8 IT 04

Virtual and Augmented Reality

UNIT II

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Professor and Head

Department of Information Technology

SEMESTER : EIGHT

Sr. No.	Subject Code	Subject	TEACHING SCHEME					EXAMINATION SCHEME								
			HOURS / WEEK					THEORY					PRACTICAL			
			Lecture	Tutorial	P/D	Total HOURS/WEEK	CREDITS	Duration Of Paper (Hr.)	Max. Marks Theory Paper	Internal Marks	Total	Min. Passing Marks	Max. Marks Int.	Max. Marks Ext.	Total	Min. Passing Marks
THEORY																
01	8IT01	Object Oriented Analysis & Design	3	--		3	3	3	80	20	100	40	--	--	--	--
02	8IT02	Professional Ethics & Management	3	--		3	3	3	80	20	100	40	--	--	--	--
03	8IT03	Entrepreneurship & Project Management	3	--		3	3	3	80	20	100	40	--	--	--	--
04	8IT04	Prof. Elective-V (PE-V)	3	--		3	3	3	80	20	100	40	--	--	--	--
PRACTICALS / DRAWING / DESIGN																
05	8IT05	Object Oriented Analysis & Design Lab	--	--	2	2	1	--	--	--	--	--	25	25	50	25
06	8IT06	Prof. Elective-V (PE-V)- Lab	--	--	2	2	1	--	--	--	--	--	25	25	50	25
07	8IT07	Project & Seminar	--	--	12	12	6	--	--	--	--	--	75	75	150	75
		Total	**12**	**--**	**16**	**28**	**20**	**--**	**--**	**--**	**400**	**--**	**--**	**--**	**250**	**--**
															Total	**650**

8IT04 : PE-V: (i) Robotics (ii) Virtual & Augmented Reality (iii) Human Computer Interaction (iv) Cross Platform Application Development

Syllabus

8IT04 (Prof. Elect.-V) (ii) VIRTUAL AND AUGMENTED REALITY

Unit I: Introduction of Virtual Reality Hours: Defining Virtual Reality, History of Virtual Reality, Human Physiology and Perception, Five Classic components of VR, Applications of VR.

Unit II: Input and Output Devices for Virtual Reality: Three dimensional position tracker and mechanical tracker, Navigation and manipulation Interfaces, Gesture Interfaces, Graphic displays, Sound Displays and Human Haptic System.

Unit III: Virtual Reality Computing Architectures: Rendering Pipeline, Graphics Rendering Pipeline, Haptic Rendering Pipeline, PC Graphics Architecture, Workstation Based Architectures and Distributed VR Architectures.

Unit IV: Introduction to Augmented Reality: Defining Augmented reality, History of augmented reality, The Relationship Between Augmented Reality and Other Technologies- Media. components of VR, Applications of VR.

Unit V: Augmented Reality Hardware and software: Major Hardware Components for AR System:-Overview of Sensor, Processor and Display. Major Software Components for AR System:-Software or editing and creating 2D and 3D Graphics. components of VR, Applications of VR.

Unit VI: Augmented Reality Applications: Define: Content, Introduction to Mobile Augmented Reality with its advantages and its disadvantages, Application Areas, Future and trends of Augmented Reality.

UNIT II

Unit II: Input and Output Devices for Virtual Reality:

Input Devices

- Three dimensional position tracker and
- mechanical tracker,
- Navigation and manipulation Interfaces,
- Gesture Interfaces,

Output Devices

- Graphic displays,
- Sound Displays and Human Haptic System.

Course Outcome CO

Course Pre-requisite:

Fundamental mathematics knowledge:

Course Objectives:

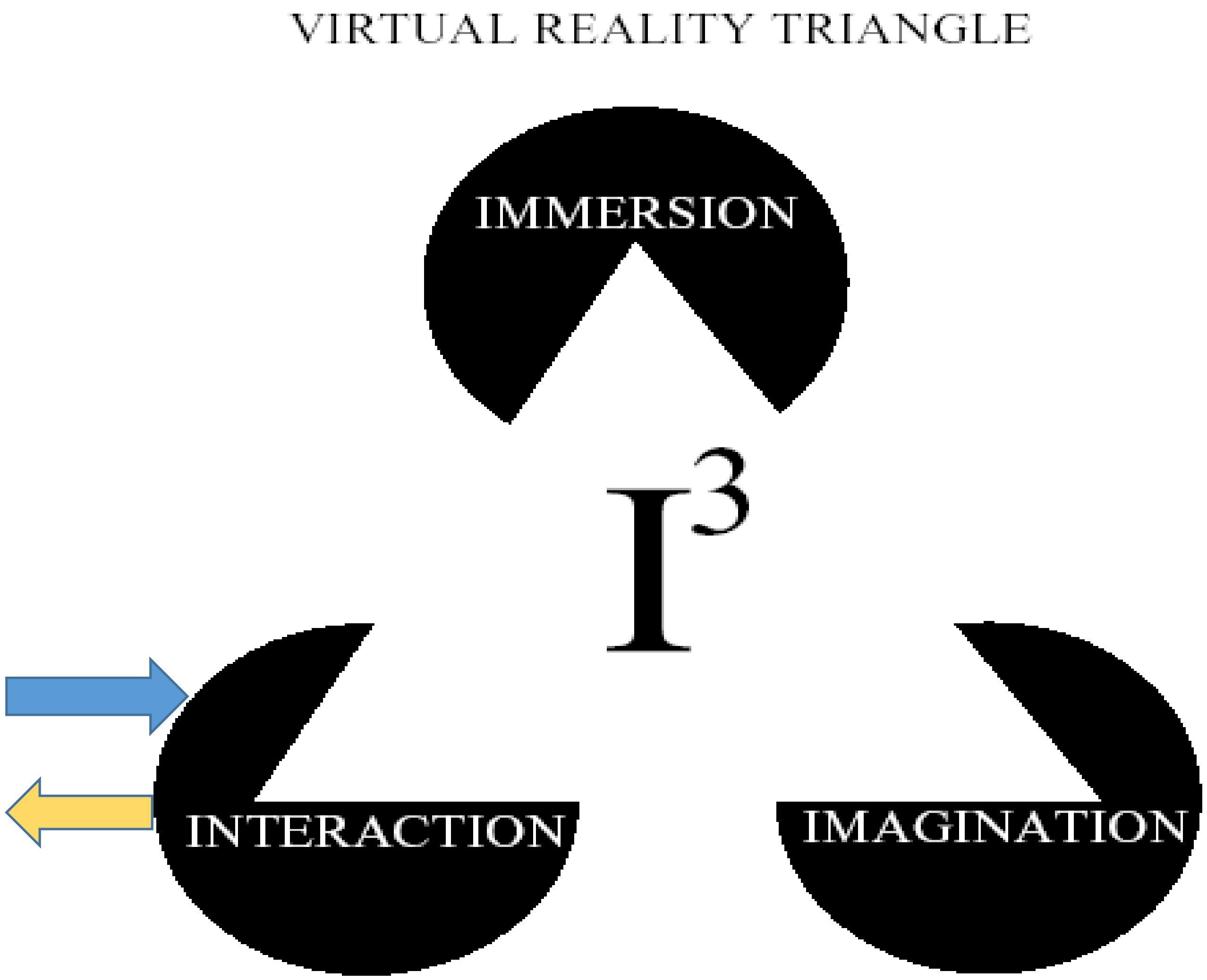
The objective of this course is to provide a foundation to the fast growing field of virtual and augmented reality and make the students aware of its applications.

Course Outcomes:

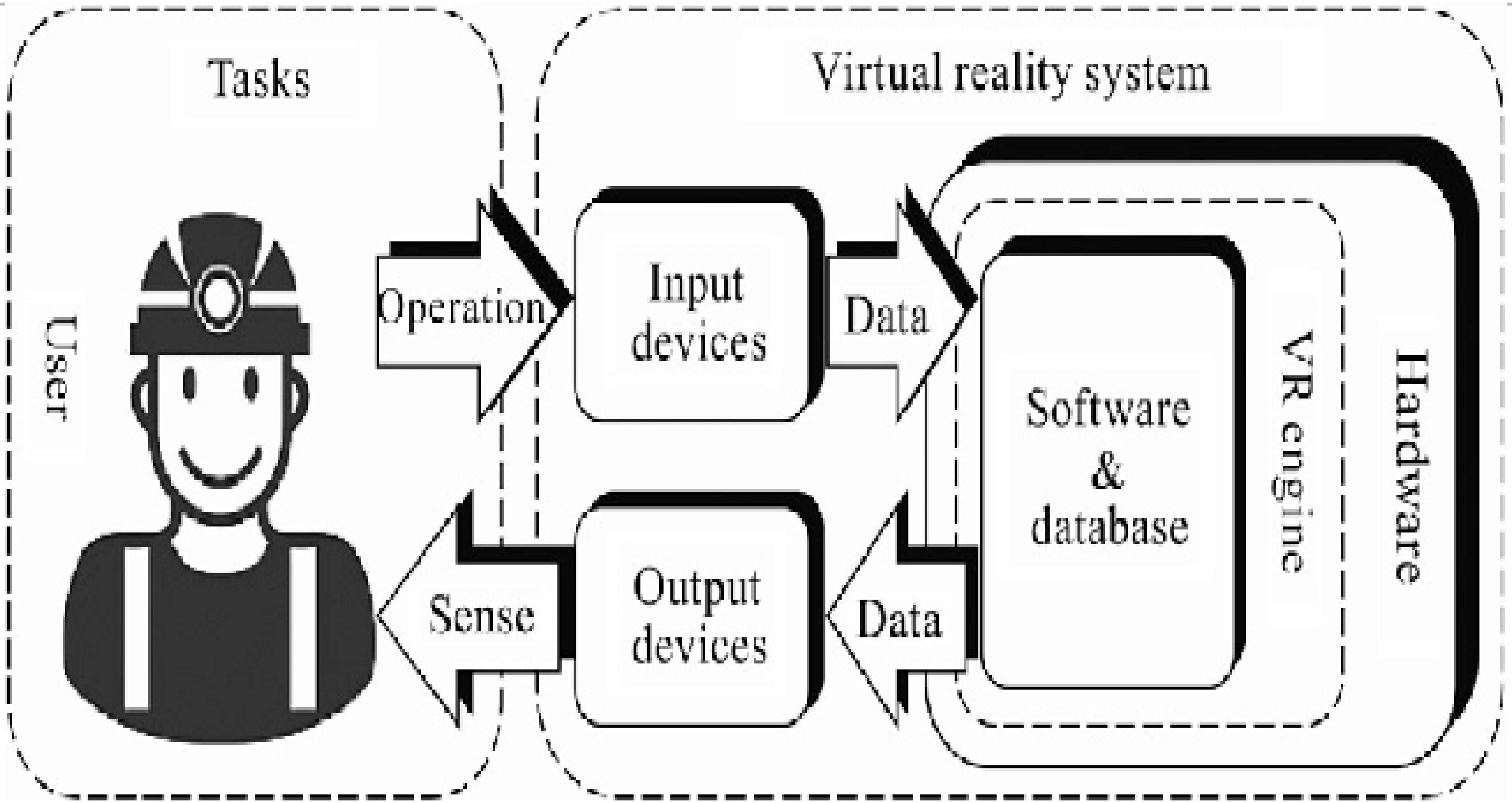
On completion of the course, the students will be able to:

1. Understand basic concepts of virtual reality with its applications.
2. Understand and describe computing architectures, hardware and software needed for virtual reality.
3. Learn the basic knowledge of augmented reality.
4. Understand and analyze hardware and software needed for augmented reality.
5. Understand the knowledge about various applications of augmented reality.

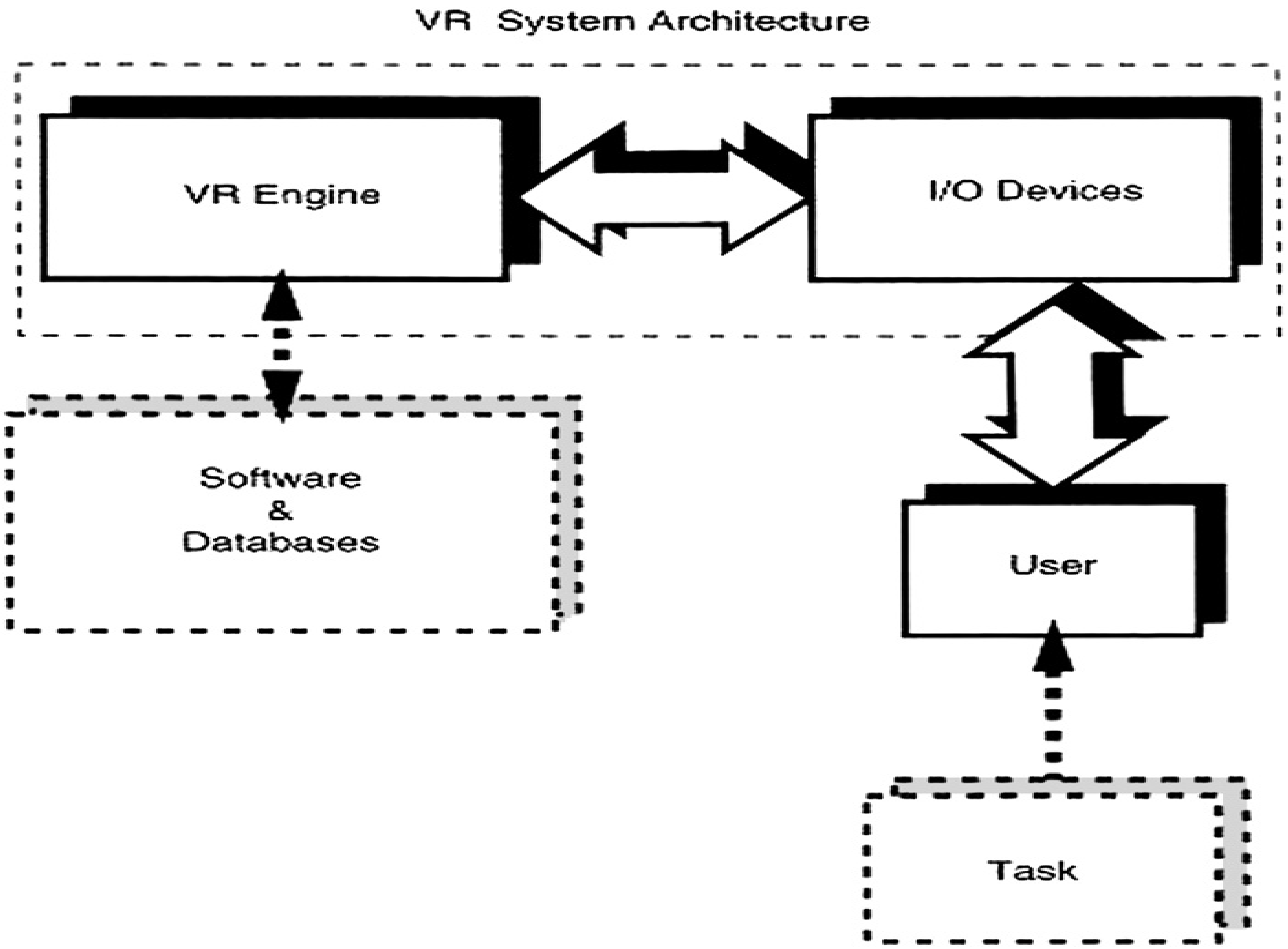
Three important I's in VR



Five Classic components of VR

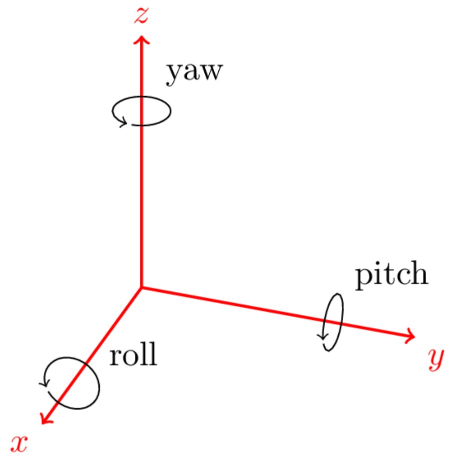


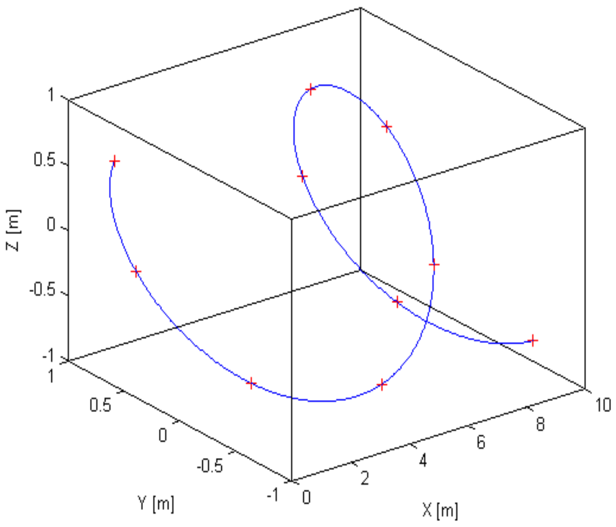
Five Classic components of VR



Three dimensional Position Trackers

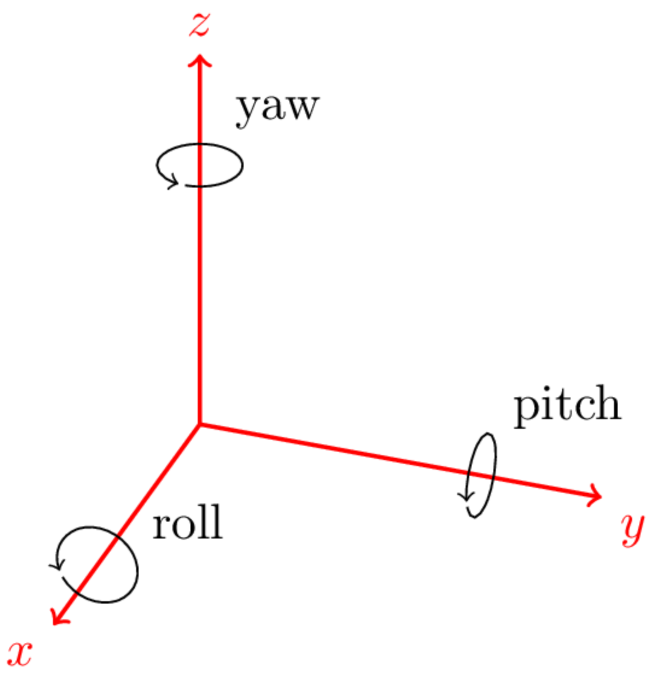
Application Domains: navigation, ballistic missile tracking, Ubiquitous Computing, Robotics , Biomechanics, Architecture, Computer Aided Design, Virtual Reality and Education require knowledge of the real time position and orientation of the moving objects with some frame of reference.

