabus:

UNIT – I: Introduction

The three I's of virtual reality, commercial VR technology and the five classic components of a VR system

Outcomes:

Students will be able to

- identify basic elements of virtual Reality with the components in VR systems
- describe various input and output devices required for interacting in virtual world along with rendering and modeling.
- differentiate various types of modeling,
- apply the concepts of Virtual Reality for an application.

Learning Material

INTRODUCTION

Michael Heim, in his new book Virtual Realism1, presents virtual reality as:
Virtual Reality is an emerging field of applied science. VR is first of all a technology. Virtual reality is an immersive, interactive system based on computable information.

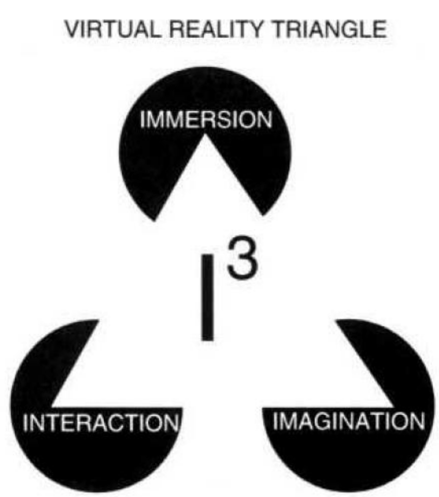
This general definition covers the fundamental concept of VR. For the purposes of this course, we are referring to VR as an *enabling technology* that can be applied to a variety of scientific and engineering challenges. This technology provides a "natural way" to interact with computers, creating the illusion of a three-dimensional world built from user's data. The data can be almost anything: an architectural environment, a model of a hearth, the result of an airflow simulation, a biochemical system, an imaginary world, an engineering design.
Since the early 1980s, scientists and engineers have been working on developing VR technology and constantly exploring its potential and benefits for a variety of fields, ranging from medicine to engineering to entertainment. These groups have provide the field with very strong theoretical and applied technical skills to accomplish the hard task of turning the concept of VR into a reality.

However, we need to acknowledge the enthusiastic participation of artists and entrepreneurs, who have had a significant impact on the development of the technology towards more accessible and easy to use implementations. They have provided a rich pool of ideas and applications that have motivated the technology to leave research laboratories and reach the general public.

More recently, we are seeing a growing interest coming from industry about VR applications and its benefits. VR technology has proven itself and it is already being accepted that VR technology has a great potential in many disciplines. The challenge now is on how to apply virtual reality, and for that, we need to understand virtual reality independently of today's technology, we have to be aware of the limitations imposed by the current technology, and, we require to establish design approaches that will lead to the creation of successful virtual experiences.

THE THREE I's OF VIRTUAL REALITY

It is clear from the foregoing description that virtual reality is both interactive and immersive. These features are the two I's that most people are familiar with. There is, however, a third feature of virtual reality that fewer people are aware of. Virtual reality is not just a medium or a high-end user interface, it also has applications that involve solutions to real problems in engineering, medicine, the military, etc. These applications are designed by virtual reality developers. The extent to which an application is able to solve a particular problem, that is, the extent to which a simulation performs well, depends therefore very much on the human imagination, the third "I" of VR. Virtual reality is therefore an integrated trio of immersion, interaction-imagination, as shown in Figure below. The imagination part of VR refers also to the mind's capacity to perceive nonexistent things. The triangle in below figure, for example, is easily "seen" by the reader, yet it only exists in his or her imagination.



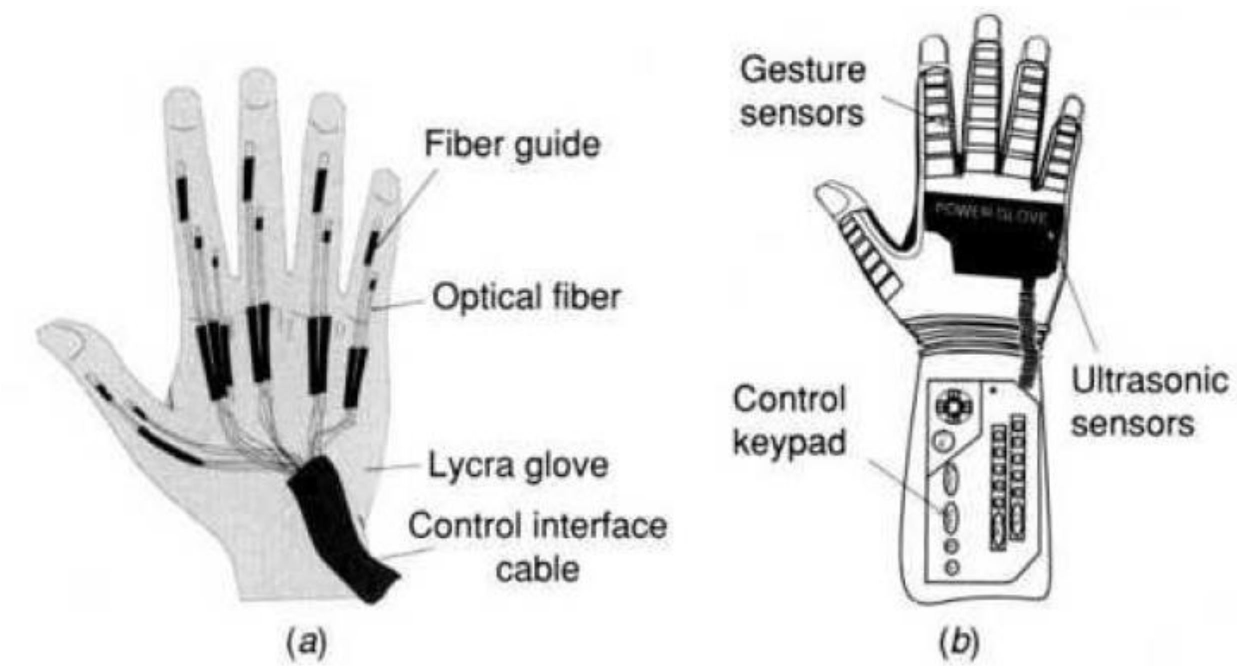
Interaction: I think interaction is the first thing need to define in VR, it's the important character of all. People want to see the action movement from the screen what is according as their ordered. And that is the basic element of VR what used as a instant operation system.

Immersion: Mouse and keyboard also are able to deal with that thing on computer, but without Immersion, they cannot be entitle VR, Immersion let people standing on a real world from the screen, feeling by their felt, moving by their order, touching by their touched.

Imagination: Mostly people don't know Imagination is a element in VR, they all thought Immersion and Interaction is the all of it. But actually the Imagination is the element which creates the VR. The solution of problem and what kind of simulate could be more useful, designer how to make the decision, all of them is lie on Imagination.

COMMERCIAL VR TECHNOLOGY

The first company to sell VR products was VPL Inc., headed by Jaron Lanier. Until its demise in 1992 this company produced the first sensing glove, called the DataGlove (Figure 1.6a) [VPL, 1987]. The standard interfaces of the time (and still today) were the keyboard and the mouse. Compared to these, the VPL DataGlove represented a quantum improvement in the natural way one could interact with computers. Its fiber-optic sensors allowed computers to measure finger and thumb bending, and thus interaction was possible through gestures. Its drawbacks were high price (thousands of dollars), lack of tactile feedback, and difficulty in accommodating different hand sizes.



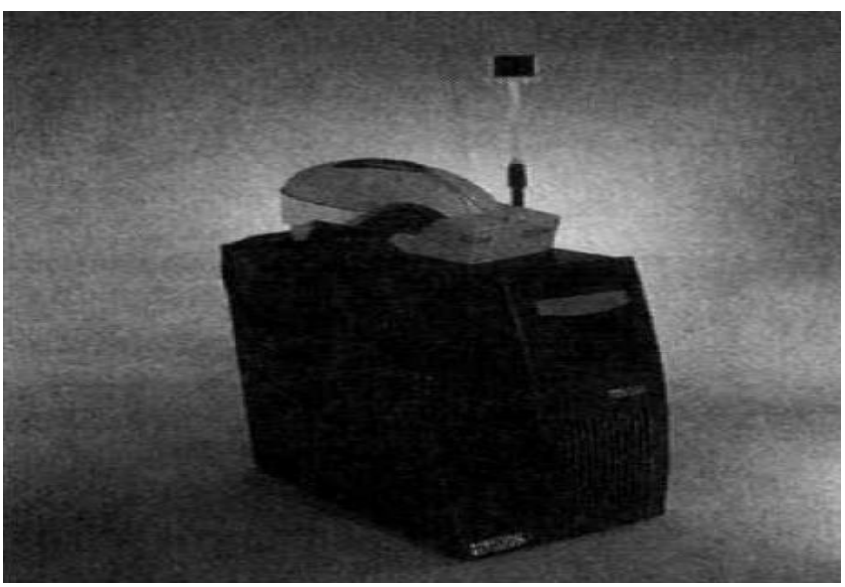
Above Fig. shows Early sensing glove technology: (a) the VPL DataGlove; (h) the PowerGlove. From Burdea [1993]. Reprinted by permission.

Shortly after the appearance of the VPL DataGlove, the game company Nintendo introduced the much cheaper PowerGlove, shown in Figure 1.6b [Burdea, 1993]. It used ultrasonic sensors to measure wrist position relative to the PC screen and conductive ink flex sensors to measure finger bending. In 1989 almost one million such new game consoles were sold in a consumer frenzy that was later repeated with the introduction of Sony Play Station. The downfall of the PowerGlove was lack of sufficient games that used it, such that by 1993 its production had stopped.

The first commercial head-mounted displays, called EyePhones, were introduced by VPL in the late 1980s. These HMDs used LCD displays to produce a stereo image, but at extremely low resolution (360 x 240 pixels), such that virtual scenes appeared blurred. Other drawbacks were high price ($11,000 each) and large weight (2.4 kg).

Researchers now had an initial set of specialized hardware with which to start developing applications. However, they first had to solve various integration issues as well as develop most of the required software from scratch. The idea of a turnkey VR system originated with VPL as well. Its RB2 Model 2 offered a rack assembly housing the EyePhone HMD interface, the VPL DataGlove Model 2 electronic unit, a spatial tracking unit for the HMD, a design and control workstation, as well as connections to an SGI 4D/3 10 VGX graphics renderer and to an optional 3D sound system.

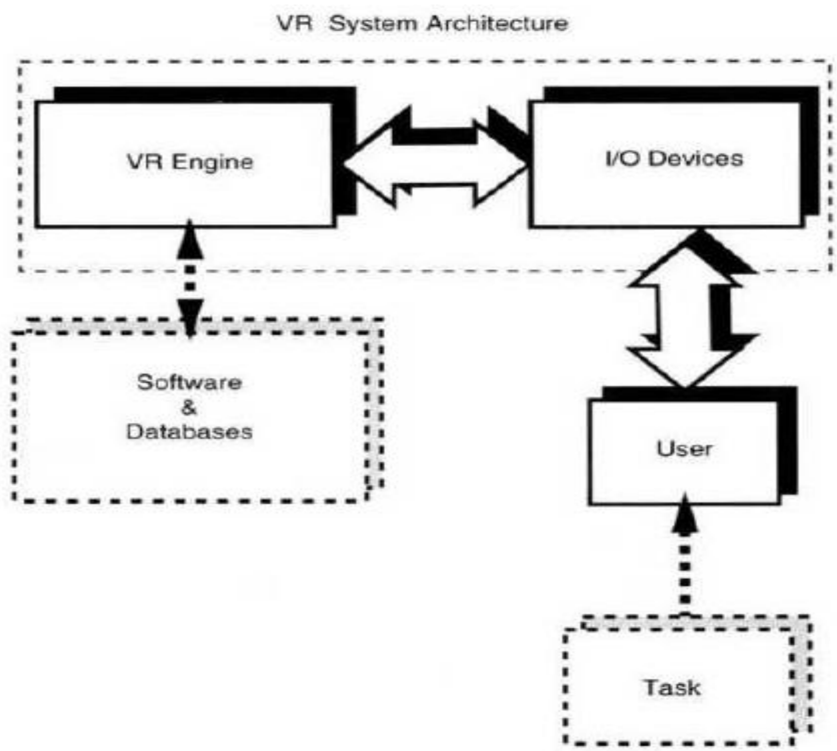
The next step in integration was to shrink each of these components and put them on a board in a
single desk-side cabinet. In early 1991 a company in the United Kingdom, Division Ltd., introduced the first integrated commercial VR workstation. It was called Vision and was followed by the more powerful Provision 100 [Grimsdale, 1992], which is illustrated in Figure 1.7. The Provision 100 parallel architecture had multiple processors, stereo display on an HMD, 3D sound, hand tracking, and gesture recognition. The architecture also had an input/output (UO) card and was scalable, allowing additional 1/0 processors to be added. Its i860 dedicated geometry processor with a custom polygon accelerator provided 35,000 Gouraud-shaded and Z-buffered polygons per second. This was a clear improvement over the speed of the HP 9000 computer used in NASA's VIEW system, but it came at a high price ($70,000).



The Provision 100 VR workstation. Courtesy of Division Ltd.

Although turnkey hardware systems appeared in early 1990s, the VR software development and debugging time continued to be a problem. In 1992, the small U.S. company Sense8 Co. developed the first version of its WorldToolKit (WTK) [Sense8 Co., 1992], a library of C functions written specifically for VR applications. With this toolkit developing VR software became more like a science, and debugging time was reduced significantly. Another popular toolkit of the 1990s was the Virtual Reality Toolkit (VRT3), developed in the United Kingdom by Dimension International (the company later became Superscape PLC) [Dimension International, 1993]. Unlike WTK, VRT3 was designed to run on multiple computing platforms without the need for (then) pricey graphics accelerators. Also, unlike WTK, which is text-based, VRT3 used graphical programming through menus and icons. This made programming easier to learn, but less rich in functionality, owing to the limited menu of available functions and the limited number of supported interfaces.

THE FIVE CLASSIC COMPONENTS OF A VR SYSTEM



Above Fig. shows The five classic components of a VR system.

Very important UO devices used either for user input (such as trackers, gloves, or mice) or output (such as HMDs, large-volume displays, force feedback robotic arms, etc.). The special-purpose computer architecture designed to match the high UO and computation demands of real-time VR simulations

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) *Objective Questions*

1. Which device contains thumbwheel, trackball and a standard mouse ball?

a) Z mouse
b) Joystick
c) Mouse
d) Trackball

2. Virtual reality, CAD, and animations are the application of

a) Z mouse
b) Digitizers
c) Data tablets
d) Image scanners

3. Which of the following device is not the input device?

a) Trackball and space ball
b) Data glove
c) Only d
d) Impact printers

4. Acronym for VRML:

(a) Virtual Reality Modeling Level
(b) Virtual Reality Modulation Language
(c) Virtual Rate Modeling Language
(d) Virtual Reality Modeling Language
(e) Virtual Reality Marketing Language.

5. A multimedia file

a) is same as any other regular file
b) Must be accessed at specific rate
c) stored on remote server cannot be delivered to its client
d) None of the mentioned

6. A Multimedia Presentation can be:

I. Linear.
II. Nonlinear.
III. Structured link.
IV. Web page.

(a) Only (I) above
(b) Only (IV) above
(c) Both (I) and (II) above
(d) (I), (II) and (III) above
(e) All (I), (II), (III) and (IV) above.

7. Virtual reality is_________________________
8. What is Computer graphics?
9. Differentiate 2D and 3D?
10. What are commonalities and differences between virtual reality and 3D computer graphics?

II) Descriptive Questions

1. What is virtual reality? And list out its applications?
2. What were the first commercial VR products?
3. What happened with the VR industry in the 1990s?
4. What are the five classic components of a VR system?
5. What was Heilig's role in the development of VR?
6. How does virtual reality differ from augmented reality and telepresence?

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions

Q1. What is / are the disadvantage(s) of using most VR systems?

1. the simulators are of higher cost than their real counterparts.
2. addiction
3. temperary nausea, dizziness
4. difficult to use

A : 1 only
B : 3 only
C : 1 and 3 only
D : 2 and 3 only
E : All of the above.

Q2. Which of the following relates most closely to Virtual Reality with respect to the audiences ?

A : Science Fiction Books
B : Comedy Drama Play
C : Action films

Q3. Which of the following(s) is / are a type of VR ?

1. A child playing a flight simulator game on a PC.
2. A drug designer viewing a drug molecule via a Head Mounted Display coupled to the computer.
3. A NASA operator controlling a space module on the moon to pick up rock samples.

A : 1 and 2 only
B : 2 only
C : 2 and 3 only
D : All of the above.

Q4. The delay that occur during the playback of a stream is called
a) stream delay
b) playback delay
c) jitter
d) event delay

Q5. Which of the following is the best definition for Virtual Reality?
A) Any computer game involving graphics.
B) A 3D simulation of a real or imagined environment using computers.
C) A simulator which requires special eye glasses.
D) The process of coding in another dimension.

Q6. Which of the following extensions would you not expect to see on a VRML file?
A) wrl
B) wrl.gz
C) wrz
D) vr

Q7. A multimedia file
a) is same as any other regular file
b) Must be accessed at specific rate
c) stored on remote server cannot be delivered to its client
d) None of the mentioned

Q8. Which one of the following is the characteristic of a multimedia system?
a) high storage
b) high data rates
c) both (a) and (b)
d) none of the mentioned

Q9. Which of the following is the MIME type for a VRML file?
A) model/vrml
B) audio/vrml
C) midi/vrml
D) 3d/vrml

Q10. Which of these is not likely to be the responsibility of a multimedia project?
(a) Create interfaces
(b) Ensure the visual consistency of the project
(c) Structure content
(d) Create budgets and timelines for the project
(e) Select media types for content.

II) Problems:

1. What are the applications of cinematic VR?

2. How do you shoot video in all directions at once?

3. How can I experience VR?

4. What if I don't have a headset or Google Cardboard?

5. Can you live-stream VR?

6. Do i need additional hardware to create VR content?

7. What Are the Best Images and Subjects to Use for Virtual Reality?

8. How Is Filming Virtual Reality Different Than Traditional Video?

UNIT-II

Objectives:

- Learn about Input Devices and familiar with the input interfaces.

Syllabus:

UNIT – II: Input Devices

Trackers, Navigation, and Gesture Interfaces- Three-dimensional position trackers, Navigation and manipulation, interfaces and gesture interfaces.

Outcomes:

Students will be able to

- Describe various input and output devices required for interacting in virtual world along with rendering and modelling.
- Identifies the various types of trackers and interfaces.
- Apply the concepts of Virtual Reality for an application.

Learning Material

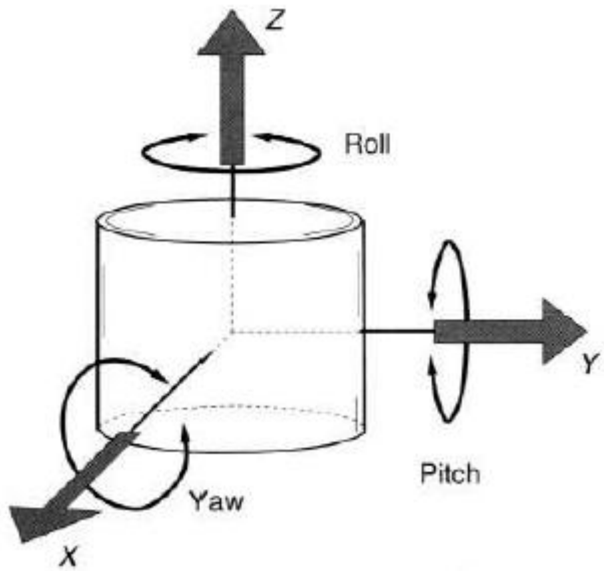
TRACKERS:

Definition:

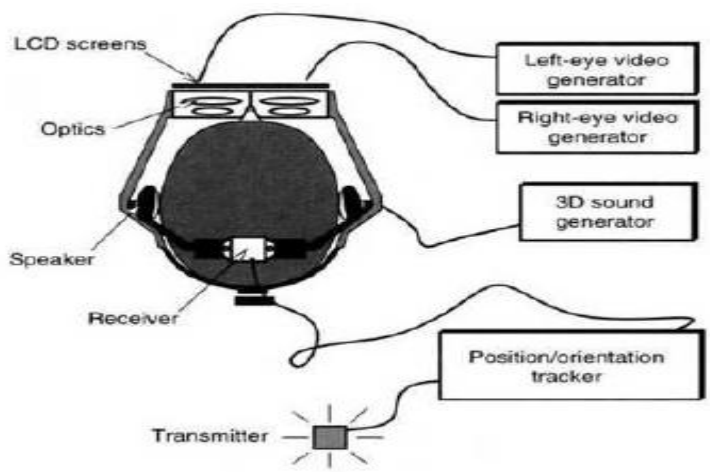
Tracking devices are intrinsic components in any VR system. These devices communicate with the system's processing unit, telling it the orientation of a user's point of view. In systems that allow a user to move around within a physical space, **trackers** detect where the user is, the direction he is moving and his speed.

Virtual reality applications typically measure the motion of the user's head, limbs or hands, for the purpose of view control, locomotion, and object manipulation .A newer tracker application in VR is for the control of an avatar, or virtual body, mapped to the user.

The tracker receiver is placed on the user's head, so that when the posture of the head changes, so does the position of the receiver. The user's head motion is sampled by an electronic unit and sent to a host computer (in this case a graphics workstation). The computer uses the tracker data to calculate a new viewing direction of the virtual scene and to render an updated image. This scene is then converted to National Television System Committee (NTSC) video signals displayed by the two LCD screens.



Another VR sensorial modality that uses tracker information is 3D sound is presented through headphones. Tracker data allow the computer to calculate sound sources with virtual objects the user sees in the simulation. This helps increase the simulation realism and the user's feeling of immersion in the synthetic world. The measurement accuracy requirements for the 3D sound application are much less stringent than those needed by the graphics feedback. As noted by Foxlin, the visual acuity is higher than the auditory localization acuity, and auditory depth perception is even weaker in humans. Several competing tracking technologies are available, such as mechanical , magnetic, optical, ultrasonic, and hybrid.



Tracker Performance Parameters:

Definition: Tracker accuracy represents the difference between the object's actual 3D position and that reported by tracker measurements.

All 3D trackers, regardless of the technology they use, share a number of very important performance parameters, such as accuracy, jitter, drift, and latency.

The more accurate a tracker, the smaller this difference is and the better the simulation follows the user's real actions. Accuracy is given separately for tracking translation (fraction of a millimeter) and rotation (fraction of a degree). Accuracy is typically not constant and is degraded with distance from the origin of the reference system of coordinates. The distance at which accuracy is acceptable defines the tracker operating range or work envelope. Accuracy should not be confused with resolution, which is the granularity or the minimum change in tracked object 3D position that the sensor can detect.

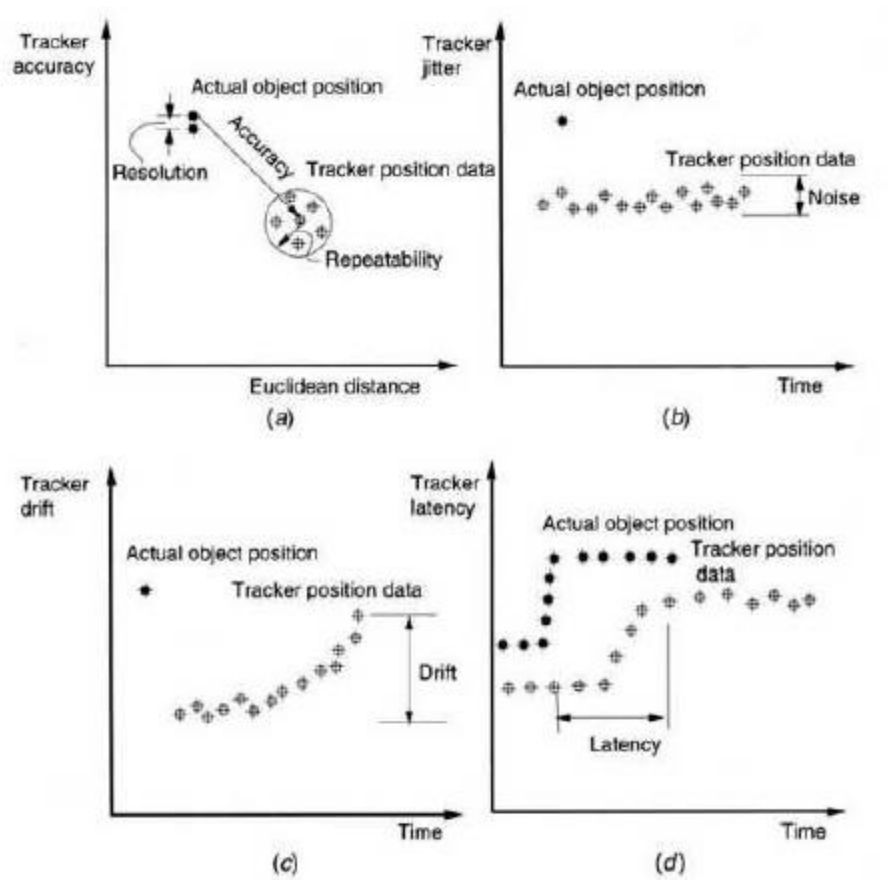


Fig: Tracker performance parameters: (a) accuracy; (b) jitter; (c) drift; (d) latency.

Definition: Tracker jitter represents the change in tracker output when the tracked object is stationary.

A tracker with no jitter (and no drift) would report a constant value if the tracked object is stationary in time. Sometimes called sensor noise, jitter makes the tracker data change randomly about an average value. Tracker jitter needs to be minimized, since otherwise it leads to unwanted effects in terms of graphics quality (tremor, jumpy virtual objects, etc.). A noisy tracker makes accurate measurements difficult. Just like accuracy, jitter is not constant over the tracker work envelope, and is influenced by environmental conditions in the tracker's vicinity.

Definition: Tracker drift is the steady increase in tracker error with time .The output of a tracker with drift that measures the position of a stationary object is shown in following Figure .As time passes, the tracker inaccuracy grows, which makes its data useless. Drift needs to be controlled by periodically zeroing it using a secondary tracker of a type that does not have drift.

Typically the tracker measurement, communication, rendering, and display loops are asynchronous, each operating at a different speed. An efficient way to reduce system latency is to synchronize the tracker and communication loops with the display loop in what is called generation lock, or gunlock .With gen lock the computer receives tracker data just in time and overall system latency is reduced (but not eliminated). Whether gen lock is used or not, a way to reduce system latency is to use fast communication lines. If the sensor data are sent to the host computer continuously, then the tracker operates in streaming mode.

Mechanical Trackers:

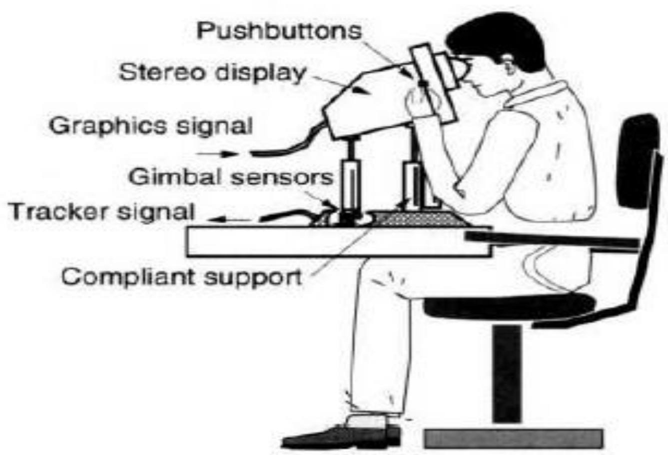
The first tracker used in a VR simulation was the mechanical arm that supported Sutherland's CRT based HMD. The motion of the user's head was tracked with regard to the ceiling arm attachment.

Definition: A mechanical tracker consists of a serial or parallel kinematic structure composed of link sinter connected using sensorized joints.

The dimensions of each link segment are known a priori and used by the direct kinematics computational model stored in the computer. This model allows the determination of the position and orientation of one end of the mechanical tracker relative to the other, based on the real-time reading of the tracker joint sensors. By attaching one end of the tracker to the desk or floor and the other to an object, the computer can track the object's 3D position relative to the fixed end of the arm.

Mechanical trackers have certain **advantages** when compared with other tracker technologies. They are simpler and easier to use. mechanical trackers have very low jitter and the lowest latency of all tracking types. Unlike optical trackers, mechanical trackers have no problem with visual occlusion of the tracked object.

A mechanical tracker is used as part of the Push display [Fakespace Labs Inc., 1998; Mead et al.2000], illustrated in Figure below. This desktop interface allows the user to navigate in virtual worlds displayed on a high-resolution stereo display. The weight of the CRT displays is supported by three compliant telescopic pistons and a bottom plate. Two of the pistons serve only for support, and their joints do not allow rotation. The third piston is connected with a three-degree-of-freedom gimbal mechanism, which allows the user to push the display in various orientations. The gimbal rotational encoders measure the degree of platform displacement front-back, left-right, and twist. The gimbal sensor data are combined with input from three buttons on the Push display handles and sent to a host computer over an RS232 serial line. The host computer uses a kinematic model to change the view to the simulation in 3D in response to the user's actions. The tracker accuracy is 4 mm, its update rate is70 datasets/sec, and its latency is extremely low (0.2 μsec).

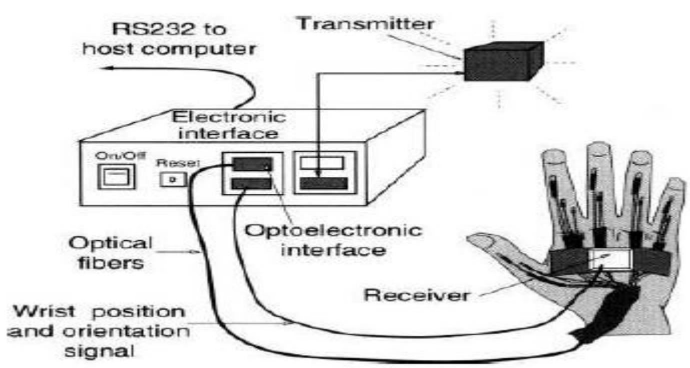


. 2.5 Mechanical tracker used in the Push 1280 stereo display. Adapted from Mead et al.

Magnetic Trackers:

Definition: A magnetic tracker is a noncontact position measurement device that uses a magnetic field produced by a stationary transmitter to determine the real time position of a moving receiver element.

The transmitter consists of three antennas formed of three mutually orthogonal coils wound on a ferromagnetic cube. These antennas are excited sequentially to produce three orthogonal magnetic fields.



' The 3D magnetic tracker used by the VPL DataGlove. From Burdea [1993].

