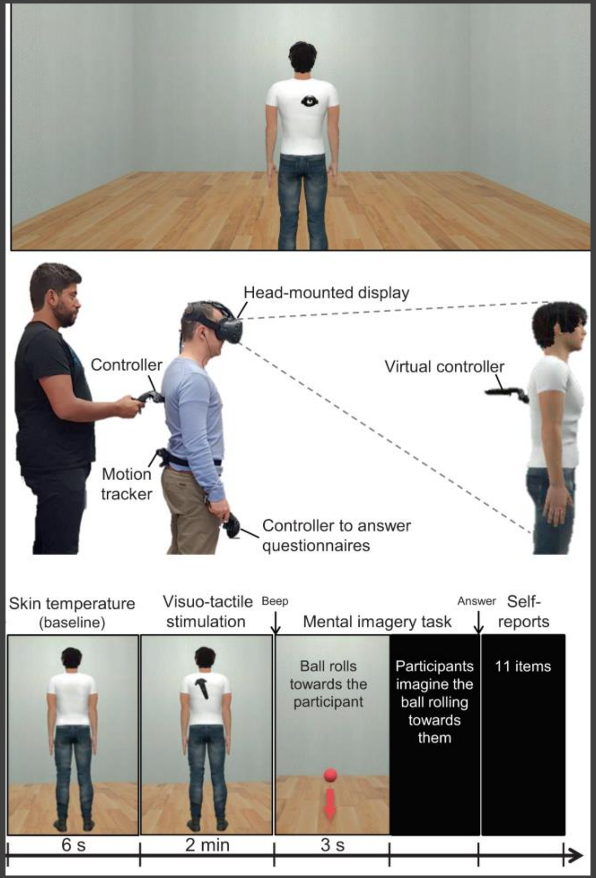


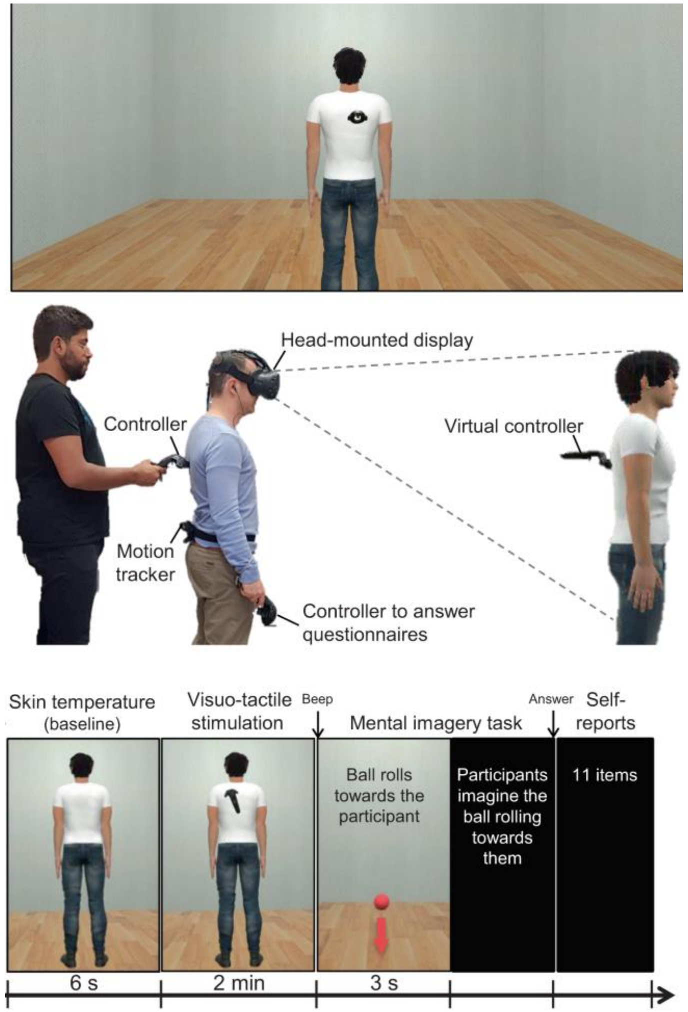
UNIT - 3

Interactive Techniques in Virtual Reality

Development Tools

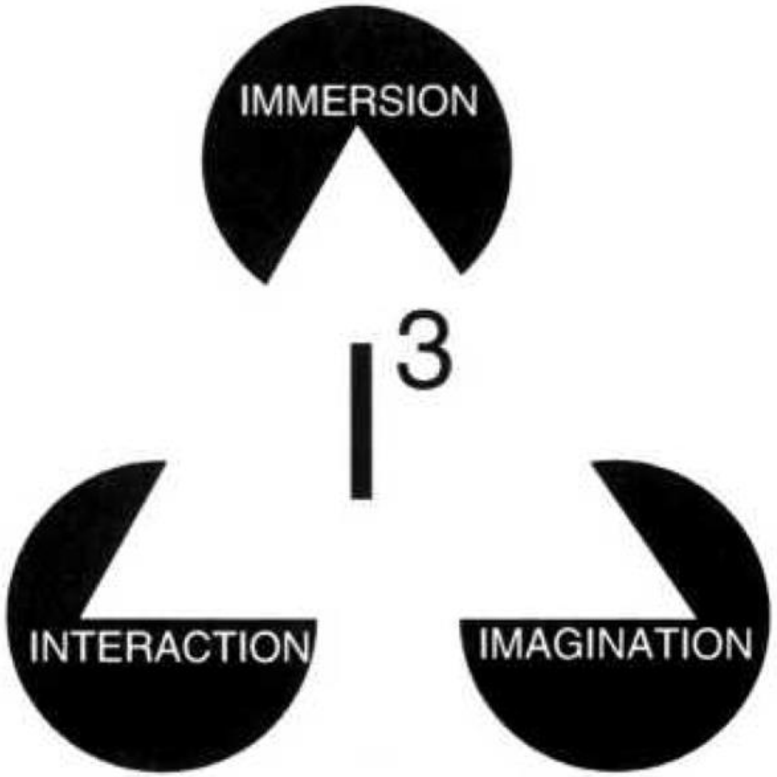
UNIT III - Interactive Techniques in Virtual Reality: Body Track - Hand Gesture - 3D Manus - Object Grasp. Development Tools & Frameworks in Virtual Reality: Frameworks of Software Development Tools in VR.