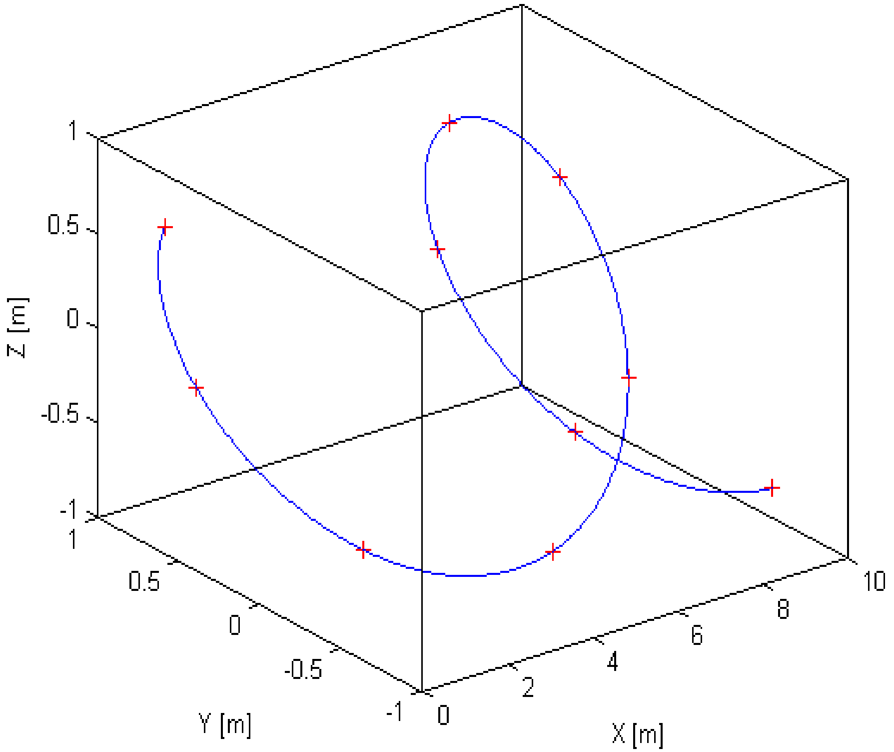




Three dimensional Position Trackers

Definition : A special purpose hardware used in Virtual Reality to measure the real time change in 3 D object position and orientation is called as a 3D position tracker.





Three dimensional Position Trackers

- Virtual Reality Applications typically measure the motion of user’s head, hands, or limbs for the purpose of view control, locomotion and object manipulation.
- A newer tracker application in Virtual Reality is for the control of **an avatar** or virtual body mapped to the user.
- In the case of the head mounted display (HMD) 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.

Three dimensional Position Trackers

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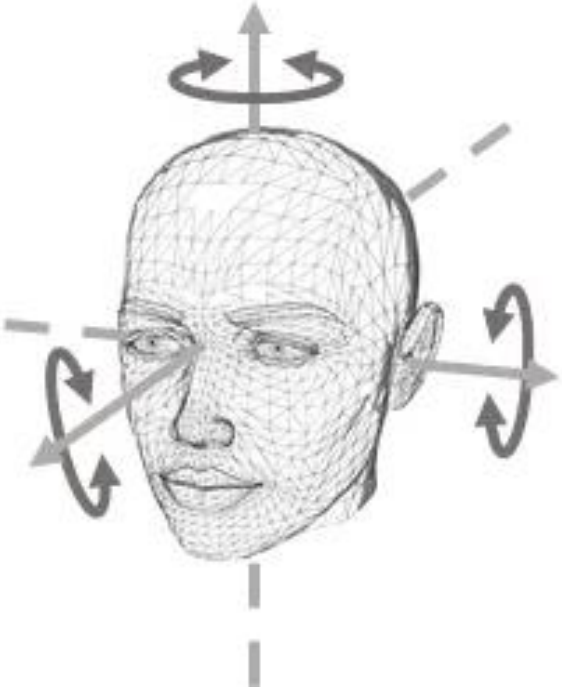

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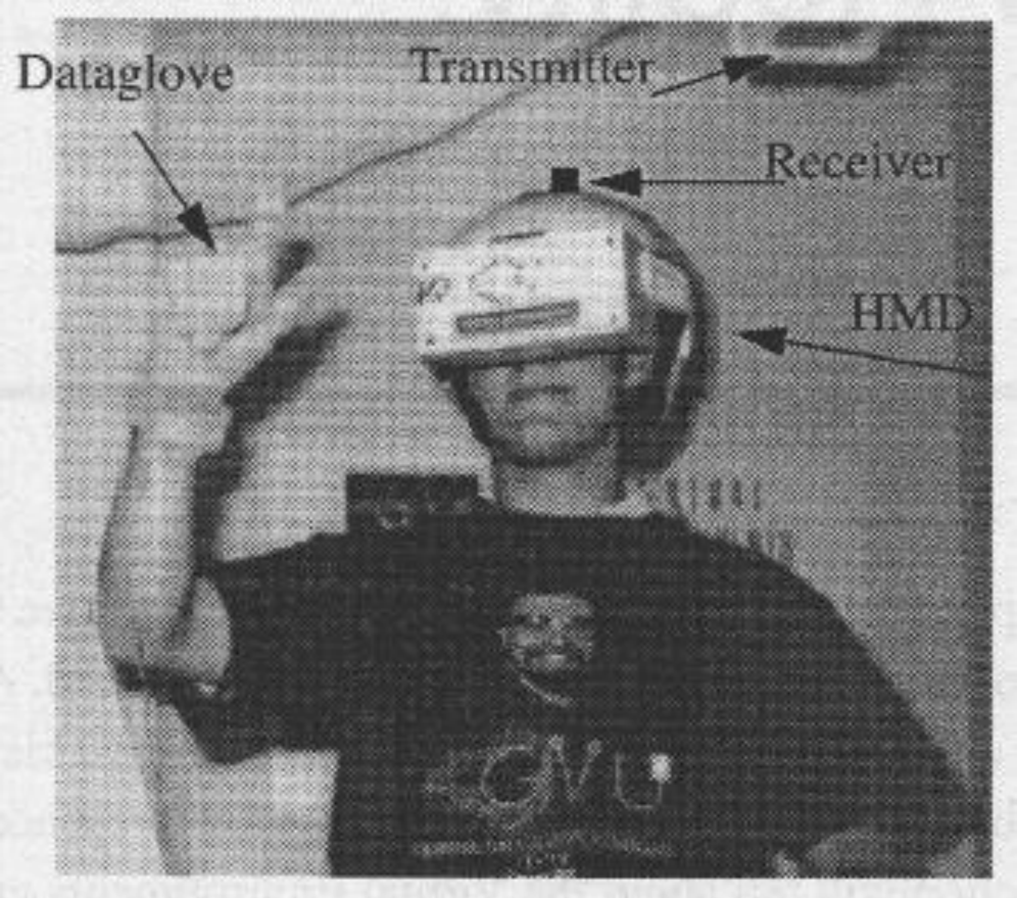

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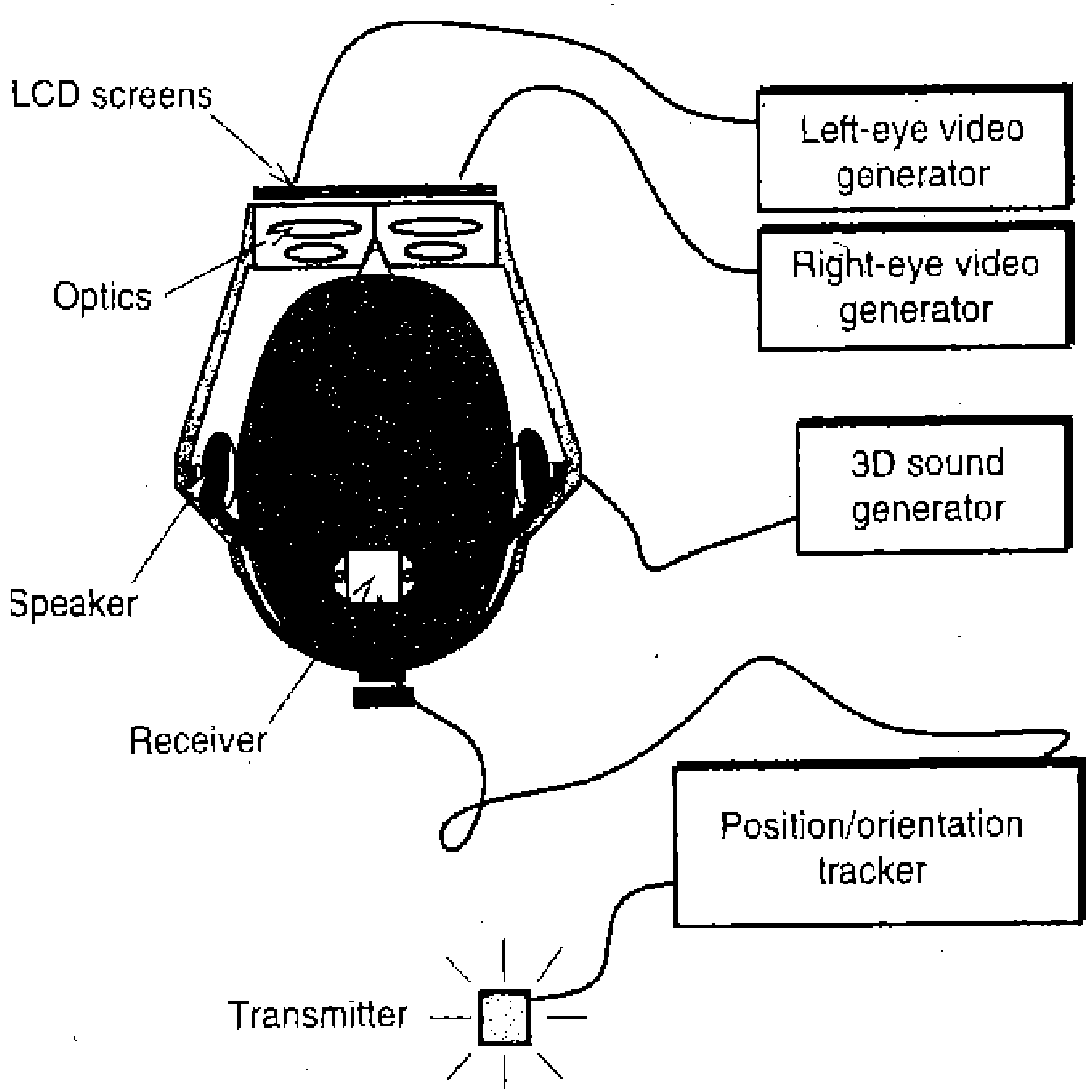
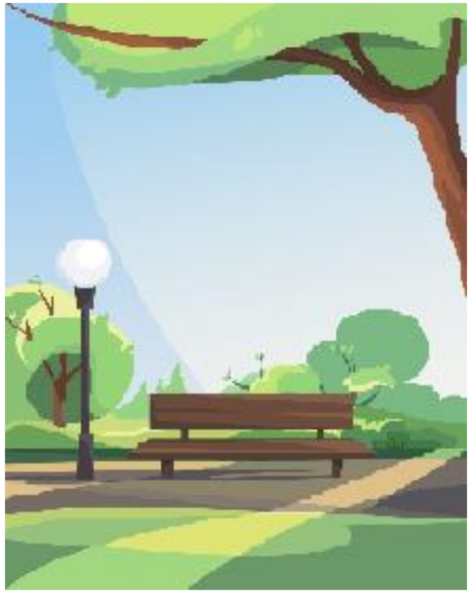
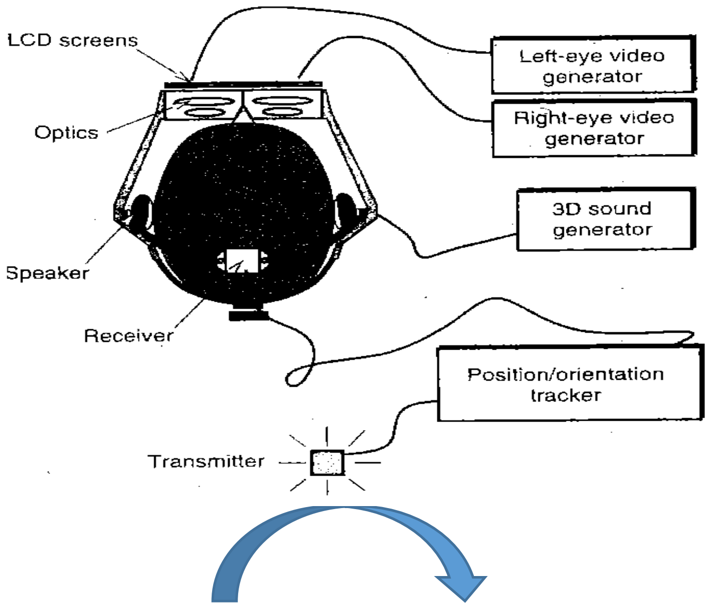


Three dimensional Position Trackers

- The user's head motion is sampled by an electronic unit and sent to a host computer.
- The computer uses the tracker data to calculate a new viewing direction of the viewing scene and to render updated the image scene.





Three dimensional Position Trackers

- Without head mounted tracker as feedback it is not possible for the computer to update the scene of the spatial view.
- Another virtual reality sensorial modality that uses tracker information is 3D sound which is presented to user through headphones.
- Tracker data allow the computer to integrate 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

Tracker Performance parameters

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

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

Drift : Tracker drift is the steady state increase in tracker error with time.

Latency: It is the time delay between action and the result. In case of the 3D tracker , latency is the time between the change in object position/orientation and the time the sensor detects this change.

Tracker update rate: It represents the number of measurements that the tracker reports every second.

Mechanical Trackers

The first tracker was used in those days when the head mounted displays were of CRT displays, in which the VR simulation was linked with mechanical arm. The motion of user's head was tracked with regard to the ceiling arm attachment.

A mechanical tracker consists of a serial or parallel kinematic structure composed of links interconnected using sensorized joints.

The dimensions of each link segment are known as priori and used by the Direct kinematics computational model stored in the computer.

This model allows to determine the position and orientation of one end of the mechanical tracker relative to the other, based on real time reading of tracker joint angles

Mechanical Trackers

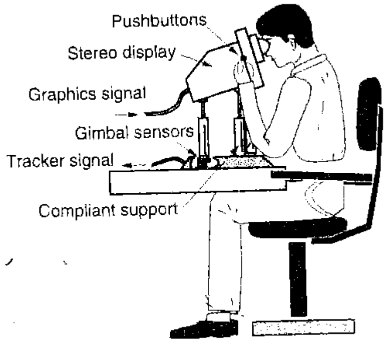
Mechanical Trackers have certain advantages when compared with other tracker technologies.

- They are simpler and easier to use.
- Their accuracy is fairly constant over the tracker work envelope and depends essentially on the resolution of the joint sensors used.
- They are interference free unlike magnetic trackers
- They have very little jitter and lowest latency of all types.
- They are occlusion free unlike optical trackers.

Mechanical Trackers

A mechanical tracker is used as part of the Push display as shown in Figure.

This desk-top interface allows the user to navigate in virtual worlds displayed on a high-resolution stereo display.



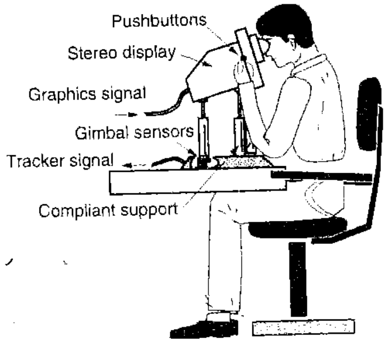
The weight of the CRT displays is supported by three compliant telescopic pistons and a bottom plate.

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.