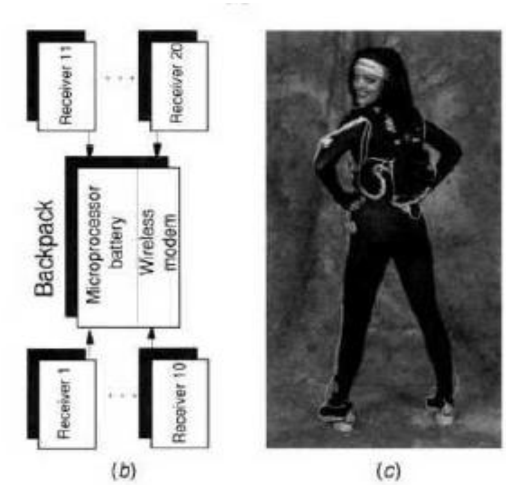


Fig. 2.12 MotionStar© wireless system: (a) block diagram; (b) back pack unit. Adapted from Ascension [2001b]; (c) User wearing the tracking suit. © Ascension Technology Co. Reprinted by permission.

Ultrasonic Trackers:

An alternative tracking solution that does not suffer from metal interference uses 3D ultrasound trackers. Definition: A ultrasound tracker is a noncontact position measurement device that uses an ultrasonic signal produced by a stationary transmitter to determine the real-time position of a moving receiver element. Ultrasound trackers have three components, a transmitter, a receiver, and an electronic unit, similar to their magnetic counterparts. The difference is that the transmitter is a set of three ultrasonic speakers mounted about 30 cm from each other on a rigid and fixed triangular frame. Similarly, the receiver is a set of three microphones mounted on a smaller rigid triangular frame. This triangular frame is placed at the top of the head mounted display, as illustrated in Figure 2.14. Alternatively the microphones may be part of 3D mice, stereo glasses (discussed in the next chapter), or other interface devices. Due to their simplicity, ultrasound trackers represent a cheaper alternative to the magnetic ones.

The control unit CPU samples the microphones, converts their readings into position and orientation based on calibration constants, then transmits the data to the host computer for graphics scene rendering. The update rate of ultrasound trackers is about 50 datasets/sec, which is less than half that of modern magnetic trackers. The reason update rates are low is the need to wait 5-100 msec to allow echoes from a previous measurement to die out before a new measurement is initiated [Foxlin,2002]. When several parts of the body (such as head and hands) have to be tracked, it is possible to use time multiplexing (similar to magnetic trackers) of up to four receivers with one transmitter.

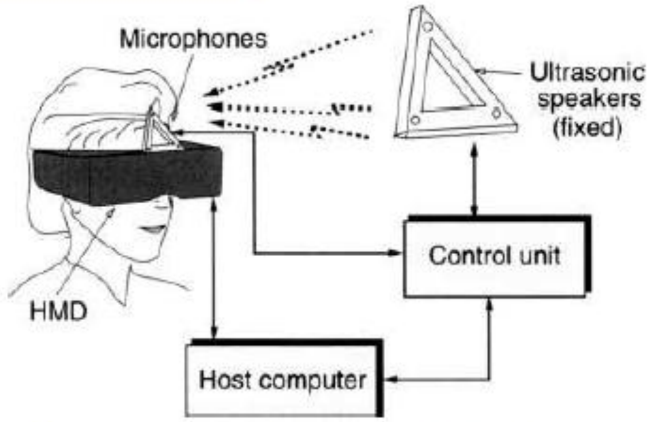


Fig. 2.14 Logitech ultrasound head tracker. From Burdea and Coiffet [1993]. © Editions Hermes. Reprinted by permission.

Optical Trackers:

Definition: An optical tracker is a noncontact position measurement device that uses optical sensing todetermine the real-time position/orientation of an object.

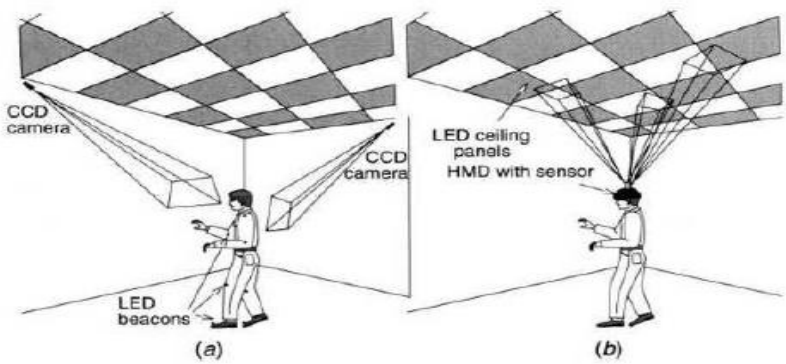


Fig. 2.16 Optical tracker arrangement: (a) outside-looking-in; (b) inside-looking-out. Adapted from Welch et al. [2001]. © 2001 Massachusetts Institute of Technology. Reprinted by permission.

Similar to ultrasonic trackers, optical trackers work through triangulation, require direct line of sight, and are immune to metal interference. Optical trackers, however, offer significant advantages over their ultrasonic counterparts. Their update rates are much higher and their latency smaller than those of ultrasonic trackers because light (whether visible or infrared) travels much faster than sound. They are also capable of (much) larger work envelopes, which is increasingly important in modem VR systems .If the tracker sensing component (charge-coupled device [CCD] camera, photodiode, or other photo sensor) is fixed and some light beacons are placed on the user, the tracker is said to e outside-looking in ,As illustrated in Figure 2.16a [Welch et al., 2001]. Position measurements are done directly, and orientation is inferred from the position data. Tracking sensitivity is degraded as the distance decreases between the beacons on the user's body and the distance increases between the user and the camera. By contrast, an inside-looking-out optical tracker has the camera(s) attached to the tracked object or user, as shown in Figure 2.16b. Its sensitivity is maximized for changes in orientation (very useful for HMD tracking), and the work envelope can be scaled theoretically at infinity (very useful for wall or room type graphics displays).

Hybrid Inertial Trackers:

Definition: Inertial trackers are self-contained sensors that measure the rate of change in an object orientation. They may also measure the rate of change of an object translation velocity.

Definition: A hybrid tracker is a system that utilizes two or more position measurement technologies to track objects better than any single technology would allow .When only orientation data are needed, such as for low-cost HMDs, then one solution is to add solid-state magnetometers aligned with the three gyroscopes

NAVIGATION AND MANIPULATION INTERFACES:

Definition: A navigation/manipulation interface is a device that allows the interactive change of the view to the virtual environment and exploration through the selection and manipulation of a virtual object of interest .The navigation/manipulation can be done in either absolute coordinates or relative coordinates. The trackers described so far are absolute, as they return the position and orientation of a moving object with respect to a fixed system of coordinates. The position of the VR object controlled on the screen is directly mapped to the absolute position of the receiver in the world (transmitter)-fixed system of coordinates.

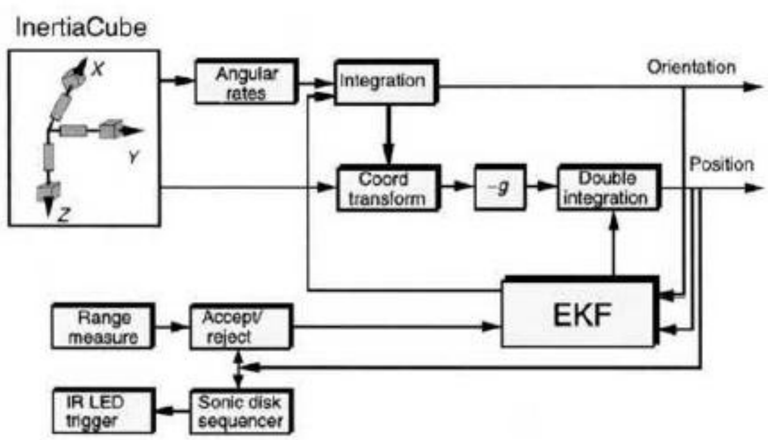


Fig. 2.20 The InterSense Inc. IS-900 software block diagram. Adapted from Foxlin et al. [1998]. © 1998 ACM Inc. Reprinted by permission.

TABLE 2.2. Performance Comparison of Various Trackers[a]

Accuracy (mm/deg)	Range (m)	Latency ($sec \times 10^{-3}$)	Update Rate[b] (datasets/sec)
0.5/0.03 HiBall	30 × 30 IS-900	0.0002 Push	2000 HiBall
0.8/0.15 Fastrack	12.2 × 12.2 HiBall	1 HiBall	256 InterTrax2
1/0.5 laserBIRD	2 laserBIRD	4 InterTrax2	240 laserBIRD
2/0.5 Flock of Birds	1.52 Logitech	7 laserBIRD	180 IS-900
4/0.2 IS-900	1.2 Flock of Birds	7.5 Flock of Birds	160 3-D BIRD
4/NA Push	0.75 Fastrack	8.5 Fastrack	144 Flock of Birds
NA/4 3D BIRD	NA 3D BIRD	10 IS-900	120 Fastrack
NA/5 InterTrax2	NA InterTrax2	15 3D BIRD	70 Push
30 Logitech	NA Push	30 Logitech	50 Logitech

[a]From top to bottom, best to worst performance. NA, Not available.
[b]For a single sensing element.

Another way to control a VR object's position is through relative sensors. Whereas absolute position data are never a zero set (even if the receiver is at rest), a relative position sensor will always return zeros if not acted upon.

Tracker-Based Navigation/Manipulation Interfaces:

Trackers offer more functionality to VR simulations than simply measuring the real time position/orientation of the user's hand and head. Integrated within a structure that houses user programmable push buttons, trackers become navigation and manipulation interfaces. Examples are the Polhemus 3Ball and the Ascension Technology 3D Mouse [Anon, 1998]. The 3Ball is a hollow billiard ball that houses a tracker receiver inside and has a pushbutton on the surface. An example of its use is to move a virtual camera that travels along the 3D vector controlled by the ball as long as the pushbutton is pressed. Another example is a wand, which projects a virtual ray along the tracker controlled vector. Any object intersected by this ray can be selected by pushing the button on the billiard ball, and then repositioned through wrist motion. The 3D Mouse offers more functionality, as it can work both as a mouse (in 2D) and as a navigation/manipulation interface in 3D, similar to the3Ball. Further functionality is obtained through the programming of the three buttons incorporated on the3D Mouse.

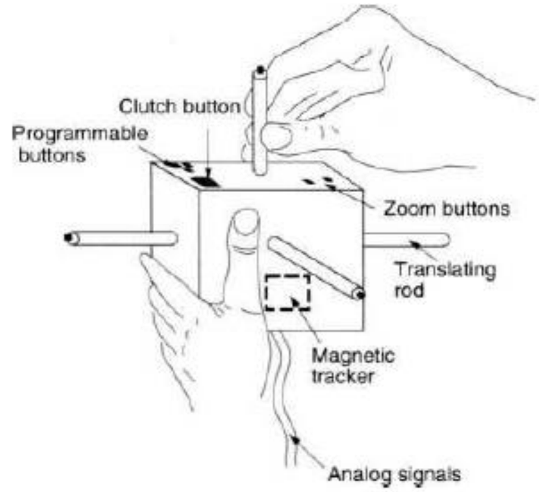


Fig. 2.21 The Cubic-Mouse. Adapted from Frohlich et al. [20001. © 2000 IEEE. Reprinted by permission.

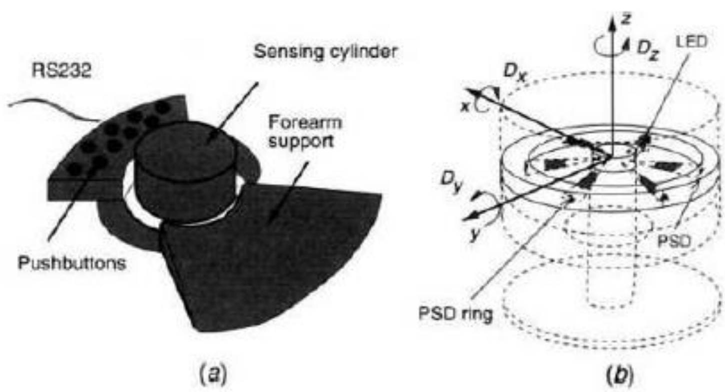


Fig. 2.22 The Magellan trackball: (a) outside configuration; (b) the sensing mechanism. Adapted from Hirzinger and Bejczy [1988]. Reprinted by permission.

2.2.2 Trackballs:

A class of interfaces that allow navigation/manipulation in relative coordinates are trackballs, such as the Logitech Magellan shown in Figure 2.22a [Anon, 1998]. This is a sensorized cylinder that measures three forces and three torques applied by the user's hand on a compliant element. Forces and torques are measured indirectly based on the spring deformation law. The central part of the cylinder is fixed and has six light-emitting diodes, as shown in Figure 2.22b [Hirzinger and Bejczy, 1988]. Correspondingly ,six photo sensors are placed on a moving external cylinder. When the user applies forces or torques on the moving shell, the photo sensor output is used to measure three forces and three torques. These forces and torques are then sent to a host computer over an RS232 serial line. Here they are multiplied by software gains to return a differential change in the controlled object position and orientation. Larger gains will result in larger speeds for the VR object the user controls, but its motion will not be smooth if the host cannot refresh the screen fast enough. An alternate way to control VR objects is through force

control, where forces measured by the trackball are used to control forces applied by the VR object on the simulated environment. The trackball can also be used to fly by in the simulation. In that case the sensor affects the velocity and orientation of a virtual camera looking at the simulated world.

Three-Dimensional Probes:

Users felt a need for an 1/0 device that would be intuitive to use, inexpensive, and allow either absolute or relative position control of the simulation. One such device is the Immersion Probe produced by Immersion Co. in the early 1990s. This was later renamed the Micro Scribe 3D and its use extended to include digitizing objects [Rosenberg et al., 2000]. It consists of a small, sensorized mechanical arm that sits on a support base, with a small 6 in. x 6 in. footprint. The probe has six joints (joints 0-5), as illustrated in Figure 2.23.Each rotary joint represents one degree of freedom, and thus the probe has six degrees of freedom ,following simultaneous positioning and orienting of its tip. A counterbalance is placed close to the base to minimize the user's fatigue. The tip position relative to the base is obtained through direct kinematics calculations, based on sensor values and the length of the links. Software on the host computer reads the joint sensors on an RS232 line, then uses its kinematic model to determine where the tip is. A binary switch on a foot pedal is used to select/deselect (release) virtual objects, navigate (start/stop), or marka point on the real object surface for digitization purposes.

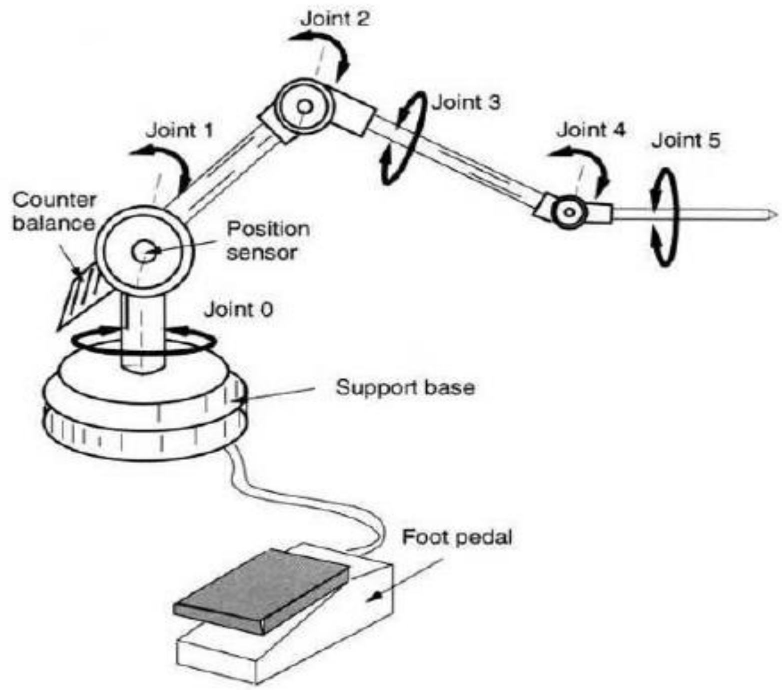


Fig. 2.23 The Immersion Co. Microscribe 3D. Adapted from Rosenberg et al. [20001. © 2000 Immersion Co. Reprinted by permission.

GESTURE INTERFACES:

Definition: Gesture interfaces are devices that measure the real-time position of the user's fingers (and sometimes wrist) in order to allow natural, gesture-recognition based interaction with the virtual environment.

Most gesture interfaces today are sensing gloves that have embedded sensors which measure the position of each finger versus the palm. Sensing gloves differ in such factors as, for example, the type of sensors they use, the number of sensors for each finger (one or several), their sensor resolution, the glove sampling rate, and whether they are tethered or wireless.

Some of the available commercial sensing gloves are the Fakespace Pinch Glove the Fifth Dimension Technology 5DT Data Glove, the Didjiglove[Anon, 2000], and the Immersion Cyber Glove. They have sensors that measure some (or all) of the finger joint angles. Some have built-in trackers as well, in order to measure the user's wrist motion. The resulting sensing glove work envelope is much larger than that of trackballs or joysticks, as illustrated in Figure 2.25. As opposed to trackballs and 3D probes, which have single point interaction with the virtual environment, sensing gloves allow dextrous, multipoint interaction at the fingertips or palm. This results in a more realistic simulation, especially for object manipulation tasks. Additionally, sensing gloves can become navigation interfaces, based on user-programmed gesture libraries .

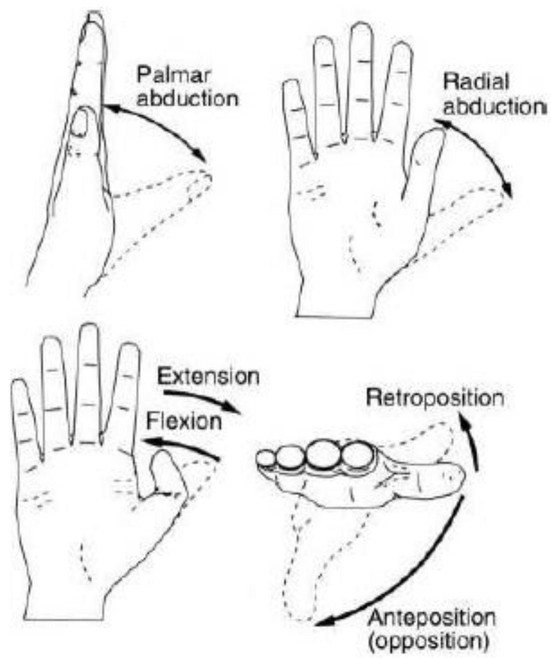


Fig. 2.24 Terminology of hand and finger motions. Adapted from American Society for Surgery of the Hand [1983]. ©1983 Elsevier Science. Reprinted by permission.

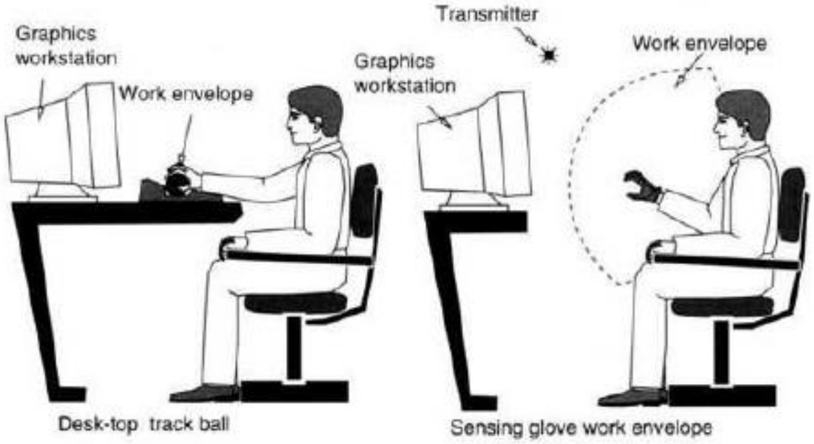


Fig. 2.25 Comparison of sensing glove work envelope and trackball work envelope. From Burdea [1993]. Reprinted by permission.

The Pinch Glove:

The drawbacks that most sensing gloves have are need for user-specific calibration, complexity, and high cost. Each person has a different hand size, with women generally having smaller hand size than men. As a consequence, the glove-embedded sensors will overlap different finger locations for different users. In order to reduce inaccuracies, most sensing gloves need to be calibrated to the particular user wearing them. Users have to place their hands in predetermined gestures (such as a flat hand or a fist) and the sensor output measured. These raw values are then converted to finger join tangles based on glove-specific algorithms .The only commercial sensing glove that makes calibration unnecessary is the Pinch Glove, which is illustrated in Figure 2.26 [McDowall et al., 2000]. The glove incorporates electrodes in the form of conductive fiber patches at the fingertips, on the back of fingers, or in the palm. Gestures are positively detected as the establishing and breaking of electrical contacts between the fingers of one hand, fingersof one hand and fingers of the other hand, fingers and palm, etc. A multiplexing chip embedded in the glove reduces the number of wires that need to be connected to an electronics control box. The control box incorporates a microprocessor, low-current power supply, timing circuits, and RS232 serial port for communication with the host computer.

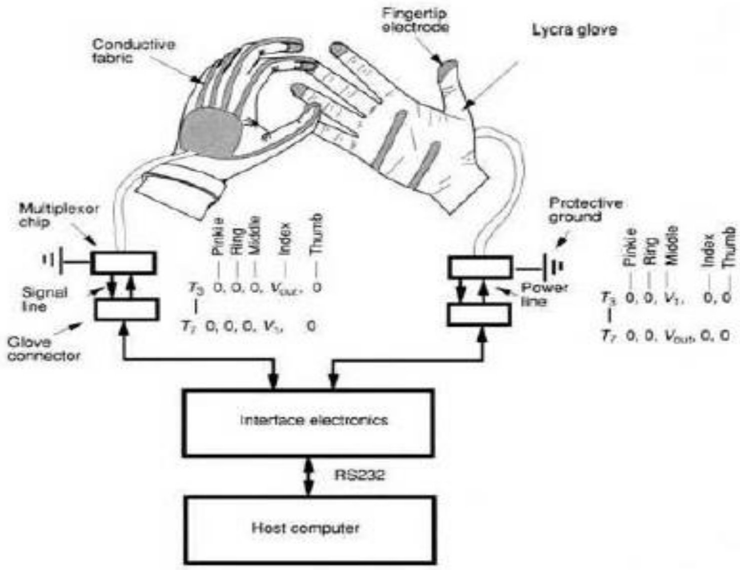


Fig. 2.26 The Pinch Glove block diagram. Adapted from McDowall et al. [2000]. Reprinted by permission of Fakespace Labs, Inc.

The Pinch Glove interface detects finger contact by applying a polling algorithm in which each finger in turn receives a voltage Vi and the interface looks for output voltages on the other fingers. At time Tl the thumb of the right hand is energized. Since it makes no contact with any finger, all the other fingers of the right hand, as well as the fingers of the left hand, will show 0 V on their output. At timeT2 the index of the right hand is energized, and again no voltages are detected on the other fingers. At time T3 the middle finger of the right hand receives voltage V1 and the interface detects a voltage V,, t on the index of the left hand, meaning the two fingers are in contact.

The 5DT Data Glove:

In order to detect incremental changes in the user's finger configuration, sensing gloves need to measure the finger joint angles over their full range of motion. The number of sensors depends on whether each joint is measured separately or not. Each finger has a fiber loop routed through attachments which allow for small translations due to finger bending. Additional sensors for minor joints as well as abduction-adduction are available in the5DT Data Glove 16 option. The advantage of fiber-optic sensors is their compactness and lightness , and users feel very comfortable wearing the glove. The optical fibers are joined to an opto electronic connector on the back of the hand. One end of each fiber loop is connected to an LED, while light returning from the other end is sensed by a phototransistor. When the fiber is straight, there is no attenuation in the transmitted light, as the index of refraction of the cylindrical walls is less than there fractive index of the core material. The fiber walls are treated to change their index of refraction such that the light will escape upon finger flexion. In this way the glove measures the finger bending indirectly based on the intensity of the returned light. The sensors used by the 5DT Data Glove 5 are similar to those incorporated in the much earlier VPL Data Glove. That glove, sold in the late 1980s, had a separate control box holding the optoelectronics circuitry, as well as analog-to-digital converters, multiplexers, and RS232 communication ports .Advances in electronics and miniaturization techniques allowed the shrinking of the electronics interface to the size of a small box placed on the user's wrist. Another technological advance is wireless communication, which significantly increases the user's work envelope to a hemisphere of 30m radius centered on the wireless receiver. The wireless receiver gets 100 samples every second(fingers and tilt sensor data), which are then sent to the host computer running the simulation. Different frequencies are used for

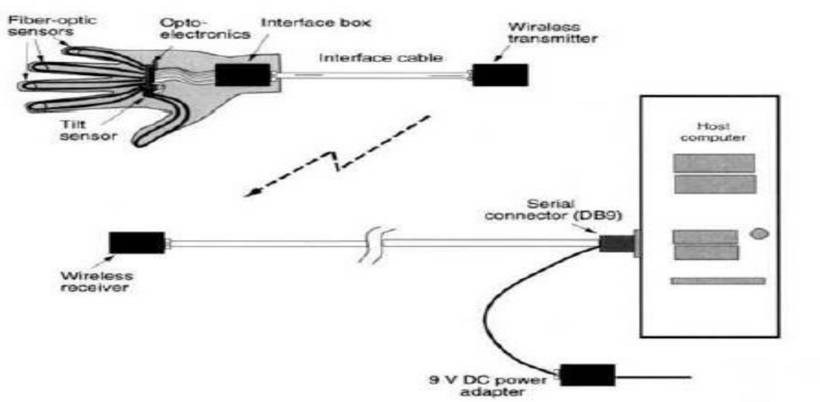


Fig. 2.27 The 5DT Data Glove 5W block diagram. Adapted from Fifth Dimension Technology Inc. [2000]. Reprinted by permission.

Fig. 2.28 The 5DT Data Glove 5 gesture library. From Fifth Dimension Technology Inc. [2000]. Reprinted by permission.

The Didji glove:

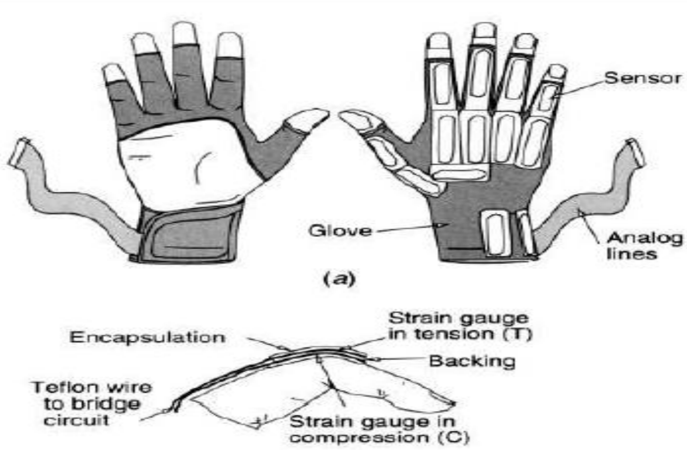
Another sensing glove is the Didjiglove, which uses 10 capacitive bend sensors to measure the positionof the user's fingers [Anon, 2000]. The capacitive sensors consist of two layers of conductive polymerseparated by a dielectric. Each conductive layer is arranged in a comblike fashion, such that theoverlapping electrode surface is proportional to the amount of sensor bending [Neely and Restle,1997]. Since capacitance is directly proportional to the overlapping surface of the two sensor electrodes, the bending angle can be measured electrically. The Didji glove interface is located on the user's cuff, similar to the 5DT Data Glove. It has an A/D converter, a multiplexer, a processor, and an RS232 line for communication with the host computer. The10-bit A/D converter resolution is 1024 positions for the proximal joint (closest to the palm) and the Inter phalangeal joint (the intermediate joint of the finger). Calibration is done similar to the 5DT Data Glove, by reading the sensor values when the user keeps the fingers extended (value set to 0) and when the fingers are bent (value set to 1023). The Didji glove was designed as an advance programming interface for computer animation, for user input to such toolkits as 3D Studio Max, Softimage, and Maya[Tehrani, 1999]. However, the small glove latency (10 msec) and its low cost make the Didgi glove useful for VR interactions as well.

The CyberGlove:

A more complex (and more expensive) sensing glove, which uses linear bend sensors, is the Cyber Glove [Immersion Co., 2001]. This glove was invented by Jim Kramer as a gesture recognition interface in order to aid persons with speech impairments [Kramer and Leifer, 1989]. It subsequently became apparent that the same device could be successfully used as a VR interface .The Cyber Glove incorporates thin electrical strain gauges placed on an elastic nylon blend material,

as shown in Figure 2.29 [Kramer et al.,1991]. The palm area (and the fingertips in some models) is removed for better ventilation and to allow normal activities such as typing, writing, etc. As a result the glove is light and easy to wear.

The glove sensors are either rectangular (for the flexion angles) or U-shaped (for adductionabductionangles). There are between 18 and 22 sensors in the glove, used to measure finger flexing(two or three per finger), abduction (one per finger), plus thumb anteposition, palm arch, and wrist yawand pitch. According to the manufacturer, sensor resolution is 0.5° and remains constant over the entire range of joint motion [Immersion Co., 2001]. It is further claimed that this glove has decoupled sensors so that outputs are independent of each other. Currently the Cyber Glove is a de facto standard for high-performance hand measurements. This isdue to its large number of sensors, its good programming support, and its extension into more complex haptic gloves (discussed in Chapter 3). Table 2.3 compares the sensing gloves described here.



VC 2.3

TABLE 2.3. Performance Comparison of Various Sensing Gloves

Specifications	Pinch Glove	5DT Data Glove	Didjiglove	CyberGlove
Number of sensors	7/glove (2 gloves)	5 or 14 /glove (1 glove)	10/glove (2 gloves)	18 or 22/glove (1 glove)
Sensor type	Electrical	Fiber-optic	Capacitive	Strain gauge
Records/sec	NA	100 (5DT 5W), 200 (5DT 5)	70	150 (unfiltered), 112 (filtered)
Sensor resolution	1 bit (2 points)	8 bit (256 points)	10 bit (1024 points)	0.5°
Communication rates	Wired (19.2 kb)	Wireless (9.600 kb), wired (19.2 kb)	Wired (19.2 kb)	Wired (115 kb)
Wrist sensors	None	Pitch (5DT 5 model)	None	Pitch and yaw

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) *Objective Questions*

1. Which of the following(s) is / are *essential* for a *Head Mounted Display (HMD)*?

1. brightness control.
2. focusing rings.
3. frequency control.
4. magnification button

A : 1 only
B : 2 only
C : 1 and 2 only
D : 2, 3 and 4 only
E : All of the above.

2. Which of the following(s) has / have been *ignored* but is / are needed for effective VR applications?

1. fast interactive time.
2. good graphic display.
3. the sense of smell and taste.
4. force feedback.

A : 1 only
B : 3 only
C : 1 and 3 only
D : 1, 2 and 3 only
E : All of the above.

3. Which of the following device is not the input device?

a) Trackball and space ball

b) Data glove
c) Only d
d) Impact printers

4. What is / are the disadvantage(s) of using *most* VR systems?
1. the simulators are of higher cost than their *real* counterparts.
2. addiction
3. temperary nausea, dizziness
4. difficult to use

A : 1 only
B : 3 only
C : 1 and 3 only
D : 2 and 3 only
E : All of the above

5. Which of the following(s) is / are a type of VR ?
1. A child playing a flight simulator game on a PC.
2. A drug designer viewing a drug molecule via a Head Mounted Display coupled to the computer.
3. A NASA operator controlling a space module on the moon to pick up rock samples.