Interactive Techniques in Virtual Reality

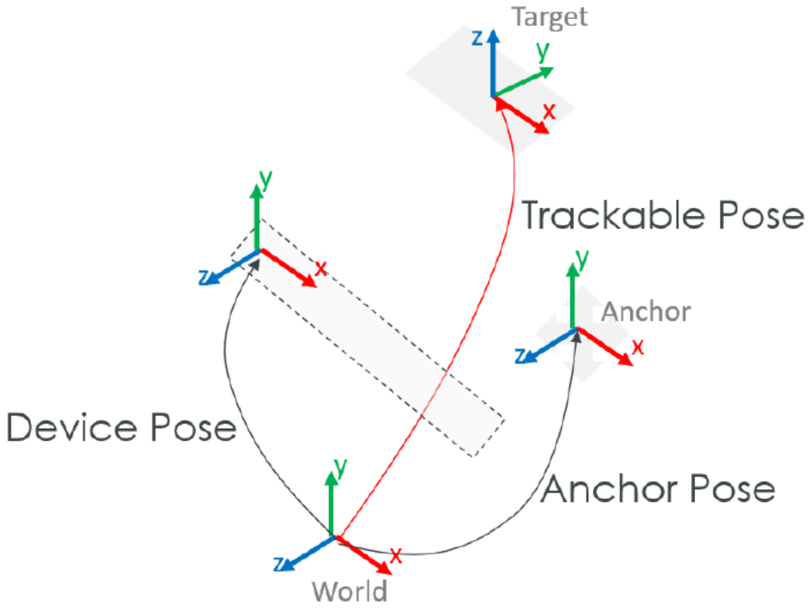


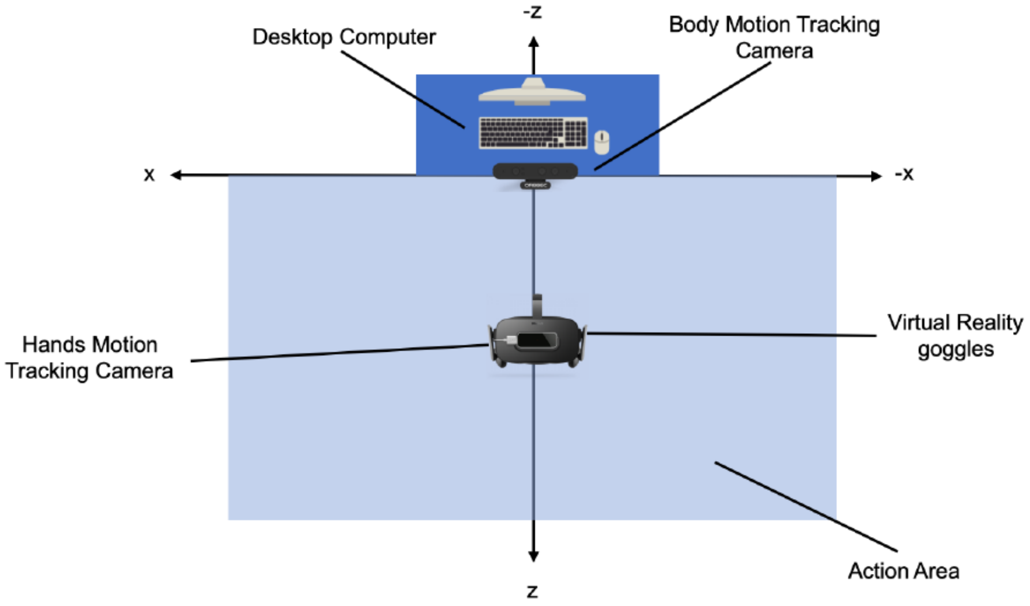
Interaction

- To allow human-computer interaction, it is necessary to use special interfaces designed to input a user's commands into the computer and to provide feedback from the simulation to the user.
- The aim is to allow faster and more natural ways of interaction with the computer and thus overcome the communication bottleneck presented by the keyboard and the computer mouse.
- Today's VR interfaces are varied in functionality and purpose, as they address several human sensorial channels. For example, body motion is measured with 3D position trackers or using sensing suits, hand gestures are digitized by sensing gloves, visual feedback is sent to stereo HMDs and large volume displays, virtual sound is computed by 3D sound generators, etc.
- VR interfaces used in tracking, navigation, and gesture input.



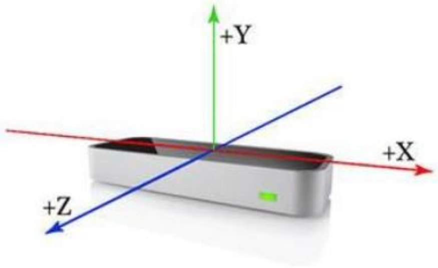
Tracking Coordinate Frames

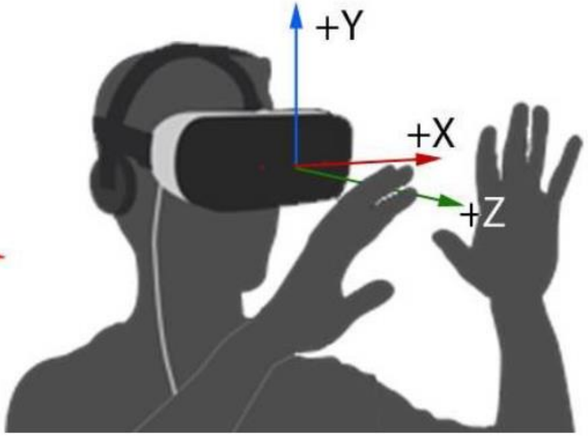




- There can be several coordinate frames to consider
  - Head pose with respect to real world
  - Coordinate fame of tracking system wrt HMD
  - Position of hand in coordinate frame of hand tracker