Mechanical Trackers

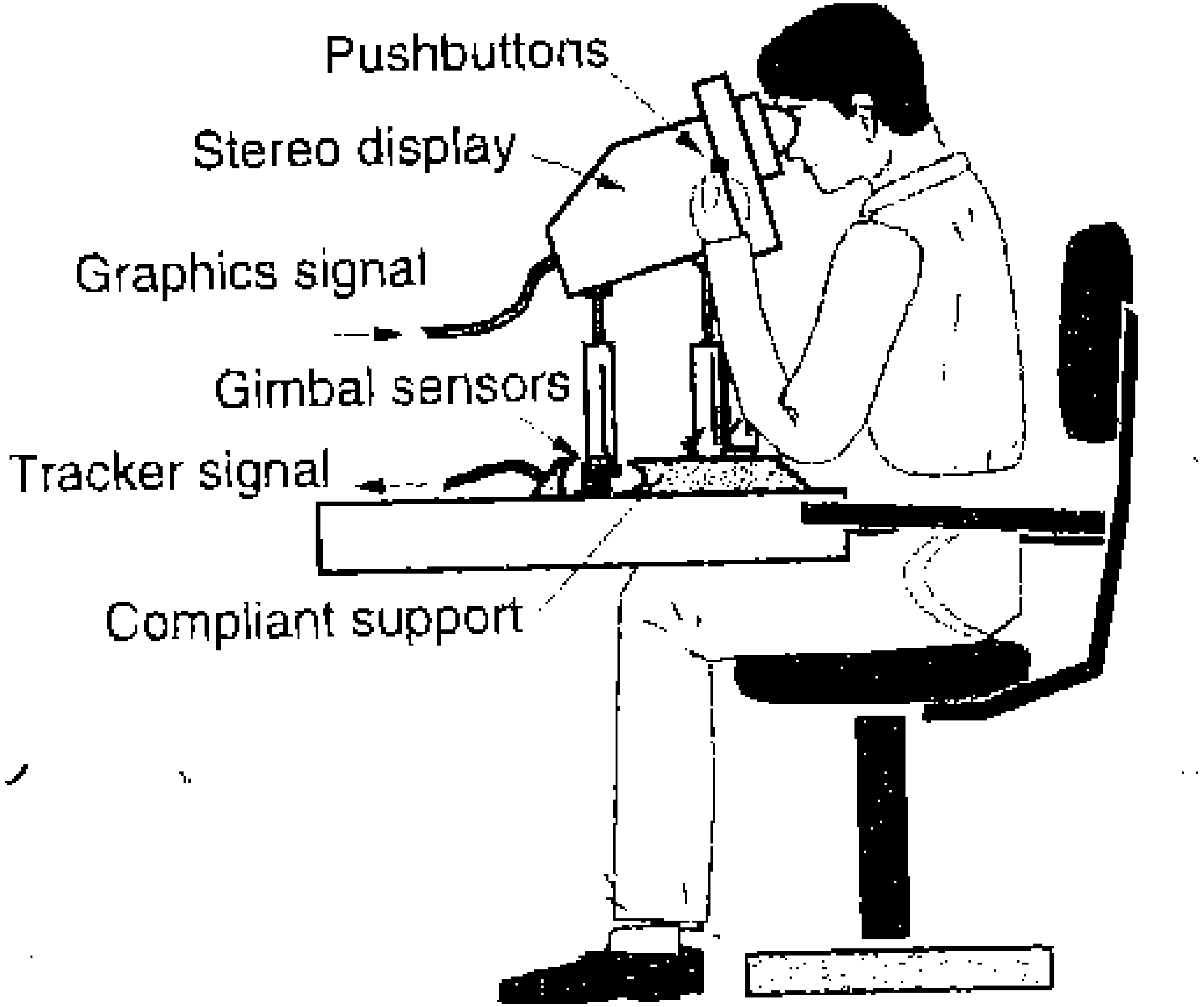
The gimbal rotational encoders measure the degree of platform displacement front-back, left-right, and twist.



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 is 70 datasets/sec, and its latency is extremely low (0.2 µsec).

Mechanical Trackers



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Mechanical Trackers

- A more complex mechanical tracker is the Gypsy motion capture suit illustrated in Figure.
- It consists of a sensorized exoskeleton worn on a Lycra suit.
- The user's 15 joint positions are measured by 42 single-turn conductive plastic precision potentiometers with an accuracy of 0.08°.
- Wires from each sensor are routed through hollow Aluminum housings at the shoulders and hips.
- The wires are then connected to three cables that go to the host computer.
- Since the sensors produce an analog signal, the length of the three connection cables is limited (60 ft) to minimize resistive losses.

Gypsy motion capture

Mechanical Trackers

- An analog-to-digital converter card is needed by the host PC in order to sample the tracking suit more than 30 times every second.
- The structure of the mechanical tracker is formed of bendable Aluminum plates, swiveling clips, and a rubber harness and weighs between 5 and 7 kg (12-17 lb), depending on the particular model.
- The mechanical tracking suit, like any other tracking suit, measures body positions relative to a body-attached reference.
- In order to simulate walking, running, and any other body position change relative to an external system of coordinates, the Gypsy tracking suit includes footstep microswitches.

Mechanical Trackers

- This is an approximate method, which works well as long as at least one foot is on the ground.

- The Gypsy 2.5 tracking suit includes a gyroscope, which improves the accuracy of footstep positional information by providing body orientation data independently of the mechanical tracker information.

Mechanical Trackers

- For all their advantages, mechanical trackers have a number of drawbacks, the most obvious being their limited range, or work envelope, due to the dimension of the mechanical arm.
- If the links are longer, their weight and inertia increase, and their susceptibility to unwanted mechanical oscillations increases.
- Another drawback is the reduction in the user's freedom of motion due to the motion interference from the tracker arm itself.
- This is compounded if several mechanical trackers need to be used simultaneously, such as for HMD and sensing gloves.
- Finally, there are clear ergonomic drawbacks related to mechanical tracker weight. This poses a problem when the tracker structure has to be supported by the user, as in the case of tracker suits.
- It can lead to fatigue as well as a diminishing sense of immersion into virtual environments.

Gypsy motion capture

Other Trackers

- Magnetic Trackers : Non Contact type position measurement using magnetic field produced by stationary transmitter and receiver at relative position/object.
- Types AC Magnetic type and DC Magnetic Type

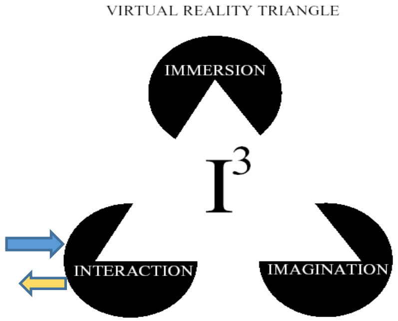
- Ultrasonic Trackers: Non Contact type position measurement that uses ultrasonic signal produced by stationary transmitter and receiver at relative position/ object.

- Optical Trackers: Non Contact type position measurement that uses Optical sensing to determine real position / orientation of an object.

- Hybrid Inertial Trackers: They are used to measure the rate of change of an object position and orientation.

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.

NAVIGATION AND MANIPULATION INTERFACES

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.

Navigation/manipulation in relative coordinates allows for incremental position control relative to the object's previous 3D position.

The position of the VR object is incremented by six signed quantities at every simulation cycle. Velocity is indirectly controlled, as a larger translation /rotation increment will result in a larger velocity of the VR object in the simulation.

NAVIGATION AND MANIPULATION INTERFACES

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 pushbuttons, trackers become navigation and manipulation interfaces.

Examples are the Polhem's 3Ball and the Ascension Technology 3D Mouse. The 3Ball is a hollow billiard ball that houses a tracker receiver inside and has a pushbutton on the surface.

NAVIGATION AND MANIPULATION INTERFACES

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 the 3Ball.

NAVIGATION AND MANIPULATION INTERFACES

Further functionality is obtained through the programming of the three buttons incorporated on the 3D Mouse.

One drawback of absolute position control of virtual objects is the user's limited arm reach. The larger the dimensions of the graphics display, the more this becomes a problem.

NAVIGATION AND MANIPULATION INTERFACES

One way to solve the disparity between the user's arm reach and the (larger) display dimensions is to-multiply the tracker readings with a constant (gain) larger than unity.

The drawback is that tracker noise is equally amplified, and selected objects appear more jittery than they would otherwise be.

An alternative is to use indexed motions, in which virtual objects are selected and deselected repeatedly. When the object of interest is deselected, it stays in place, while the user moves his or her arm back and then reselects the object and moves it using the tracker, and so on.

NAVIGATION AND MANIPULATION INTERFACES

Track Ball :

A class of interfaces that allow navigation/manipulation in relative coordinates are trackballs.

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

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.

NAVIGATION AND MANIPULATION INTERFACES

Track Ball

- 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.

NAVIGATION AND MANIPULATION INTERFACES

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. Several pushbuttons are integrated with the trackball support, within reach of the user's fingers. These buttons are binary on/off and can be programmed according to the application. For example, one button can be used to increase the simulation gains (or VR object speed), and another button to couple and decouple the trackball with the VR object it controls. Finally, some buttons may be used to start and stop the simulation, or to reset the simulation to a default start location, if the user becomes disoriented.

NAVIGATION AND MANIPULATION INTERFACES

Trackballs suffer from sensor coupling. Although the user may wish to have the VR object translate, but not rotate, the VR object may do both translations and rotations. This is due to nonzero sensed torques when pure forces are applied by the user's fingers on the cylinder. These unwanted motions can be suppressed with software filters that only read forces and not torques, or by hardware filters. These hardware filters are pushbuttons (available on some trackballs) that allow users to select translation-only, rotation-only, or dominant-motion input.

NAVIGATION AND MANIPULATION INTERFACES

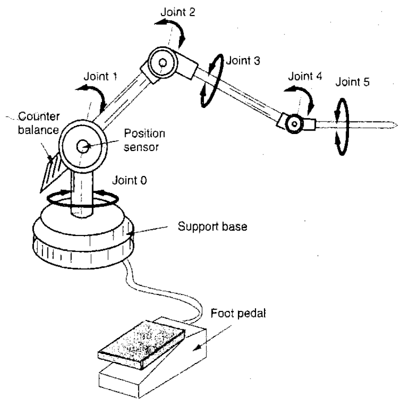
3D Probes :

Users felt a need for an I/O 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 MicroScribe 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

NAVIGATION AND MANIPULATION INTERFACES

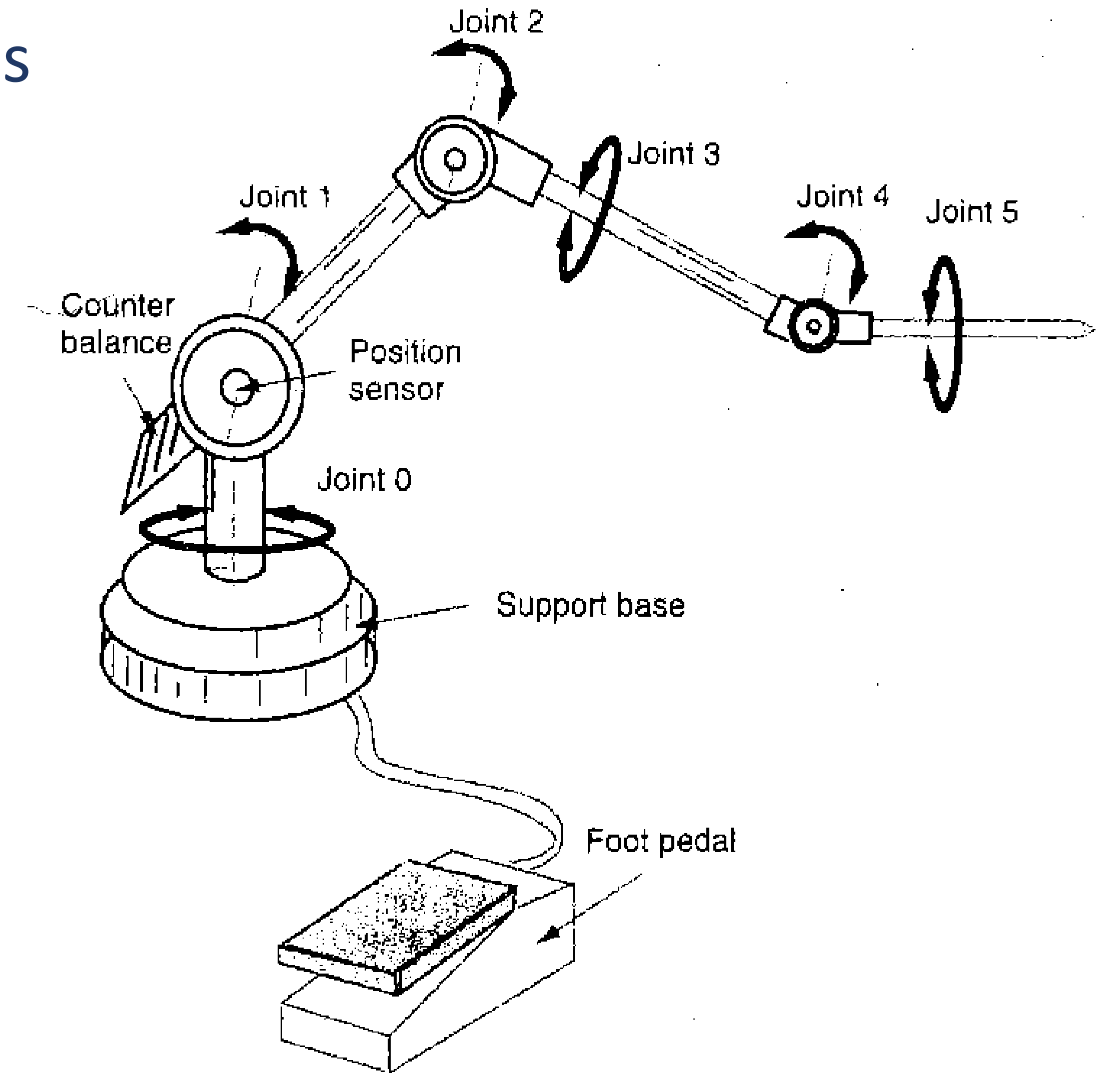
3D Probes :

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, allowing 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 mark a point on the real object surface for digitization purposes.



NAVIGATION AND MANIPULATION INTERFACES

3D Probes



NAVIGATION AND MANIPULATION INTERFACES

In 3D Probes, Alternatively, the foot pedal may also be used to control the flying speed in the virtual scene.

The direction of the velocity vector is then given by the probe tip (last link) orientation.

The MicroScribe 3D workspace depends on its model, ranging from a 50-in.-radius hemisphere (models 3D and 3DX) to a 66-in.-radius hemisphere (models 3DL and 3DLX).

NAVIGATION AND MANIPULATION INTERFACES

These measurements are not affected by magnetic fields, as the probe is a mechanical structure.

It is thus possible to measure over 1000 positions/sec with minimal latency.

The difference between the probe's actual and measured positions and orientations represents its accuracy.

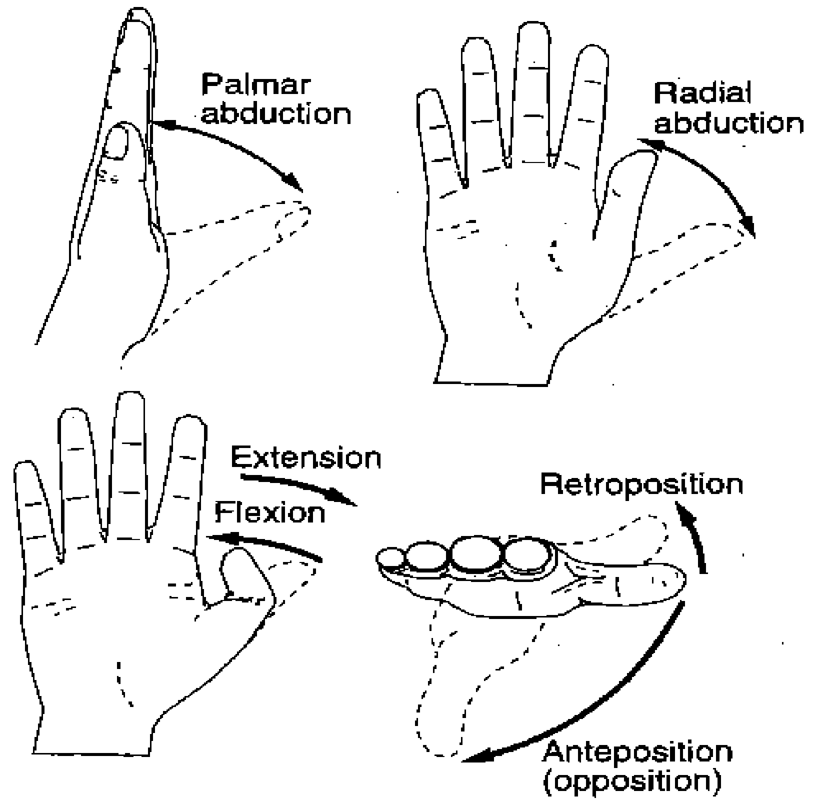
Errors will occur owing to the joint sensor resolution, temperature variations, or joint tolerances.

GESTURE INTERFACES

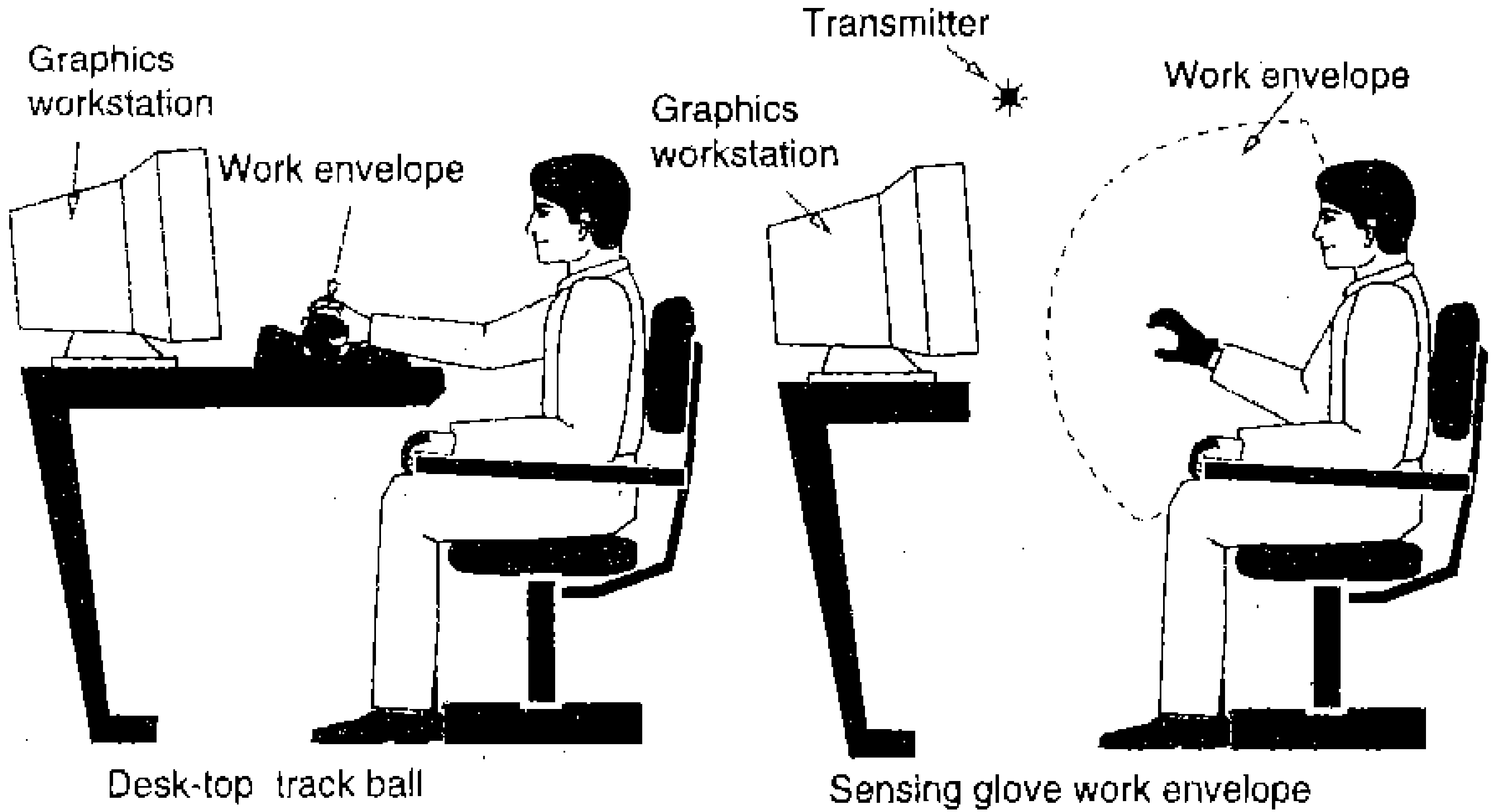
- Trackballs and 3D probes have the advantage of simplicity, compactness, and quiet operation. By their nature they limit the freedom of motion of the user's hand to a small area close to the desk,
- Therefore the natural motion of the user's hand is sacrificed, and interaction with the virtual world is less intuitive.
- In order to have large gesture-based interactions with the VR simulation, it is necessary that the I/0 devices maintain the hand freedom of motion within a certain volume.
- It is also desirable to allow additional degrees of freedom by sensing individual finger motions.