A : 1 and 2 only
B : 2 only
C : 2 and 3 only
D : All of the above.

6. Which of the following relates *most* closely to Virtual Reality with respect to the audiences ?
A : Science Fiction Books
B : Comedy Drama Play
C : Action films

7. 3-Dimensional tracker is____________________________
8. Describe Navigation?
9. List out types of trackers?
10. What are commonalities and differences between 3D trackers and Gesture interfaces ?

II) Descriptive Questions

1. What are trackers? Enumerate some important tracker characteristics (make drawings to illustrate your concepts).
2. How does a wireless tracking suit work? Give examples?
3. What is the difference between an absolute and a relative position input device?
4. What are hybrid trackers?
5. What are gesture input devices and explain?
6. How do Inter Sense trackers differ from magnetic ones?
7. How does the Cyber Glove work?

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions

Q1. A Simulated experience generated by computer, like visiting the surface of the sun is called

A. Artificial Solar visitation
B. Extended experience
C. Virtual reality
D. Vicarious actuality

Q2. A device used for 3-D positional information in virtual reality systems is the:

(a) optical mouse
(b) split keyboard
(c) track ball
(d) data glove
(e) touch screen

Q3. The device which is used to position the screen cursor is
a) Mouse
b) Joystick
c) Data glove
d) Both a and c

Q4. Trackball is
a) Two-dimensional positioning device
b) Three- dimensional positioning device
c) Pointing device
d) None of these

Q5. Pressure-sensitive joysticks are also called
a) Non movable stick
b) Joystick
c) Isometric joystick
d) None of these

Q6. Which is the device that is constructed with the series of sensors that detects hand and finger motion?
a) Digitizers
b) Data glove
c) Joystick
d) Track ball

Q7. A common device for drawing, painting, or interactively selecting coordinate positions on an object is a
a) Image scanner
b) Digitizers
c) Data glove
d) Touch panels

Q8. Which device is used to input two-dimensional coordinates by activating a hand cursor on a flat surface?
a) Graphic tablet
b) Data tablet
c) Only b
d) Both a and b

Q9. ___________ can be used to determine the position on the data tablet.
a) Strip microphones
b) Signal strength
c) Coded pulse
d) Either Signal strength or coded pulse

Q10. Space ball provide________ degree of freedom.
a) 10 degree
b) 6 degree
c) 8 degree
d) 12 degree

II) Problems:

1. Describe an alternative input system to using keyboards for entering and outputting data.

2. **What input devices can I use with the Virtual Reality?**

3. Is virtual reality devices can be used in pilot training simulations?

4. can we use touch screen is both an input and output device?

5. Explain the advantages of using virtual reality headsets and data gloves.

6. Do i need additional hardware to interact VR system?

7. Explain how disabled users might find voice synthesisers useful??

8. Explain how users interact with a virtual scene displayed with different output devices?

UNIT-III

Objectives:

- Learn about Output Device and get familiar with graphic and sound displays .

Syllabus:

UNIT – III: Output Device

Graphics displays, sound displays & haptic feedback

Outcomes:

Students will be able to

- identify basic elements of virtual Reality with the components in VR systems
- describe various input and output devices required for interacting in virtual world along with rendering and modeling.
- differentiate various types of modeling,
- apply the concepts of Virtual Reality for an application.

Learning Material

GRAPHICS DISPLAYS:

Definition: A graphics display is a computer interface that presents synthetic world images to one or several users interacting with the virtual world. Other ways to characterize graphics displays are according to the type of image produced (stereo scopicor, monoscopic), their image resolution (number of pixels in the scene), the field of view (portion of the viewing volume they cover), display technology (LCD- or CRT-based), ergonomic factors (such as weight), and cost. The great variety of graphics displays is a result of the fact that vision is the most powerful human sensorial channel, with an extremely large processing bandwidth. Some VR systems may not incorporate 3D sound or haptic feedback interfaces, but all will have some type of graphics display.

The Human Visual System:

Designing or selecting a graphics display cannot be done meaningfully without first understanding the human visual system. An effective graphics display needs to match its image characteristics to those of the user's ability to view the synthetic scene.

Personal Graphics Displays:

Definition A graphics display that outputs a virtual scene destined to be viewed by a single user is called a personal graphics display. Such images may be monoscopic or stereoscopic, on ocular (for a single eye), or binocular (displayed on both eyes).

Head-Mounted Displays:

This project an image floating some 1-5 m (3-15 ft) in front of the user as illustrated in Figure 3.2. They use special optics placed between the HMD small image panels and the user's eyes in order to allow the eyes to focus at such short distances without tiring easily. Optics is also needed to magnify the small panel image to fill as much as possible of thee yes' field of view (FOV). As can be seen in Figure 3.2 [Robinett and Rolland, 1992], the unfortunate by product is that the distance between display pixels (At, A2) is amplified as well. Therefore the "granularity" of the HMD displays (expressed in arc-minutes/pixel) becomes apparent in the virtual image.

The HMD weight, comfort, and cost are additional criteria to be considered in comparing the various models on the market. Technology has made tremendous advances in miniaturizing the HMD displays and associated optics. The first LCD-based HMD (the VPL Eye Phone), which was available in the early 1990s, had a resolution of 360 x 240 pixels, a FOV of 100° horizontally and 60° vertically, and a weight of 2.4 kg (2400 grams). This large weight induced user fatigue. Modern LCD-based HMDs, such as the Olympus Eye-Trek, shown in Figure 3.4a [Isdale, 2000], weighs only about 100grams (24 times less!). This class of HMDs resembles eyeglasses, and so they are also called face mounted displays (FMDs). Key to the compactness and lightness of the Olympus FMD is the placement of its small active matrix LCD (AMLCD) display panels eccentrically, directly above the optics (as shown in Figure 3.4b) [Olympus Co., 2001]. This obviates the need for a half-mirror as used in the earlier Sony Glastron FMD. Since there is less light loss (due to the absence of the half-mirror), the image seems brighter.

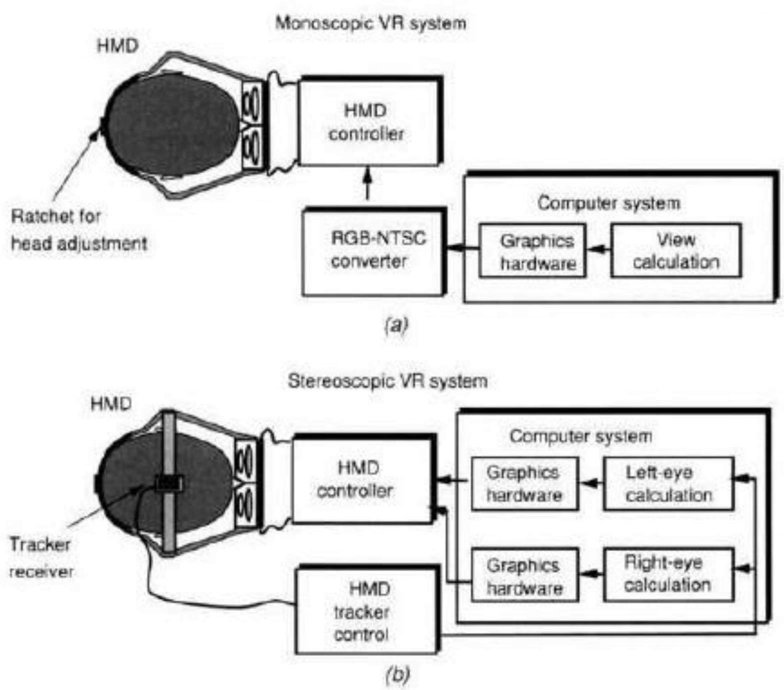


Fig. 3.3 Head-mounted display (HMD) integration in a VR system for: (a) consumer (monoscopic) HMD; (b) professional (stereoscopic) HMD. Adapted in part from Pimentel and Teixeira [19931. Reprinted by permission.

For all its ergonomic advantages, the Olympus FMD 200 has a number of drawbacks. It cannot be easily retrofitted with a head tracker, for which there are no attachments provided. A tracker receiver placed on top of the FMD will make the whole assembly fall off due to the added weight and the lack ofa restraint at the back of the head. Another problem is the FMD 200 resolution, which is only 267 x 225(or 180,000 pixels/LCD panel). Recognizing this problem, Olympus developed the FMD 700, which has the same FOV and four times the resolution of the FMD 200 model. The FMD 700 resolution of 533x 450 (720,000 pixels/LCD panel) is obtained by adding special polarization and double-refraction effects, a process which Olympus calls optical super resolution.

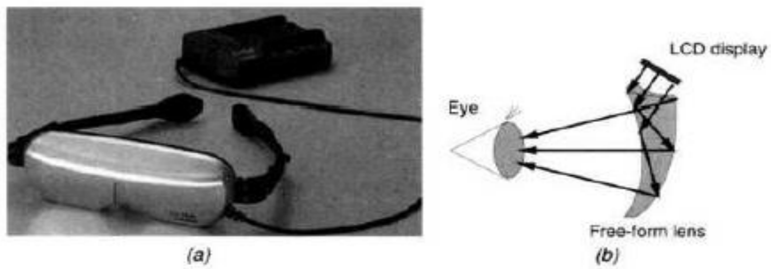


Fig. 3.4 The Olympus LCD-based Eye-Trek FMD: (a) the FMD 200; (b) optics arrangement. Adapted from Olympus Co. [2001]. Reprinted by permission.

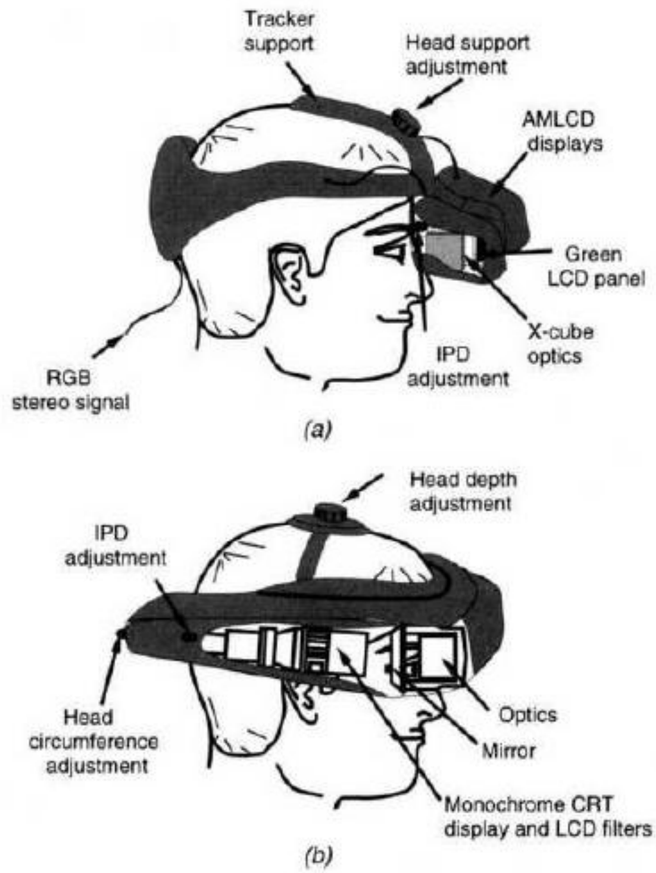


Fig. 3.6 Stereoscopic HMDs. (a) ProView XL35. Adapted from Kaiser Electro-Optics [2001]. Reprinted by permission. (b) Datavisor HiRes. Adapted from n-vision Inc. [1998].

Floor-Supported Displays:

Floor-supported displays use an articulated mechanical arm to offload the weight of the graphics display from the user. More importantly, floor-supported displays integrate sensors directly in the mechanical support structure holding the display. If six sensors are used, it is possible to determine the position and orientation of the end of the supporting arm relative to its base. This concept was developed by NASA in their counter balanced CRT-based stereoscopic viewer (CCSV) McDowall etal., 1990] and is used in the modern Boom3C display produced by Fakespace Labs [Fakespace Labs,2001].

Desk-Supported Displays:

Excessive display weight becomes an issue for HMDs and hand supported personal displays due to the user's fatigue, which can lead to neck and arm pain. Even for floor-supported displays, excessive weight is undesirable, as it increases inertia when the display is rotated and can lead to unwanted pendulum oscillations. One category of displays where weight is not an issue is desk supported displays. Unlike previously discussed personal displays, desk-supported displays are fixed and designed to be viewed while the user is sitting. Thus the user's freedom of motion is limited when compared to HMDs or HSDs.

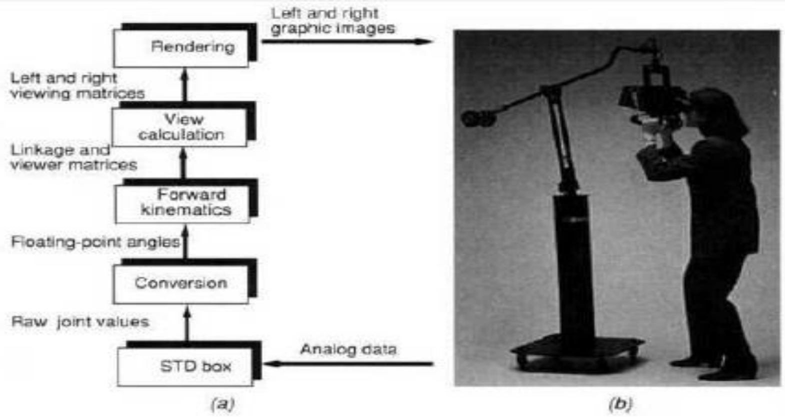


Fig. 3.8 The Boom3C floor-supported display: (a) data flow. Adapted from McDowall et al. [1990]. Reprinted by permission. (b) General appearance. Courtesy of Fakespace Labs Inc.

Large-Volume Displays:

Definition Graphics displays that allow several users located in close proximity to simultaneously view a stereo or monoscopic image of the virtual world are called large volume displays.

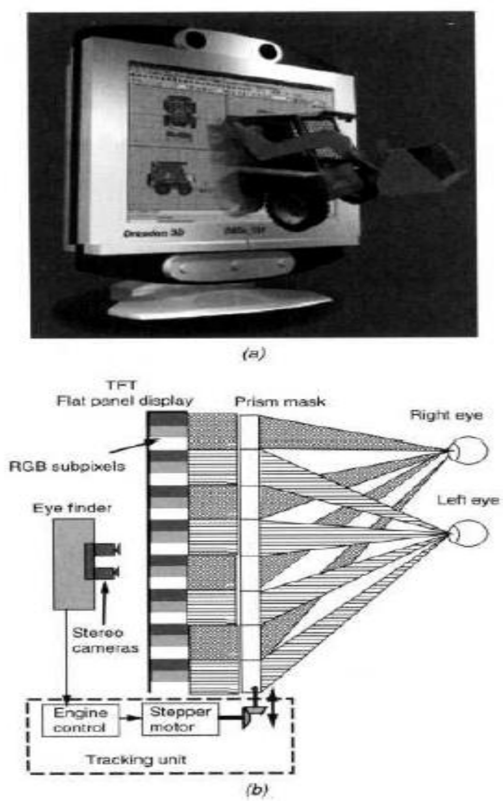


Fig. 3.11 Elsa Ecomo4D autostereoscopic display. (a) Outside apearance.Courtesy of Elsa Ag. (b)position-adaptive backlighting. Adapted from Dresden 3D [2001]. Reprinted by permission.

TABLE 3.1. Performance Comparison of Various Personal Graphics Displays[a]

Manufacturer, Display Name	Type	Resolution (pixels)	FOV (H × V)	Weight (g)	Price (10^3 $)
Olympus Eye-Trek	AMLCD, FMD	267 × 225	30° × 23°	100	0.5
Daeyang cy-visor	LCOS, LCD, FMD	800 × 600	60° × 43°	160	1
Kaiser ProView XL35	AMLCD, HMD	1024 × 768	28° × 21°	992	20
n–vision Inc. Datavisor	CRT, HMD	1280 × 1024	78° × 39°	1,587	35
NVIS Inc. Virtual binoculars SX	LCOS, LCD, HSD	1280 × 1024	42° Diagona	1,000	19.9
Fakespace Labs Boom3C	CRT, FSD	1280 × 1024	85° × H	NA	≤100
Virtual Research WindowVR	Flat panel, FSD	1280 × 1024	21 in. Diagonal	NA	13.9
Dimension Technologies Virtual Window	TFT, LCD, autostereo	1280 × 1024 2D, 640 × 1024 3D	18.1 in. Diagonal	11,250	7
Elsa Ag. Ecomo4D	TFT, LCD, autostereo	1280 × 1024 2D, 640 × 1024 3D	18 in. Diagonal	17,000	15

Monitor-Based Large-Volume Displays:

The smallest large-volume stereo display uses active glasses in connection with one stereo-ready monitor. As illustrated in Figure 3.12a, each user wears a set of shutter glasses and looks at the monitor. The stereo-ready monitor is of a special design that is capable of refreshing the screen at double the normal scan rate, or between 120 and 140 scans/sec. A computer sends two alternating, slightly offset images to the monitor, as illustrated in Figure 3.12b. An infrared (IR) emitter located on top of the CRT display is synchronized with the RGB signal and controls the active glasses in a wireless mode. The IR controller directs orthochromatic liquid crystal shutters to close and occlude one eye or the other alternately.

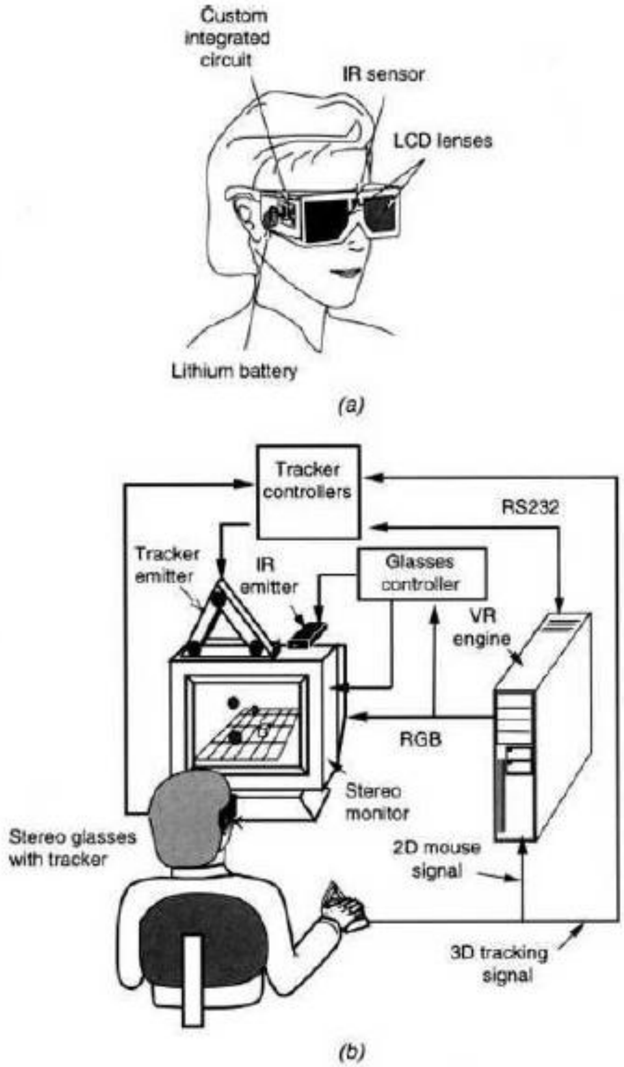


Fig. 3.12 Single CRT-based large-volume display. (a) Active stereo glasses. From Burdea [1993]. Reprinted by permission. (b) Communication diagram. From Burdea and Coiffet [1993]. © Editions

Projector-Based Displays:

A CRT projector uses three tubes (R, G, B) to produce a high-resolution (1280 x 1024 pixels) image at 120 Hz [Barco, 1999a]. When operating in frame sequential stereo mode, the projector splits the number of scan lines in two, and the user wearing active glasses sees a stereo image refreshed at 60 Hz. Special "fast green" coating is needed for the phosphor used in the CRT tube to reduce its visual persistence, otherwise the stereo effect is lost since both images will be projected at the same time. CRT projectors have a number of drawbacks related to cost and their inability to project bright images. High-end CRT projectors have luminance on the order of 200-300 lumens, such that they are adversely affected by ambient light. This requires light-tight enclosures (or drapes) to be constructed round the display, consuming additional space and resources. More recently digital projectors have started to replace the older CRT ones, as they have an order-of-magnitude higher luminance. The key component of a digital projector is the digital micro mirror device (DMD) [Younse, 1993] developed by Texas Instruments Inc. The DMD consists of a chip with an array of very small (16 gm) aluminium mirror elements.

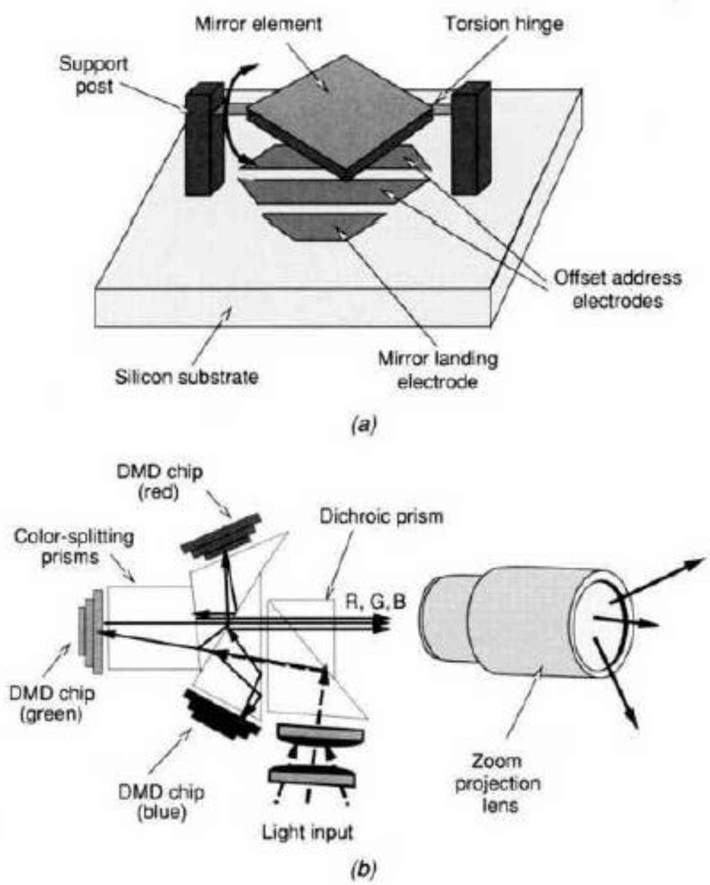


Fig. 3.15 Digital Micromirror Device (DMD) display: (a) the micromirror element. Adapted from Younse [19931; (b) the Texas Instruments DMD-based projector. Adapted from Lubell [20001. © 1993, 2000

SOUND DISPLAYS:

Definition: Sound displays are computer interfaces that provide synthetic sound feedback to users interacting with the virtual world. The sound can be monoaural (both ears hear the same sound) or binaural (each ear hears a different sound).

Sound displays play an important role in increasing the simulation realism by complementing the visual feedback provided by the graphics displays previously discussed. Assume a user is looking at a virtual ball bouncing in a virtual room that is displayed on a CRT monitor. The user's mind says that he or she should also hear a familiar "plop-plop-plop" sound. When sound is added, the user's interactivity, immersion, and perceived image quality increase. In this scenario simple mono aural sound is sufficient, as the ball is always in front of the user and being displayed by the monitor.

The Human Auditory System:

Three-dimensional sound displays cannot be effective without an understanding of the way we localize sound sources in space. Humans perceive sound through vibrations arriving at the brain via the skeletal system or via the ear canal. Within the scope of this book we are interested in the ear's ability to detect the position of a sound source relative to the head.

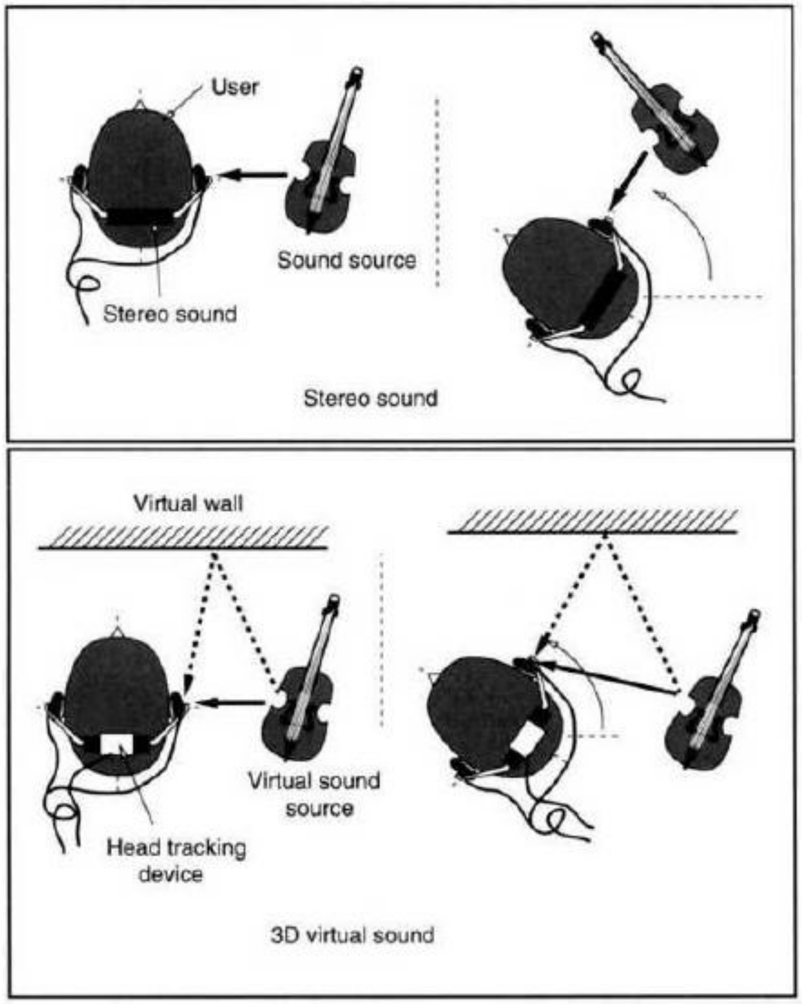


Fig. 3.20 Stereo sound versus 3D virtual sound. From Burdea and Coiffet [1993]. @ Editions Hermes. Reprinted by permission.

The Convolvotron:

The user then has the sensation of hearing that sound as coming from a virtual speaker placed in space accordingly. This signal processing technique, called convolving, was developed by researchers at NASA, and works well to produce 3D sound.

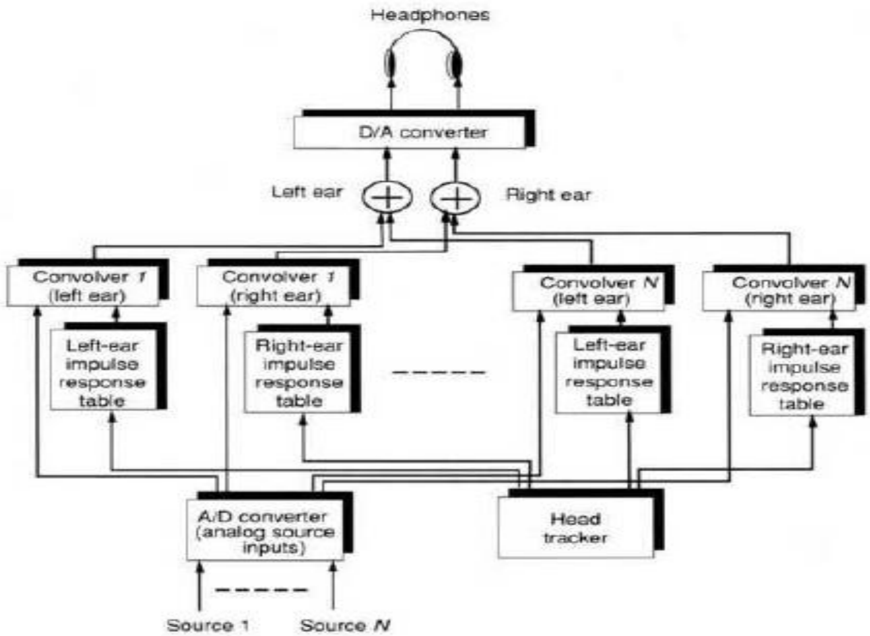


Fig. 3.23 The generic Convolvotron block diagram.

Speaker-Based Three-Dimensional Sound:

The high price of the Huron 20 (approximately $40,000) makes it impractical for consumers who want to add 3D sound to their PC or home theatre electronics. Such setups typically do not incorporate head trackers, and display sound on multiple loudspeakers rather than on head phones. The simplest multi speaker audio system is the stereo format, which produces sound that appears to come from the plane defined by the two speakers. An improvement is the quad format, where two speakers are in front and two are behind the user. Another setting is the "5.1 surround" format, in which three speakers are in front of the user, two are lateral (left and right), and one is a subwoofer. Such multichannel audio systems produce a richer sound than stereo, but are more expensive and complex and occupy more space. Furthermore, the sound clearly comes from the loudspeakers, not the environment, and seems to stick around the perimeter of the room. Since HRTFs are not used, the illusion of sound coming from a location other than the speakers cannot be realized [Kraemer, 2001].

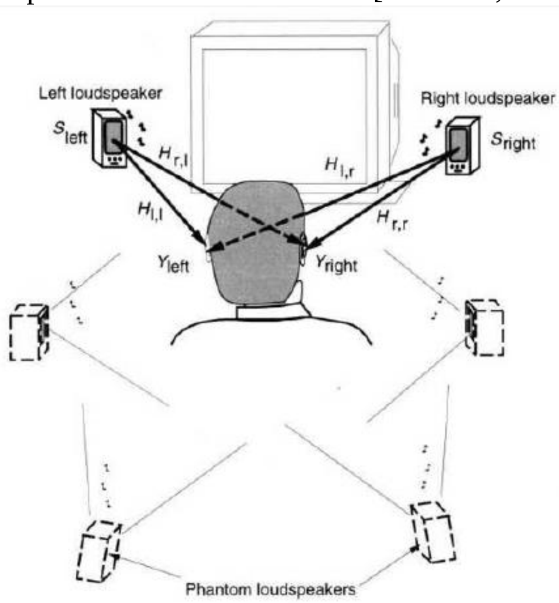


Fig. 3.25 Speaker-based 3D audio. Adapted from Kraemer [2001]. © 2001 IEEE. Reprinted by permission.