Example: Finding your hand in VR





- Using Lighthouse and LeapMotion
- Multiple Coordinate Frames
  - LeapMotion tracks hand in LeapMotion coordinate frame (H_{LM})
  - LeapMotion is fixed in HMD coordinate frame (LM_{HMD})
  - HMD is tracked in VR coordinate frame (HMD_{VR}) (using Lighthouse)
- Where is your hand in VR coordinate frame?
  - Combine transformations in each coordinate frame
  - $H_{VR} = H_{LM} \times LM_{HMD} \times HMD_{VR}$

Need - Tracker

- VR require knowledge of the real-time position and orientation of moving objects within some frame of reference.
- A moving object in 3D space has six degrees of freedom, three for translations and three for rotations. If a Cartesian coordinate system is attached to the moving object, then its translations are along the X, Y, and Z axes. Object rotations about these axes are called yaw, pitch, and roll, respectively. These define a dataset of six numbers that need to be measured sufficiently rapidly, as the object may be moving at high speed.

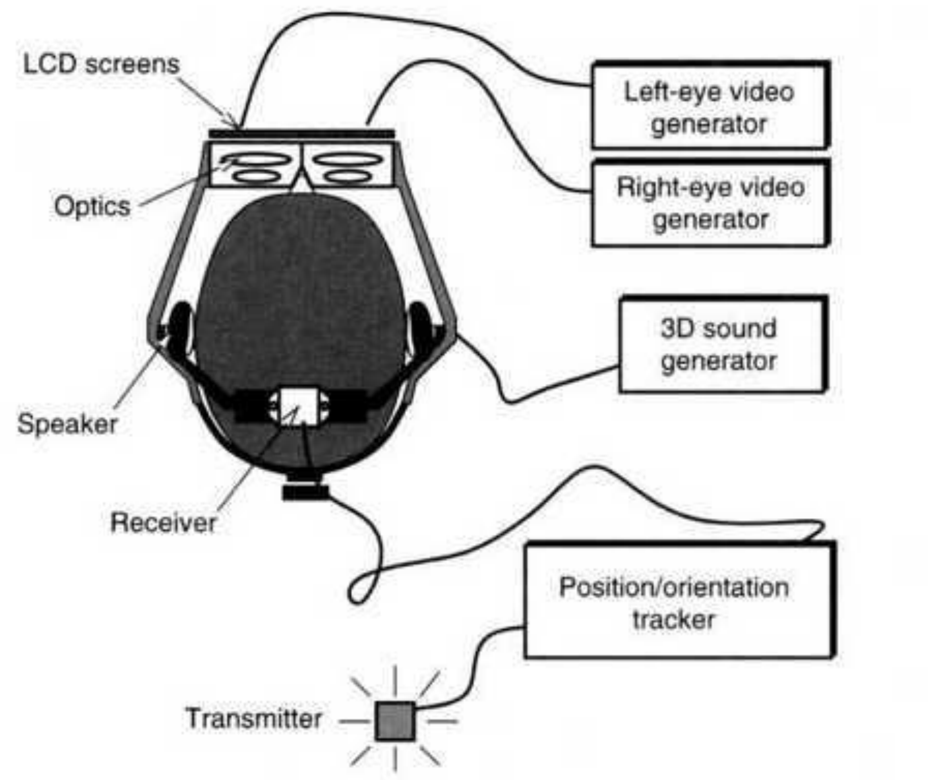
Tracker

- The special-purpose hardware used in VR to measure the real-time change in a 3D object position and orientation is called a **tracker**.
- 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.

HMD Tracker

In the head-mounted display, the tracker receiver is placed on the user's head, 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. 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.

An example illustrates the use of a ***HMD tracker***, the display could have been a much larger immersive Workbench, but the requirement to measure the user's viewing direction remains. Without the 3D head tracker the computer could not have changed the spatial view to match the user's head posture, and the "immersion" sensation would have been lost.