GESTURE INTERFACES

The human fingers have degrees of freedom associated with flexion—extension and lateral abduction—adduction, as shown in Figure. Additionally, the thumb has an anteposition—retroposition motion, which brings it in opposition to the palm.



GESTURE INTERFACES



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.

GESTURE INTERFACES

Some of the available commercial sensing gloves are: the Fakespace Pinch Glove, the Fifth Dimension Technology 5DT Data Glove , the Anon Technology Didjiglove, and the Immersion Technology CyberGlove .

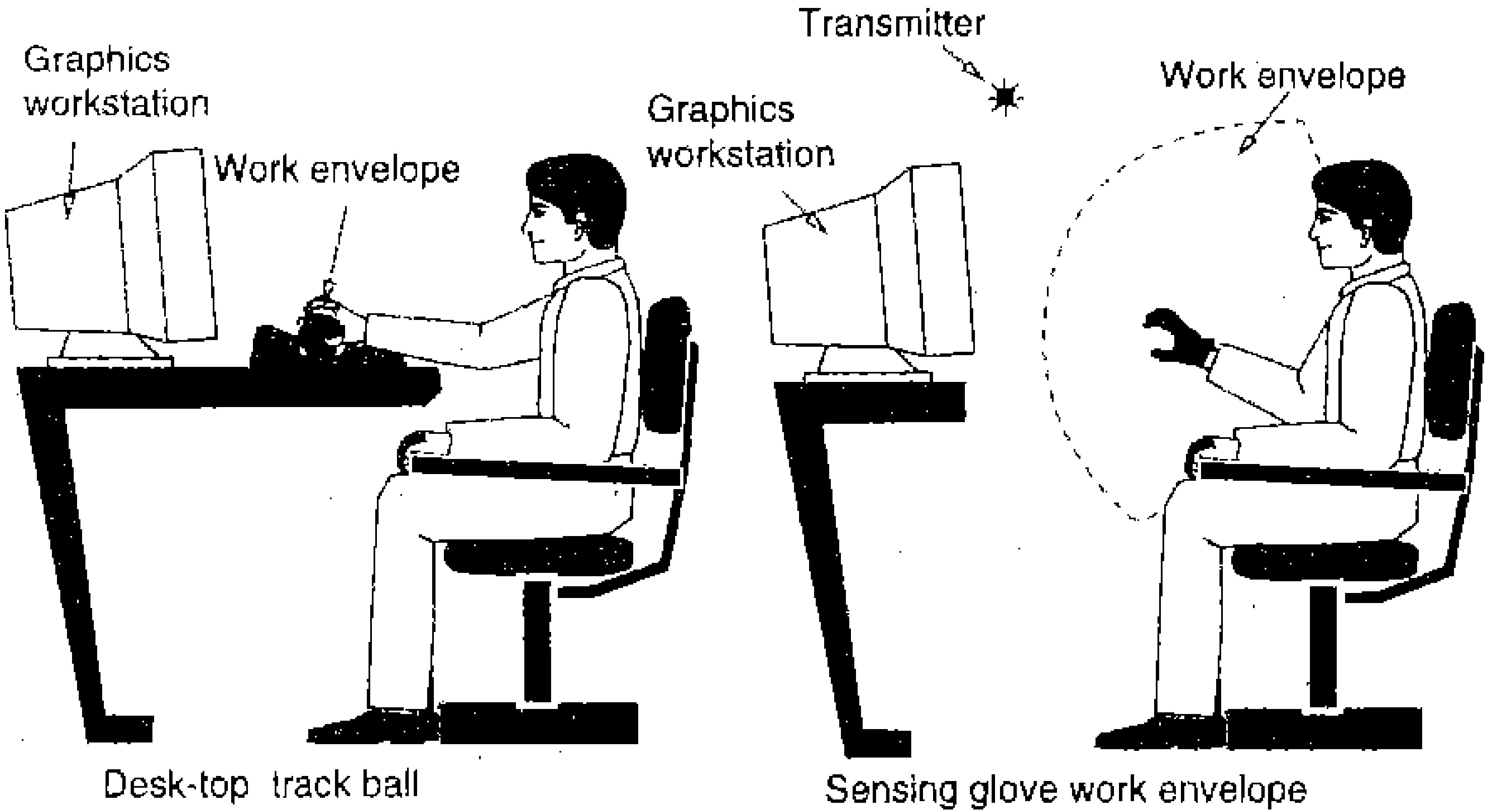
In short there are following four types of interfaces available for gesture Interfaces

1) Pinch Glove,
2) 5DT Data Glove ,
3) Didjiglove, and
4) CyberGlove .

GESTURE INTERFACES

- 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 shown in Figure.
- 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.

GESTURE INTERFACES



GESTURE INTERFACES

Pinch Glove

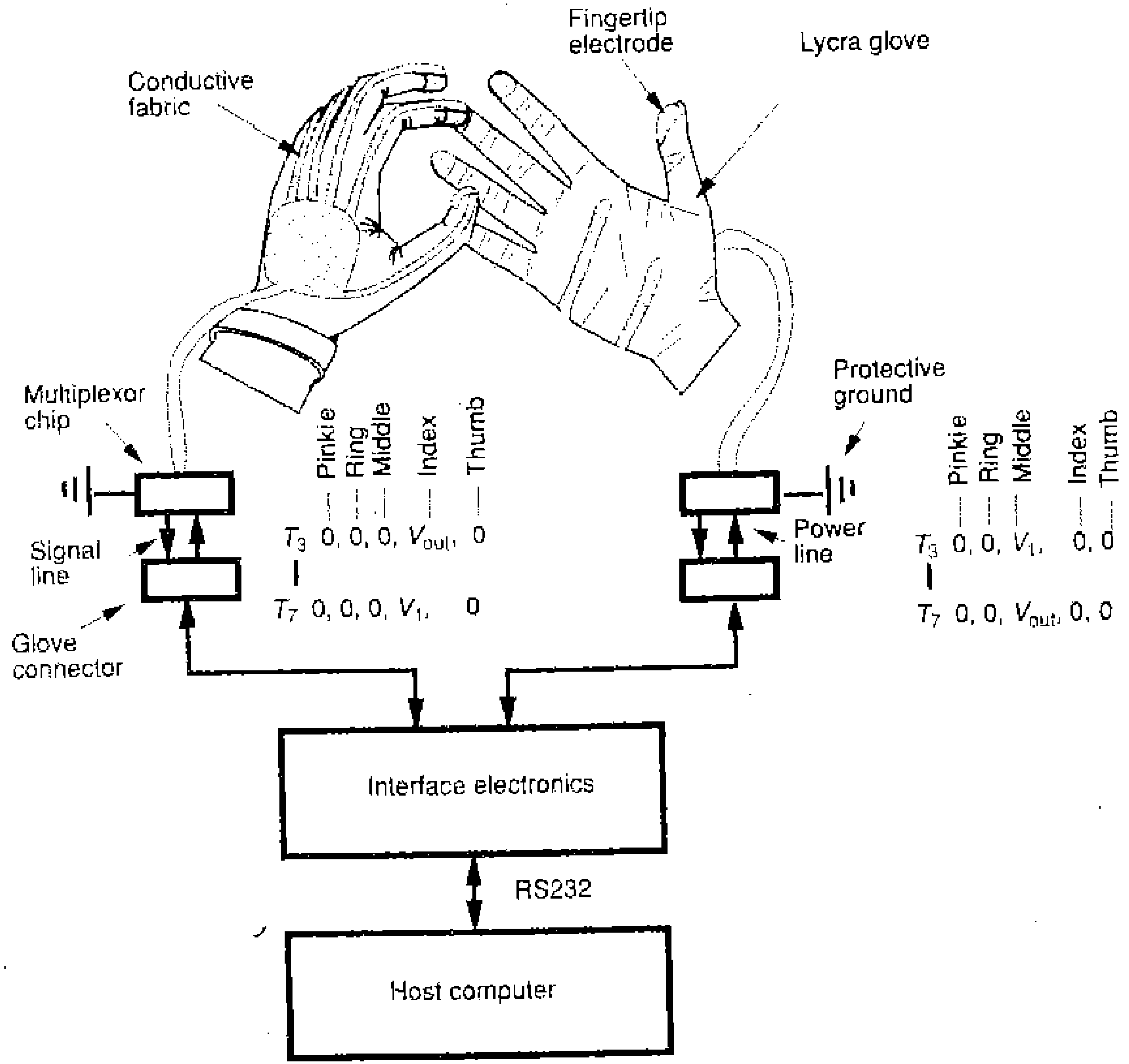
- The drawbacks that most sensing gloves have are need for user-specific calibration; complexity, and high cost.
- Each person has a different hand size, with women generally having smaller hand size than men.
- As a consequence, the glove-embedded sensors will overlap different finger locations for different users. In order to reduce inaccuracies, most sensing gloves need to be calibrated to the particular user wearing them.

GESTURE INTERFACES

Pinch Glove

- 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 joint angles based on glove-specific algorithms. The only commercial sensing glove that makes calibration unnecessary is the Pinch Glove, which is illustrated in Figure

GESTURE INTERFACES



GESTURE INTERFACES

Pinch Glove

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, fingers of one hand and fingers of the other hand, fingers and palm, etc.

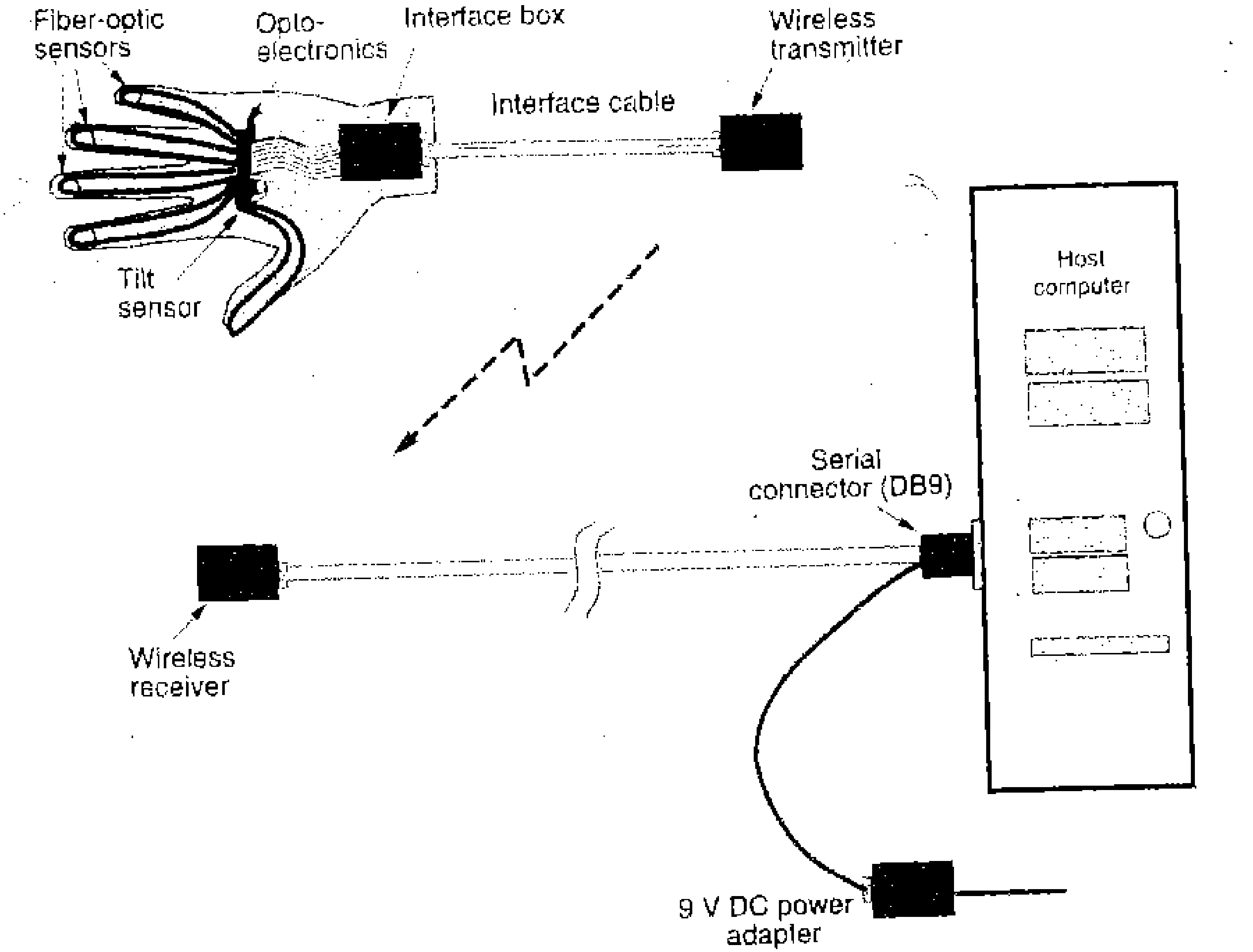
A multiplexing chip embedded in the glove reduces the number of wires that need to be connected to an electronics control box.

The control box incorporates a microprocessor, low-current power supply, timing circuits, and RS232 serial port for communication with the host computer.

GESTURE INTERFACES

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. The simplest configuration, used by the 5DT Data Glove 5W sensing glove illustrated in Figure, is to have one sensor per finger and a tilt sensor to measure wrist orientation.
- Each finger has a fiber loop routed through attachments which allow for small translations due to finger bending.



Fiber-optic sensors
Opto-electronics
Interface box
Wireless transmitter
Interface cable
Tilt sensor
Host computer
Serial connector (DB9)
Wireless receiver
9 V DC power adapter

GESTURE INTERFACES

The 5DT Data Glove

- Additional sensors for minor joints as well as abduction—adduction are available in the 5DT 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 optoelectronic 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.

GESTURE INTERFACES

The 5DT Data Glove

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 the refractive 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.

GESTURE INTERFACES

The Didjiglove

- Another sensing glove is the Didjiglove, which uses 10 capacitive bend sensors to measure the position of the user's fingers.
- The capacitive sensors consist of two layers of conductive polymer separated by a dielectric.
- Each conductive layer is arranged in a comb-like fashion, such that the overlapping electrode surface is proportional to the amount of sensor bending.
- Since capacitance is directly proportional to the overlapping surface of the two sensor electrodes, the bending angle can be measured electrically.

GESTURE INTERFACES

The Didjiglove 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.

The 10-bit A/D converter resolution is 1024 positions for the proximal joint (closest to the palm) and the interphalangeal joint (the intermediate joint of the finger).

GESTURE INTERFACES

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 Didiglove was designed as an advance programming interface for computer animation, for user input to such toolkits as 3D Studio Max, Softimage, and Maya.

However, the small glove latency (10 msec) and its low cost make the Digiglove useful for VR interactions as well.

GESTURE INTERFACES

The CyberGlove:

A more complex (and more expensive) sensing glove, which uses linear bend sensors, is the CyberGlove.

This glove was invented by Jim Kramer as a gesture recognition interface in order to aid persons with speech impairments.

It subsequently became apparent that the same device could be successfully used as a VR interface.