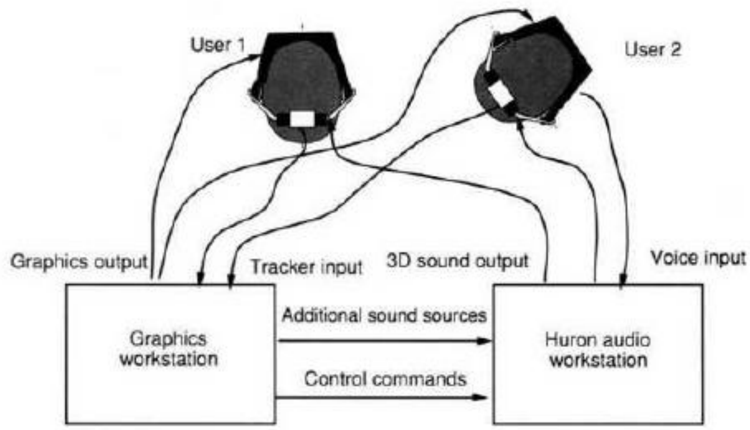


Fig. 3.24 The Huron 20 audio workstation. Adapted from Lake Technology [2002]. © Lake Technology Ltd. Reprinted by permission.

HAPTIC FEEDBACK:

The last category of 1/0 devices discussed in this chapter is haptic interfaces. Named after the Greekterm hapthai (meaning "touch"), they convey important sensorial information that helps users achieve tactile identification of virtual objects in the environment and move these objects to perform a task[Cutt, 1993; Burdea, 1996]. When added to the visual and 3D audio feedback previously discussed, haptic feedback greatly improves simulation realism.

Definition Touch feedback conveys real-time information on contact surface geometry, virtual object surface roughness, slippage, and temperature. It does not actively resist the user's contact motion and cannot stop the user from moving through virtual surfaces.

Definition Force feedback provides real-time information on virtual object surface compliance, object weight, and inertia. It actively resists the user's contact motion and can stop it (for large feedback forces).

The Human Haptic System:

Input to the human haptic system is provided by the sensing loop, while output to the environment (in this case the Haptic interface) is mediated by the sensory-motor control loop. The input data are gathered by a multitude of tactile, proprioceptive, and thermal sensors, while the output is forces and torques resulting from muscular exertion. The system is not balanced, in the sense that humans perceive hapticly much faster than they can respond.

Haptic Sensing:

In order to interact physically with humans and the unstructured environments in which they live, robots will need an accurate and sophisticated sense of touch.

The sense of touch

We use our sense of touch to interact with each other and with our environment. It has been said that of all the senses, if lost, touch has the most detrimental effect on a person’s quality of life. With the absence of a tactile sense, humans are no longer able to control objects, or even their own limbs, without significant visual feedback and effort, as well as losing the ability to meaningfully interact and communicate with each other physically. The sense of touch is an essential part of autonomous independent existence and has a significant role in emotional interaction between humans.

The mechanics of the fingertip skin, on both the macro and micro scale, have vital and often overlooked roles to play in our sense of touch. By exploiting some key features of the skin we aim to gain new tactile sensor designs that have the same high compliance needed to be highly sensitive and detailed tactile sensors and strength to be capable and versatile gripping and manipulating tools.

Fingertip design

The micro structure of the fingertip skin has specific functional features that have yet to be exploited in tactile sensor design. This research has developed a hypothesis of the functional morphology of the Dermal Papillae and the Meissner's Corpuscles in creating an edge encoding of tactile information. This hypothesis determines that these skin features actually act as an edge filter to the tactile information we receive, before any neuro physiological processing. This 'computational morphology' is heavily dependent on the high compliance and strength of the fingertip skin macro structure.

Sensory-Motor Control:

The tactile, proprioceptive, and kinesthetic sensing is used by thebody's sensory-motor control system to affect the forces applied on the haptic interface. Key aspects of the human sensory-motor control are maximum force exertion capability, sustained force exertion, force tracking resolution, and force control bandwidth.

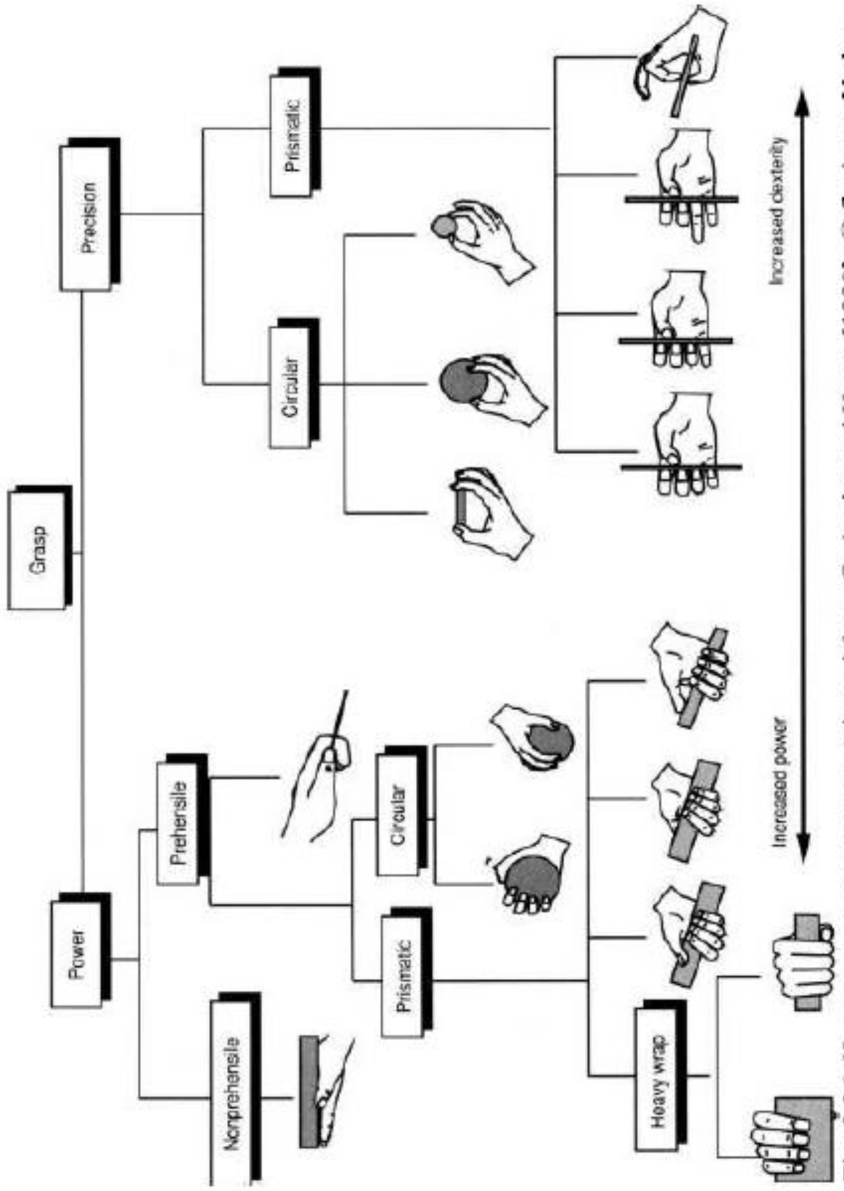


Fig. 3.26 Human grasp geometries Adapted from Cutkosky and Howe [1990]. © Springer-Verlag GmbH. Reprinted by permission.

Tactile Feedback Interfaces:

The first category of haptic interfaces discussed here is tactile feedback devices for the hand. There are many ways in which skin tactile receptors can be stimulated, ranging from air bellows and jets, to electrical actuators producing vibration, to micropin arrays, direct electrical stimulation, and functional neuromuscular stimulations. Electro tactile feedback provides electric pulses to the skin (with varying width and frequency). Neuromuscular stimulation provides the signal directly to the user's primary cortex. Both techniques are considered by the authors to be risky and are not discussed here. Instead we discuss commercially available interfaces for the hand that provide vibrotactile feedback and temperature feedback.

The Tactile Mouse:

The computer mouse is a standard interface, serving as an open-loop navigation, pointing, and selecting device. By open-loop we mean that the information flow is unidirectional, being sent from the mouse to the computer.

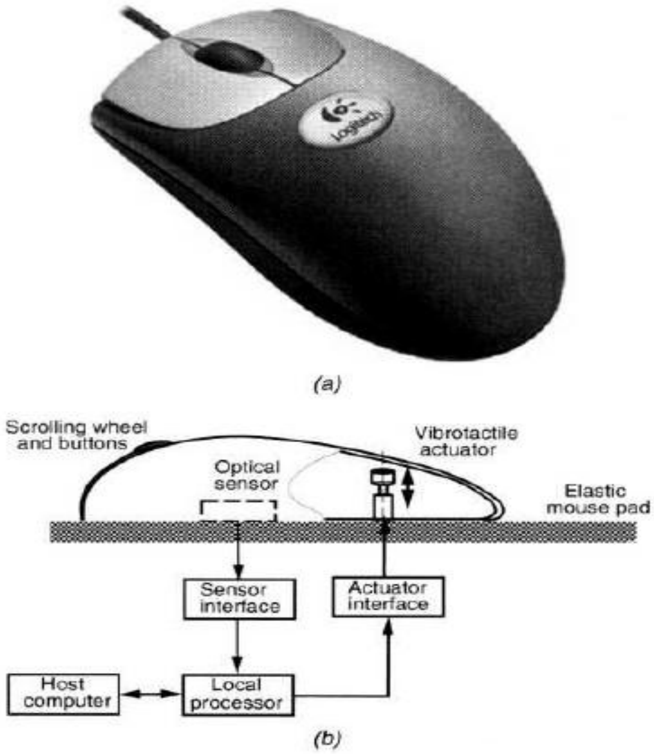


Fig. 3.27 The iFeelTM tactile feedback mouse. (a) Outside appearance. From Logitech Co. [2002]. © 2002 Logitech. All rights reserved. Logitech, the Logitech logo, and other Logitech marks are owned by Logitech and may be registered. Reprinted by permission. (b) Tactile feedback system. Adapted from Rosenberg and Martin [2001]. © 2001 Immersion Co. Reprinted by permission.

The Cyber Touch Glove:

This is another haptic interface that provides vibro tactile feedback to the user. As illustrated in Figure 3.28, the device is a Cyber Glo veretro fitted with six vibrotactile actuators.

Cyber Touch glove is most suitable for dexterous manipulation tasks, where contact is at the fingertips, since it has the ability to provide feedback to individual fingers. This is a definite advantage over their Feel mouse previously described. Furthermore, by exciting more than one actuator at a time it is possible to generate complex tactile feedback patterns with a relatively light structure (5 oz). Finally, the Cyber Touch glove significantly increases the user's freedom of motion compared with the iFeelmouse, which requires that the user's hand be kept on the desk.

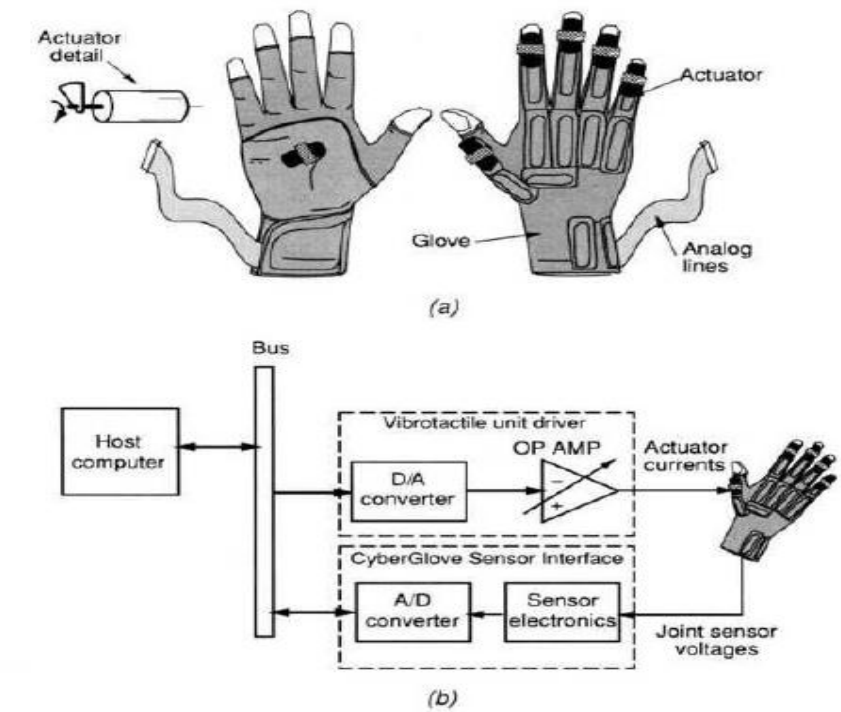


Fig. 3.28 The CyberTouch glove. Adapted from Tremblay and Yim [2000]. © 2000 Immersion Co. Reprinted by permission.

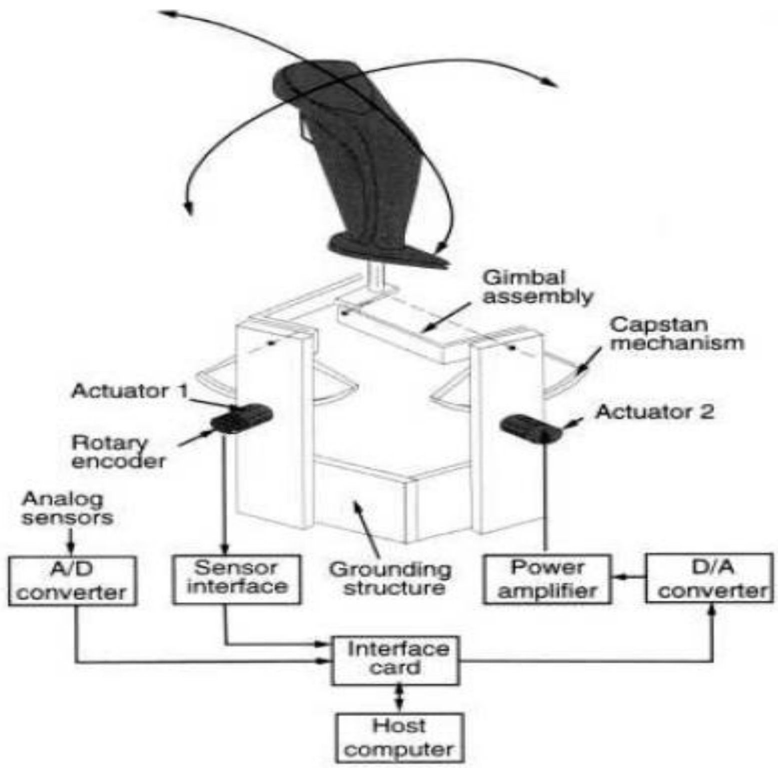
Force Feedback Interfaces:

Definition The mechanical bandwidth of a force feedback interface represents the frequency of force and torque refreshes (in hertz) as felt by the user (through finger attachments, handles, gimbals, etc.). Force feedback interfaces are devices that differ in several aspects from the tactile feedback interfaces previously discussed. First, the requirement to provide substantial forces to stop user's motion implies larger actuators, heavier structures (to assure mechanical stiffness), larger complexity, and greater cost. Furthermore, force feedback interfaces need to be grounded (rigidly attached) on some supportive structures to prevent slippage and potential accidents. Force feedback interfaces such as joysticks and haptic arms are not portable, since they are grounded on the desk or on the floor.

Force Feedback Joysticks:

These are some of the simplest, least expensive and most widespread force feedback interfaces today. These have a small number of degrees of freedom and a compact shape and produce moderate forces with high mechanical bandwidth. One illustrative example is the Wing Man Force 3D joystick shown in Figure 3.30a [Logitech Co., 2001], which costs $60. The joystick has three degrees of freedom, two of which have force feedback, as well as analog buttons and switches used in gaming. The force feedback structure is housed in the joystick base and consists of two DC electrical actuators connected to the central handle rod through a parallel kinematic mechanism [Rosenberg, 1998]. Each actuator has a capstan drive and pulley, which moves a gimbal mechanism, composed of two rotating linkages.

(a)



(b)

Fig. 3.30 The WingMan© ForceTM 3D joystick. (a) Outside appearance. From Logitech Co. [20011. © Logitech. All rights reserved. Logitech, the Logitech logo, and other Logitech marks are owned by Logitech and maybe registered. Reprinted by permission. (b) The force feedback system. Adapted from Rosenberg [1998]. © 1998 Immersion Co. Reprinted by permission.

SECTION-A

1. What is HMD , describe the human visual system?

2. Explain graphics display with any of two graphics displays?

3. Explain convolvotron with neat sketch?

4. Give explanation about human auditory system with an example?

5. What is haptic feedback and how human haptic system works?

6. Which the areas relies most heavily on advanced haptic hardware in the area of VR interaction?

SECTION-B

1. A term for Illusion of immersion by projecting stereo images on the walls and floor of a room.

a) CAVE b) BOOM c) GUI d) HMD

2. It is a mediated environment which creates the sensation in a user of being present in a (physical) surrounding.

a) WWW **b) VR** c) HMD d) GUI

3. A type of VR environment in which subjects are visually isolated from the real environment.

a) Immersive b) Semi immersive

c) Non immersive d) Augmented

4. In this type of VR environment, the subjects can perform both in the real and virtual environment.

a) Immersive **b) Semi immersive**

c) Non immersive` d) Augmented

5. In this type of VR environment, the three-dimensional scene is considered as a part of the physical environment.

a) Immersive b) Semi immersive

c) Non immersive d) Augmented

6. A device produces an illusion of movement from a rapid succession of static pictures. **a)Zoetrope** b)Thaumatrope c)Phenakistoscope d) HMD

7. The _____________ is a piece of equipment designed to make cartoons more realistic and enjoyable. It uses stacked panes of glass each with different elements of the animation. **a)Multiplanecamera** b)VR
c)Thaumatrope d) Phenakistoscope

8. ____________ animation is used to animate things that are smaller than life size. a)Immersive b)Claymotion **c)Stopmotion** d) Augmented

9. ____________ is an emerging branch in computer science, which interprets means and method of making computers think like human beings. a)Blockchain b)VR **c)AI** d) Cloud computing

10. A term in computer terminology is a change in technology a computer is/was being used.
a)development **b)generation**
c)advancement d) growth

IV UNIT

Human Factors

Syllabus:

Methodology and terminology
- Data Collection and Analysis
- Usability Engineering Methodology

User performance studies
- Testbed Evaluation of Universal VR Tasks
- Influence of System Responsiveness on User Performance

VR health and safety issues
- Direct Effects of VR Simulations on Users
  - Direct Effects on the Visual System
  - Direct Effects on the Auditory System
  - Direct Effects on the Musculoskeletal System
- Cyber sickness
  - Neural Conflict
  - Influence of System Characteristics
  - The Influence of User Characteristics
- Guidelines for Proper VR Usage

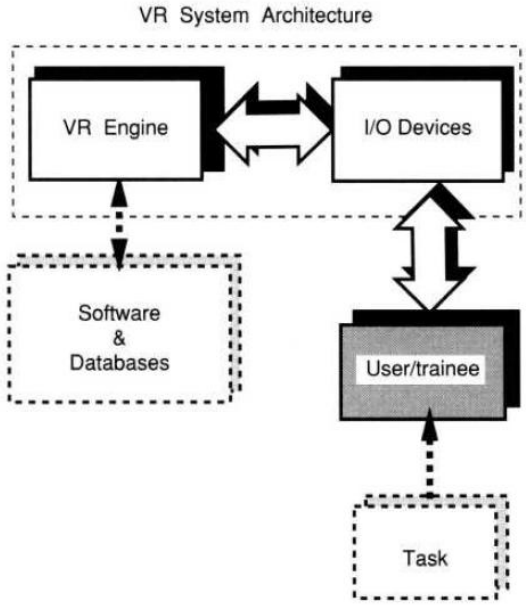
Applications

Medical Applications
- Virtual Anatomy
  - Endoscopic Examinations
- Surgery
  - Open Surgery
  - Minimally Invasive Surgery

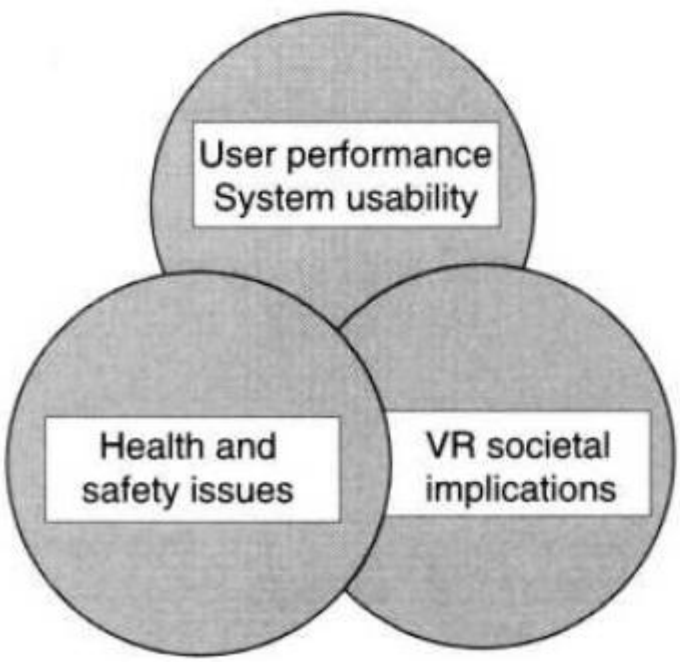
Military and Robotics Applications
- Army Use of VR
  - Single-Soldier Simulators
  - Platoon Leadership Training
  - Company and Battalion-Level Simulators
- VR Applications in the Navy
  - Virtual Environment for Submarine Ship Handling Training
  - VR-Based Close-Range Naval Artillery Training
- Air Force Use of VR
  - The Unit Trainer and the Virtual Cockpit
  - Distributed Mission Training

Methodology and terminology

HUMAN FACTORS IN VR



The preceding chapters described various VR I/O devices, rendering architectures, the way virtual worlds are modeled, and the essentials of VR programming. It was argued that multimodal interfaces (with graphics, sound, and haptics feedback), realistic modeling, and fast rendering pipelines (high frame refresh rate, reduced system latency), and increased system stability combine to produce quality simulations. It is now time to measure the user's performance when interacting with the simulation. It is also important to gauge the user's response to the technology in order to iteratively improve the VR system or the particular application design. Furthermore, it is necessary to understand why some user responses lead to simulation sickness, what are its causes, and what can be done to minimize its effects. Finally, at a higher level, it is wise to consider the benefits and negative effects that VR can have with regard to society at large.

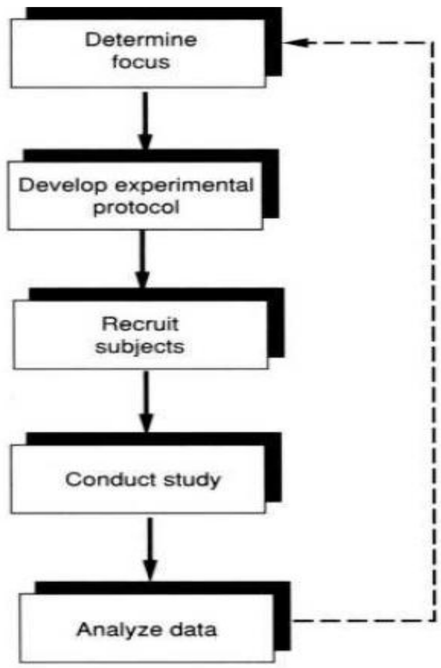


No comprehensive model of human behavior exists owing to its multidimensionality as well as large individual variability. The validity or goodness of a simulation is qualitative at best and cannot be easily quantified mathematically. It is therefore understandable that it is even more difficult to analyze human-machine interaction. The more human parameters are involved (as is the case with VR), the more difficult it is to have a valid understanding of such an interaction. Thus, determining the performance of a VR simulation is somewhat subjective. Despite these difficulties, the remainder of this chapter presents a structured approach which builds upon an increasing body of human factors research knowledge.

METHODOLOGY AND TERMINOLOGY

Definition VR human factors studies consist of a series of experiments, performed under very rigorous conditions, aimed at determining users' response to VR technology, VR technology usability, VR user safety, and the related societal impact of VR.

Regardless of their particular focus, human factors studies have to adhere to a well-documented experimental protocol. This establishes the structured sequence of experiments that all participants in the study need to perform. This sequence consists of trials, sessions, and rest periods.



Definition A trial represents a single instance of the experiment to be performed as part of a human factors study. A sequence of repeated trials constitutes a session. Sessions (and sometimes trials) are separated by rest periods for the participant in the study.

Definition A control study divides the subjects into experimental and control groups. The subjects in the experimental group perform the experiments as specified in the protocol, while the subjects in the control group do not. They are used as a basis of comparison.

Before the start of the study, subjects are recruited through advertisements, targeted e-mails, Web postings, support/focus groups, and other such venues. During the recruitment process subjects are screened for suitability for the study. For example, poor vision would preclude a subject from being enlisted in a study aimed at graphics-oriented research. Subjects are then assigned a code to protect their identity and privacy and sign a release for use of data (including photographs) in research, publications, recruitment of other subjects, etc.

Data Collection and Analysis

Virtual reality has great advantages compared to classical (paper and pencil) methods of data collection. First, the amount, temporality, and diversity of data that can be sampled during trials using a VR system are much larger than those obtained by manual recordings. Second, VR systems allow researchers to have a comprehensive view of all subject's actions while immersed in the simulation and to do so from varying viewpoints. Third, the subjects' actions can be recorded online and played back during task debriefing (as is regularly done in military training). Lastly, researchers need not be colocated with the subjects owing to the use of LANs and WANs and distributed virtual environments.

The last stage of the human factors study is to analyze the data stored in the experimental database. This data analysis usually uses the analysis of variation (ANOVA) [Stockburger, 1996], which determines whether there are statistically significant differences between data corresponding to different trials or different conditions. Experimental findings are then used to fine tune the interfacedesign, the control algorithm, or the application features. Sometimes these findings uncover new problems, which lead to a follow-up study.

Subject performance measures are based on objective and subjective criteria. Objective criteria refer to such variables as subject's task completion time, error rates, and task learning time. Subjective criteria refer to the subject's expressed preference (or lack of same) for a given interface device, control modality, or application feature. Subjective criteria also involve the degree of perceived difficulty or fatigue experienced when using a given interface or a simulation application.

Definition Task completion time represents the time span between the subject starting and ending a particular action (or sequence of actions) constituting the task.

Time is measured from the moment a subject performs the given action, for example, when first touching a virtual object or when first seeing a moving target. The end of the experiment is also linked to an action, such as releasing the virtual object, hitting a target, etc. Time can be measured online (using the system clock on the computer running the experiment) or offline with a stopwatch. Alternatively, time can be measured through the processing of a signal from a sensor actuated by the subject.

Definition Task error rate measures the type, magnitude, and frequency of errors made by the subject when performing the simulation task.

Usability Engineering Methodology

Hix and Gabbard [2002] developed a methodology of conducting VR usability studies. As illustrated in Figure 7.4a, their methodology consists of four stages: user task analysis, expert guidelines-based evaluation, formative usability evaluation, and summative evaluation. In what follows we discuss this methodology and the way it was applied in the study of a military command and control application called Dragon.

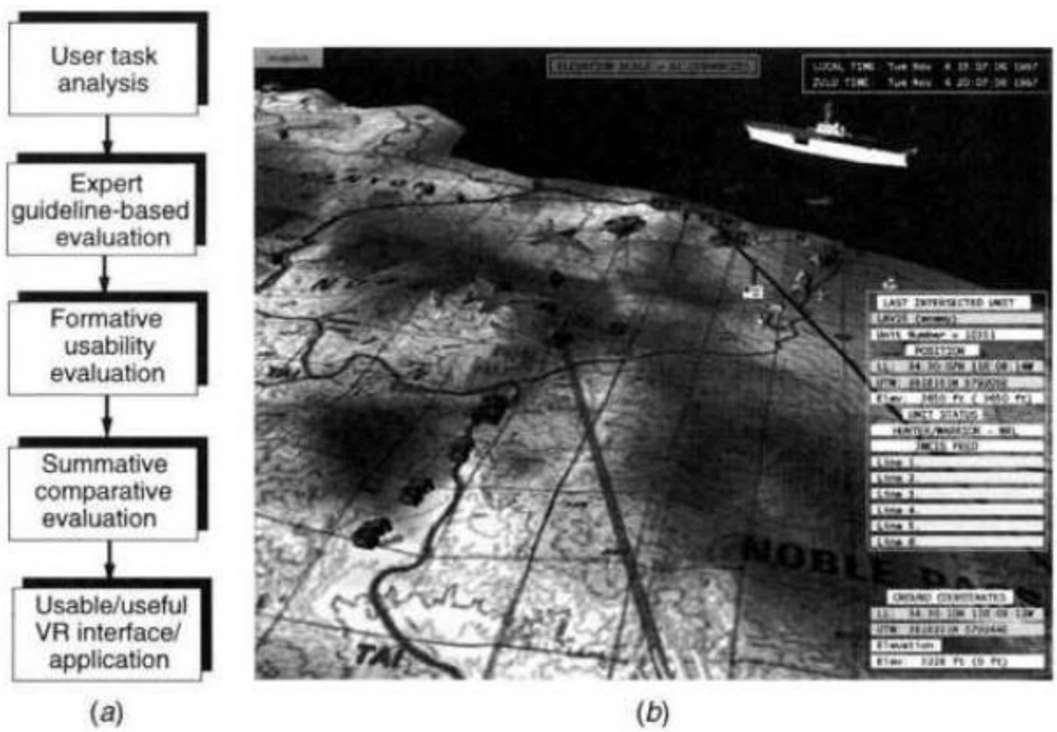
User task analysis is the first stage of a usability study. It identifies and describes the tasks and compiles a list of user actions and system resources needed to accomplish those tasks. The techniques used involve questionnaires, interviews with typical users, direct observation, and analysis of technical documentation (technical specifications or previous systems). The results of the task analysis need to identify not only actions, but also interrelationships (dependences and order sequences) between such actions. Thus, proper analysis results in structured understanding of the task, including the user's information flow during the execution of that task. Poor (missing or incomplete) task analysis is a frequent cause of bad product design (a product that is difficult to use).

The Dragon military command and control simulation involves a digital map that users (unit commanders) need to interact with during battle. As shown in Figure 7.4b, the map depicts a 3D view of the battlefield (in this case an amphibious assault), with 3D icons for airplanes, ships, tanks, trucks, etc. This differs from classic military maps, which are 2D and use 2D symbols of friendly and enemy units drawn on transparent (acetate) overlays.

It is intuitive that the ease of use (degree of usability) of such an application is critical in view of the consequences of human error in lost lives. Furthermore, the situation is complicated by the stress under which the military commander operates.

Expert guidelines-based evaluation (sometimes called heuristic evaluation) is the second stage of usability studies. It aims at identifying potential usability problems early in the design cycle and indicate why the particular components/techniques are problematic. This is a pencil-and-paper comparison of the user's actions during the task to established guidelines. Several evaluators (experts) first inspect the design alone. Subsequently, they communicate as a group in order to determine where there is consensus and what differences exist in their individual findings.

The Dragon expert evaluation concentrated on the critical task of navigation. Ease of navigation was identified as key feature since it conditioned other tasks (such as object selection, query, and manipulation of 3D icons).