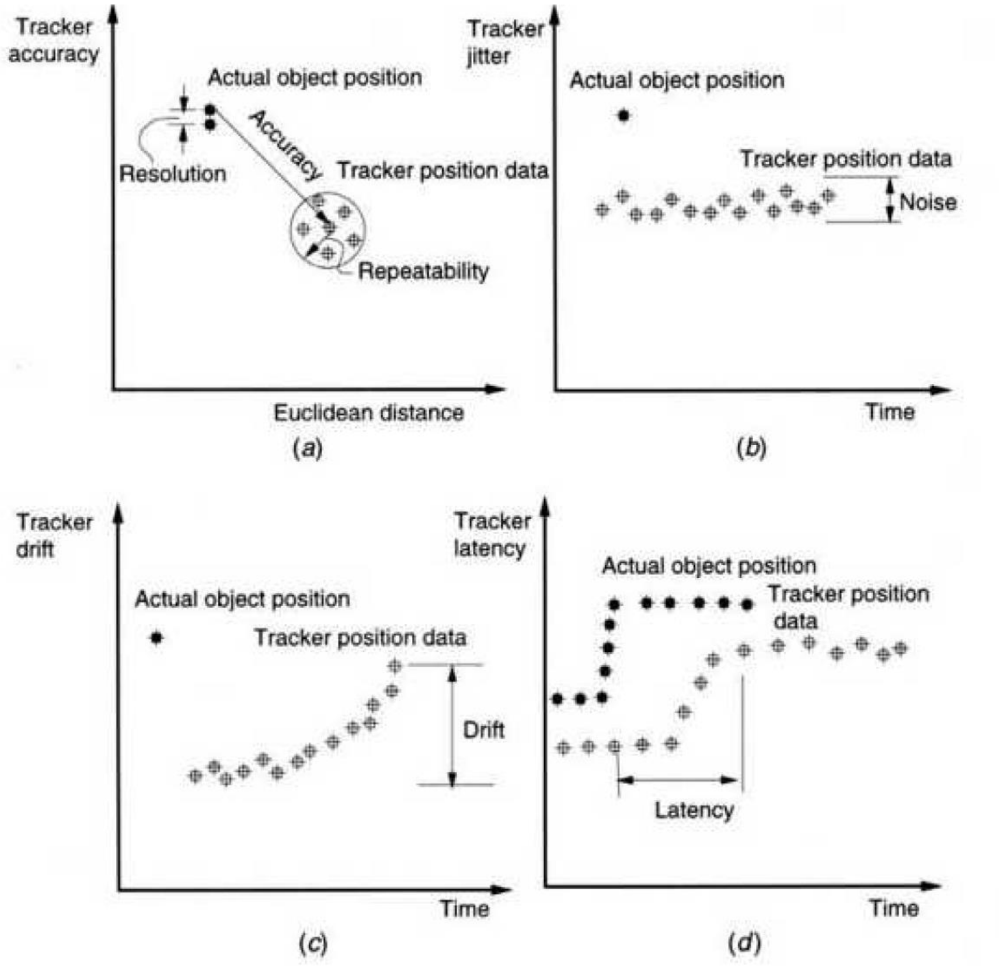
3D sound - Tracker

- VR sensorial modality that uses tracker information is 3D sound through headphones. Tracker data allow the computer to collocate 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. 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, inertial and hybrid.

Tracker Performance Parameters

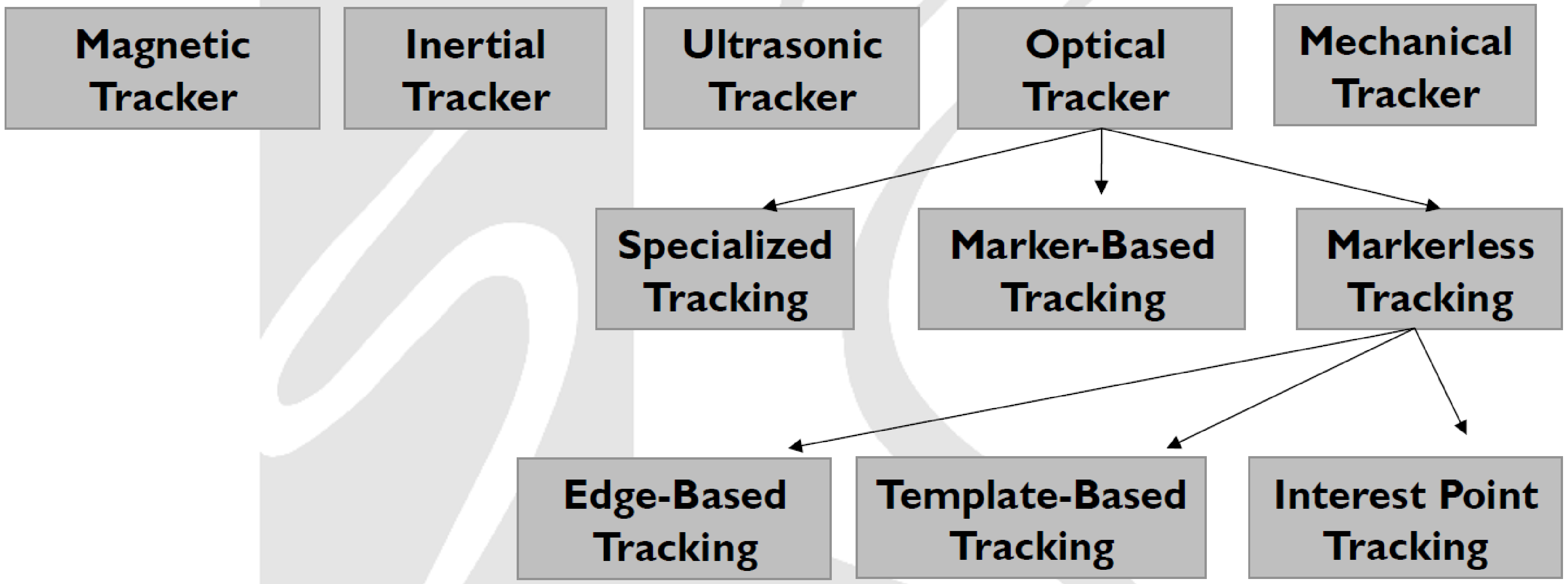
Necessary to look at tracker performance parameters in order to match their measurement capabilities to different sensorial channel requirements and available budgets. The tracker performance parameters are:

- ***Tracker accuracy*** represents the difference between the object's actual 3D position and that reported by tracker measurements.
- ***Tracker jitter*** represents the change in tracker output when the tracked object is stationary.
- ***Tracker drift*** is the steady increase in tracker error with time.
- **Latency** is the time delay between action and result. In the 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*** represents the number of measurements (datasets) that the tracker reports every second.