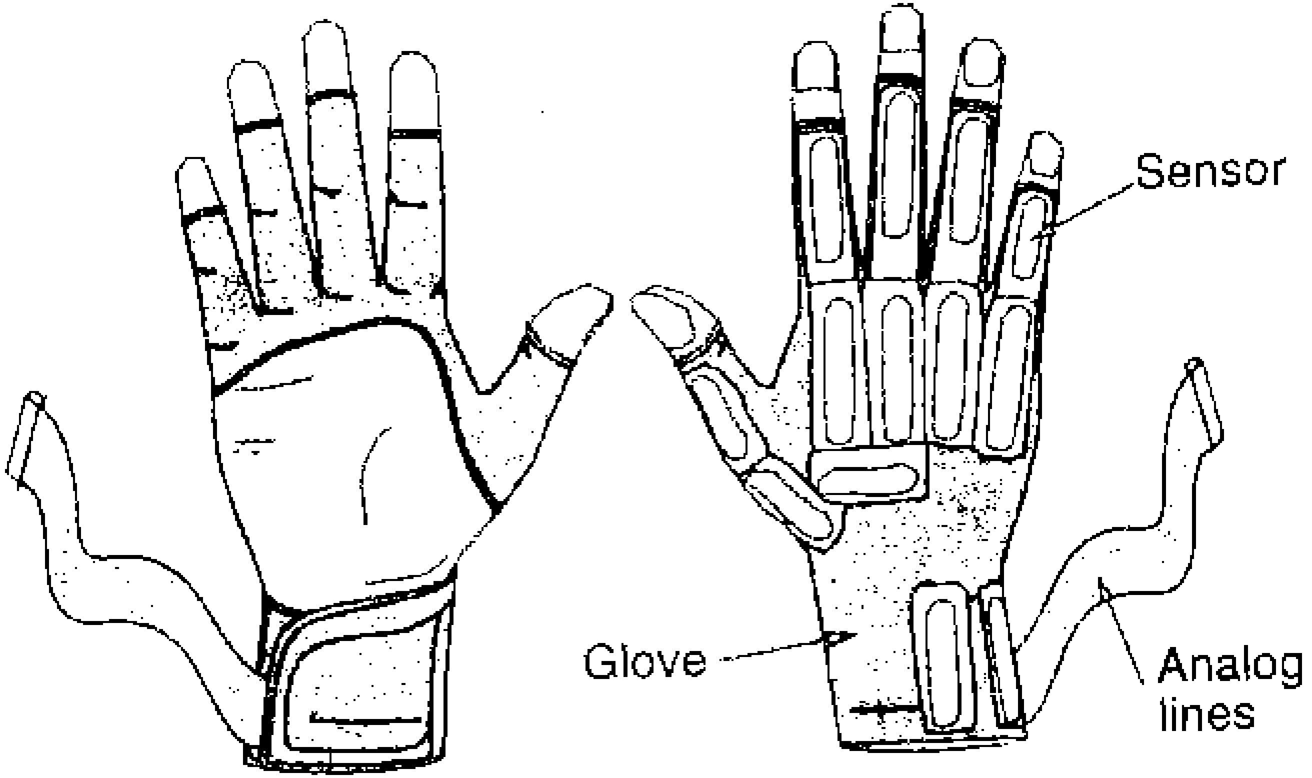
GESTURE INTERFACES

The CyberGlove:

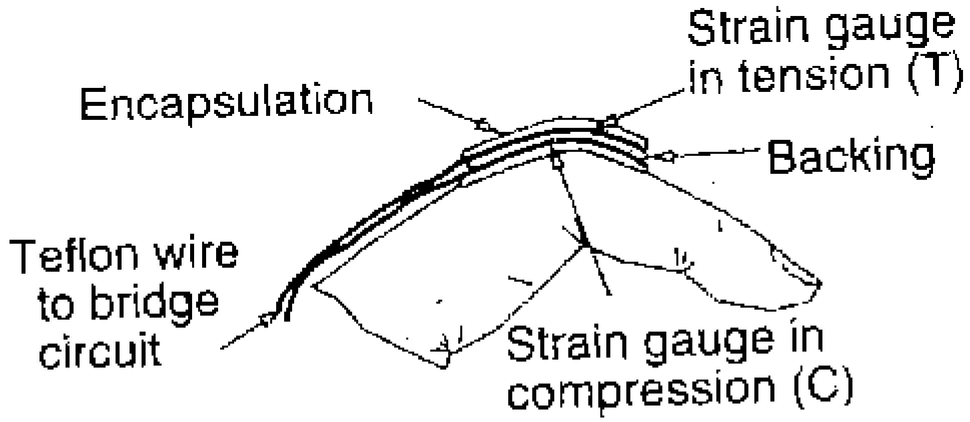
The CyberGlove incorporates thin electrical strain gauges placed on an elastic nylon blend material, as shown in Figure in next slide.

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.


Sensor
Glove
Analog
lines

(*a*)


Strain gauge
in tension (T)
Encapsulation
Backing
Teflon wire
to bridge
circuit
Strain gauge in
compression (C)

GESTURE INTERFACES

The CyberGlove

The glove sensors are either rectangular (for the flexion angles) or U-shaped (for adduction-abduction angles).

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 yaw and pitch. According to the manufac-turer, sensor resolution is 0.5° and remains constant over the entire range of joint motion.

GESTURE INTERFACES

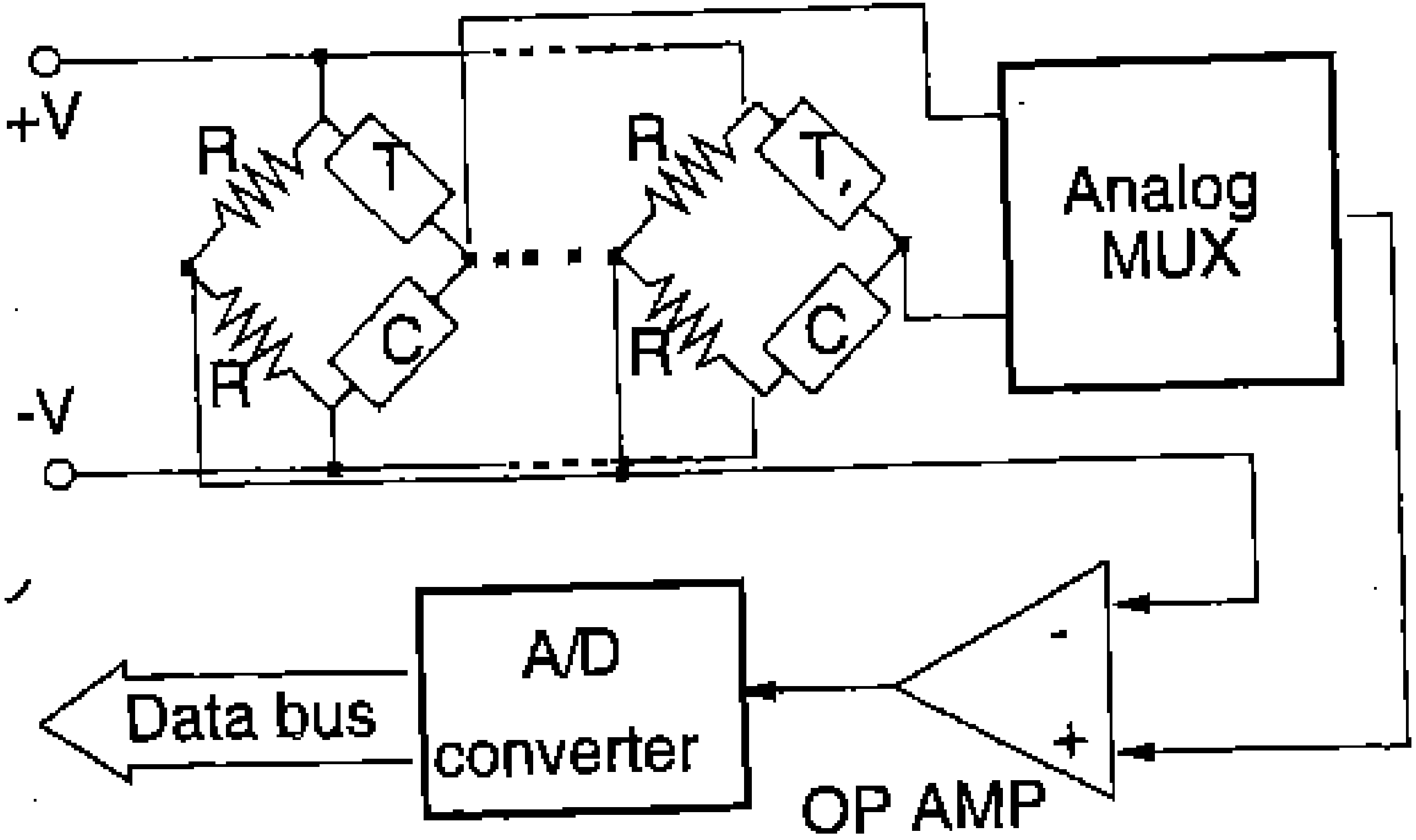
The CyberGlove

It is further claimed that this glove has decoupled sensors so that outputs are independent of each other.

Joint angles are measured indirectly by a change of resistance in a pair of strain gauges.

During finger motion one of the strain gauges is under compression (C), while the other is under tension (T). Their change in resistance produces a change in voltage on a Wheatstone bridge, as shown in Figure on next slide. There are as many Wheatstone bridge circuits as sensors on the glove. These differential voltages are then demultiplexed, amplified, and subsequently digitized by an A/D converter.

GESTURE INTERFACES



GESTURE INTERFACES

The CyberGlove:

The glove data from its 18 sensors are then sent to the host computer over an RS232 serial line.

The communication rate (currently 115.2 kbaud) allows a maximum of 150 datasets to be sent every second.

The sampling rate drops to 112 datasets when filtering is used (to reduce sensor noise), and drops further for the 22-sensor CyberGlove model.

GESTURE INTERFACES

The CyberGlove:

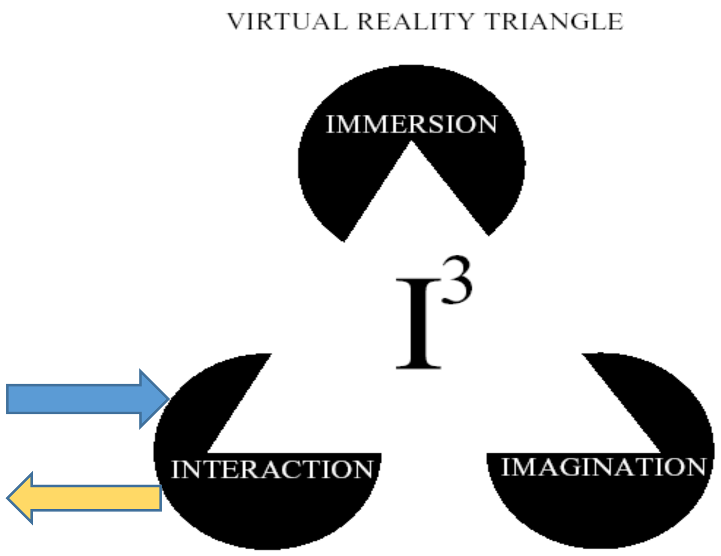
Calibration is required to account for the user's hand size and to convert strain gauge voltages to joint angles.

Currently the CyberGlove is a de facto standard for high-performance hand measurements.

This is due to its large number of sensors, its good programming support, and its extension into more complex haptic gloves (discussed in Chapter 3). Table 23 compares the sensing gloves described here.

OUTPUT DEVICES

- Graphic displays,
- Sound Displays and Human Haptic System.



OUTPUT DEVICES

- The previous section described 3D trackers, trackballs, and sensing gloves, which are devices used to mediate the user's input into the VR simulation.
- Now we look at special hardware designed to provide feedback from the simulation in response to this input.
- The sensorial channels fed back by these interfaces are
  - **sight** (through graphics displays),
  - **sound** (through 3D sound displays), and
  - **touch** (through haptic displays).
-

OUTPUT DEVICES

- For reasons of simplicity, this section treats each sensorial feedback modality separately.
- A further simplification here is the decoupling 61 sensorial feedback from the user's input.
- Modem VR systems are, however, multimodal, and feedback interfaces usually incorporate hardware to allow user input (such as trackers, pushbuttons, etc.).

OUTPUT DEVICES

- Combining several types of sensorial feedback in a simulation increases the user's immersion into VR.
- Furthermore, combining several sensorial modalities improves the **simulation realism** and therefore the usefulness of VR applications.

OUTPUT DEVICES

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 (stereoscopic or monoscopic), their image resolution (number of pixels in the scene), the field of view (portion of the eye's viewing volume they cover), display technology (LCD- or CRT-based), ergonomic factors (such as weight), and cost.

OUTPUT DEVICES

- 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.

OUTPUT DEVICES

- 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.
- Therefore, before attempting to describe any particular viewing hardware, it is necessary to describe the human visual perception mechanism.

OUTPUT DEVICES

- The eye has over 126 million photoreceptors, with an uneven distribution over the retina.
- The central area of the retina (several degrees around the eye's viewing axis) is called the fovea.
- It represents a high-resolution, color perception area.
- This is surrounded by low-resolution, motion perception photoreceptors covering the rest of the viewing field.
- The portion of the displayed image that is projected on the fovea represents the focus area.

OUTPUT DEVICES

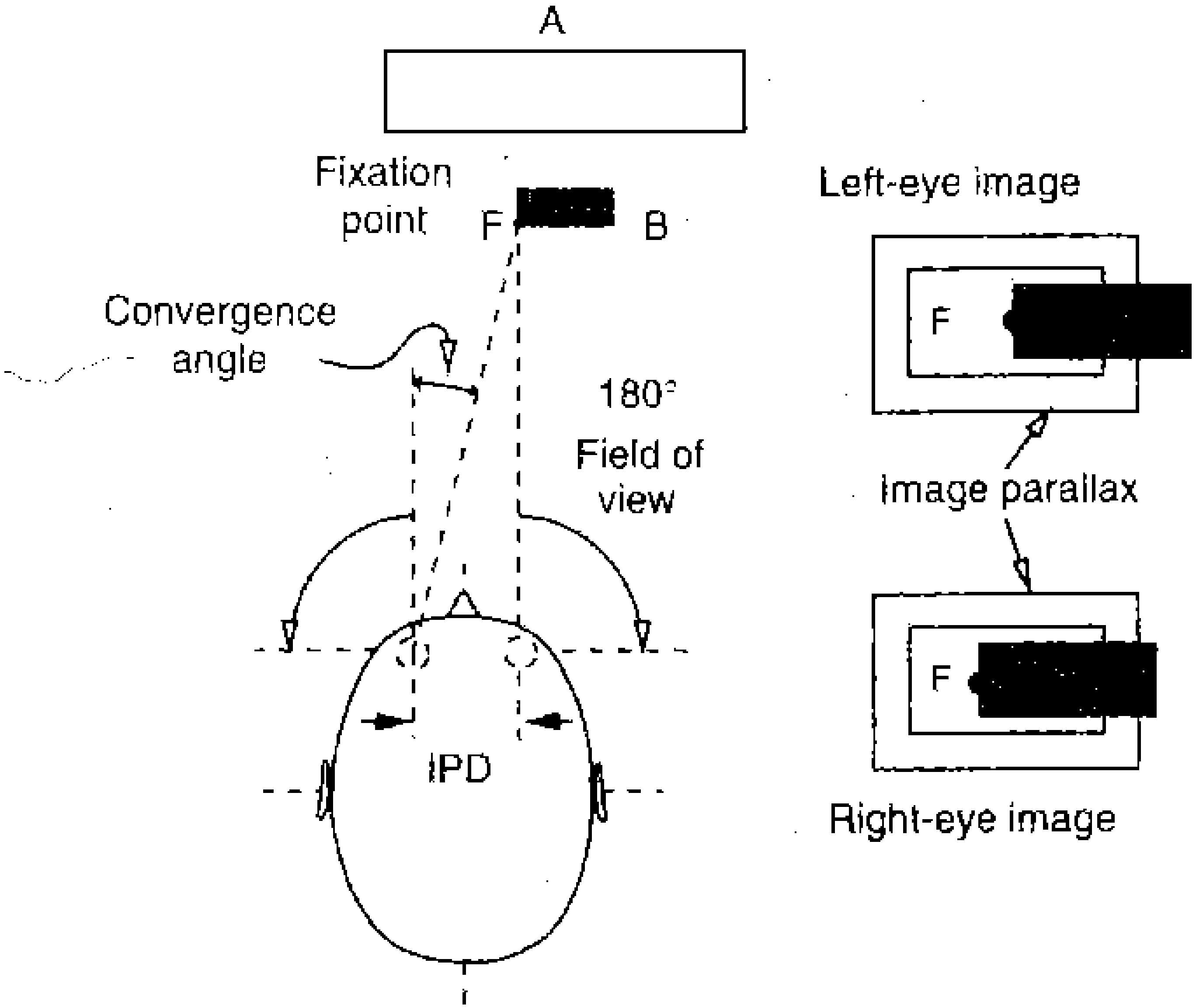
- A viewer's focus changes dynamically and un-consciously during a simulation and Can be detected if the eye motion is tracked.
- Unfortunately, the eye tracking technology is at present too bulky to be meaningfully integrated with personal displays.
- Since we do not know what portion of the display is viewed by the fovea, the whole scene needs to be rendered at high resolution.
- This represents a waste of graphics pipeline processing.

OUTPUT DEVICES

- Another important characteristic of the human vision system is the field of view.
- This is approximately 150° horizontally and 120° vertically when one eye is used and grows to 180° horizontally and 120° vertically when both eyes are used.
- A central portion of this viewing volume represents the area of stereopsis, where both eyes register the same image.
- This binocular overlap is approximately 120° horizontally. The brain uses the horizontal shift in image position registered by the two eyes to measure depth, or the distance from the viewer to the virtual object presented in the scene.