Usability engineering methodology. (a) Main stages. From Hix and Gabbard [2002]. (b) Military command and control application example. From Naval Research Laboratory

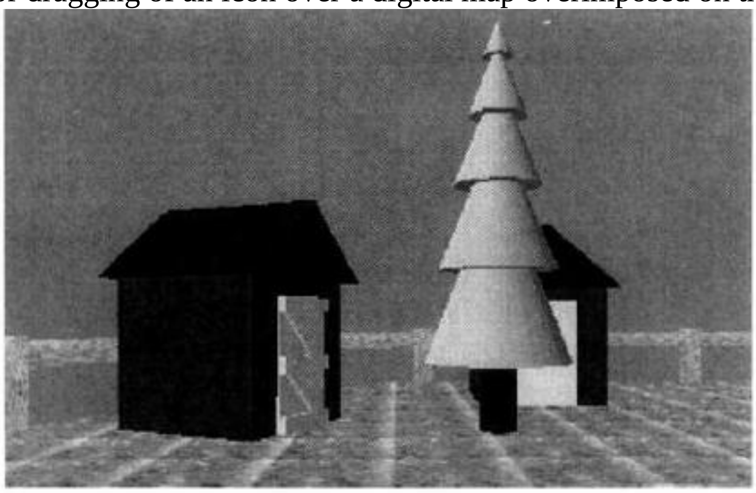
USER PERFORMANCE STUDIES

Evaluating a subject's performance during interactions with virtual worlds is a complex endeavor due to its dependence on many factors. These include the particular virtual world simulated (its complexity), the user's characteristics (age, prior computer or task knowledge), system characteristics (graphics mode, latency, I/O devices used), as well as the task characteristics and interaction techniques used.

Testbed Evaluation of Universal VR Tasks

VR testbeds are composed of a small number of universal VR tasks. These tasks, such as travel in an environment, object selection, and object manipulation, can be found in most VR applications. While more time-consuming and expensive than other types of human factors studies, testbeds provide a structured way to model subject performance. By constructing task taxonomies and analyzing performance at the subtask level, testbeds make it possible to predict a subject's performance in applications that incorporate those tasks, subtasks, and interaction techniques.

The environment contained several types of obstacles (such as fences and trees) that could be placed randomly such that travel from start to target was not immediate. Similarly, the targets (flags placed in the environment) could be randomly changed. The 38 subjects who completed the study (32 men and 6 women) were divided into seven groups of at least 5 subjects each. Each subject group traveled using a different interaction technique. These were steering-based, manipulation-based, and target-specification techniques. The subjects in the three steering-based navigation groups used pointing, gaze tracking, or torso tracking, respectively. Manipulation-based travel used HOMER or go-go techniques. HOMER interaction involves ray casting to select an object and manipulation to reach it. The go-go technique allows subjects to stretch a virtual hand much further in the VR than natural reach (using nonlinear mapping), grasp an object, and pull the view of the virtual camera forward. Finally, targetspecification techniques allow subjects to be moved by the simulation to a specified target object. Such techniques used either ray casting or dragging of an icon over a digital map overimposed on the scene.



(a)

Technique	Think time	Travel time	Total time
Gaze-directed	2.16	18.28	20.44
Pointing	2.20	22.33	24.53
Torso-directed	2.77	27.00	29.77
HOMER	4.20	37.66	41.86
Map dragging	29.54	52.39	81.93
Ray-casting	1.86	34.95	36.81
Go-go	3.29	21.48	24.77

(b)

Fig. 7.6 Testbed evaluation of navigation and searching tasks: (a) graphics scene; (b) thinking and travel time (in sec.) as a function of interaction technique. From Bowman et al. [20011. © 2001 Massachusetts Institute of Technology. Reprinted by permission.

VR health and safety issues

Definition Direct effects of VR simulations on the user involve energy transfer at the tissue level and are potentially hazardous. Indirect effects are neurological, psychological, sociological, or cybersickess and affect the user at a higher functional level.

Direct Effects of VR Simulations on Users

Direct effects of VR simulations affect mainly the user's visual system (as interactions are visually dominated), but also the user's auditory, skin, and musculoskeletal systems.

Direct Effects on the Visual System: These occur when a user is subjected to high-intensity light directed at his or her eyes. The combination of light intensity and duration of exposure exceeding tolerable limits will result in comeal burns, retinal burns, and other injuries. One example of potential damage is the laser used in miniature wearable displays, which directly illuminates the retina. Continuous viewing without hazard is only possible with Class 1 lasers of 400 nanowatts or less. comparison, the simple laser pointer belongs to Class 3a and if directed at the retina, will cause damage.

Direct Effects on the Auditory System: These affect the user if the simulation noise level is too high. According to the U.S. Occupational Safety and Health Administration, people should not hear sounds of 115 dB for more than 15 minutes/day. If the intensity is reduced to 105 dB, exposure duration increases up to 1 hour/day. In VR simulations that have 3D sound sources, the perceived intensity depends on the user's position. If the user navigates too close to a very loud simulated sound source, then the recommended limits of exposure may be exceeded and damage to the auditory system will result. The same direct effects are present if the user is stationary and the sound source is navigating in the environment. This is the case in military training where the simulation involves virtual airplanes which periodically fly over the user (trainee).

Direct Effects on the Musculoskeletal System: These effects relate to the use of haptic interfaces which can apply high level of forces or push the user's limbs beyond anatomical range limits. These hazards are present in force feedback gloves that pull fingers backward or in motion platforms that move ankles beyond normal rotation angles. These hazards may result in tendonitis, muscle pain, and other orthopedic problems. Fractures from fall may also result due to tripping over cables and tethers so prevalent in today's VR systems.

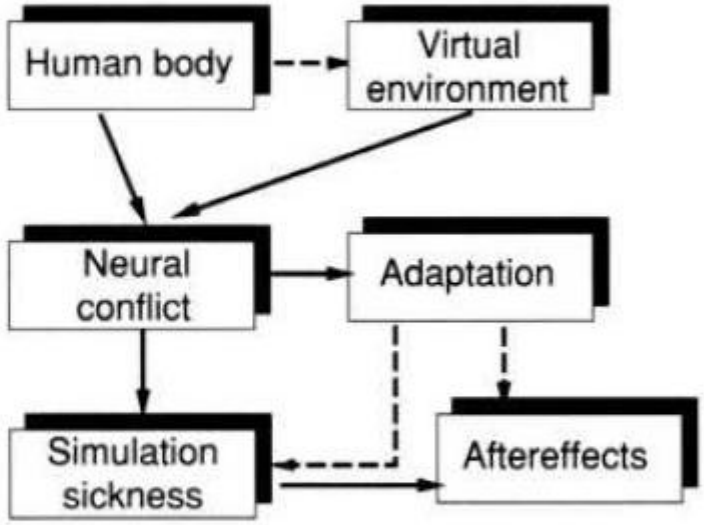
Cybersickness

Perhaps the most troublesome effect of VR simulation on the user is the onset of cybersickness. The term is used here in a more restrictive way than motion sickness and simulation sickness. Motion sickness may be induced without immersion in a simulation by simply pivoting with the eyes closed or riding a roller-coaster in an amusement park. Simulation sickness is a byproduct of interacting with a simulation, which need not involve exposure to virtual environments.

Definition Cybersickness is a form of motion sickness that results from interaction with or immersion in virtual environments. Its main symptoms are eye strain, disorientation, postural instability, sweating, pallor, drowsiness, nausea, and (in rare cases) vomiting.

The present state of VR technology and our limited understanding of human sensorimotor response explain the current high incidence of cybersickness among users. For example, 78% of users experience some form of oculomotor problems, 70% get nauseated, and 67% are disoriented following VR interactions [Stanney et al., 2002]. For some users these symptoms are so severe that they have to exit the simulation. These staggering statistics point to the need to understand the causes of cybersickness and consider probable aggravating factors (such as exposure intensity and duration). This knowledge will help us develop ways to reduce or eliminate the (negative) aftereffects of VR exposure.

Neural Conflict: This occurs when information from several sensorial channels is not in agreement, as in the case of purposely induced sensorial illusions. In other instances the sensorial conflict is due to VR's technological limitations and may trigger the onset of cybersickness, as illustrated below.



A proposed model for cybersickness

Neural conflicts associated with VR navigation involve either conflicts between sensorial data from the vestibular and visual systems or the absence of such data. A flight simulator that does not have a motion platform will only provide visual feedback, but vestibular sensors will not be excited if the head is kept still. Conversely, a properly functioning motion platform may cause sensorial conflict when the simulation involves flying through fog, with the visual feedback remaining unchanged.

Influence of System Characteristics: System characteristics such as tracking errors can affect the visual-vestibular coupling of users wearing an HMD. Such errors also affect the coupling between the motion of avatars shown in the scene and the user's proprioceptive system providing sensory information on limb motion.

TABLE 7.2. Proposed VR Motion Dynamics Classification System[a]

	Head Movement	Vehicular Movement
Rotation	Active (equivalent, altered, distinct)	Active or passive (equivalent, altered, distinct)
Translation	Active (equivalent, altered, distinct)	Active or passive (equivalent, altered, distinct)

Visual feedback characteristics are also important and potentially aggravating factors of cybersickness. Eye strain is induced by poor resolution or images presented through misaligned HMD optics. Large-FOV displays (such as display walls) can also induce a form of cybersickness called vection. This is a compelling sensation of selfmotion experienced when sitting still in an auditorium and watching rapidly changing realistic scenes projected on a large display. This is in no doubt due to the dominance of the visual sensorial channel (so-called visual capture) over the proprioceptive one.

The Influence of User Characteristics: The response to sensorial conflict differs from person to person. In other words, we are not all created equal when it comes to cybersickness. Some people exhibit cybersickness symptoms after very little time on a simulator, while other users of the same system are more "resistant," and exhibit fewer or no symptoms. Thus it is important to consider the role the user's characteristics play in making some people more prone than others to cybersickness.

It is widely believed that susceptibility to motion sickness (and thus to cybersickness) is agedependent. Susceptibility is greatest between the ages of 2 and 12 years and declines thereafter, such that at age 25 we are half as susceptible as we were at age 18. Perhaps the reason for this age-induced resistance relates to the level of neurohormonal substances in the body, since some hormones improve the user's ability to adapt to visuovestibular sensorial conflicts. Generally speaking, female users are approximately three times more susceptible to cybersickness than male users. Their susceptibility is also affected by such factors as pregnancy and the menstrual cycle, factors that are known to affect the level of hormones in the body.

Influence of a User's Degree of Interactivity: This factor, expressed as a user's navigation techniques, also influences cybersickness. Recall that in Table 7.2 we distinguished between passively experienced navigation and navigation under the user's active control. When users interact with the simulator through an interface, they exercise their muscles and move their limbs, and thus the proprioceptive/haptic system provides additional sensorial data to the central nervous system. Such data play a positive role in reducing the effects of cybersickness through accelerated adaptation.

Guidelines for Proper VR Usage

We conclude our discussion on the effects of VR exposure by compiling a set of guidelines meant to minimize the onset and severity of cybersickness. These guidelines, outlined in below Table, are largely qualitative owing to the variability in hardware performance, application domains, and interaction techniques encountered in today's VR systems. The guidelines are based largely on the usage protocols developed at the University of Central Florida, on the results of the human factors studies previously presented, and on common sense. They are neither all-encompassing nor static. Indeed, as VR technology and interaction techniques improve, some of the guidelines presented here will become obsolete. We may very well reach a point where all that has to be controlled is immersion time, primarily to prevent VR overdose.

TABLE 7.3. VR Design and Usage Guidelines Aimed at Minimizing Cybersickness[a]

During system development
Minimize latencies and make them stable
Avoid pulsating light sources of low frequency
Reduce spatial frequency content in large displays
Ensure that HMDs have properly aligned optics and sufficient resolution
Reduce intensity and duration of loud 3D sound sources
Use accurate trackers and remove sources of interference
Assure consistency in multimodal displays
Before immersion
Screen users whenever possible for susceptibility to cybersickness
Place warning labels and educate users about potential adverse effects from VR exposure
Limit exposure to users who are free from drugs and alcohol consumption
Encourage users to be well rested before exposure
Discourage VR usage by those with cold, flu, binocular anomalies, or susceptibility to migraines or photic seizures
During immersion
Provide proper airflow and comfortable air temperature (preferably below 70°F)
Ensure equipment fits users comfortably through necessary adjustments
Minimize initial exposure time for strong stimuli (10 minutes or less)
Monitor users for signs of cybersickness
Inform users they can/should discontinue the simulation if they so wish
After immersion
Measure user hand–eye coordination and postural stability
Introduce a time period immediately after VR exposure in which users are not allowed to perform high-risk activities (driving, piloting, biking, etc.)
Possibly reimmerse users in a readaptation simulation
If necessary, follow up with users to monitor prolonged aftereffects
Introduce intersession periods of 3–5 days.

In recent years increased computer and Internet usage in medicine has started to change the way health care is delivered. The power of computing allows online medical education, patient databases, presurgery simulation, use of robotics, remote consultation, digital radiography, expert systems, and so on.

Medical VR is a form of medical informatics, which has seen a steady, albeit slow growth over the past decade. The process has been hampered by a lack of standards in data format and validation measures, expensive VR technology, and the requirement to show cost savings put in place by managed healthcare organizations. That is why, of the multibillion dollars of medical informatics expenditures made in 1996, only $20 million was spent on VR. Despite these limitations, VR brings numerous advantages to the medical community. These include improved medical training (errors made on virtual, rather than real patients; modeling of unusual and rare cases), more realistic certification procedures (objective measures of surgical skill, for example), and more enjoyable treatment (in the case of virtual rehabilitation). The examples given here in the areas of human anatomy, diagnosis, surgical skill training, and virtual rehabilitation should make these advantages more apparent.

Virtual Anatomy

We start our discussion with anatomy teaching, as it is the basis of medical education throughout the world. Until now, the art of teaching medical students has not kept pace with advances in knowledge and technology. The majority of current anatomy courses use textbooks (reminiscent of the atlases introduced in the 16th century) and cadavers for dissection. Unfortunately for the student, textbooks are becoming larger and more expensive, while access to cadavers is harder to get.

Earlier efforts to improve teaching efficiency used digitized photographs and 2D (non-immersive) anatomy models on CD-ROM. By the mid 1990s a much more detailed anatomical database, called the Visible Human, became available.

With the creation of the Visible Human, researchers and educators throughout the world had a common database on which to test 3D shape extraction and animation algorithms necessary in the development of realistic anatomy course material. Creating animations of 3D organ models based on the Visible Human database is a precursor to developing a computerized anatomy teaching curriculum. An example is the Anatomic VisualizeR created at the University of California at San Diego and now being used by the Uniformed Services University of the Health Sciences (Bethesda, MD). The Anatomic VisualizeR provides a virtual dissection room in which students can explore various aspects of anatomy organized into teaching modules (skull, ear, thorax, abdomen, and neuroscience). Each lesson allows a student wearing active glasses to view an interactive anatomical model rendered in stereo by an SGI workstation. Students can create and manipulate cross-section views, measure and identify structures, change the opacity of organs (for better view of hidden components), draw lines, link modules, and so on. Below figure is a view of the ear module, showing a larger-than-life model of the intricate inner ear structures.

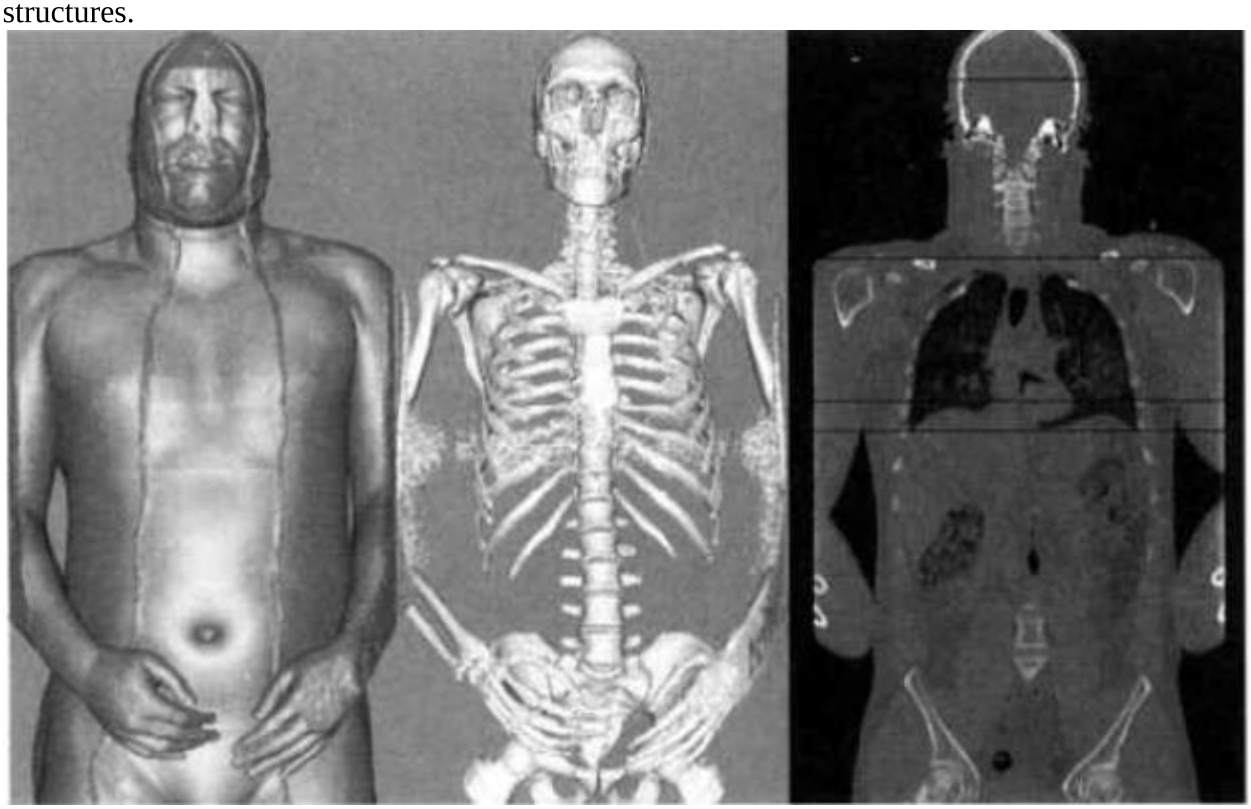


Fig. Anatomical reconstruction of the Visible Man.

Endoscopic Examinations:

These are routinely done to detect cancer or diagnose other diseases affecting various parts of the body. The procedures are performed by inserting a flexible viewing device (the endoscope) in body cavities and viewing the images of the body interior displayed on an adjacent monitor. Depending on the region of interest, such examinations are called colonoscopies (for the lower intestine), bronchoscopies (for the airway-nasal area, vocal chords, trachea, and bronchies), and angioplasties (for the blood circulatory system).

Regardless of their name, endoscopic examinations are invasive (since the endoscope is inserted into the patient), uncomfortable (requiring patient anesthesia), and can lead to injury and complications (even death) if the endoscope scrapes or perforates the cavity wall. Thus the procedure requires good reasoning and manual skills.

The foregoing discussion highlights the need for medical simulators that would allow physicians to make errors without affecting real patients, would allow physicians to resharpen their skills periodically, and could be used in medical certification. In 1998 HT Medical Systems Inc. (now part of Immersion Co.) introduced the PreOp bronchoscopy simulator, shown in Figure [HT Medical Systems Inc., 1998a]. The system consists of a real fiber-optics flexible endoscope introduced in a robotic interface that provides haptic feedback, and a PC running the VR simulation. The graphics consists of a textured anatomical model of the airway (based on the Visible Man database), which responds dynamically to trainee's actions.

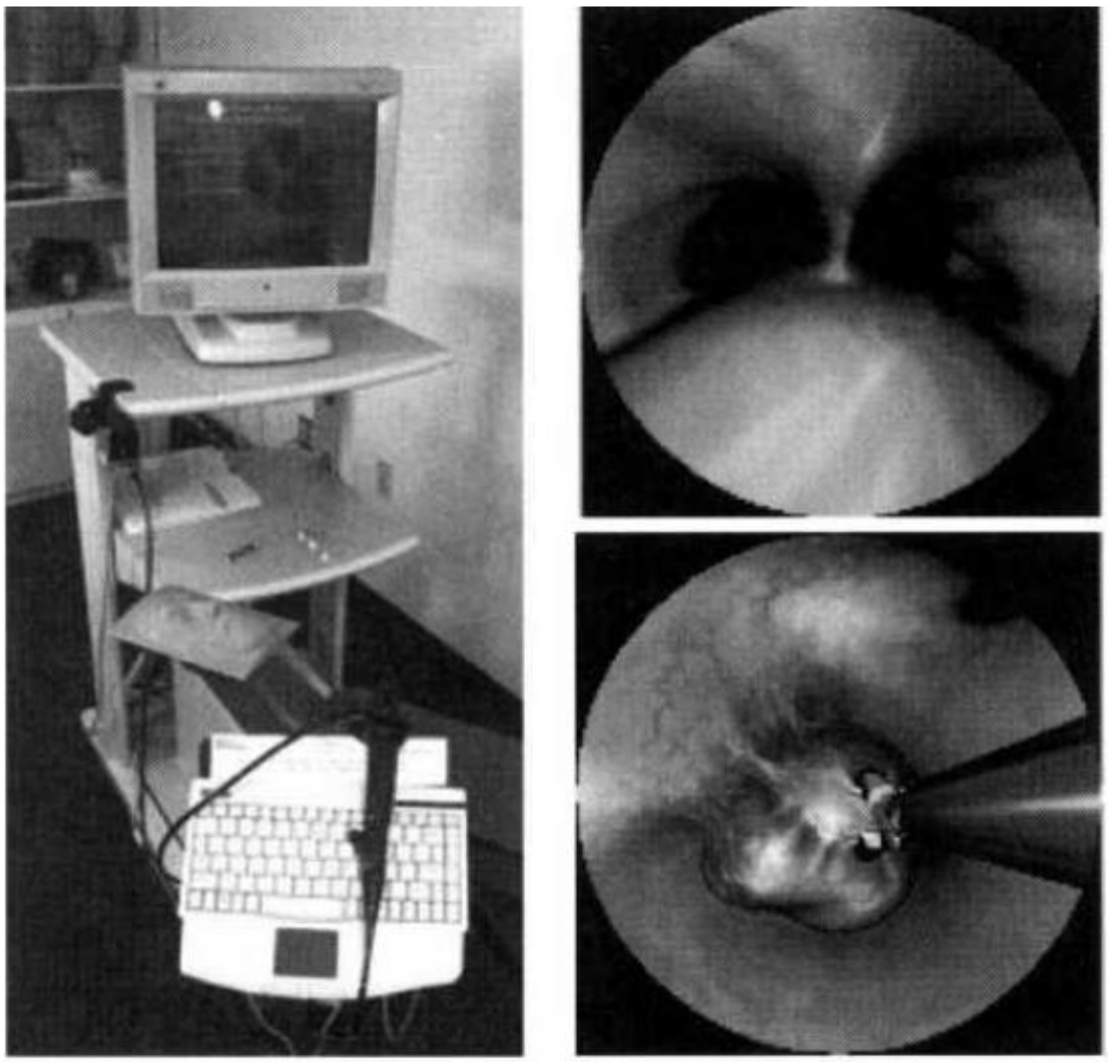


Fig. Virtual bronchoscopy: (a) simulator system; (b) views of the tracheobronchial anatomy. From HT Medical Systems Inc. [1998a].

Colt and his colleagues [2001] performed a human factors study to determine the efficacy of the PreOp simulator in training novice physicians. They used an experimental group of five physicians-intraining with minimal exposure to flexible fiberoptic bronchoscopy (FFB) and a control group of four experienced physicians. These control subjects had performed over 200 FFB procedures each prior to the study. The subjects in the experimental group had an 8-hour training on FFB using the PreOp system, which included 4 hours of individual practice. The experimental task was a thorough inspection of the airway of a normal virtual patient. The measured variables were speed (duration of bronchoscopy), dexterity (number of contacts with the bronchial wall), and accuracy (segments missed).

Improving physician's skills in performing invasive endoscopic procedures is one way of reducing the patient's discomfort and complications. A more radical way would be to make the procedure noninvasive.

Surgery

If the diagnostic procedures described in the foregoing lead to the conclusion that the patient has a tumor, he or she will most probably undergo surgery. The use of VR in surgery affects a number of distinct areas. These include training anesthesiologists and nurses in intravenous procedures, open and minimally invasive procedure training for new surgeons, surgical planning of complex procedures, navigational and informational aids during surgery, and prediction of operational outcomes.

A novice surgeon training on real cadavers cannot repeat a given procedure in case of a mistake, as the body organs have been altered. The learning curve of a surgeon thus continues long after graduation. An internationally known expert in eye surgery has told the authors that "it takes thousands of procedures to become really proficient." Who would want to be one of the first hundreds of cases? What is needed are simulators that allow surgeons to learn by repetition, the way airline pilots do, while at the same time reducing the risks for patients. Such surgical simulators have started to become commercially available and to be gradually incorporated in teaching curricula. We now describe available simulators for intravenous procedures, open surgery, and minimally invasive surgery (MIS).

Open Surgery

Open surgery is performed whenever a large organ (or portion of one) needs to be removed. The advantages for the surgeon are direct sight of the surgical area (the surgeon looks directly at his or her hands) and good haptic feedback. For the patient, however, open surgery is more invasive than MIS and there is a longer recovery time postsurgery.

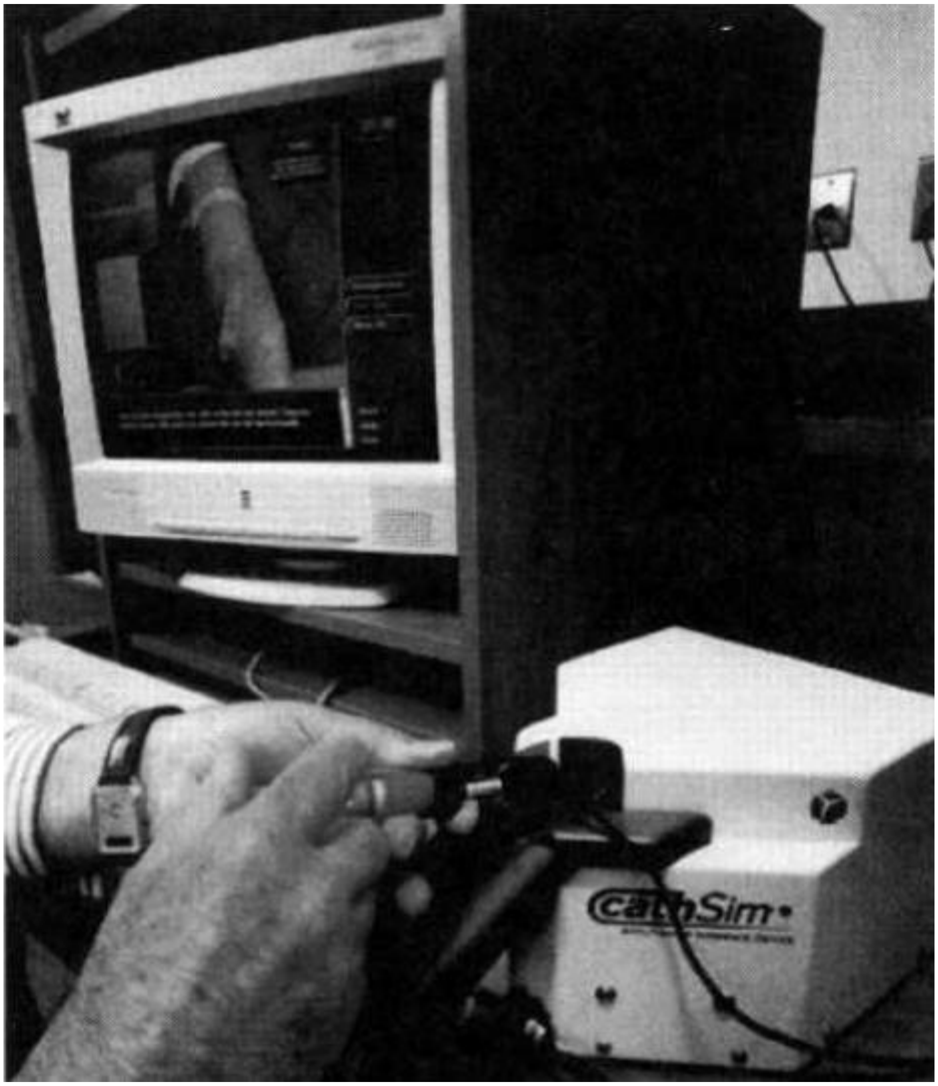


Fig. CathSim system view showing the AccuTouch haptic interface and the graphics display of a virtual forearm.

Examples of open surgery are abdominal procedures, where vessels have to be cut and then reattached after organ removal. Since open surgery predates MIS, it is not surprising that one of the earliest surgical simulators was intended for training in abdominal surgery. The user (surgeon) interacted with a virtual abdomen through two VPL DataGloves, seeing the scene displayed on a stereo HMD and hearing 3D sound. The simulated surgical procedure was a coupling of the ends of a dissected bowel (also called anastomosis). The virtual world included various abdominal organs, the surgical instruments (bowel coupler, syringe, purse string, clamps, needles), as well as the operating table and lights. Interactivity with the simulated environment was very good, as the surgeon picked up the instruments in a very natural way. The frame refresh rate was also high (30 frames/sec). However, limitations in the computing hardware available in the early 1990s led to tradeoffs in the scene complexity (organs appeared cartoonish), simplified organ behavior when the organ was deformed, and lack of haptic feedback.

Minimally Invasive Surgery

This represents a newer way of performing certain types of abdominal, knee, nasal, or intestinal surgery. Patients prefer MIS since it needs smaller incisions than open surgery, thus allowing faster recovery and less chances for complications. For example, a patient having a gall bladder removed through MIS can be discharged from hospital on the same day. The same procedure done in open surgery would require a 1-week stay in the hospital. In 1991 there were 200,000

MIS procedures performed in the United States. Tens of millions of such procedures are performed today.

The two major MIS techniques are endoscopic surgery, performed with a flexible endoscope, and laparoscopic surgery, which is done using a rigid assembly of handle, stick, and cutting scissors, called a laparoscope. Both use tiny cameras inserted in the patient's body in order to allow the surgeon to view the cutting area. During an MIS procedure the surgeon is thus forced to watch a TV monitor and look away from his or her hands, contrary to what happens during open surgery. Furthermore, laparoscopic surgery suffers from the fulcrum effect, which reverses the motion of the cutting element inside the ptient's body relative to that of the surgeon's hand holding the handle outside the body. Finally, there is a filtering of haptic feedback due to the laparoscope itself, which distorts the forces felt by the surgeon. These drawbacks require significant surgical dexterity and excellent hand-eye coordination, which are obtained only through intensive training.

MILITARY VR APPLICATIONS

The military has long understood the importance of simulation and training under the doctrine "we train as we fight and we fight as we train." The current trend toward increased technological complexity and shorter military hardware lifespan requires simulators that are flexible, upgradeable, and less expensive. After all, if a simulator is designed only for a given tank model or aircraft model, it will get obsolete when those weapons do. Another trend in modern military training is networking. This allows remote simulation without having to transport trainees to the simulator site. Networking is also needed in team simulations, which are more realistic than singleuser ones. Virtual reality is networkable, flexible, and easily upgradeable, therefore it ideally matches the needs of military simulation outlined here.