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

Tracking Types

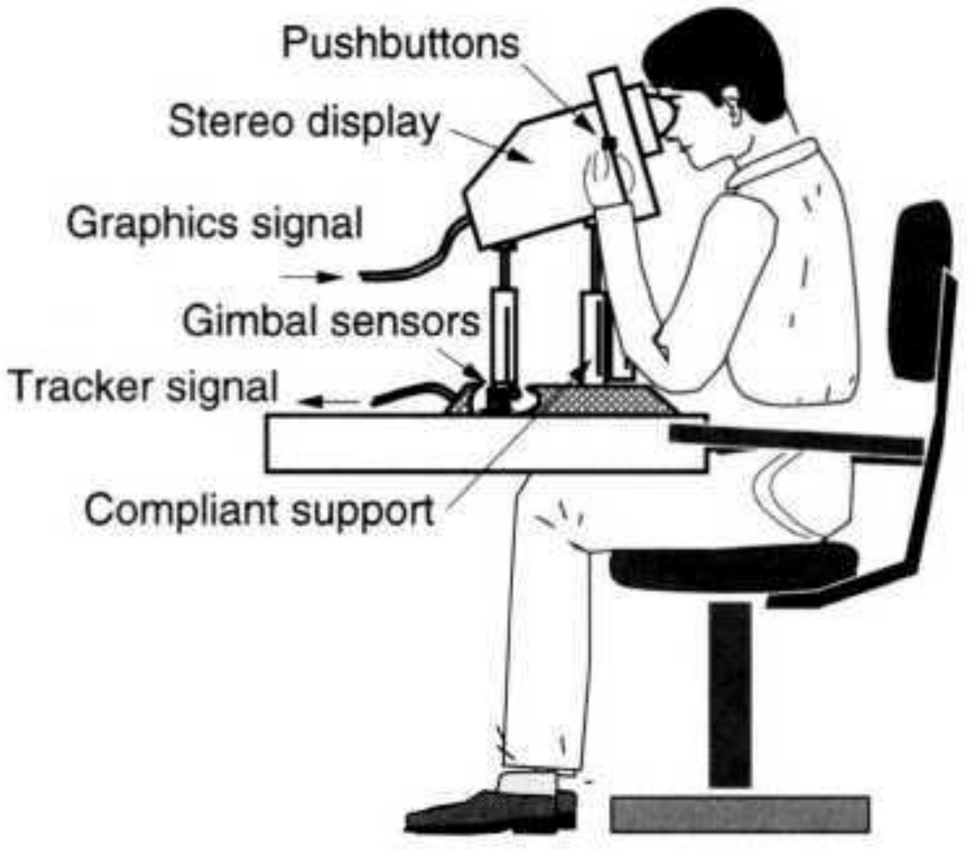


Mechanical Tracker -

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

Advantages:

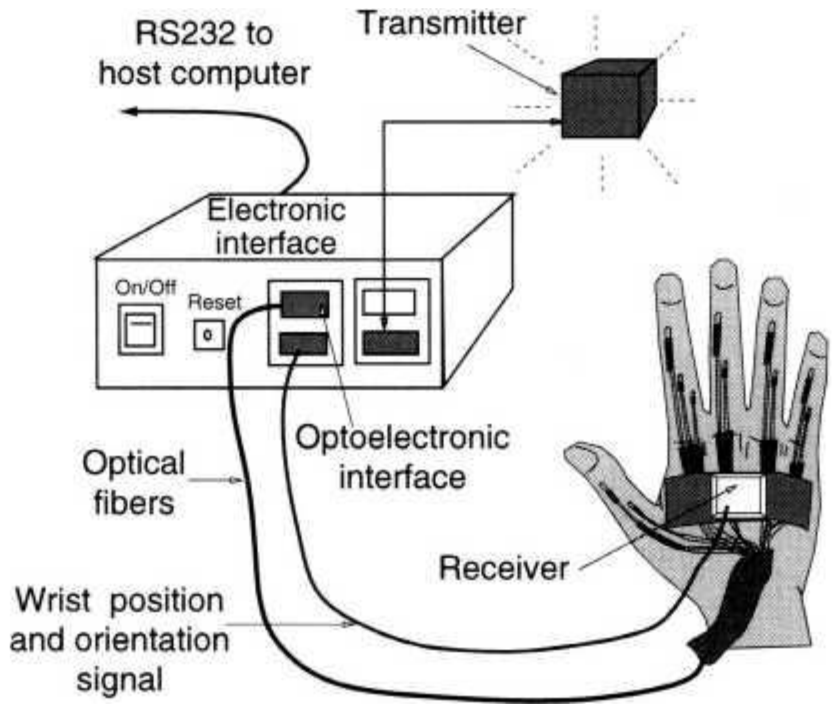
- They are simpler and easier to use.
- Their accuracy is fairly constant over the tracker work envelope, and depends essentially on the resolution of the joint sensors used.
- Unlike electromagnetic trackers, mechanical ones are immune to interference from metallic structures or magnetic fields that may exist in their vicinity.
- 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.