OUTPUT DEVICES

➢



OUTPUT DEVICES

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, monocular (for a single eye), or binocular (displayed on both eyes). Within the personal display category are grouped as

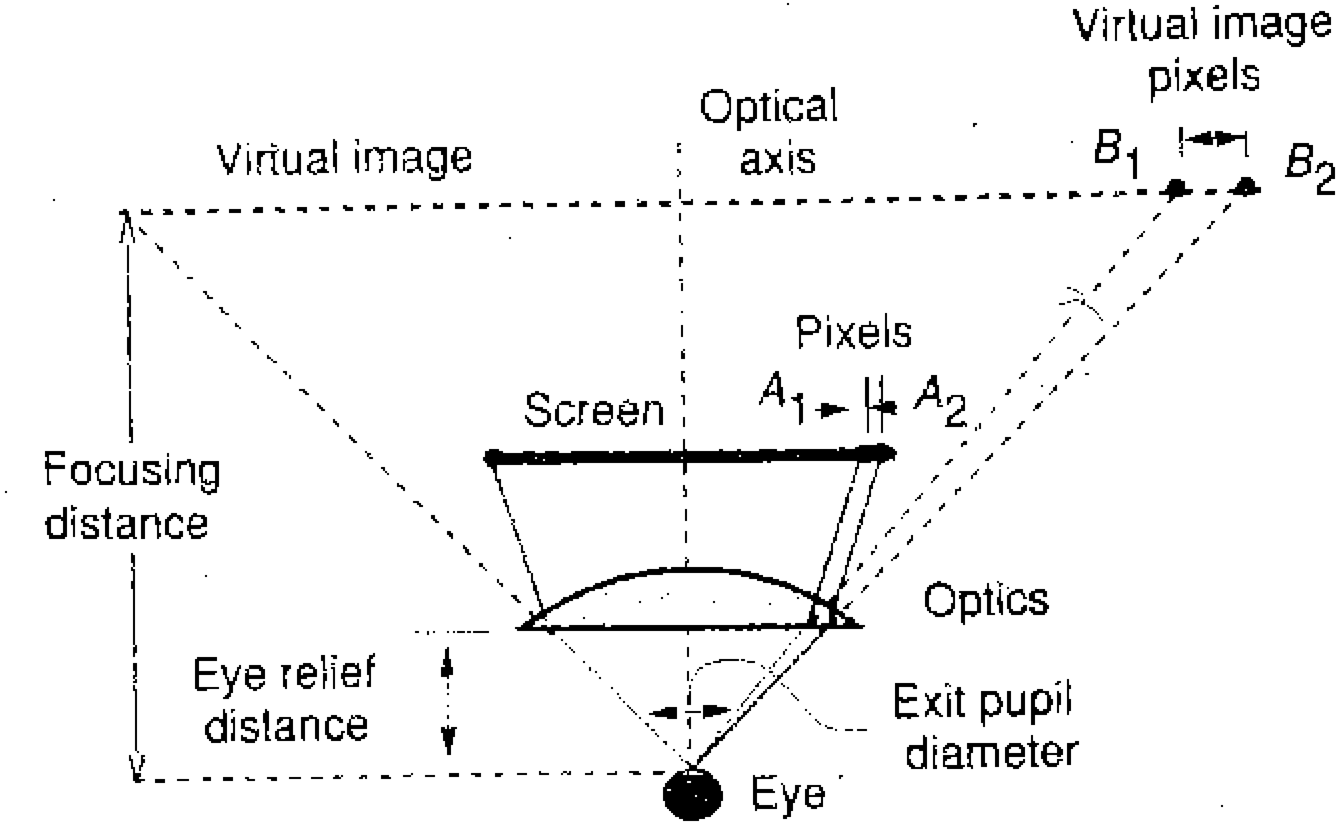
- head-mounted displays (HMDs),
- hand-supported displays,
- floor-supported displays, and
- autostereoscopic monitors.

OUTPUT DEVICES

- 1) Head-Mounted Displays.
- These project an image floating some 1-5 in (3-15 ft) in front of the user as shown in figure.
- 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 the eyes' field of view (FOV).
- As can be seen in Figure , the unfortunate byproduct is that the distance between display pixels (Ai: A2) is amplified as well. Therefore the "granularity" of the HMD displays (expressed in arc-minutes/pixel) becomes apparent in the virtual image.
- The lower the HMD resolution and the higher the FOV, the greater is the number of arc-minutes of eye view corresponding to each pixel.

OUTPUT DEVICES

- Pa



OUTPUT DEVICES

- Older HMDs had very low resolution (as discussed in Chapter 1) and incorporated a diffuser sheet overlaid on-the input to their optics. These diffusers blurred the edges between pixels somewhat, and the image was perceived to be better.
- Modern HMDs have resolutions up to extended video graphics array (XVGA; 1024 x 768) or better.

OUTPUT DEVICES

- Even these resolutions may be unsatisfactory if the optics amplifies the pixel dimension too much in order to enlarge the apparent FOV. Furthermore, very large FOVs force large exit pupil diameters, which can produce shadows around the edges of the perceived image.
- Another HMD characteristic is the display technology used. Consumer-grade HMDs use LCD displays, while more expensive professional-grade devices incorporate CRT-based displays, which tend to have higher resolution. Since consumer HMDs are designed primarily for private viewing of TV programs and for video games rather

OUTPUT DEVICES

HMDs accept NTSC (in Europe, phase alternating line, PAL) monoscopic video input.

When integrated within a VR system, they require the conversion of the graphics pipeline output signal red—green—blue (RGB) format to NTSC/PAL.

The HMD controller allows manual adjustment for brightness and forwards the same signal to both HMD displays.

Professional-grade HMDs are designed specifically for VR interaction and accept RGB video input.

In the graphics pipeline two RGB signals are sent directly to the HMD control unit (for stereoscopic viewing).

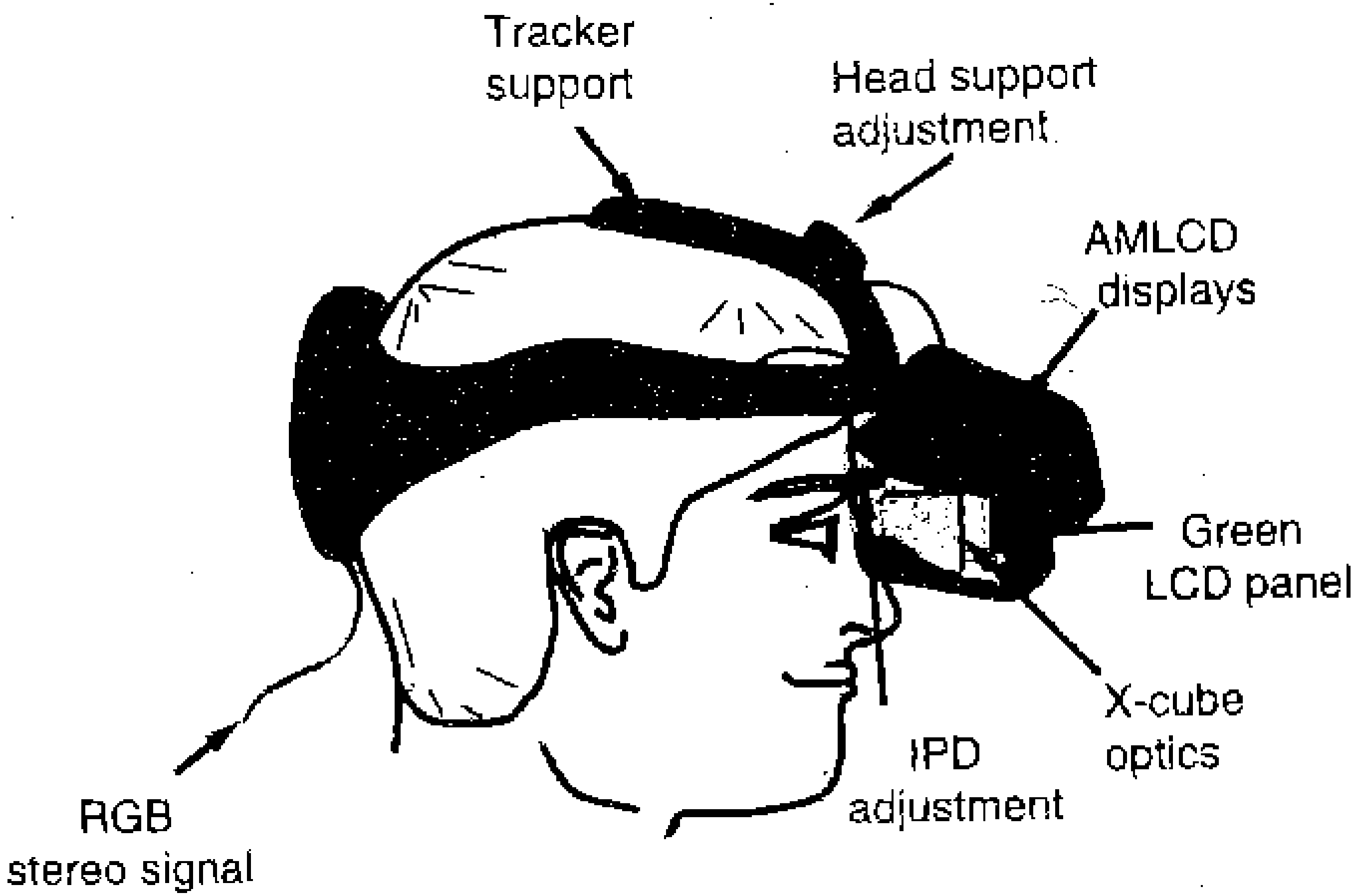
OUTPUT DEVICES

- The control unit also receives stereo sound, which is then sent to the HMD built-in headphones.
- The user's head motion is tracked and position data sent back to the VR engine for use in the graphics computations.
- A ratchet on the back of the HMD head support allows comfort adjustment for various head sizes.

OUTPUT DEVICES

- 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 EyePhone), 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). So this heavy weight induces user fatigue.

OUTPUT DEVICES



Arrangements of Head Mounted Device

OUTPUT DEVICES

- HMDs, such as the Olympus Eye-Trek, shown in Figure , weighs only about 100 grams (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).
- 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.

OUTPUT DEVICES

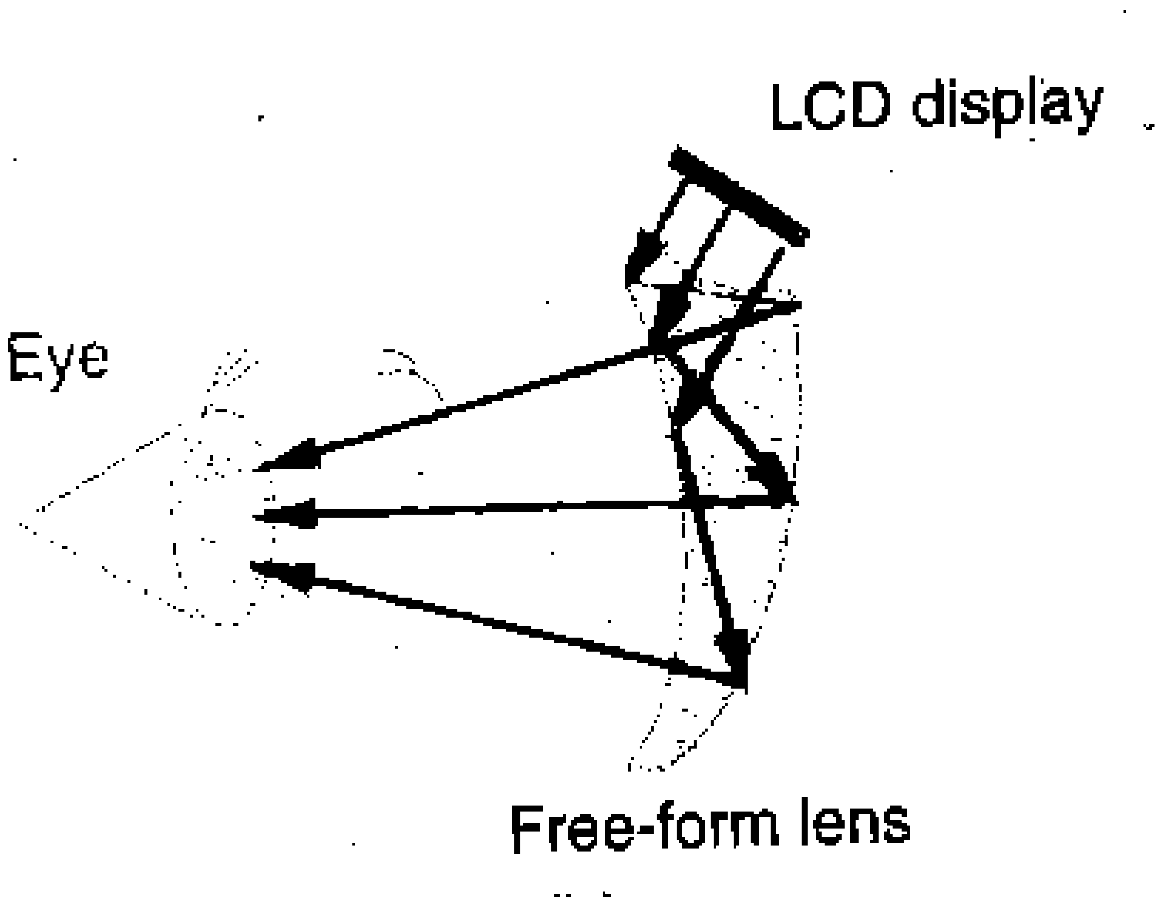


Figure : Optics arrangement in FMD inspired from Olympus

OUTPUT DEVICES

- In order to compensate for optics-induced image distortions (or aberrations), the Olympus team invented a variable-curvature free-form lens. The result is a monoscopic FMD with a field of view of 30° horizon-tally and 22.7° vertically, a very low weight, a fixed IPD.
- The virtual image seen by the user has a 1.3 m (62 in.) diagonal at a fixed focusing distance of 2 m in front.
- An interesting enhancement of the FMD 200, recently introduced in Europe, is the cordless TV. A pair of miniature TV transmitter and receiver units, operating in the 2.4-GHz audio/video frequency range, allows viewing up to 100 m from the TV.
- This greatly enhances the user's freedom of motion

OUTPUT DEVICES

2) Hand-Supported Displays (HSDs),

These are personal graphics dis-plays that the user holds in one or both hands in order to periodically view a synthetic scene.

This means that the user can go in and out of the simulation as required by the application.

HSDs are similar to HMDs in their use of special optics to project a virtual image in front of the user.

In addition, HSDs incorporate features not present in HMDs, namely push buttons used to interact with the virtual scene.

OUTPUT DEVICES

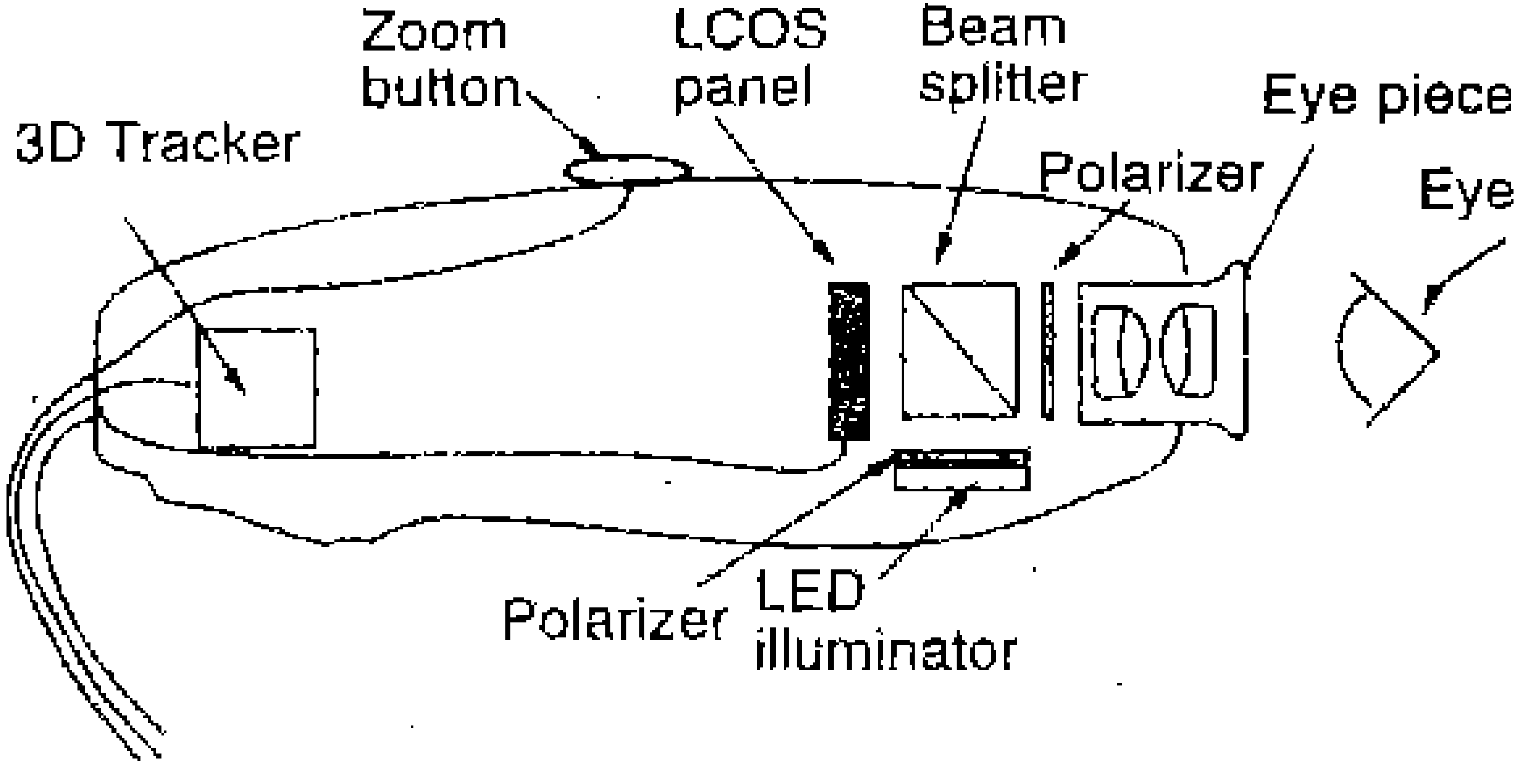


Figure : Hand Supported System Virtual Binoculars

OUTPUT DEVICES

- An example of a hand-supported graphics display is the virtual binoculars SX shown in Figure.
- These are constructed to resemble the look and feel of regular binoculars, to help the realism of the simulation.
- Internally, however, virtual binoculars incorporate two miniature LCOS displays and a tracker, which measures the user's viewing direction.
- The computer then updates the graphics based on tracker and pushbutton information, similar to trackball-mediated interaction.
- The use of LCOS displays results in a high-resolution image (1280 x 1024 pixels) and low granularity (1.6 arc-minutes/pixel).
- However, the disadvantages mentioned earlier for CRT-based HMDs, namely large weight (about 1 kg, without the tracker)

OUTPUT DEVICES

- 3) Floor-Supported Displays.
- The HMDs and HSDs previously discussed rely on 3D trackers to measure the user's head position.
- When the user moves his or her head he or she expects the displayed image to move in the opposite direction.
- If the time delay between corresponding head and image motions is too large, simulation sickness may occur.
- In order to alleviate the problem of simulation sickness, it is necessary to have almost instantaneous response to the user's head motion, which suggests the use of a mechanical tracker.