Modern armies are called upon to perform a variety of missions, from military campaigns to peacekeeping operations and disaster relief, and to do this in many parts of the world. Training thus needs to be more flexible than ever before, allowing mission simulation ahead of execution and advanced debriefing after completion. VR matches this need for mission profile flexibility while allowing training at various levels of military hierarchy (from dismounted soldier to platoon, battalion, and so on). All military branches use some form of VR simulators, which rely increasingly on Al to control both friendly and enemy "automated" forces. The discussion here is structured along the various military branches (the Army, the Navy, and the Air Force). Owing to space limitations, we mention only a few of the multitude of existing VR defense applications.

Army Use of VR

The U.S. Army was an early adopter of VR-based training in the form of simulators for large-scale motorized units. This was appropriate for the envisioned large tank battles of the Cold War era (which fortunately never happened in reality). The current trend for small-scale conflicts (such as the so-called war on terrorism) emphasizes, however, the need to better train individual soldiers. Thus our discussion starts with single soldier simulators, followed by platoon-level leadership training. We then describe the SIMNET company-size tank simulator and its follow-up, the Close Combat Tactical Trainer (which adds aviation units attached to the Army).

Single-Soldier Simulators

These are made possible by the dramatic reduction in computing hardware cost and substantial increase in its performance. Such simulators are useful not only for improving marksmanship, but also for better training in operating expensive weaponry. An example is the Virtual Stinger Trainer, shown in Figure 8.26a, which was developed in Holland by TNO Physics and Electronics Laboratory.

The Stinger is a compact shoulder-fired missile designed as a defense against low-flying aircraft and is in use in many armies around the world. The standard Stinger Trainer used by the military consists of a 20-m-diameter projection dome. The background landscape is projected by a single projector with a fish-eye lens mounted on top of the dome. Two moving video projectors mounted on mechanical arms project two independent images of attacking aircraft. Instructors determine the attack scenario and track the progress of the trainees using a workstation. The virtual simulation developed by TNO uses an HMD, interactive sound, and 3D tracker integrated with a workstation running the simulation.

A fullsize plastic mock-up of the Stinger was constructed in order to give the trainee a better tactile feel of the simulation. The 3D tracker is integrated inside the mock-up support handle so that it can track the position of the missile launcher. Pushbuttons are used to replicate the weapon's switches (safety, uncaging, and firing triggers). The software consists of a terrain model projected on the HMD, a model of the Stinger, and models of the attacking aircraft (including trajectory). The virtual Stinger model simulates only the essential weapon parts (launch tube, separable grip lock, battery/coolant unit, sight assembly, and missile). Attacking aircraft models are ported from the existing (domed) simulator system. Interactive sound is used to give the trainee an audio cue for target acquisition, in a similar fashion to the real weapon. The trainee hit/miss ratio together with any errors in the proper firing sequence are automatically stored by the system and reported to the instructor.

Single-soldier simulators.

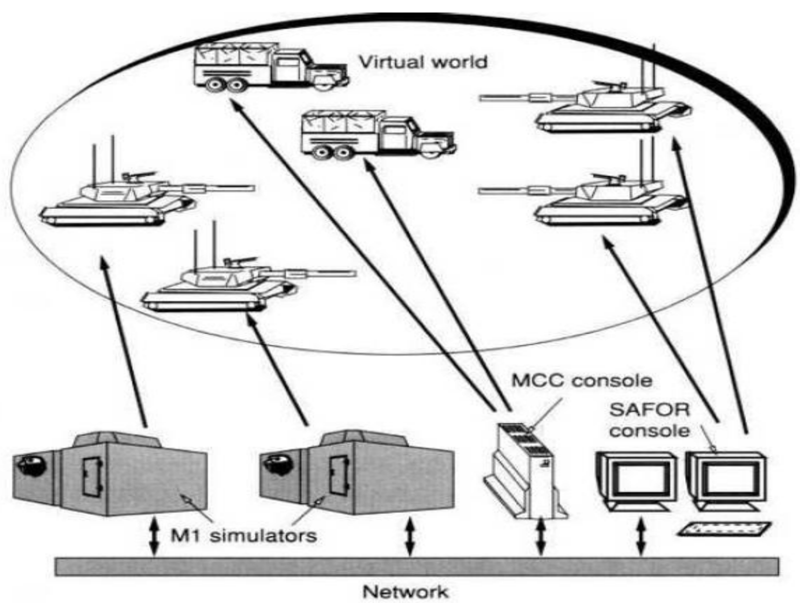
Platoon Leadership Training:

This training is required in order to improve decision making for young lieutenants commanding these small units. Increasingly they are faced with the need to take difficult decisions under pressure, sometimes in circumstances not mentioned in training manuals and in unfamiliar surroundings. A case in point is peacekeeping operations, where the media can turn any error into an international incident. Having understood that traditional training is not sufficient, the U.S. Army created in 1999 a joint venture with the University of Southern California called the

Institute for Creative Technologies. It was tasked to create realistic, highly emotional training Mission Rehearsal Exercises (MREs) developed by teams of artists and computer scientists.

Platoon leadership training for a peacekeeping operation

Company and Battalion-Level Simulators:
These are used to train armored units and their artillery and close air support. In the early 1980s the Defense Advanced Research Projects Agency (DARPA) began the development of the first realistic virtual battlefield in order to train tank crews in joint exercises. The primary motivation for this endeavor was a reduction in training costs, but considerations also included increased safety and reduced environmental impact (explosions and tank tracks do great damage to the training area). The project, called Simulation Network (SIMNET), linked over 200 tank simulators in the United States and Germany. Each SIMNET simulator replicates the interior of an M 1 battle tank, complete with navigation, weapons, sensors, and displays.



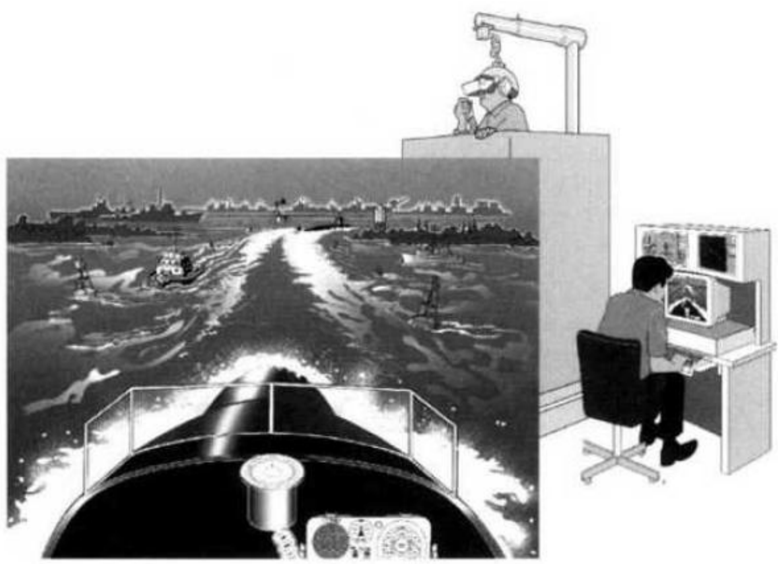
The Simulation Network virtual battlefield.

VR Applications in the Navy

The U.S. Navy started its own studies in the use of virtual reality in the early 1990s. These studies, conducted at the Naval Command, Control and Ocean Surveillance Center in California, were prompted by the realization that the complex displays of a ship were producing operator overload. Earlier human factors studies had shown that operator performance improved with reduced workload, and the effect was amplified over prolonged use. There was a need to create new displays that were more natural to understand and that took advantage of human perceptual and cognitive skills. Perceptual and cognitive skills are particularly important during submarine surface navigation and the operation of close-range naval artillery.

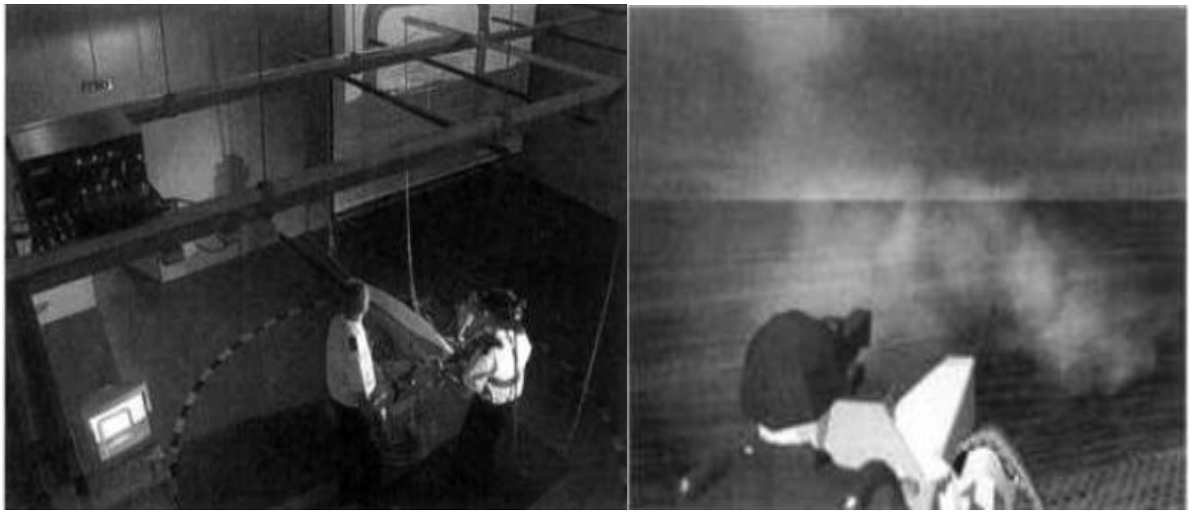
Virtual Environment for Submarine Ship Handling Training (VESUB):
This simulator for "officer on deck" (OOD) training is currently in use at the Naval Submarine School in Groton, Connecticut. Navigating a surfaced submarine close to shore is difficult owing to the low profile of the vessel and the abundance of other vessels and obstacles ("contacts" in maritime parlance). The development of the VR simulator was prompted by the realization that older shore-based OOD trainers were inadequate. As a consequence, junior officers needed to learn on the job during the limited time of surface steaming, a situation that was risky.

The VESUB simulator, which became operational in early 2001, is illustrated in below figure. The trainee officer stands in a mock-up of a submarine deck while wearing a high resolution stereo HMD. The trainee's head motion is tracked such that he or she can see a 360" view of the submarine and its surroundings. The virtual scene is rendered by an SGI workstation and input to the simulation is through voice commands given over a mock communication system. Voice traffic (from simulated stations inside the virtual submarine) as well as other sounds (wind, ocean, harbor pilot, etc.), are fed back on the HMD headphones. The HMD can also be used as virtual binoculars allowing zooming in on distant contacts. The training scenario is controlled by an instructor sitting at an adjacent workstation. The instructor monitors the trainee's view on one of the workstations while changing weather conditions, seaport databases (four harbor models), or introducing emergencies (man overboard, or shallow water under the boat).



View of the VESUB simulator.

VR-Based Close-Range Naval Artillery Training:
This is used in the British Royal Navy to replace shore-based live fire training. The VR-based simulator, which entered service in 2001, is modular in design, allowing training for 20-mm and 30-mm rapid-fire cannons and other close-range artillery. Its fielding was necessary due to the high cost of ordinance as well as the negative impact on ocean habitats, which led to the suspension of shore-based live fire training in the United Kingdom. Further costs reduction resulted from the use of commercial hardware as opposed to proprietary defense computing hardware.


Close-range naval artillery training: (a) simulator system; (b) gunner avatar seen by the gunner Director

Air Force Use of VR

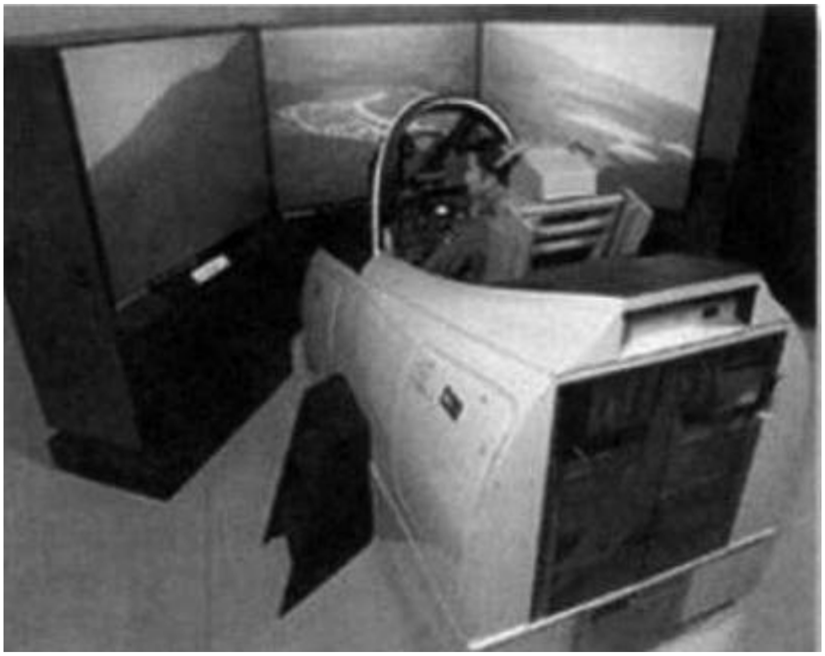
Unlike doctors, pilots (civilian and military) have a long tradition of simulator-based training owing to the grave consequences human error has on passengers. The traditional flight simulator has been a large domelike structure placed on a motion platform and housing an identical replica of an airplane cockpit. While such training is very realistic (including engine sounds, airflow turbulence, and other effects), it is also very expensive. One hour on such simulators can cost $5000. As a consequence, motion platform-supported dome simulators are housed in dedicated (fixed) facilities to which airlines send their pilot trainees.

Air forces around the world have to be on constant readiness and often redeploy aircraft and crews as missions dictate. It is thus becoming increasingly impractical to send crews to distant simulator facilities. What is needed is a smaller, transportable simulator that can travel with the squadron to accompany it in the combat zone. Furthermore, such unit simulator needs to be reconfigurable in order to keep up with frequent hardware upgrades.

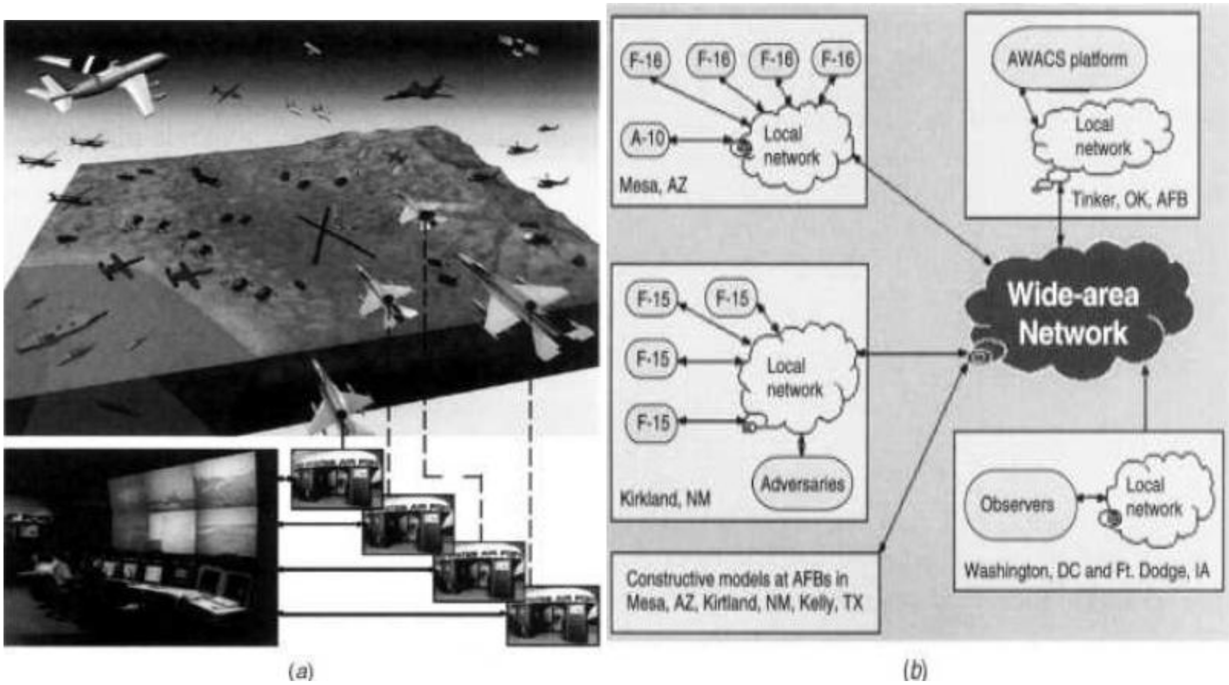
The Unit Trainer and the Virtual Cockpit:

Those are examples of the newer generation of simulators. They serve as multitask trainers, allowing both standalone and networked simulations (necessary to train pilot teams and tactics).

Below figure shows a unit simulator for the A-10 ground attack airplane [Air Force Research Laboratory, 2002a]. The pilot sits in an exact replica of the cockpit, which gives direct haptic feedback and increased simulation realism. The scene is projected on three side-by-side portable displays, which are easily assembled on site. They create a 214° (horizontal) x 108° (vertical) field of view with a 1024 x 768 resolution. The computers are compact enough to be housed in the aircraft body, such that the simulator can be rolled in and assembled in a regular office room. The system also includes an instructor station such that pilots can train with their squadron and do so without use of real munitions or of bombing ranges. They can also get familiarity with the local flying area on an overseas deployment by using appropriate databases.


Single-aircraft trainers. (a) A-10 simulator with real cockpit.

Distributed Mission Training (DMT)
This networked simulation environment is being created by the U.S. Air Force Research Laboratory (Mesa, Arizona) in order to allow team pilot training [Air Force Research Laboratory, 2002b]. As illustrated in Figure 8.33a, mission team level training is based on networked nodes of four fighter simulators, Air Warning System (AWACS) simulators, and synthetic (computer-generated) enemy forces ("bandits"). An instructor station has six tiled displays that show the mission in real time. Several such mission training simulators can then be networked over a WAN in order to allow remote Air Force units to train in complex missions. Of particular importance are missions in which pilots are in numerical inferiority, the so-called "four versus many Dissimilar Air Combat Tactics" (4 v X DACT) [Jensen and Crane, 1999]. Such training is rarely done on firing ranges owing to cost, safety concerns, and limited air space availability. However, DMT is ideal for this type of training since there is no limit on air space, altitude, or time spent in the mission. The DMT thus allows pilots to train their radar operating and communication skills in a highly realistic VR environment where opposing forces can either be other pilots or automated forces. The whole simulation is taped, allowing postmission debriefing either at the local node level or global battle space level. Typically, pilots fly two 1-hour missions each day, with a debriefing after each mission. The morning debriefing analyzes the mission mistakes, which pilots can improve upon by repeating the same simulation in the afternoon.



Distributed Mission Training (DMT) simulators. (a) Networked units. From Air Force Research Laboratory [2002b]. Reprinted by permission. (b) RoadRunner'98 DMT largescale exercise configuration.

Assignment-Cum-Tutorial Questions

A. Questions testing the remembering / understanding level of students

I) Objective Questions

1. The resulting increase in the quality of ____________________ makes up for increased equipment costs.

2. ___________________and _____________________ were used to extract skin, organ, and skeletal structures.

3. Creating animations of 3D organ models based on the _______________________.

4. In 1998 HT Medical Systems Inc. (now part of Immersion Co.) introduced the ________________ simulator.

5. Improving physician's skills in performing ___________________________ is one way of reducing the patient's discomfort and complications.

6. ________________________ are performed on approximately 80% of patients admitted to hospitals.

7. The small resistance at the moment of contact with the skin is fed back to the trainee through a cable and actuator assembly in the AccuTouch box. (T/F)

8. ____________________________ represents a newer way of performing certain types of abdominal, knee, nasal, or intestinal surgery.

9. The two major MIS techniques are endoscopic surgery, performed with a flexible endoscope, and laparoscopic surgery. (T/F)

10. A VR-based ______________________________ was developed at Rutgers University in collaboration with Stanford Medical School.

II) Descriptive Questions

1. What is the Digital Anatomist project, and why is it increasing access for students?
2. Describe the system architecture and use of the BioSimMER system.
3. Give examples of single-soldier VR-based training systems.
4. Describe the SIMNET architecture.
5. What is the AVCTT, and how is it used for training?
6. What is a virtual cockpit? Give examples.
7. What is the architecture of the close-range artillery trainer used in the British Royal Navy?
8. Give examples of VR use in robot programming. Make a drawing and explain.

B. Question testing the ability of students in applying the concepts.

I) Multiple Choice Questions

1)VR simulators mainly rely on which of the following technology?

a)Big data b)cloud computing

c)**Artificial intelligence** d)Data analytics

2)Find an example Single-solider simulator used in army?

a) **Virtual Stinger Trainer** b)Demining training system

c) Virtual mines and probing pattern d)None

3) Virtual Stinger Trainer was developed in which year?

a)1994 b)1990 c)1989 d)**1993**

4)An aviation CCTT (AVCCTT) mobile unit configuration contains how many manned configuration module?

a)8 b)4 c)5 d)**6**

5) VESUB simulator, which became operational in which year?

a)1990 b)1997 c)1991 d)**2001**

6)Which of t\he fiollowing used as multitask trainer in airforce?

a) Virtual Stinger Trainer b) Demining training system

c) **Unit Trainer and the Virtual Cockpit** d)None

7)Which of the following are the applications of VR in manufacturing?

a)Virtual prototyping b)Marketing

c)Erognomic analysis d) **all of the above**

8) ERGONAUT analysis tool is used in which level of Ergonomic analysis?

a)5 b)1 **c)3** d)4

9) Simulation package used in Ergonomic analysis marketed by Electronic Data Systems (EDS)?

a**) Task Analysis Toolkit** b) Demining training system

c) Unit Trainer d) None

10) Which of the following is the use of VR in marketing?

a) **Consumer purchasing behavior** b) Purchasing decisions

c) Billing d) None

II) Problems:

1. What are the most important VR application domains and geographic areas, according to the CyberEdge Information Systems [2002] survey?
2. Describe the prostate palpation trainer. Comment on its human factors testing results.
3. How is VR used for patients with fear of flying? What is the system architecture and study outcomes?
4. How is VR being used in education (at college, high school, and elementary school levels)? Give examples and comment.
5. How do location-based VR experiences compete with the home-based systems? Give examples.
6. How is leadership training at the platoon level done more realistically in VR? Describe the Bosnia accident scenario.
7. What is the VESUB? What did the Hays et al. [1998] study show?
8. Why is DMT important for military pilots? How is it being combined with Army CCTT simulators?

UNIT-V

AUGMENTED REALITY

Introduction, Head-Up-Displays, Helmet-mounted sights and displays, Smart Glasses and augmented displays.

INTODUCTION:

What is Augmented Reality?

Augmented Reality (AR) is a field of computer research which deals with the combination of real -world and computer generated data.

Augmented Reality (AR) is a live direct or indirect view of physical, real-world environment whose elements are augmented (or supplemented) by computer generated sensory input such as sound, video, graphics or GPS data.

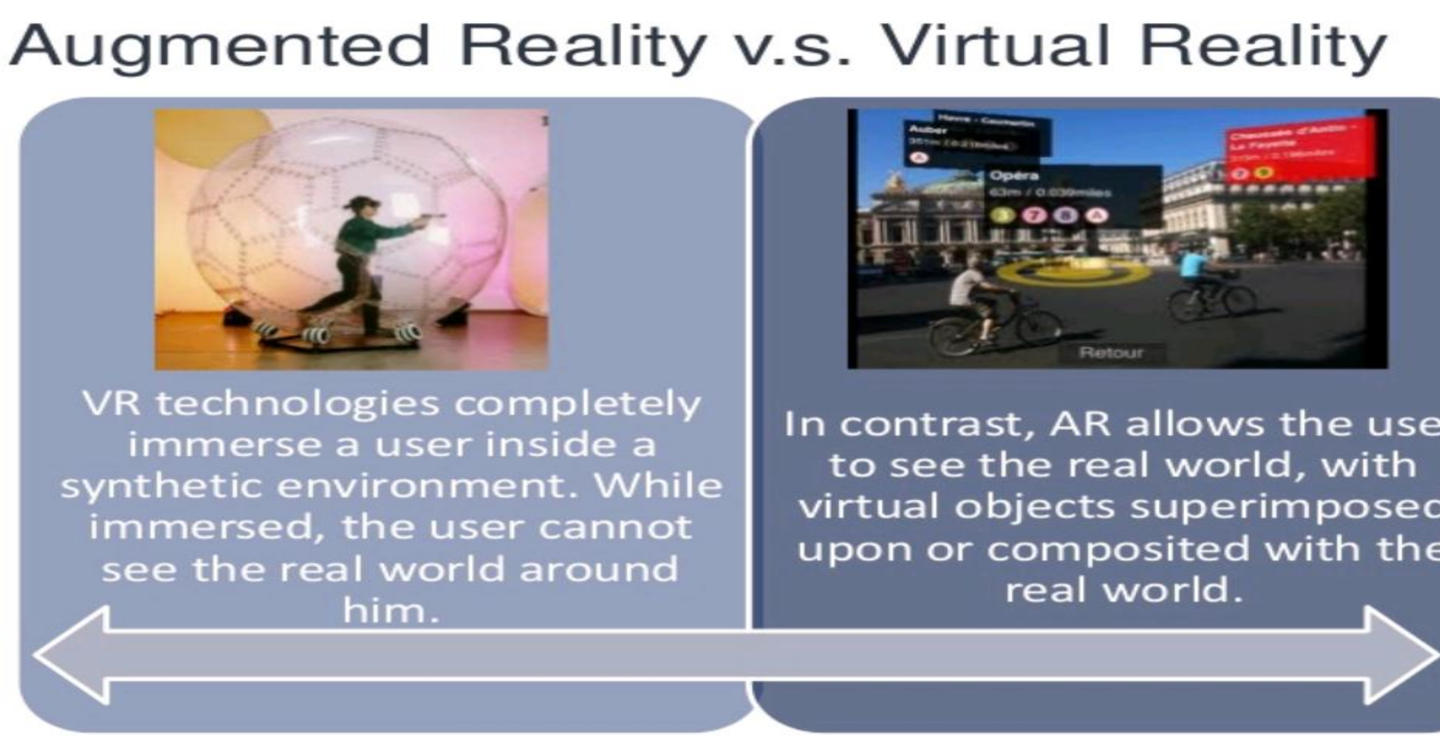
Augmentation is conventionally in real time and in semantic context with environmental elements.

eg: sports scores on TV during a match.

AR systems have following three characteristics.

1. Combines real and virtual objects in a real environment
2. Is interactive in real-time
3. Registers (aligns) real and virtual objects with each other.

Augmented vs Virtual Reality:



Augmented Reality Interactions:

- With the help of advanced AR technology (e.g. adding computer vision and object recognition) the information about the surrounding real world of the user becomes interactive.
- Artificial information about the environment and its objects can be overlaid on the real world.
- In order to benefit from it you need a dedicated device
  - laptop or computer
  - Handheld like Smartphone or Tablets
  - Smart Glasses
  - Gesture based solution(Kinect, Leapmotion)

AR Components

Scene Generator : The scene generator is the device or software responsible for rendering the scene. Rendering is not currently one of the major problems in AR, because a few virtual objects need to be drawn, and they often do not necessarily have to be realistically rendered in order to serve the purposes of the application.

Tracking System: The tracking system is one of the most important problems on AR systems mostly because of the registration problem. The objects in the real and virtual worlds must be properly aligned with respect to each other, or the illusion that the two worlds coexist will be compromised. For the industry, many applications demand accurate registration, especially on medical systems.

Display: The technology for AR is still in development and solutions depend on design decisions. Most of the Displays devices for AR are HMD (Head Mounted Display). When combining the real and virtual world two basic choices are available: optical and video technology. Each of them has some tradeoffs depending on factors like resolution, flexibility, field-of-view, registration strategies, among others. Display technology continues to be a limiting factor in the development of AR systems. There are still no see-through displays that have sufficient brightness, resolution, field of view, and contrast to seamlessly blend a wide range of real and virtual imagery. Furthermore, many technologies that begin to approach these goals are not yet sufficiently small, lightweight, and low-cost. Nevertheless, the past few years have seen a number of advances in see-through display technology.

HEAD-UP-DISPLAYS (HUD):

Head-Up-Display (HUD) enables a driver to view information with his head positioned "up" and looking forward, instead of angled down looking at lower instruments. By adding the Augmented Reality technology, targets, like people and cars, can be marked to alarm to the drivers to avoid the potential accidents.

Traditional 2D AR HUD projects information messages at a certain distance away from the driver. It asks a driver to observe the projection along the optical axis at a certain point. When the driver moves his head, a miss-matching projection occurs between the projected data and the target in the real world.

In this 3D AR HUD technology, a 3D virtual display can be projected in front of the driver. AR messages will be dynamically projected according to the 3D locations of the targets. In our 3D HUD, a virtual display is projected into a three-dimensional world, so there will be no mismatch when the driver moves.