Push display

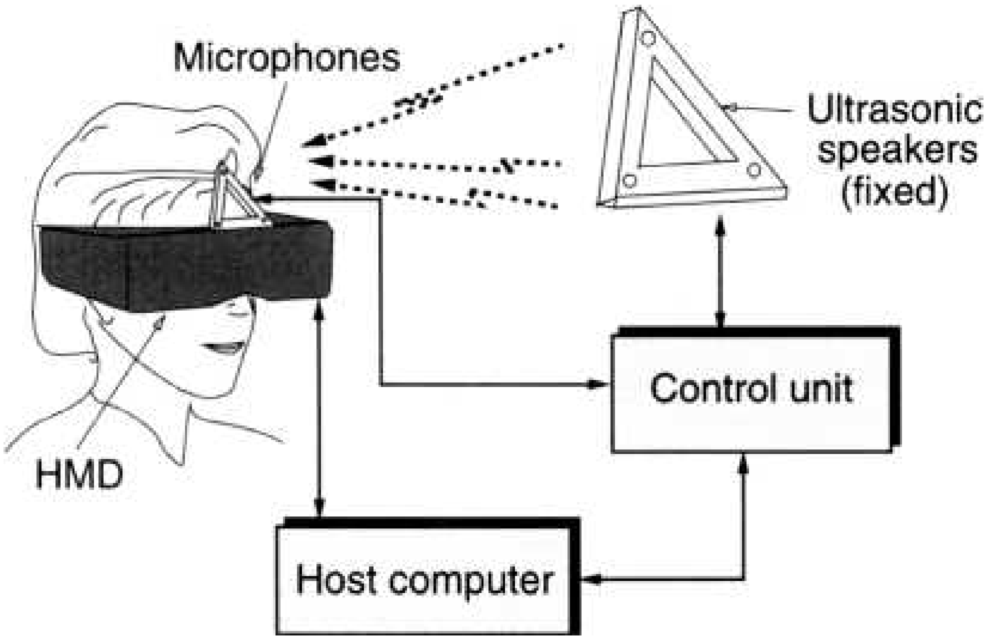
Magnetic tracker – Non-contact position measurement device that uses a magnetic field produced by a stationary transmitter to determine the real time position of a moving receiver element.

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. These are either alternating fields of 7-14 kHz (for AC magnetic trackers) or pulsed fields (for DC magnetic trackers). The fields penetrate the receiver producing a signal that consists of nine voltages (three for each of the orthogonal transmitter fields). DC magnetic trackers add another three voltages obtained when the transmitter is turned off. These voltages correspond to the local value of Earth's DC magnetic field. The *receiver* consists of three small orthogonal coils when AC magnetic fields are used and three magnetometers (or alternatively Hall effect sensors) when DC magnetic fields are used. The receiver voltages are sampled by an electronic unit which uses a calibration algorithm to determine the position/orientation of the receiver in relation to the transmitter. These data packets (three positions and three rotation angles) are subsequently transmitted to a host computer via communication lines.



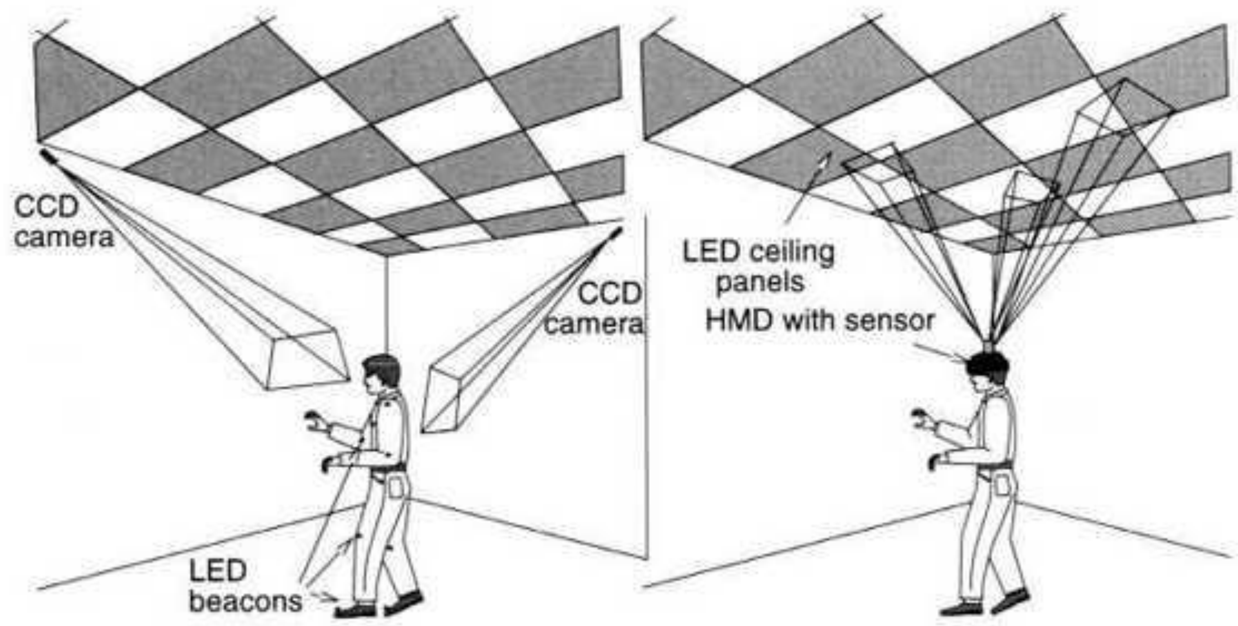
Ultrasound tracker - Noncontact position measurement device that uses an ultrasonic signal produced by a stationary transmitter to determine the real time position of a moving receiver element.

- 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. Alternatively the microphones may be part of 3D mice, stereo glasses, or other interface devices. Due to their simplicity, ultrasound trackers represent a cheaper alternative to the magnetic ones.
- Does not suffer from metal interference uses
- 3D ultrasound trackers.