OUTPUT DEVICES

- 3) 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.

OUTPUT DEVICES

4) 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.

OUTPUT DEVICES

4) 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.

An interesting type of desk-supported displays are autostereoscopic ones, which produce a stereo image while viewed with unaided eyes.

Such displays have a special "column-interlaced" image format, which alternates individual columns assigned to the left-eye view and the right-eye view

OUTPUT DEVICES

Thus, rather than using two display panels (one for each eye), autostereoscopic displays present the stereo-pair images simultaneously on a single panel.

Special optics or illumination mechanisms need to be used in order to assure that each eye sees only its corresponding image columns, which results in the perception of two images, and through parallax, a sin-gle stereo image floating in front of the autostereoscopic display.

OUTPUT DEVICES

The advantage of this approach is the ability to present a stereo image without requiring the user to wear any vision apparatus.

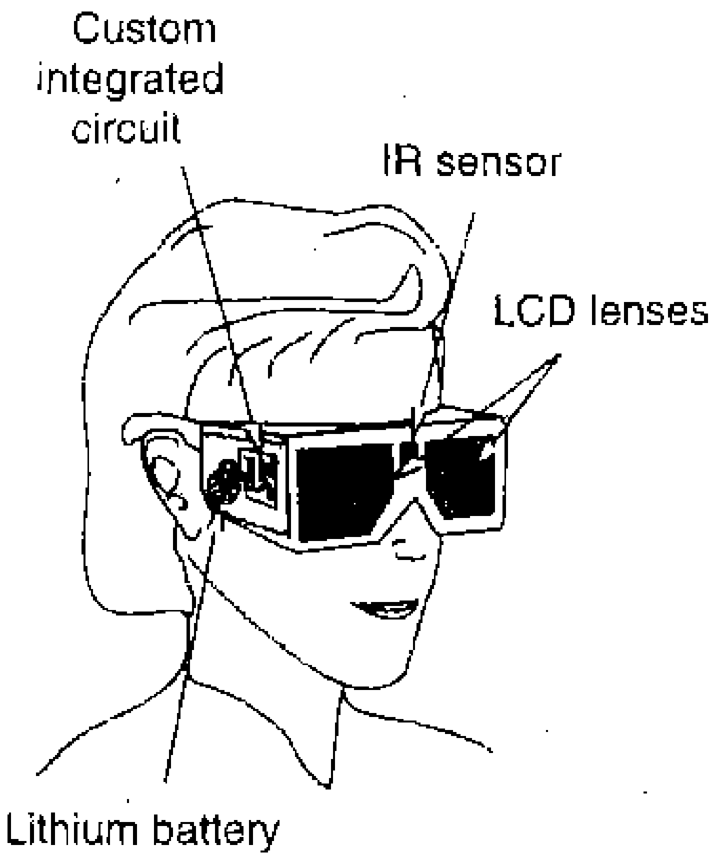
One disadvantage is reduced horizontal image resolution (since half of the columns display one eye's image and half the other eye's image).

Other disadvantages are increased system complexity (due to the added illumination or viewing optics op dedicated hardware integrated within the display) and increased cost (compared with CRTs or flat panel displays of equal size).

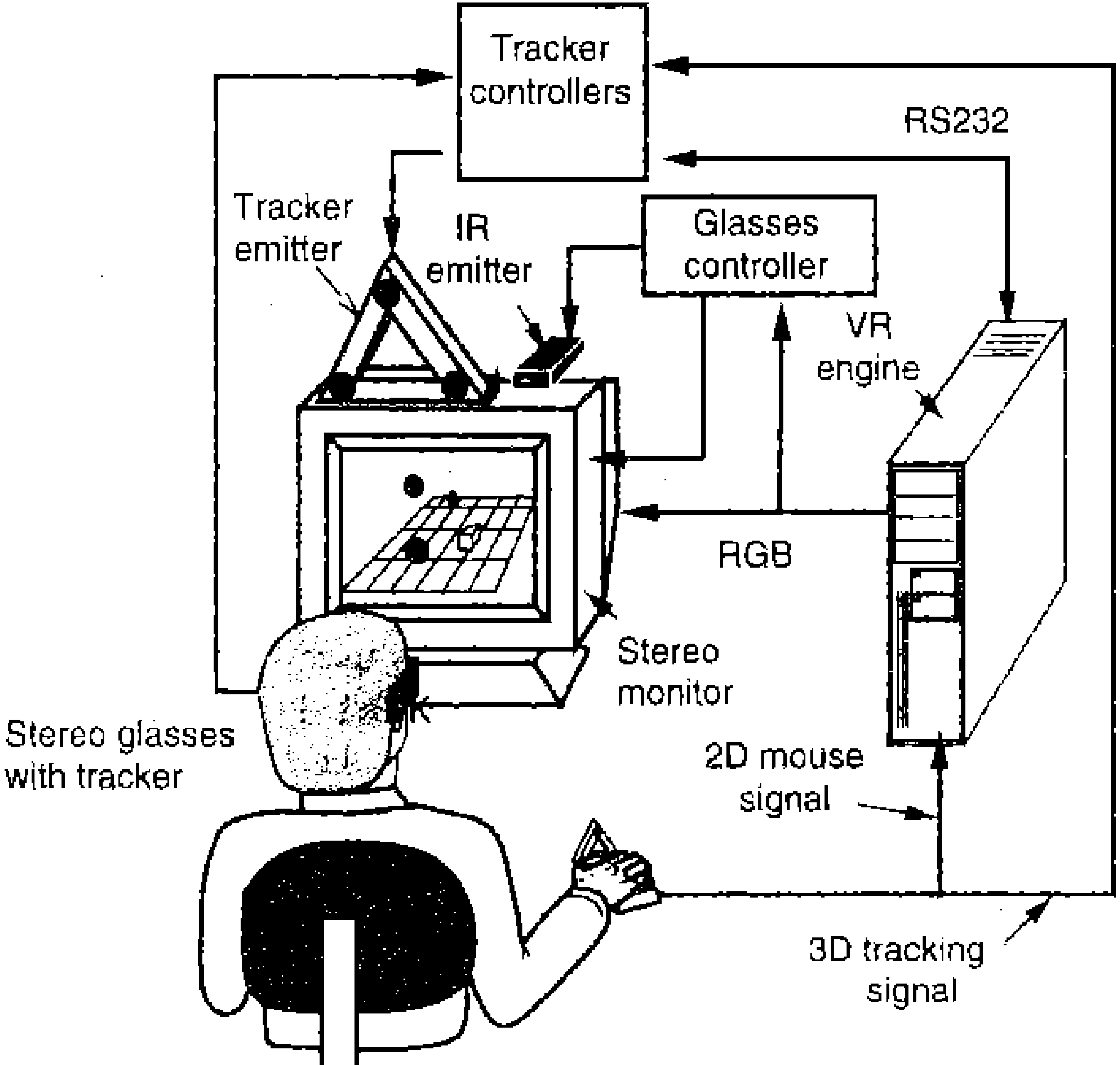
OUTPUT DEVICES

- Large Volume Displays
- Monitor Based Large Volume Display
- Projector Based Large Volume Display

Monitor Based Large Volume Display

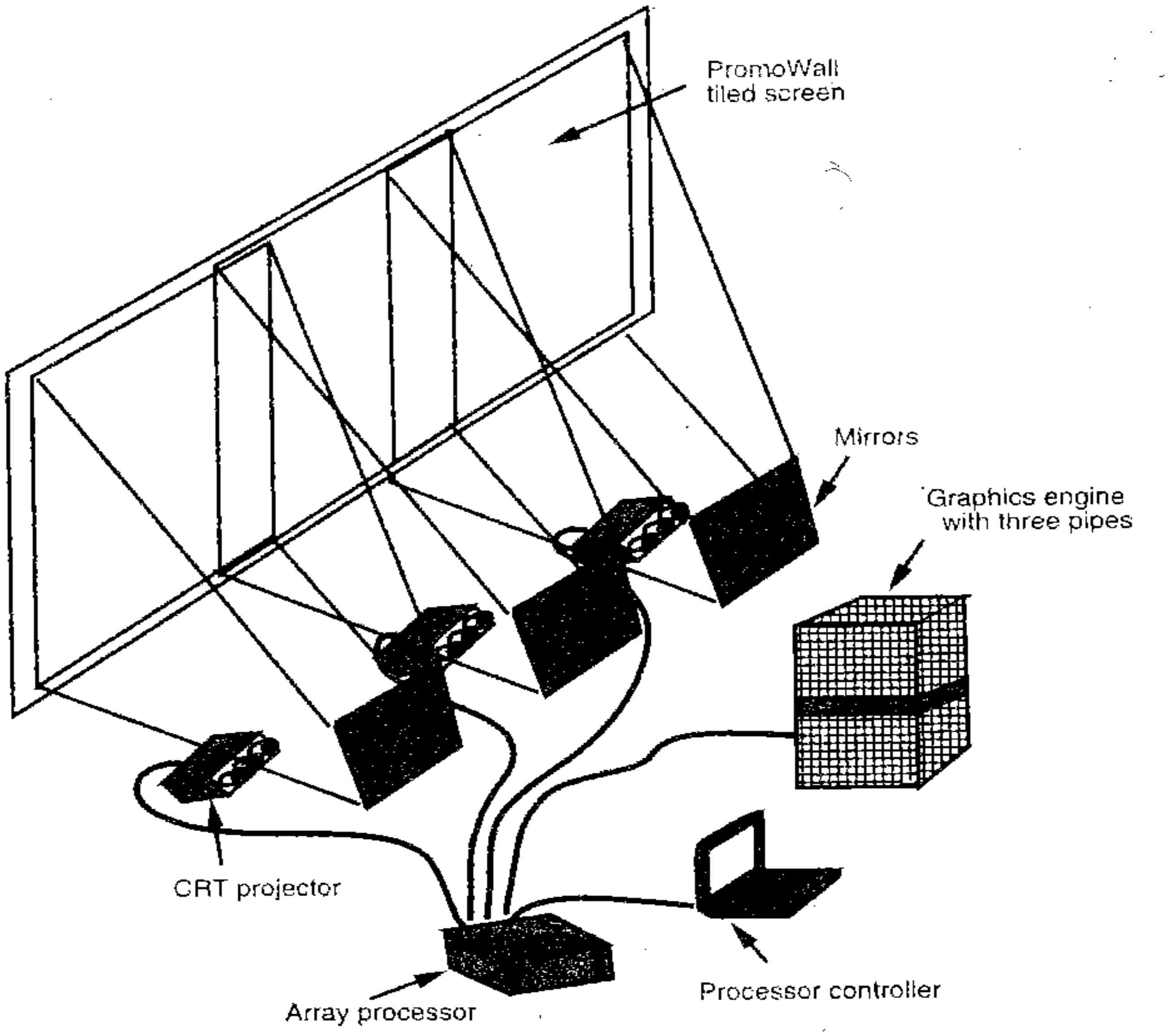


Monitor Based Large Volume Display



Projector Based Large Volume Display

➢



OUTPUT DEVICES

SOUND DISPLAYS

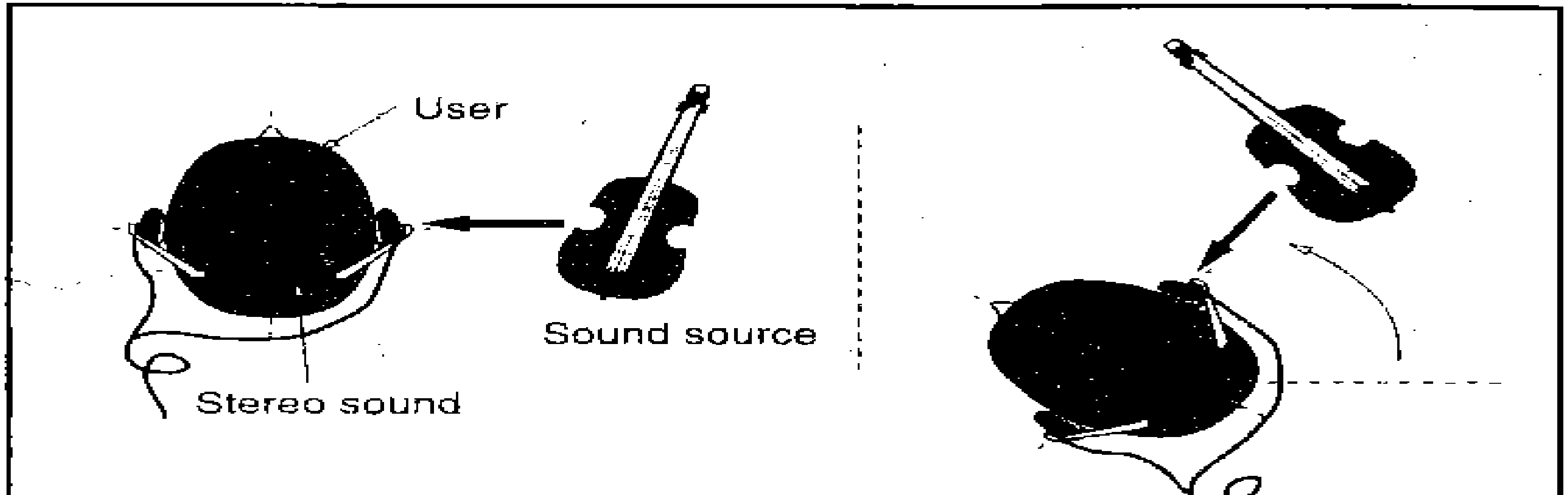
- Definition Sound displays are computer interfaces that provide synthetic sound feedback to users interacting with the virtual world. The sound can be monoaural (both ears hear the same sound) or binaural (each ear hears a different sound).
- Sound displays play an important role in increasing the simulation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

OUTPUT DEVICES

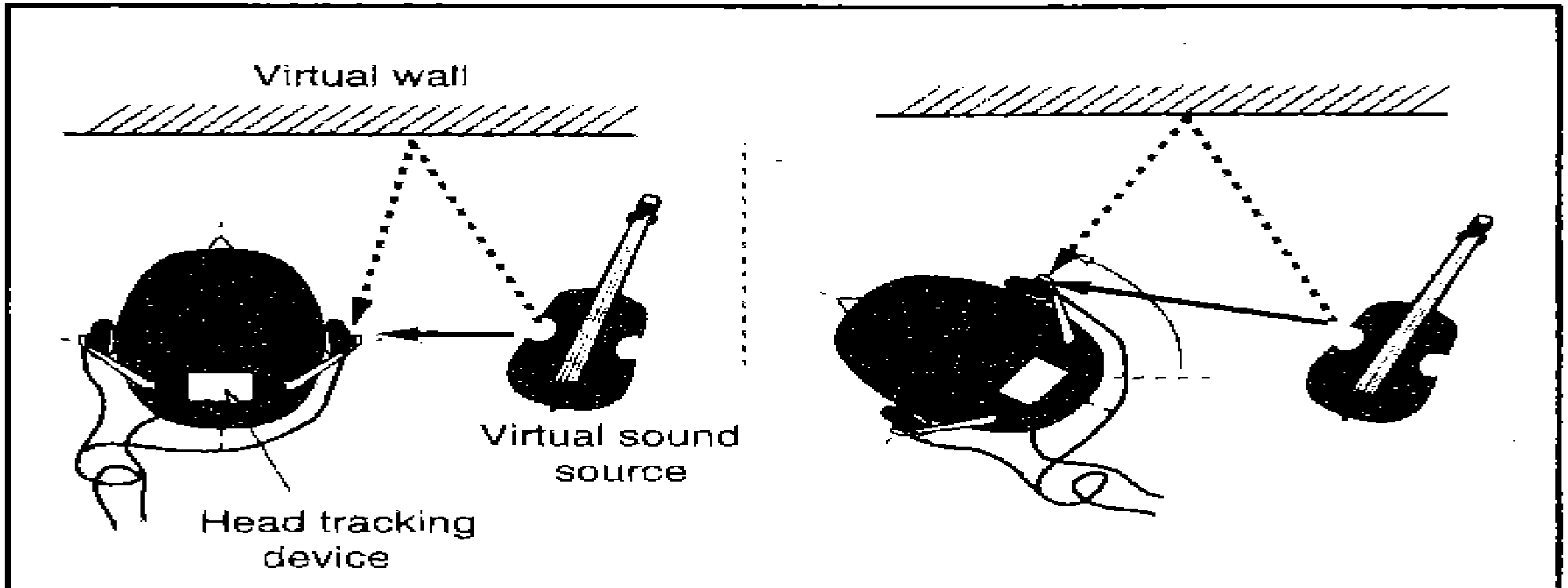
- 3.2 SOUND DISPLAYS
- When sound is added, the user's interactivity, immersion, and perceived image quality increase. In this scenario simple monoaural sound is sufficient, as the ball is always in front of the user and being displayed by the monitor.
- Let us now consider another user, who looks at the same virtual world, this time displayed by an HMD If the ball bounces away, outside the field of view (as balls in the real world sometimes do), then the user cannot tell where the ball went based on visual information or on monoaural sound alone.
- Now the simulation needs a device that provides binaural sound in order to localize the "plop-plop-plop" sound in 3D space relative to the user.

OUTPUT DEVICES

- 3.2 SOUND DISPLAYS
- This example illustrates an important distinction within the sound feedback modality.
- Highly immersive virtual reality simulations should have 3D sound, also called virtual sound, in addition to graphics feedback.
- The distinction between 3D sound and stereo sound is illustrated in Figure.
- Stereo sound on headphones seems to emanate inside the user's head. In other words it is not externalized, as real sounds are.