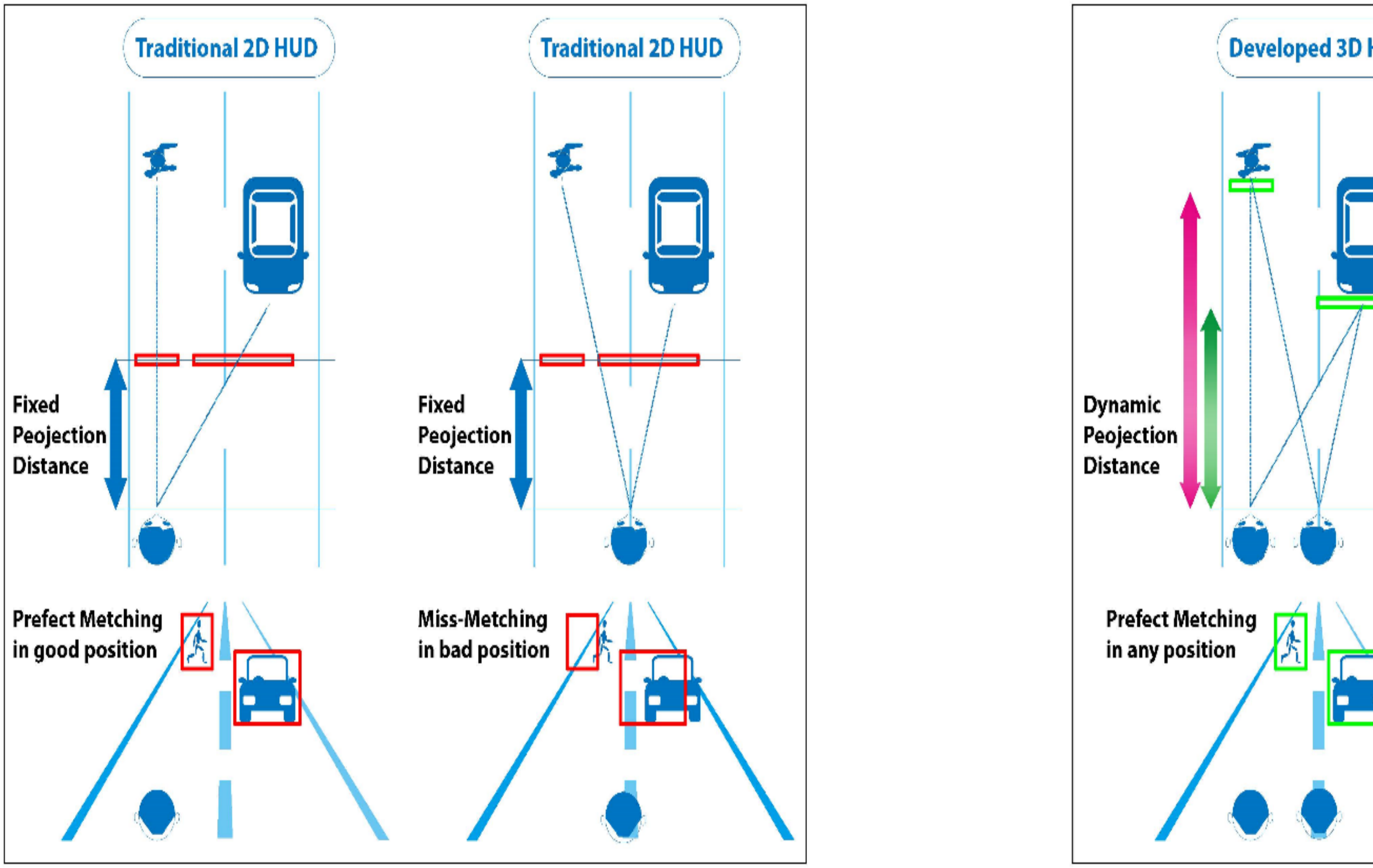


Figure 1: (Left) When a user observes in a good position that follows the specified optical axis, the projected data and the target will be well matched. However, when the observing axis have any movement, in position (b), there will be a mismatch projection between the display and the real world.. (Right) In this 3D HUD technology, a 3D virtual display can be projected. AR markers will be dynamically projected according to the 3D locations of the targets. Because the message is projected into a three dimensional world, there will no mismatch even when the drivers moves.

It is difficult to design and fabricate a head-up display (HUD) with a large asymmetric field of view (FOV) while maintaining a good image quality. In this paper, we design and develop such a holographic HUD system. To improve luminance and enhance the environmental adaptability of the HUD, we use a liquid crystal display with high brightness as we...

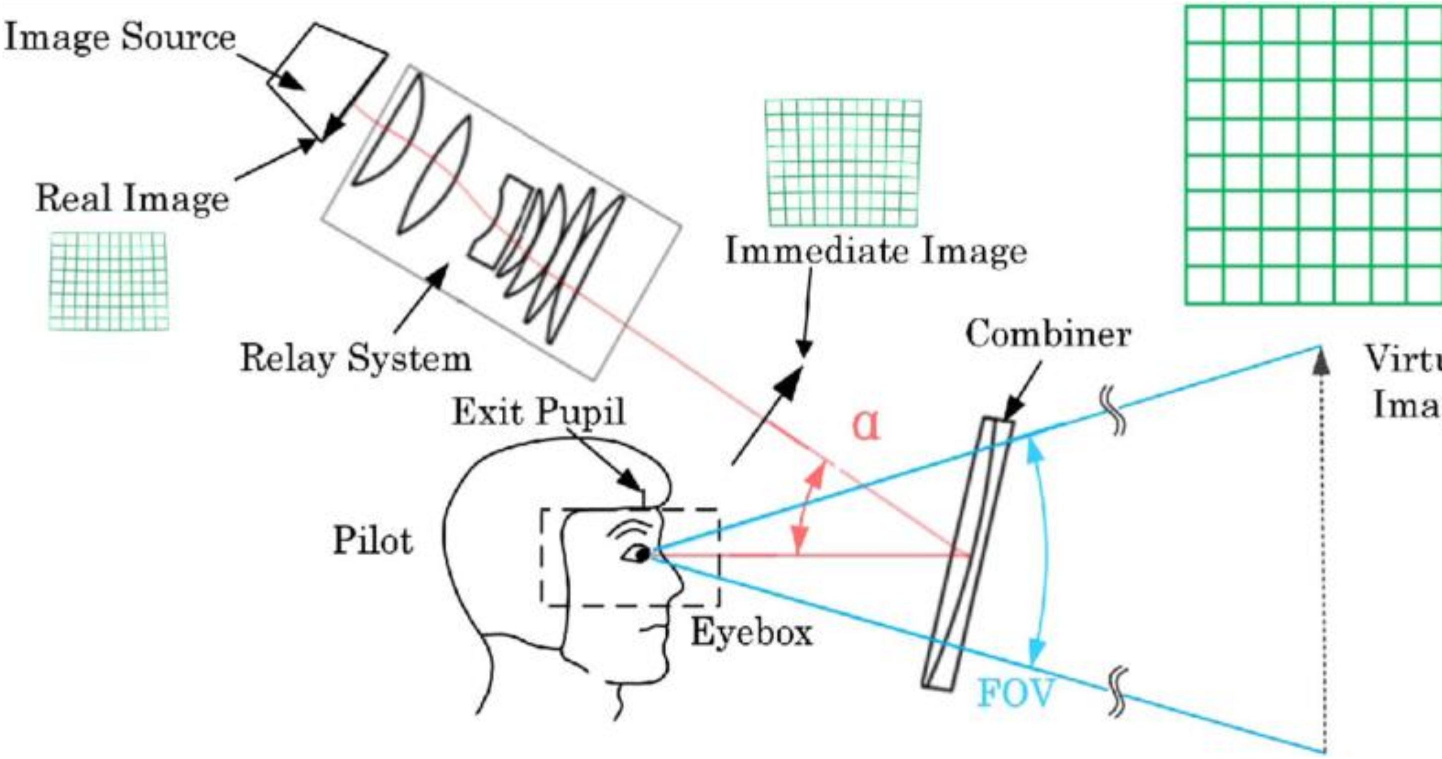


fig: Schematic diagram of HUD.

Holographic Combiners Improve Head-Up Displays

Combiners are semitransparent surfaces used in head-up display (HUD) and augmented reality (AR) systems to overlay an image presented by a projector on top of the viewer's physical world. The combiner is transparent and lets the viewer see through it, while simultaneously reflecting dynamic digital information.

Over the years, combiners have evolved from simple semitransparent flat surfaces that passively reflected light from projectors to sophisticated conformational holograms that diffract selective wavelengths and act as relay lenses. This evolution has been driven by a desire to maximize the field of view (FOV) of the projected image, to maintain a comfortable eye box, and to minimize the size of the projector. These same constraints have motivated a transformative revolution in combiner design, which utilizes a waveguide instead of free-space optics.

Direct reflection

New AR and HUD systems are offered to the public on a regular basis. Current systems feature a smaller form factor and better optical characteristics than were possible as recently as a year ago. The key enabler for this new technology is a combiner element that uses both holograms and waveguide properties to achieve large FOV and eye box.

From an optical perspective, AR and HUD systems are very similar; viewers see a projected image overlaid on their physical worlds. This feat is achieved using a semitransparent combiner element positioned in front of the viewer that reflects a projected image toward the eyes (Figure 1).

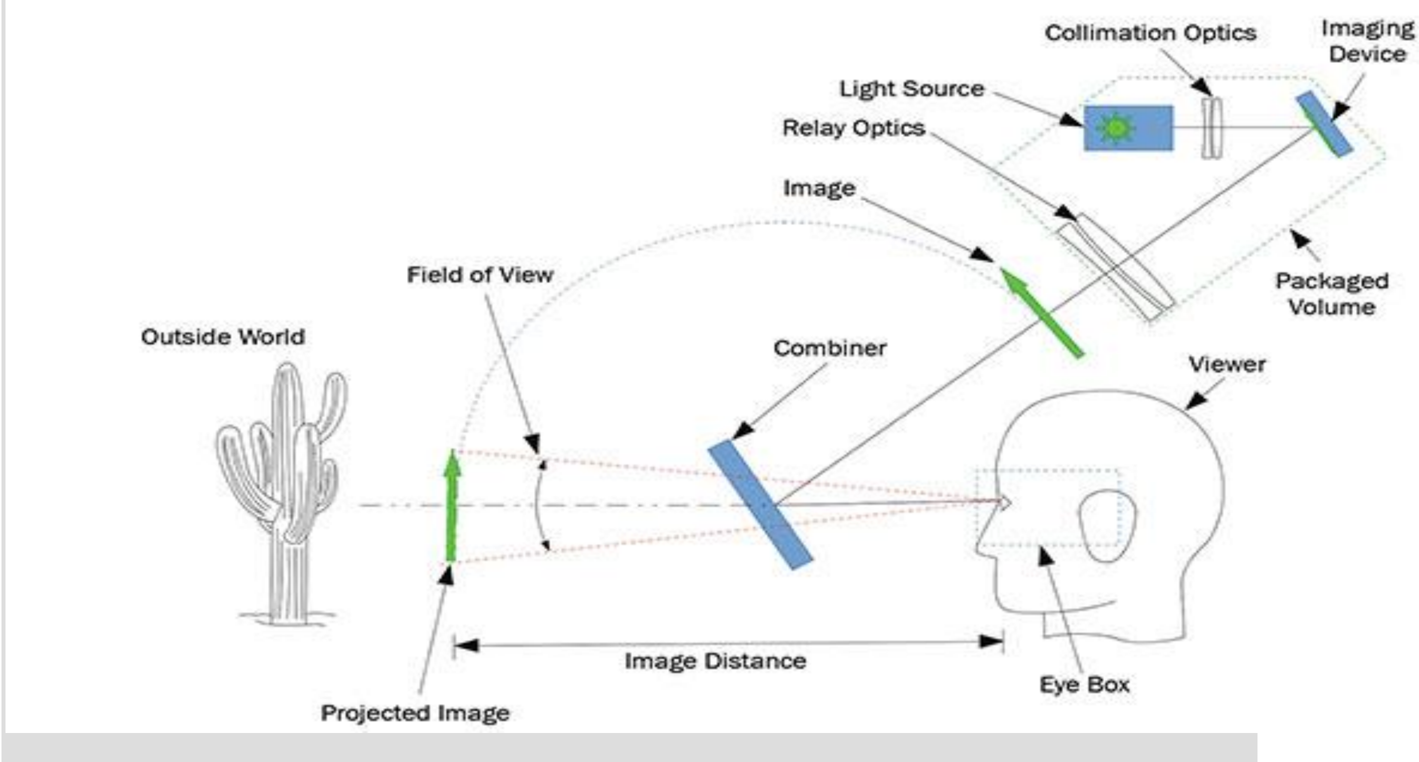


Figure 1. Working principle of a head-up display (HUD)/ augmented reality (AR) optical system. A projection system creates an image that is overlaid to the outside world by a semitransparent combiner. Courtesy of Pierre-Alexandre Blanche.

The simplest of all combiner technologies is just a flat piece of transparent material that redirects an image using Fresnel reflection, which is the result of an index difference between the material and the air. This simple reflection phenomenon can be used in a car by placing a cellphone near the windshield. Most navigation apps have an HUD mode that flips the image to allow this usage.

One problem with this crude approach is that there are reflections from both front and back surfaces of the material, which double the image (Figure 2). To prevent doubling, an antireflection coating can be applied on one of the materials' surfaces.

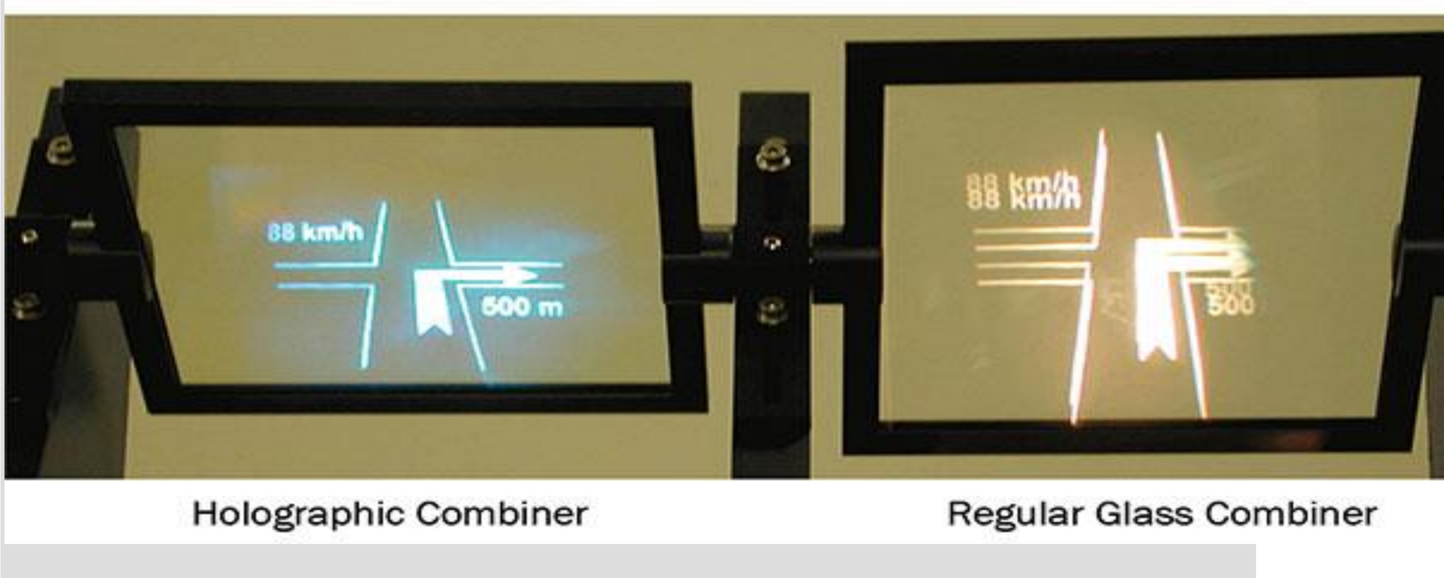


Figure 2. A holographic combiner (left) and a regular glass combiner (right). Note the doubling of the image in the case of the simple glass combiner. Courtesy of Pierre-Alexandre Blanche.

HELMET-MOUNTED SIGHTS AND DISPLAYS

A **helmet-mounted display** (HMD) is a device used in aircraft to project information to the pilot's eyes. Its scope is similar to that of head-up displays (HUD) on an aircrew's visor. An HMD provides the pilot with situation awareness, an enhanced image of the scene, and in military applications cue weapons systems, to the direction their head is pointing. Applications which allow cuing of weapon systems are referred to as helmet-mounted sight and display (HMSD) or helmet-mounted sights (HMS).

The Helmet Mounted Sight (HMS) or Display (HMD) is a relatively recent addition to the fighter cockpit. The first devices in this category emerged during the late seventies, as an aid to targeting second generation heatseeking missiles. Given the limitations of both sight and missile technology of that period, the HMS slipped into obscurity for several years, only to be resurrected with the advent of fourth generation heatseeking missiles (WVR AAMs). At this time the HMS and newer, more capable HMDs are seeing a resurgence in the marketplace and can now be expected to become a standard feature in the cockpit of any new build fighter aircraft.

The fundamental idea behind all HMD/HMS designs is that of using the pilot's Eyeball Mk.1 as a cueing device to direct a missile seeker at a target, to facilitate a rapid lock and missile shot. This was not a very strong requirement with second and third generation heatseeking missiles, since the capable Air Intercept (AI) radars which proliferated with the teen series (and teenski series) fighters typically had several dogfighting modes which were designed to rapidly acquire and track a target. The missile seekers were "slaved" to the antenna boresight, and thus once the radar locked on to the target the missile seekers would also lock very shortly thereafter. Each missile would be fed with an elevation and azimuth signal produced by the radar, and these signals would be used to steer the missile seeker direction relative to the airframe.

When the first fourth generation missiles appeared, the Soviet Vympel R-73 (AA-11 Archer) and shortly thereafter the Israeli Rafael Python 4, it was clearly apparent that with very large off boresight angles, typically in excess of 60 degrees of arc, the AI intercept radar would no longer be adequate. The reason was simple, in that most antennas could not be easily slewed to angles beyond about 60 degrees. Space under radomes was limited, radome designs not optimised for beam quality at large off-boresight angles, gimbal design limits and servomotor slew rates all contributed to this situation. Last but not least, the cost of retrofitting large numbers of radars would not be trivial. And with the latest fourth generation missiles, like the AIM-132 ASRAAM, the missile itself could be fired over the shoulder at targets in the aft hemisphere. Therefore the HMS idea was resurrected.

At this time many manufacturers are producing or developing such devices. Notable examples are the ELBIT DASH series, the derived VSI/Kaiser JHMCS, and designs by Pilkington Optronics for the Eurofighter, and Sextant Avionique for the Rafale. Existing users of Flanker and Fulcrum employ a Russian HMS design.

Technology Issues in Helmet Mounted Sights and Displays

While the idea of using the pilot's helmet to point a missile seeker is conceptually simple, implementation can be often quite tricky. A number of issues must be addressed for such a design to be robust and deliver the performance required.

Key design issues can be summarized as:

Accuracy - what is the angular error between the pilot's line-of-sight and the derived measurement?

Slew rate - what is the maximum angular rate at which the pilot can slew his helmet and the system still produce an accurate measurement ?

Field of regard - what is the angular range over which the sight can still produce a suitably accurate measurement ?

Weight and balance - how heavy is the helmet and sight assembly, where is its centre of gravity, how will it affect pilot fatigue levels in high G manoeuvre, and does it pose a safety problem during ejection?

Optical characteristics - is the pilot's sighting reticle focussed at infinity ? How accurately can the sight be calibrated ? Is the symbology sharp ?

Robustness - can the design handle the wear and tear of day to day combat squadron operations ?

Safety - how easily can the helmet be disconnected from the aircraft's systems during an ejection ?

Flexibility - can the design be used for other purposes, like the display of symbology and imagery ?

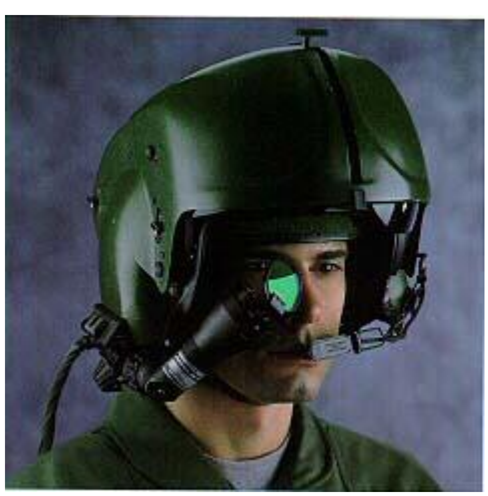
Cost - how expensive is the HMS/HMD and its supporting electronics and the integration of these into the aircraft's weapon system.

Clearly these are non-trivial requirements, and should a design fall short in any area, its utility may be seriously impaired. As a critical component in the close-in weapons targeting loop, failure to perform could cause th loss of a fighter and a pilot in combat, an expensive proposition indeed.

Head Position Sensing

The starting point for the discussion of HMS/HMD designs must be the area of position sensing, since it bears directly on issues such as accuracy, slew rate, field of regard, weight and robustness. A position sensing system must be capable of measuring the elevation, azimuth and tilt of the pilot's head relative to the airframe with the required accuracy, even during rapid head movement and at some very odd angles. Moreover, this assumes that the helmet "boresight" is the reference direction to which the missiles are to be pointed. Further on this later.

Two basic methods are used in current HMS/HMD technology - optical and electromagnetic. Optical systems employ infrared emitters in the cockpit (or helmet) and position sensing infrared detectors on the helmet (or cockpit), to measure the position of the pilot's head. The principal limitations of this approach are the potential for a restricted field of regard, and potential sensitivity to sunlight entering the cockpit.



SMART GLASSES

smart glasses are wearable computer glasses that add information along side or to what the wearer sees. Alternatively, smart glasses are sometimes defined as wearable computer glasses that are able to change their optical properties at runtime. Smart sunglasses which are programmed to change tint by electronic means are an example of the latter type of smart glasses.

Superimposing information onto a field of view is achieved through an optical head-mounted display (OHMD) or embedded wireless glasses with transparent heads-up display (HUD) or augmented reality (AR) overlay. These systems have the capability to reflect projected digital images as well as allow the user to see through it or see better with it. While early models can perform basic tasks, such as serving as a front end display for a remote system, as in the case of smart glasses utilizing cellular technology or Wi-Fi, modern smart glasses are effectively wearable computers which can run self-contained mobile apps. Some are hands free and can communicate with the Internet via natural language voice commands, while others use touch buttons.

Like other computers, smart glasses may collect information from internal or external sensors. It may control or retrieve data from other instruments or computers. It may support wireless technologies like Bluetooth, Wi-Fi, and GPS. A small number of models run a mobile operating system and function as portable media players to send audio and video files to the user via a Bluetooth or Wi-Fi headset. Some smart glasses models also feature full life logging and activity tracker capability.

Smart glasses devices may also have features found on a smart phone. Some have activity tracker functionality features (also known as "*fitness tracker*") as seen in some GPS watches.

Features and applications

As with other life logging and activity tracking devices, the GPS tracking unit and digital camera of some smart glasses can be used to record historical data. For example, after the completion of a workout, data can be uploaded into a computer or online to create a log of exercise activities for analysis. Some smart watches can serve as full GPS navigation devices, displaying maps and current coordinates. Users can "mark" their current location and then edit the entry's name and coordinates, which enables navigation to those new coordinates.

Although some smart glasses models manufactured in the 21st century are completely functional as standalone products, most manufacturers recommend or even require that consumers purchase mobile phone handsets that run the same operating system so that the two devices can be synchronized for additional and enhanced functionality. The smart glasses can work as an extension, for head-up display (HUD) or remote control of the phone and alert the user to communication data such as calls, SMS messages, emails, and calendar invites.

Security applications

Smart glasses could be used as a body camera. In 2018, Chinese police in Zhengzhou and Beijing were using smart glasses to take photos which are compared against a government database using facial recognition to identify suspects, retrieve an address, and track people moving beyond their home areas.

Google Glass is a brand of smart glasses—an optical head-mounted display designed in the shape of a pair of eyeglasses. It was developed by X (previously Google X) with the mission of producing a ubiquitous computer. Google Glass displayed information in a smart phone-like, hands-free format. Wearers communicated with the Internet via natural language voice commands.

AUGMENTING DISPLAYS

Display

Various technologies are used in augmented reality rendering, including optical projection systems, monitors, handheld devices, and display systems, which are worn on the human body.

A head-mounted display (HMD) is a display device worn on the forehead, such as a harness or helmet-mounted. HMDs place images of both the physical world and virtual objects over the user's field of view. Modern HMDs often employ sensors for six degrees of freedom monitoring that allow the system to align virtual information to the physical world and adjust accordingly with the user's head movements. HMDs can provide VR users with mobile and collaborative experiences.[23] Specific providers, such as uSens and Gestigon, include gesture controls for full virtual immersion.[24][25]

In January 2015, Meta launched a project led by Horizons Ventures, Tim Draper, Alexis Ohanian, BOE Optoelectronics and Garry Tan. On 17 February 2016, Meta announced their second-generation product at TED, Meta 2. The Meta 2 head-mounted display headset uses a sensory array for hand interactions and positional tracking, visual field view of 90 degrees (diagonal), and resolution display of 2560 x 1440 (20 pixels per degree), which is considered the largest field of view (FOV) currently available.

Eyeglasses

AR displays can be rendered on devices resembling eyeglasses. Versions include eyewear that employs cameras to intercept the real world view and re-display its augmented view through the eyepieces and devices in which the AR imagery is projected through or reflected off the surfaces of the eyewear lens pieces.

HUD

Headset computer

Head-up display

A head-up display (HUD) is a transparent display that presents data without requiring users to look away from their usual viewpoints. A precursor technology to augmented reality, heads-up displays were first developed for pilots in the 1950s, projecting simple flight data into their line of sight, thereby enabling them to keep their "heads up" and not look down at the instruments. Near-eye augmented reality devices can be used as portable head-up displays as they can show data, information, and images while the user views the real world. Many definitions of augmented reality only define it as overlaying the information. This is basically what a head-up display does; however, practically speaking, augmented reality is expected to include registration and tracking between the superimposed perceptions, sensations, information, data, and images and some portion of the real world.

Contact lenses

Contact lenses that display AR imaging are in development. These bionic contact lenses might contain the elements for display embedded into the lens including integrated circuitry, LEDs and an antenna for wireless communication. The first contact lens display was reported in 1999, then 11 years later in 2010-2011. Another version of contact lenses, in development for the U.S. military, is designed to function with AR spectacles, allowing soldiers to focus on close-to-the-eye AR images on the spectacles and distant real world objects at the same time.

The futuristic short film *Sight* features contact lens-like augmented reality devices.

Many scientists have been working on contact lenses capable of different technological feats. A patent filed by Samsung describes an AR contact lens, that, when finished, will include a built-in camera on the lens itself. The design is intended to control its interface by blinking an eye. It is also intended to be linked with the user's smart phone to review footage, and control it separately. When successful, the lens would feature a camera, or sensor inside of it. It is said that it could be anything from a light sensor, to a temperature sensor.

In Augmented Reality, the distinction is made between two distinct modes of tracking, known as marker and *marker less*. Markers are visual cues which trigger the display of the virtual information. A piece of paper with some distinct geometries can be used. The camera recognizes the geometries by identifying specific points in the drawing. Marker less tracking, also called instant tracking, does not use markers. Instead, the user positions the object in the camera view preferably in a horizontal plane. It uses sensors in mobile devices to accurately detect the real-world environment, such as the locations of walls and points of intersection.

Virtual retinal display

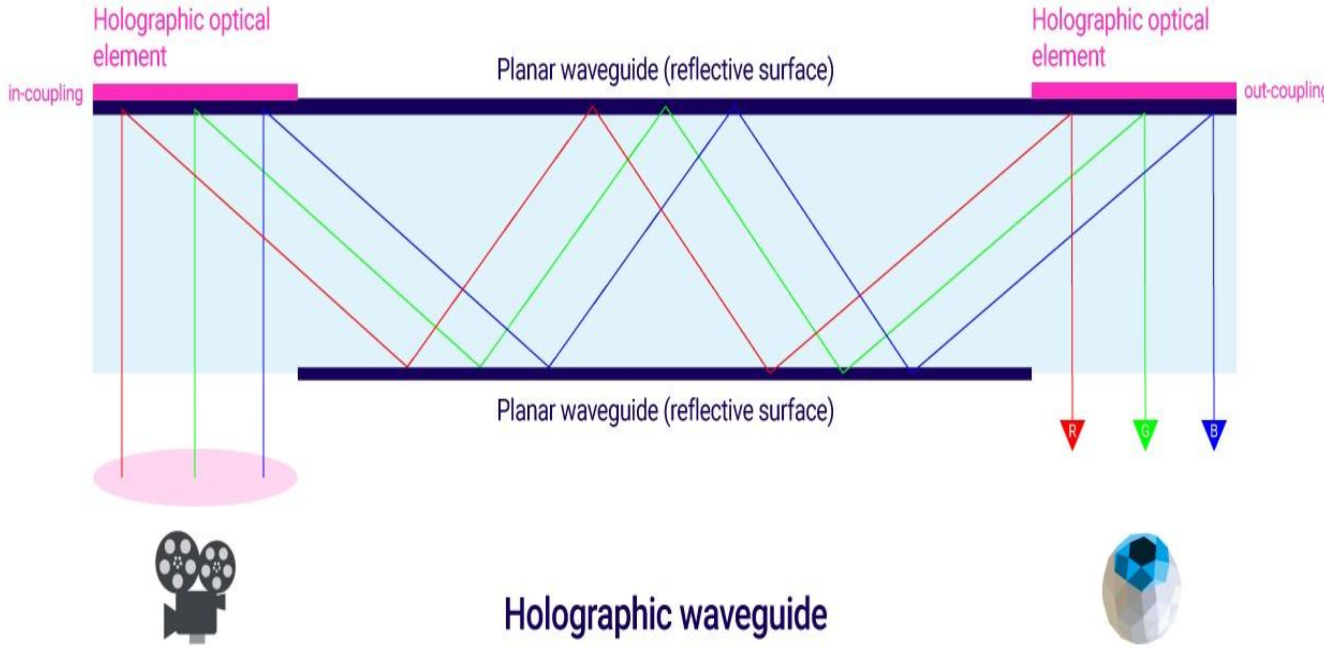
A virtual retinal display (VRD) is a personal display device under development at the University of Washington's Human Interface Technology Laboratory under Dr. Thomas A. Furness III. With this technology, a display is scanned directly onto the retina of a viewer's eye. This results in bright images with high resolution and high contrast. The viewer sees what appears to be a conventional display floating in space.

Several of tests were done to analyze the safety of the VRD. In one test, patients with partial loss of vision—having either macular degeneration (a disease that degenerates the retina) or keratoconus—were selected to view images using the technology. In the macular degeneration group, five out of eight subjects preferred the VRD images to the cathode-ray tube (CRT) or paper images and thought they were better and brighter and were able to see equal or better resolution levels. The Keratoconus patients could all resolve smaller lines in several line tests using the VDR as opposed to their own correction. They also found the VDR images to be easier to view and sharper. As a result of these several tests, virtual retinal display is considered safe technology.

Virtual retinal display creates images that can be seen in ambient daylight and ambient room light. The VRD is considered a preferred candidate to use in a surgical display due to its combination of high resolution and high contrast and brightness. Additional tests show high potential for VRD to be used as a display technology for patients that have low vision.