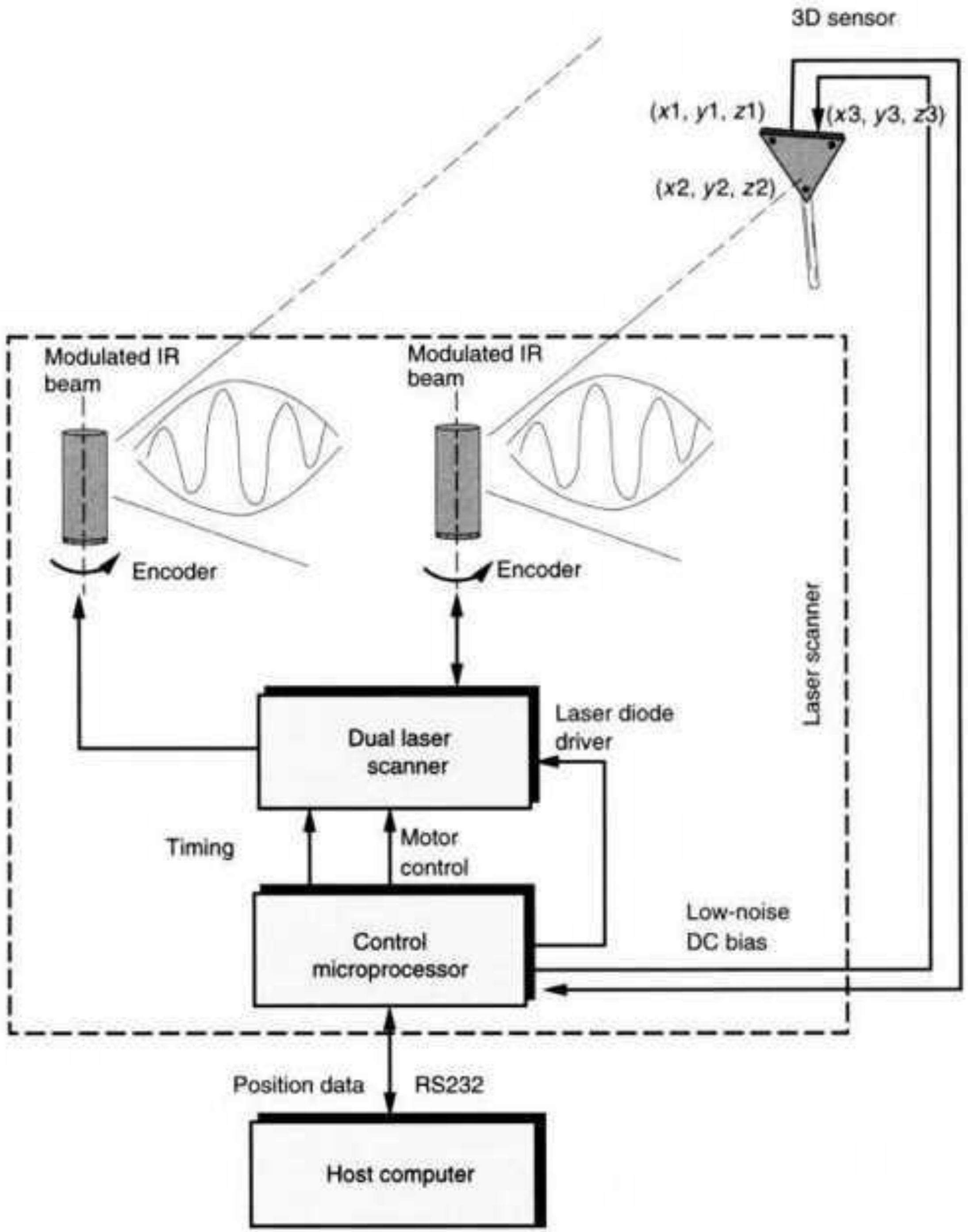
Optical tracker

- An optical tracker is a noncontact position measurement device that uses optical sensing to determine the real-time position/orientation of an object.
- Outside – in and Inside - out

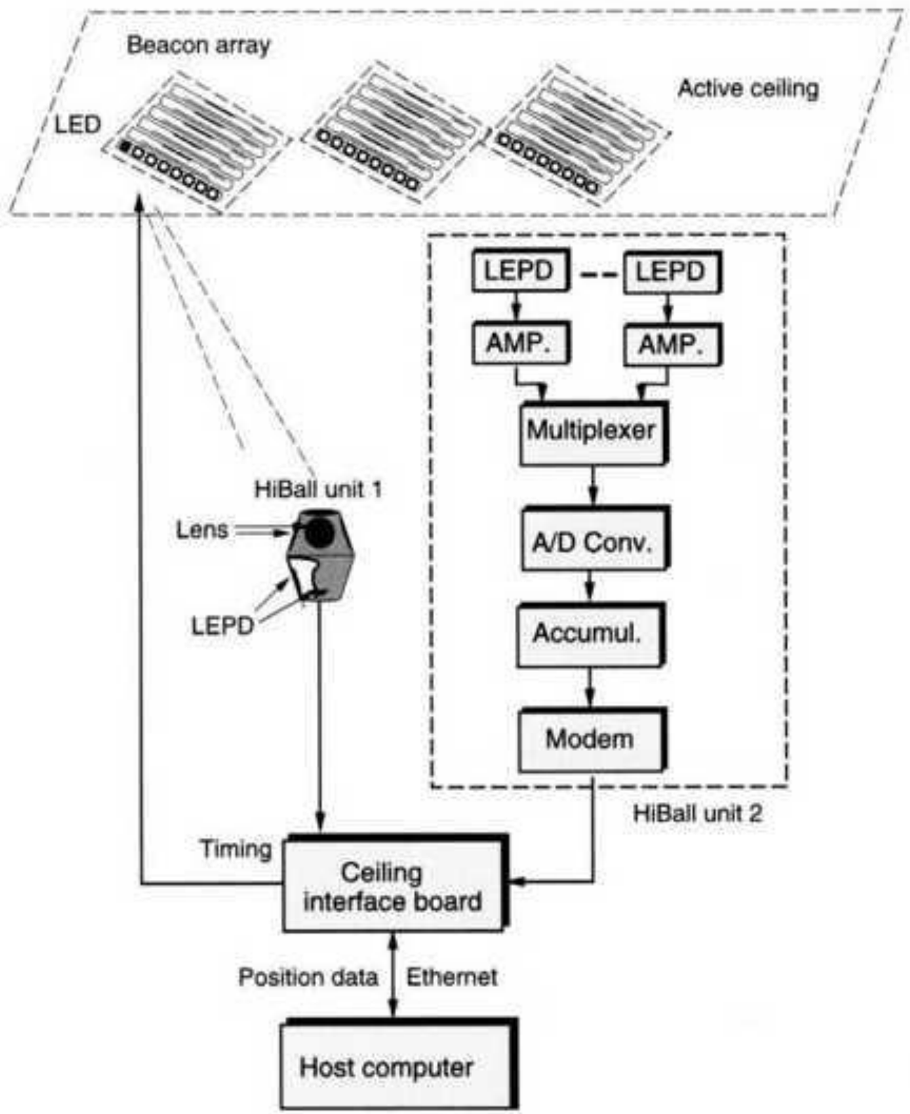


(a) Outside – in (b) Inside – out

Inside – out (LaserBird)