Stereo sound



3D virtual sound

OUTPUT DEVICES

SOUND DISPLAYS

- When the user wears simple stereo headphones, the violin will turn to the left following the user's head motion.
- A 3D sound presented on the same headphones or on speakers contains significant psychoacoustic information to alter the user's perception into believing that the recorded sound is actually coming from the user's surroundings.

OUTPUT DEVICES

SOUND DISPLAYS

- In Figure, the 3D sound is synthesized using head tracker data, and the virtual violin remains localized in space. Therefore its sound will appear to move to the back of the user's head. Sound in a real room bounces off the walls, the floor, and the ceiling, adding to the direct sound received from the violin.
- The realism of the virtual room therefore requires that these reflected sounds be factored in.

OUTPUT DEVICES

- 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.

OUTPUT DEVICES

The Vertical-Polar Coordinate System.

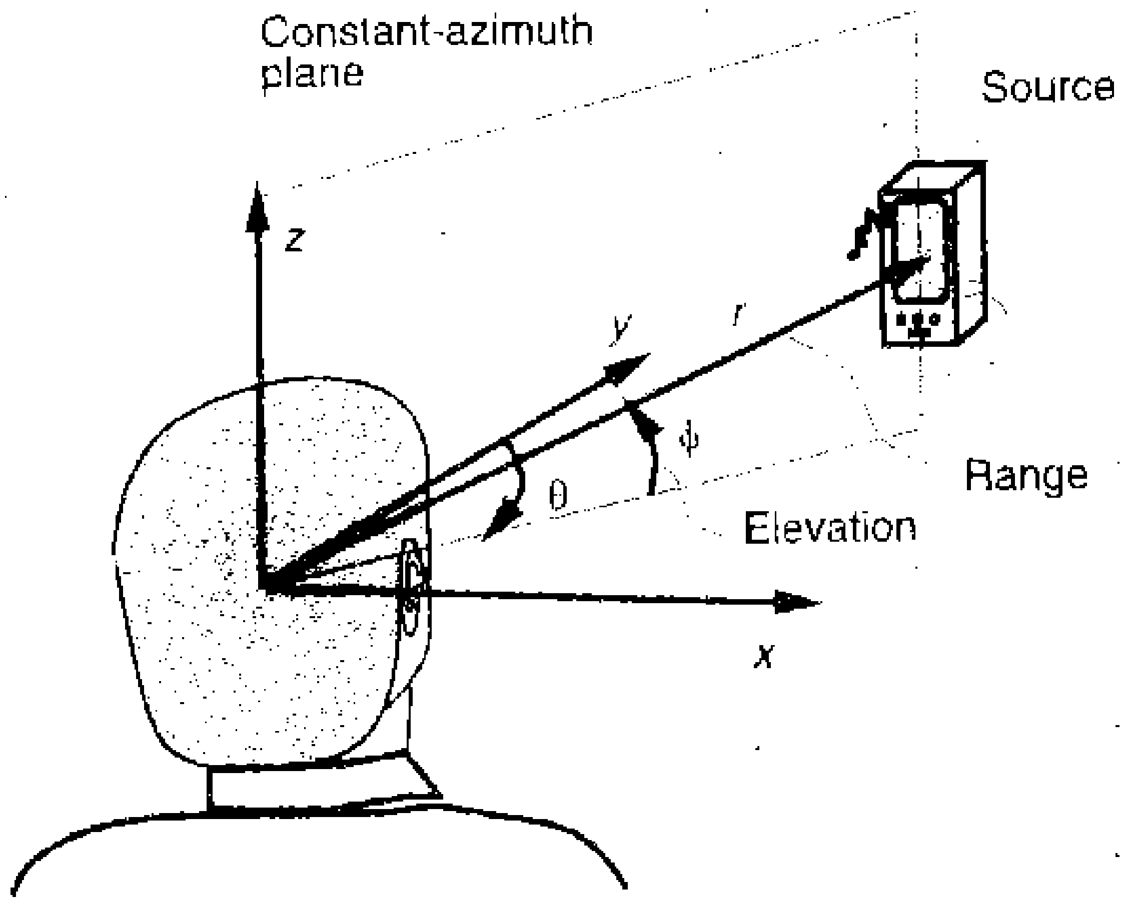
- In order to measure position it is necessary to establish a head-attached system of coordinates.
- If such a system of coordinates is Cartesian, then the location of a sound source relative to the head can be expressed by the triad (x, y, z).
- Alternatively, the same 3D sound source position can be expressed in a spherical system of coordinates called the vertical—polar coordinate system.

OUTPUT DEVICES

- The sound source location is uniquely determined by three variables, namely azimuth, elevation, and range.
- The azimuth is the angle θ between the nose and a plane containing the source and the vertical axis z.
- The source elevation is the angle ϕ made with the horizontal plane by a line passing through the source and the center of the head.
- Finally, the range r is the distance to the source measured along this line. The sound source azimuth can vary anywhere between +180°, while the elevation has a range of ±90°.
- Finally, source range can only be positive and larger than the head radius.

OUTPUT DEVICES

- Pa



OUTPUT DEVICES

- The brain estimates the source location (azimuth, elevation, and range) based on intensity, frequency, and temporal cues present in the sound perceived by the left and right ears.
- Azimuth Cues. Since sound has a fixed propagation velocity in air, it will reach first the ear that is closer to the source. As the sound wave reaches the right ear last, since it has to travel an extra distance. The difference in the arrival time of the sound at the two ears, called the interaural time difference.
- Elevation Cues. If the head is modeled as having simple holes for ears, than there are source locations in space where the time and intensity cues are the same. The so-called cones of confusion result in perceptual reversal, or front—back confusion.

OUTPUT DEVICES

Confusion on a source that is actually behind the user is perceived as being in front, or vice versa.

In reality ears are not simple holes, on the contrary, the outer ear, or pinna, is very important, as sound is reflected by it and guided to the inner ear.

Sound coming from a source located above the user's head has quite a different reflection path than sound coming from a source in front of the user.

OUTPUT DEVICES

Some frequencies are amplified and others attenuated.

This attenuation is due to interference between the direct sound and that reflected by the pinna.

Since the path difference between the direct and pinna-reflected sound changes with the elevation angle, the pinna provides the primary cue for source elevation.

OUTPUT DEVICES

HAPTIC FEEDBACK

- The last category of I/O devices discussed in this chapter are haptic interfaces. Named after the Greek term 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.
- When added to the visual and 3D audio feedback previously discussed, haptic feed-back greatly improves simulation realism. It becomes mandatory wherever the visual feedback is corrupted (occluded objects that need to be manipulated) or lacking entirely (dark environments).

OUTPUT DEVICES

Haptic Sensing.

The skin houses four types of tactile sensors (or receptors), namely

Meissner corpuscles (the majority),

Merkel disks,

Pacinian corpuscles, and

Ruffini corpuscles.

OUTPUT DEVICES

When excited they produce small electrical discharges, which are eventually sensed by the brain.

The slow-adapting (SA) sensors (Merkel and Ruffin) maintain a constant rate of discharge for a long time in response to a constant force being applied on the skin.

On the contrary, the fast-adapting (FA) ones (Meissner and Pacinian) drop their rate of discharge so fast that the constant contact force becomes undetected.

Such different behavior is related to the particular type of contact the tactile sensors detect.

OUTPUT DEVICES

- If the contact has a strong time variation (vibrations on the skin, or accelerations), then FA receptors are needed.
- Conversely, if the contact is quasi steady state (edges, skin stretch, static force), then SA receptors are used.
- As a consequence, Merkel and Ruffini receptors are most sensitive to low-frequency stimuli (0-10 Hz), while Meissner and Pacinian sensors respond to stimuli of higher frequencies (50-300 Hz).

OUTPUT DEVICES

Sensory-Motor Control.

The tactile, proprioceptive, and kinesthetic sensing is used by the body'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.

Finger contact forces depend on whether the action is volitional or reflex, on the way objects are grasped, as well as on user's gender, age, and skill. The grasping geometry can be classified into precision grasp and power grasp,

OUTPUT DEVICES

- Precision grasps are used in dextrous object manipulation where contact is made at the fingertips.
- Power grasps allow higher stability and force exertion because the object is held between the palm and the closed fingers, but lack dexterity (fingers are locked around the grasped object).
- Clinical studies measured the human manual force exertion capability. It was found that males can exert a maximum force of 400 N during power grasping, while female hand strength ranges from 60% to 80% of that of males.

OUTPUT DEVICES

- Note that such high forces are not the ones haptic interfaces need to produce.
- A large grasping force cannot be maintained by a user for a long time without experiencing discomfort and (eventually) pain.

OUTPUT DEVICES

- 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. Electrotactile feedback provides electric pulses to the skin (with varying width and frequency).

OUTPUT DEVICES

- Neuromuscular stimulation provides the signal directly to the user's primary cortex.
- Both techniques are considered by the authors to be risky
- Instead we discuss commercially available interfaces for the hand that provide vibrotactile feedback and temperature feedback.

OUTPUT DEVICES

- 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 (either as relative X, Y position increments or as button states).
- The interface loop is therefore closed through the vision and auditory channels (highlights of selected menu options and sounds confirming an action)

OUTPUT DEVICES

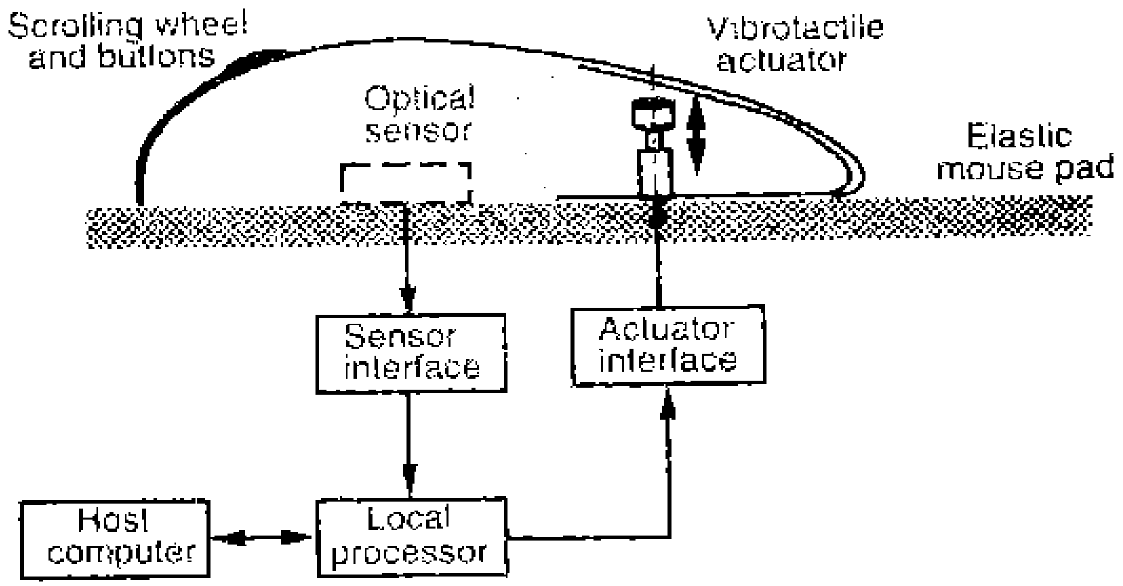
The Tactile Mouse.

- The standard way of using the mouse requires that the user look at the screen all the time, lest control be lost.
- Tactile feedback can remedy this by adding another cue in response to the user's actions, one that can be felt even if the user looks away.
- Further advantages stem from the ability to characterize menu-options, icons, or virtual objects hapticly, such that they will feel differently.
- In view of the advantages that tactile feedback can bring to mouse-mediated inter-actions, it is not surprising that a number of tactile mice have been introduced on the market.

OUTPUT DEVICES

The Tactile Mouse.

- One example is the iFeel Mouse illustrated in Figure 3.27a. Its outside appearance, weight (132 grams), and price ($40) are similar to those of standard computer mice. The difference is the addition of an electrical actuator that can vibrate the mouse outer shell.



OUTPUT DEVICES

- The actuator shaft translates up and down in response to a magnetic field produced by its stationary element.
- The shaft has a mass attached to it, creating inertial forces of more than I. N, which are felt by the user's palm as vibrations.
- The actuator is oriented perpendicular to the mouse base, such that the vibrations occur in the Z direction. This design minimizes the negative effects vibrations could have on the X—Y mouse translation and resulting pointing inaccuracy.
- The mouse pad needs to be thicker than usual, and elastic in order to absorb the reaction forces from the supporting desk.

OUTPUT DEVICES

- Furthermore, the iFeel mouse uses optical position measurement rather than the mechanical ball used by many other mouse designs.
- This solution is necessary because vibrations produced by the actuator can interfere with the ball-roller assembly used to measure X—Y displacements.
- The optical sensor data are used by a microprocessor located in the mouse to determine the amount of mouse translation.
- This data are sent to the host computer over a universal serial bus (USB) line that can also provide power.
- The host software detects contact between the screen arrow controlled by the mouse and hapticly enabled window borders, icons, or surfaces.

OUTPUT DEVICES

- As a result, haptic commands indicating the onset and type of tactile feedback are sent to the mouse processor. The processor then converts the high-level commands into vibration amplitude and frequency and drives the actuator through an actuator interface. The sensation that the user has is that of a haptic "bump" if only an impulse command is sent by the PC, or of haptic textures if complex amplitude-modulated commands are sent.

OUTPUT DEVICES

The CyberTouch Glove.

- This is another haptic interface that provides vibrotactile feedback to the user.
- The device is a CyberGlove retrofitted with six vibrotactile actuators (one on the back of each finger and one in the palm).
- Each actuator consists of a plastic capsule housing a DC electrical motor. The motor shaft has an off-centered mass, which produces vibrations when rotated. Thus, by changing the speed of rotation, it is possible to change the vibration frequency between 0 and

OUTPUT DEVICES

The Temperature Feedback Glove.

- This glove allows users to detect thermal characteristics that can help identify an object material.
- Such variables are surface temperature, thermal conductivity, and diffusivity.
- Materials that have high conductivity (such as steel) will feel cold when grasped, while those with low conductivity (wood) will feel warm.
- This is due to the heat flow from the finger to the object (the finger is usually warmer).

OUTPUT DEVICES

The Temperature Feedback Glove.

Adding temperature feedback to manipulation tasks in VR increases the simulation realism.

Temperature feedback is also useful when navigating in very cold or very warm virtual worlds.

Therefore we end our discussion of tactile feedback with a description of technology that provides computer-controlled temperature feedback to the fingertip.

A thermal actuator used to recreate the thermal signature of virtual objects needs to be light and compact, so that the user's freedom of motion is not diminished.

OUTPUT DEVICES

The Temperature Feedback Glove.

- It also needs to be clean and fast, so that rapid temperature changes can be produced.
- Such actuators are thermoelectric heat pumps that function on the Peltier principle.
- This states that a DC current applied to dissimilar materials placed in contact creates a temperature differential.
- Modern Peltier pumps consist of solid-state N- and P-type semiconductors sandwiched between ceramic electrical insulators.

OUTPUT DEVICES

The Temperature Feedback Glove.

- The ceramic plates serve as thermal conductors and mechanical supports.
- One is called a heat source and the other a heat sink.
- When current from a DC source is applied to the heat pump, the P and N charges move to the heat sink plate, where they transfer heat.
- This results in a drop in temperature of the heat source plate and a corresponding rise in temperature of the heat sink plate.

OUTPUT DEVICES

The Temperature Feedback Glove.

- The larger the current, the larger is the temperature difference between the two plates, up to approximately 65°C.
- Our discussion on human haptic sensing mentioned that the user's thermal comfort zone is 13-46°C.
- Thus one such thermoelectric heat pump is sufficient for VR simulation purposes.
- The Displaced Temperature Sensing System (DTSS) developed by C&M Research consists of eight thermodes and a control interface unit.

OUTPUT DEVICES

Force Feedback Interfaces

- 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 feed-back interfaces need to be grounded (rigidly attached) on some supportive structures to prevent slippage and potential accidents.

OUTPUT DEVICES

Force Feedback Interfaces

- Force feedback interfaces such as joy-sticks and haptic arms are not portable, since they are grounded on the desk or on the floor.
- More portable interfaces, such as force feedback gloves, are grounded on the user's forearm. This allows more freedom of motion for the user and more natural interaction with the simulation, at the expense of potential arm fatigue due to the interface weight.
- An important characteristic of force feedback interfaces is mechanical bandwidth.

Force Feedback Interfaces

- 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.).
- Mechanical bandwidth should not be confused with control bandwidth, which represents the frequency of command updates received by the interface actuators.
- The control bandwidth of force feedback interfaces will always be larger than their mechanical bandwidth, owing to the inertia of the feedback structure.
- Therefore, the larger the force feedback interface, the larger are its output forces and the smaller is its mechanical bandwidth.

OUTPUT DEVICES

Force Feedback Joysticks.

- These are some of the simplest, least ex-pensive 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 WingMan Force 3D joystick.

OUTPUT DEVICES

Force Feedback Joysticks.

- 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.

- Each actuator has a capstan drive and pulley, which moves a gimbal mechanism composed of two rotating linkages. The two actuator-gimbal assemblies are oriented perpendicular to each other, allowing the tilting of the central rod front—back and sideways (left—right).

OUTPUT DEVICES

Force Feedback Joystick

- The tilting of the joystick is measured by two digital encoders coaxial with the motor shafts. These angles are processed by the joystick onboard electronics (sensor interface) and sent to the host PC over a USB line.
- Also sent to the computer is the status of the joystick buttons after their analog signal is digitized by an A/D converter.

OUTPUT DEVICES

Force Feedback Joystick :

- The computer then changes the simulation based on the user's actions and provides feedback in case of haptic events (shooting, explosions, inertial accelerations).
- These commands are transformed into analog signals by the joystick D/A converter, amplified, and sent as driving currents to the DC actuators. I
- n this way the control loop is closed and the user feels the vibrations and jolts or spring like forces produced by the joystick. These forces have a maximum of 3.3 N.

Virtual and Augmented Reality

End of UNIT II

THANK YOU STUDENTS