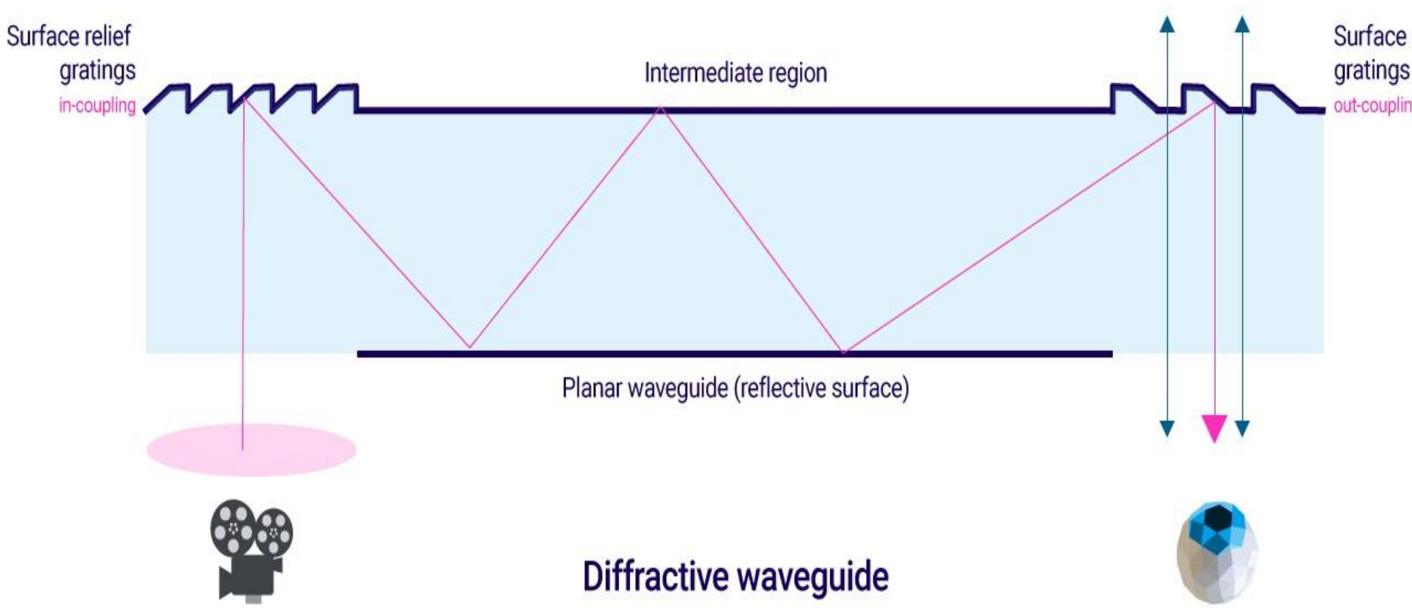
Holographic waveguide

This is a fairly simple type of wave-guide with optical elements like lenses used for in-coupling (entry) and out-coupling (exit) through a series of internal reflections. This type of waveguide is used in Sony's Smart Eyeglass displays.

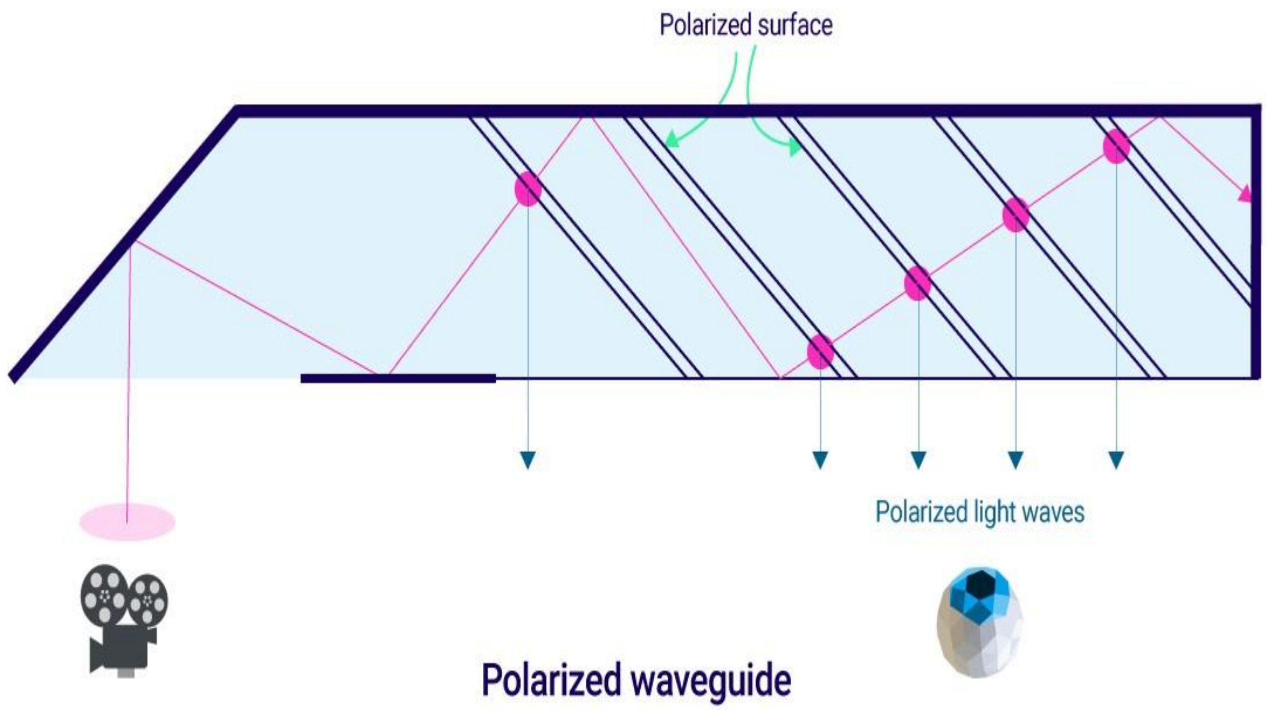


Diffractive waveguide

Precise surface relief gratings are used to achieve internal reflections for a seamless overlay of 3D graphics through the display. These waveguides are used in a number of Vuzix displays and Microsoft's Hololens.

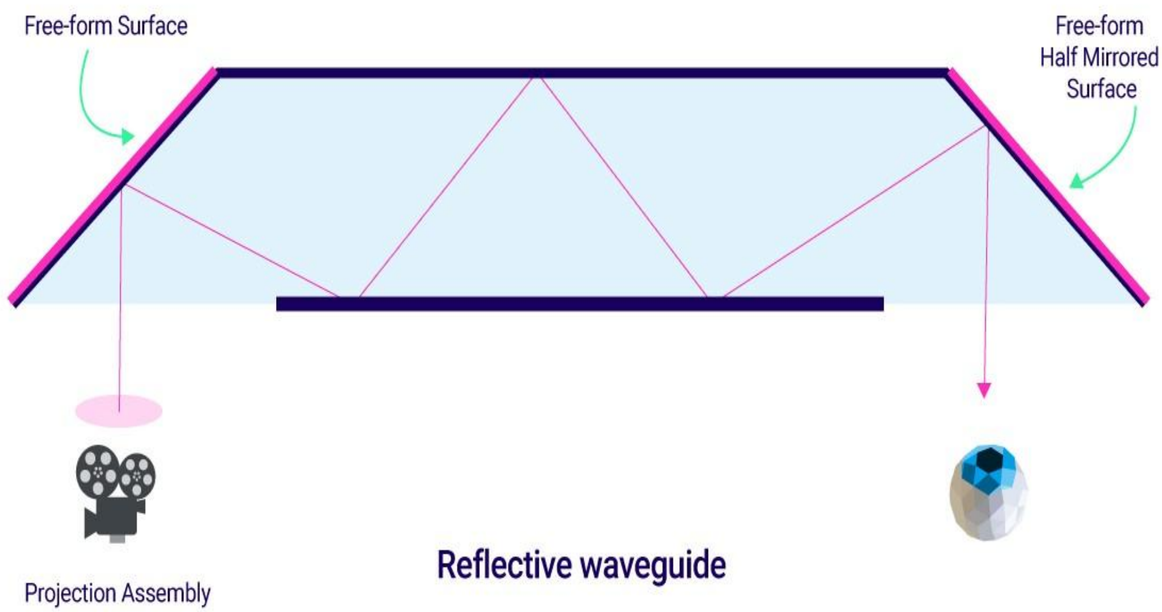


Polarized waveguide
Light enters the waveguide and through a series of internal reflection on a partially reflective polarized surface. Selected light waves cancel out (polarization) exiting into the viewer's eye. The method is used by the Lumus DK-50 AR glasses.



Reflective waveguide

This is similar to the holographic waveguide in which a single planar light guide is used with one or more semi-reflective mirrors. This type of waveguide can be seen in Epson's Moverio as well as Google Glass.

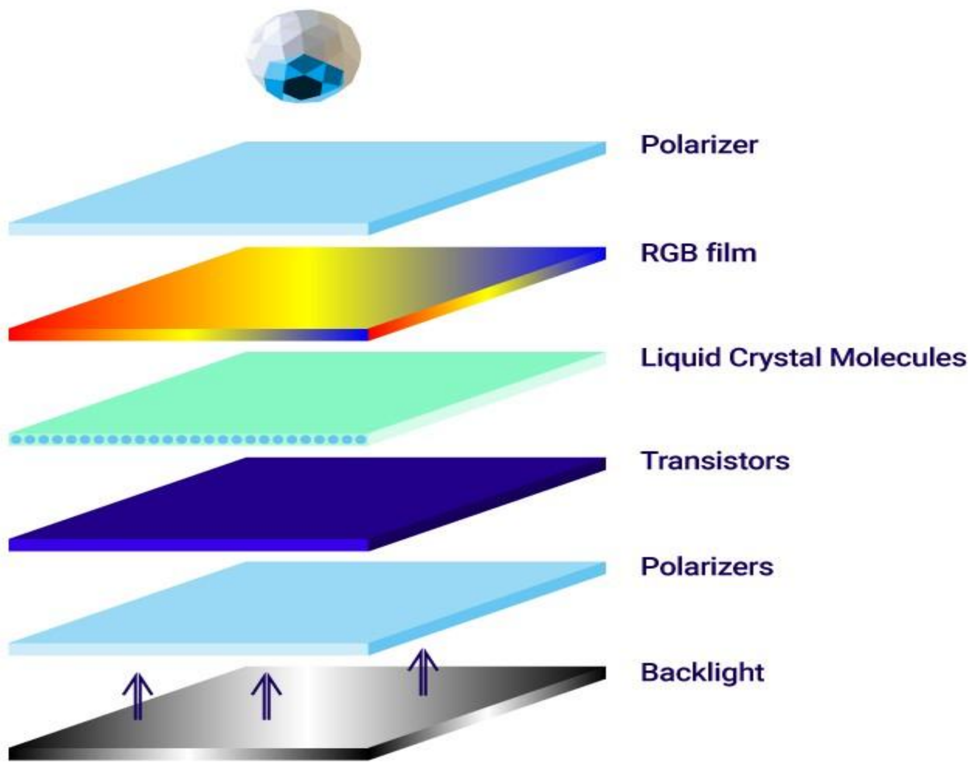


Imaging technologies

Imaging and display technologies have improved greatly in the past few decades. High end CRTs have been mostly replaced by four key imaging technologies:

Liquid Crystal Displays (LCD)

LCDs are common in high definition televisions and have been used in ARVR displays since 1980s. This display type consists of an array of cells containing liquid crystal molecules sandwiched between two polarizing sheets. This contraption rests between thin glass substrates printed with millions of transistors. For colored LCDs, an additional substrate containing red, green and blue filters is positioned over each cell of the substrate. A single RGB liquid crystal cell is called a sub pixel. Three sub pixels form one pixel. A electric current is passed through the glass substrates. Varying the current allows the LCD to modulate the passage of light to create a precise color. If all sub pixels are fully open, it creates a white light. Liquid crystal cells do not emit their own light and require backlighting. The liquid crystal cells can only vary the passage of light to create the desired color and subsequently an image.



LCD structure

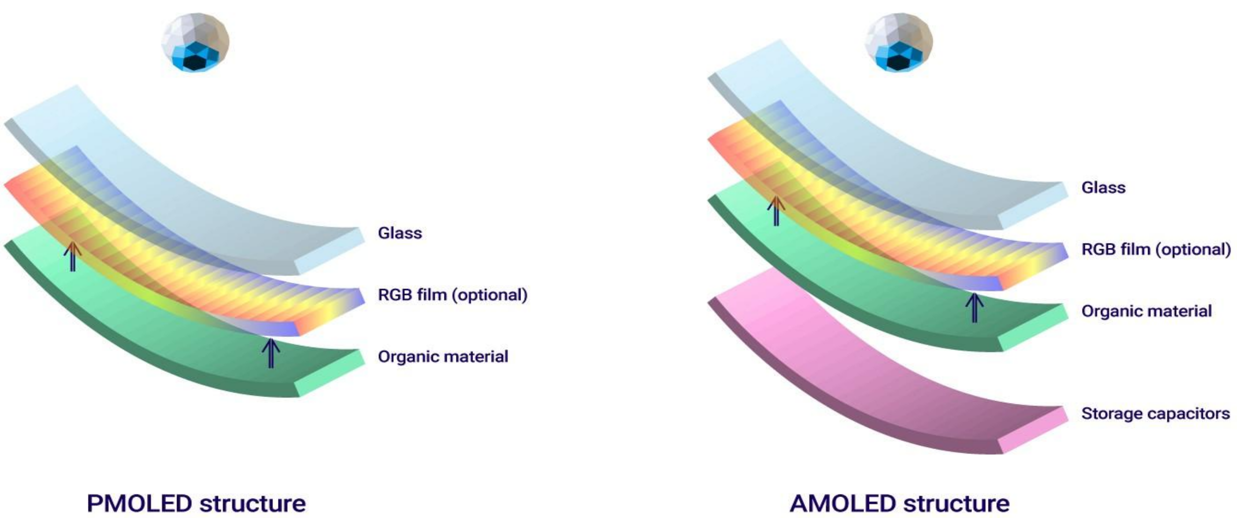
Organic Light Emitting Diode (OLED)

This display technology is based on organic (carbon and hydrogen bonded) materials that emit light when an electric current is applied. This is a solid-state display technology where energy passed through the organic sheet is released in the form of light, also known as electroluminescence. Colors can be controlled by carefully crating organic emission, however most manufacturers add red, green and blue films in the OLED stack. There are two types of OLED panels:

1. Passive Matrix OLED (PMOLED):
   Like CRTs, this display type consists of a complex electronic grid to sequentially control individual pixels in each row. It does not contain storage capacitors making update rates slow and a high power consumption to maintain a pixel's state. These are mainly used for simple character and iconic displays.

2. Active Matrix OLED (AMOLED):
   Unlike PMOLEDs, AMOLEDs consist of a thin transistor layer that contains a storage capacitor to maintain each sub pixel's state providing greater control over individual pixels. In case on AMOLEDs, individual pixels can be completely switched off enabling deeper blacks and higher contrast.

These are most suitable display types for near-eye virtual and augmented reality devices.

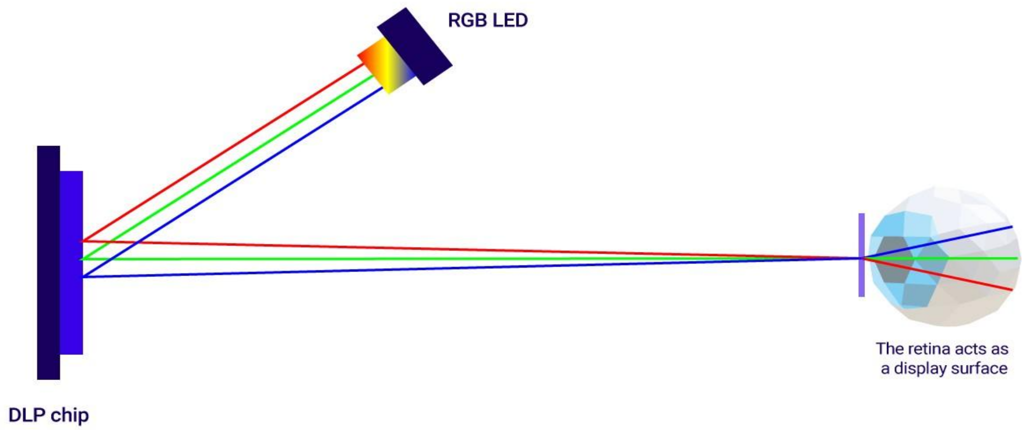


OLEDs are flexible

OLEDs and AMOLEDs in particular are far superior to LCDs. Their construction is relatively simpler and they can be extremely thin since there is no need of external backlighting. In addition to this they consume significantly less power, have faster refresh rates, high contrast, great color reproduction and higher resolutions. Most fully immersive HMDs utilize this technology.

Digital Light Projector (DLP) Micro display

Originally developed by Texas Instruments, DLP chip is also referred to as a Digital micro mirror device (DMD). The display consists of about 2 million individually controlled micro mirrors each which can be used to represent a single pixel. Each of these micro mirrors measure approximately 5.4 microns. What is interesting about these displays is that the retina of the eye itself serves as a display surface. RGB light is reflected on these micro mirrors which tilt towards and away from the light source. As each micro mirror can be reoriented in either direction thousands of times in a second, varying the reflected color can produce different shades of light on the retina.



DLP micro-display

DLP Micro displays are one of the fastest display technologies in existence. Their speed of color refresh, low latency, low power consumption and extreme high resolutions (0.3 inch array diagonal enables a 1280 x 720 image) make them ideal candidates for building head-mounted displays.

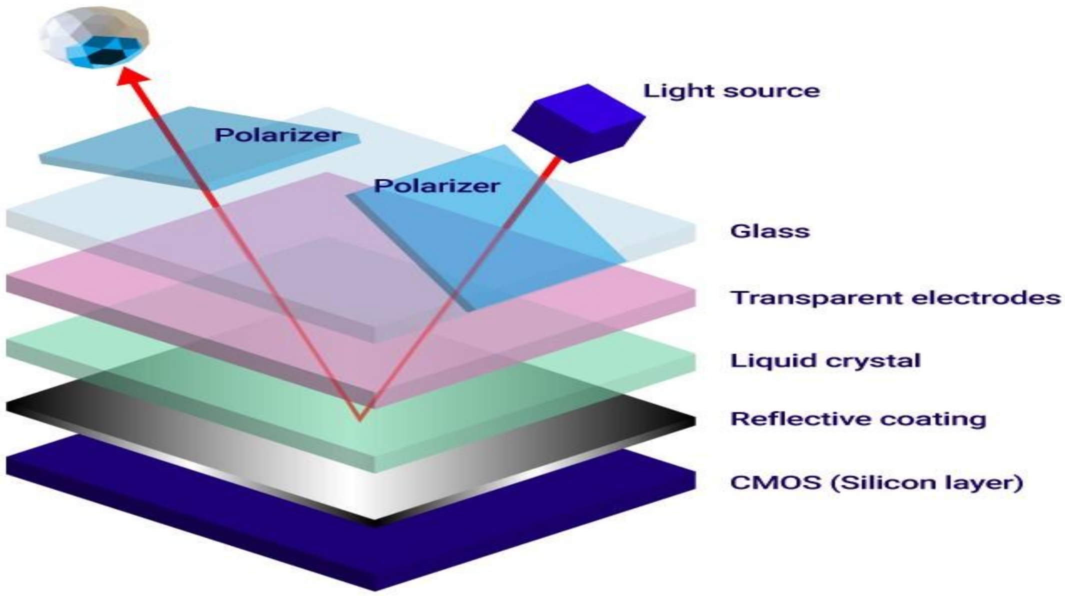
DLP micro-display comparative scale

Scale of DLP Micro displays

Liquid Crystal On Silicon (LCOS) Micro display

LCoS Displays lie somewhere in between LCD and DLP displays. LCD is a transmissive technology where the image is generated and transmitted to the user while DLP is a reflective technology where individual sub pixels are reflected through micro mirrors. Light source is passed onto a reflective surface. As the light reflects, it passes through a series of sub filters that modulate the light intensity and color. Similar to DLP displays, their small size enables considerable flexibility when integrating with small form factor devices.

Microsoft's Hololens, Google Glass and even the Magic Leap One uses an implementation of LCoS Micro displays.



LCoS micro-display

LCoS modulates light from an external source to produce the image

Given the extreme resolutions of display technologies in development, it is almost certain that flat panel based HMDs might become a thing of the past for AR devices.

SECTION-A

1.------------technology is able to take an existing environment and add a layer of virtual information on top of it.

A. VR B. AR C. Invested reality D. Reality augmentation [ ]

2.Which defines AR?

A. medical enhancement B. mechanical enhancement [ ]

C. computer enhancement D. None of the above

3.which is caused by AR?

A. Hologram B. Holocaust C. Screensaver D. Holophrastic
[ ]

4.One of these is a feature of augmented reality.
[ ]

A. Readily available B. Affordable C. Very expensive D. None of the above

5.How is VR different from AR?

A. Speed B. Accessibility C. Affordable D. Computer generation
[ ]

6.Which is an example of AR?

A. Pikachu B. Pokemon Go C. Gta D. SpongeBob
[ ]

7.In immersive technology, what does MR stand for?

A. Mixed Reality B. Measured Reality
[ ]
C. More Reality D. Mirrored Reality

8. Which one of the following is not an essential factor in integrating the HMD with the helmet?

A. Must not interfere with the oxygen mask
[ ]
B. Protect eyes and head during high-speed ejection
C. Geometry of the cockpit
D. Overall minimum weight for comfort

9. What are the advantages of HMS (Helmet Mounted Sights) over HMD?

A. Display flight data in the pilot's line of sight
[ ]
B. Provide target locking capabilities by looking at the target
C. Provide a FOV of 360°
D. Provide enhanced vision by combining radar and FLIR

10.------------keep track of position.

A. motion analyzer B. Motion trackers C. HMD D. SMD
[ ]

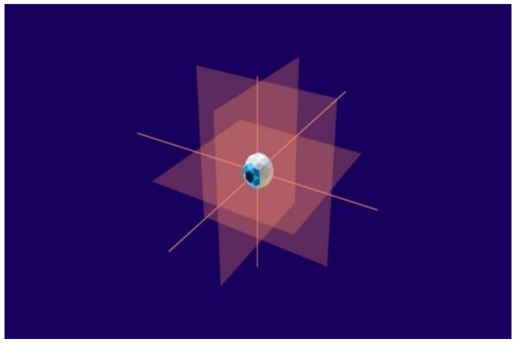
SECTION-B

1.Differentiate Virtual Reality and augmented Reality?
2. List and give explanation about the augmented reality components?
3. Define HUD and explain how it works with neat sketch?
4.How does HMD use and example?
5. Explain working principle of smart glasses?
6.Explain augmented display with any of two displays?

UNIT – VI

Understanding Virtual Space

A computer's understanding of space for Augmented Reality



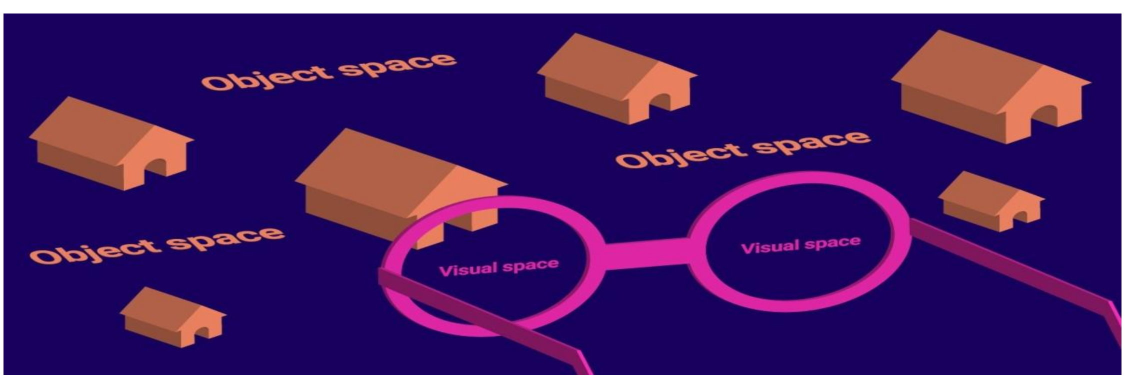
The goal of Augmented Reality is to superimpose the computer's perception of space with human's understanding of it. In computer science, space is simply a metaphor for commonly agreed and scientifically validated concepts of space, time and matter. A computer's understanding of space is nothing more than a mathematically defined 3D representation of objects, location and matter. It can be simply understood by means of coordinate systems without the need of confusing jargon like hyper-realties or alternate universes. Although these are definitely interesting thought experiments. A virtual space is nothing but a computer's understanding of the real world as provided by humans.

Humans are spatial beings. We interact with and understand a large portion of our realities in three dimensions. As Augmented reality tries to simulate virtual worlds into human reality, it is important to understand the basic aspects of virtual 3D spaces.

Visual space and object space

What we perceive as location of objects in the environment is the reconstruction of light patterns on the retina. A visual space in computer graphics can be defined as perceived space or a visual scene of a 3D virtual space being experienced by a participant.

The virtual space in which the object exists is called the object space. It is a direct counterpart of the visual space.



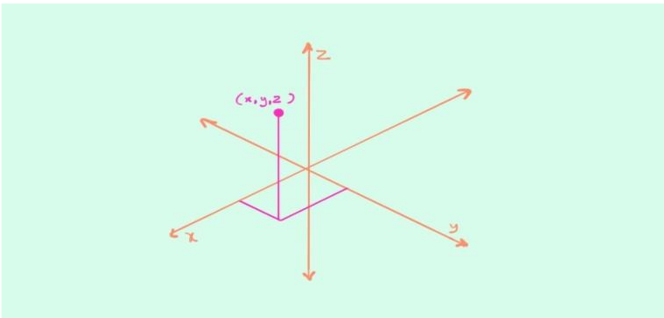
Each eye sees the visual space differently. This is a critical challenge of computer graphics for binocular virtual devices or smart glasses. In order to design for virtual worlds, it is important to have a common understanding of the position and orientation of virtual objects in the real world. Common co-ordinate and orientation systems greatly help here.

Position and coordinates

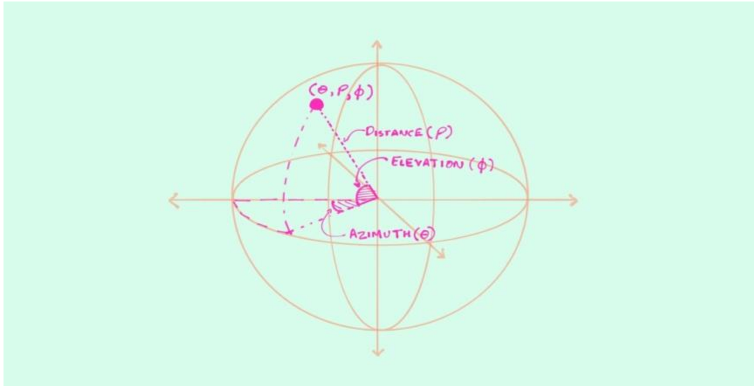
Three types of coordinate systems are used for layout and programming of virtual and augmented reality applications:

Cartesian Coordinates

The Cartesian coordinate system is used mainly for it's simplicity and familiarity and most virtual spaces are defined by it. The x-y-z based coordinate system is precise for specifying location of 3D objects in virtual space. The three coordinate planes are perpendicular to each other. Distances and locations are specified from the point of origin which is the point where the three planes intersect with each other. This system is mainly used for defining visual coordinates of 3D objects.

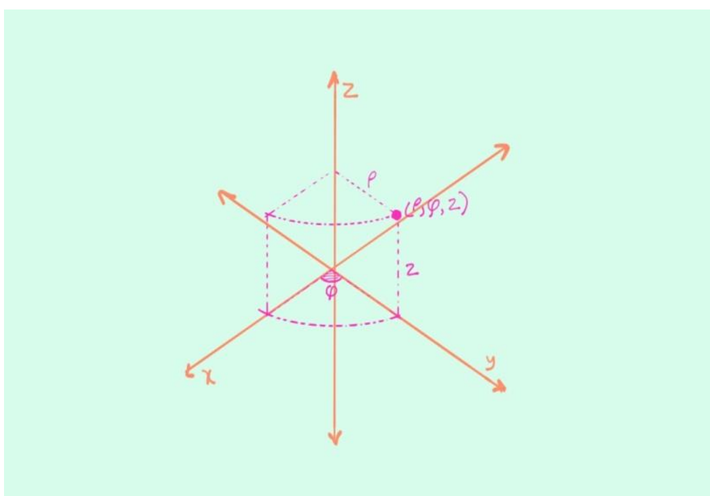


The Cartesian system defines the positions of 3D objects often with respect to an origin point. A system of spherical polar coordinates is used when locating objects and features with respect to the users' position. This system is used mainly for mapping of a virtual sound source, or the mapping of spherical video in the case of first person based immersive VR. The Spherical coordinate system is based on perpendicular planes bisecting a sphere and consists of three elements: azimuth, elevation and distance. Azimuth is the angle from the origin point in the horizontal/ground plane, while the elevation is the angle in the vertical plane. Distance is the magnitude or range from the origin



Cylindrical Coordinates

This system is mainly used in VR applications for viewing 360 degree panoramas. The cylindrical system allows for precise mapping and alignment of still images to overlap for edge stitching in panoramas. The system consists of a central reference axis (L) with an origin point (O). The radial distance (ρ) is defined from the origin (O). The angular coordinate (φ) is defined for the radial distance (ρ) along with a height (z). Although this system is good for scenarios that require rotational symmetry, it is limited in terms of it's vertical view.



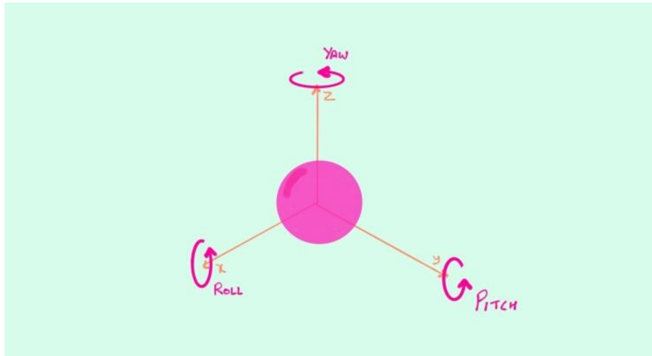
Defining orientation and rotation

It is necessary to define the orientation and rotation of user viewpoints and objects along with their position in the virtual space. Knowing this information is especially important when tracking where the user is looking at or for knowing the orientation of virtual objects with respect to the visual space.

Six degrees of freedom (6 DOF)

In virtual and augmented reality, it is common to define orientation and rotation with three independent values. These are referred as roll (x), pitch (y) and yaw (z) and are know an Tait-Byan angles. A combination of position (x-y-

z) and orientation (roll-pitch-yaw) is referred to as six degrees of freedom (6 DOF).



Navigation

Navigation and way finding are two of the most complex concepts in virtual space especially for VR and AR. It can be handled by either physical movement of the user in real space or by use of consoles for traversing larger distances. For example, the physical movement might refer to movement of your hands and legs for shooting in a game like Call of duty while virtual movement would refer to the player going to an enemy base. There are a large number of devices that enable virtual movement from keyboards, game controllers to multi-directional treadmills. A single universal interface to navigate both virtual and physical space could possibly be the holy grail for navigation controller design.

Assignement-Cum-Tutorial Questions

SECTION-A

I. Descriptive Questions

1) What are two types of visual space?

2) Define Orientation and rotation?

3) What is navigation and explain it?

4) What is 6DOF? Explain with an example?

5) Explain Co-ordinates with example briefly?

6) Differentiate visual space and object space?

7) Differentiate Cartesian coordinate and cylindrical coordinate?

SECTION-B

1.Which organization used augmented reality as a navigation tool in 1990s?

A) NASA B)British Royal Navy C)United States Air Force D)M16

2. Which industry was the first to use augmented reality for commercial purposes/

a) Fashion b) Film **c) Auto** d) Food

3. _______ generation of computer started with using vacuum tubes as the basic components.

a)1st b)2nd c)3rd d) 4th

4. Which popular Netflix show also put AR on the mainstream map, with one particularly spooky episode featuring AR in gaming?

a) House of cards **b) Black Mirror** c)Master of None d) Sense

5. Retail is one industry predicted to be significantly disrupted by AR. Approximately what percentage of consumers are ready to experience AR when shopping?

a)3% b)10% c)16% **d)29%**