Hiball



Beacon array
Active ceiling
LED
LEPD
LEPD
AMP.
AMP.
Multiplexer
A/D Conv.
Accumul.
Modem
HiBall unit 2
HiBall unit 1
Lens
LEPD
Timing
Ceiling interface board
Position data
Ethernet
Host computer

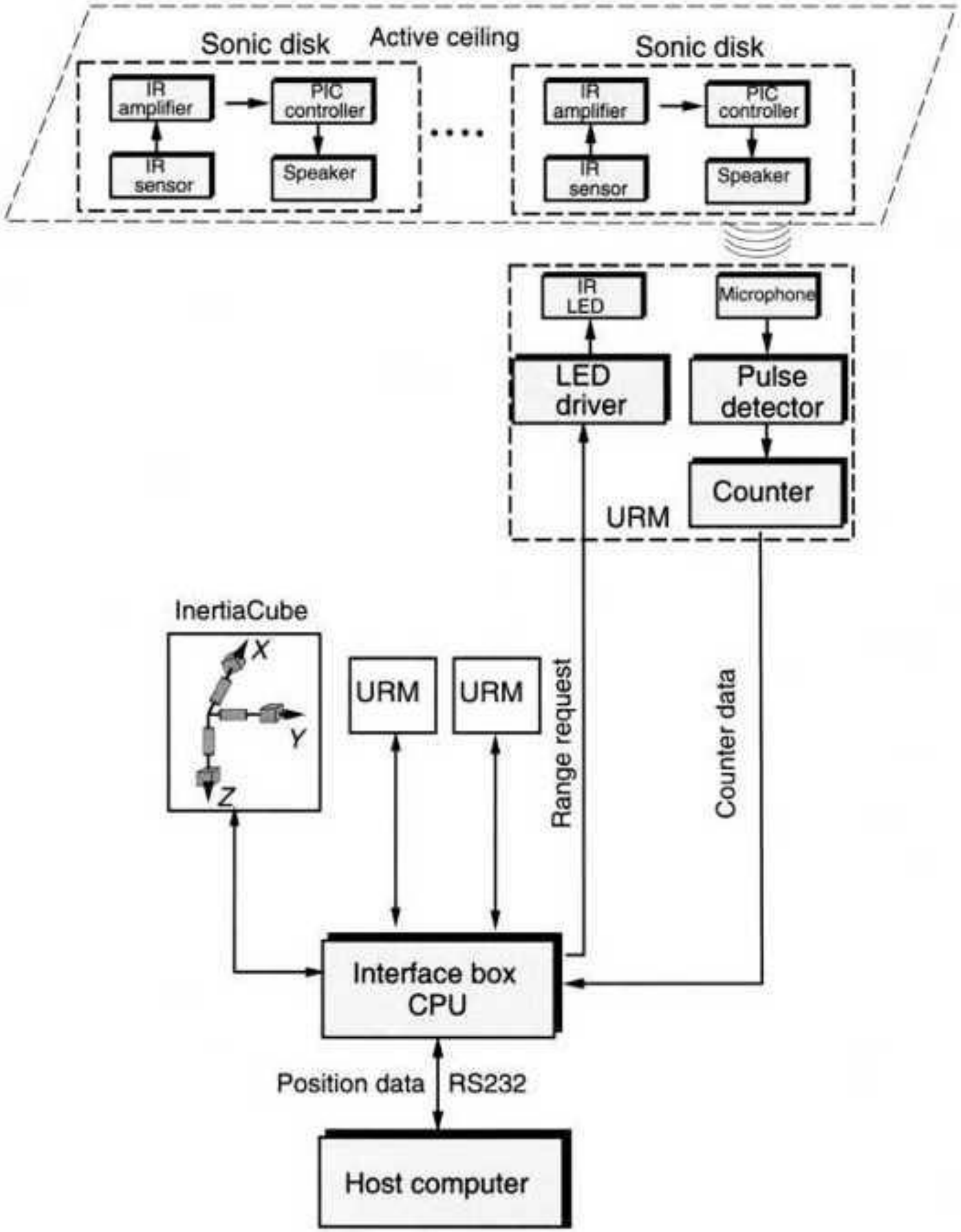
Inertial tracker - self-contained sensors that measure the rate of change in an object orientation. They may also measure the rate of change of an object translation velocity.

Modern inertial trackers are solid-state structures that use microelectromechanical systems (MEMS) technology. The rate of change in object orientation, or angular velocity, is measured by Coriolis-type gyroscopes. Three such gyroscopes are machined on mutually orthogonal axes, measuring yaw, pitch, and roll angular velocities. The orientation angle about the three orthogonal axes is then determined through integration over time. Inertial trackers measure the rate of change in translation velocity, or acceleration, using solid-state accelerometers. Three accelerometers machined coaxially with the three gyroscopes are needed to measure body-referenced accelerations. Knowing the tracked object orientation (from gyroscopic data) and subtracting gravitational acceleration allows the computation of accelerations in world coordinates. The tracked object position is finally obtained through double integration over time and knowledge of starting position (calibration).

Hybrid Tracker- System that utilizes two or more position measurement technologies to track object.ts

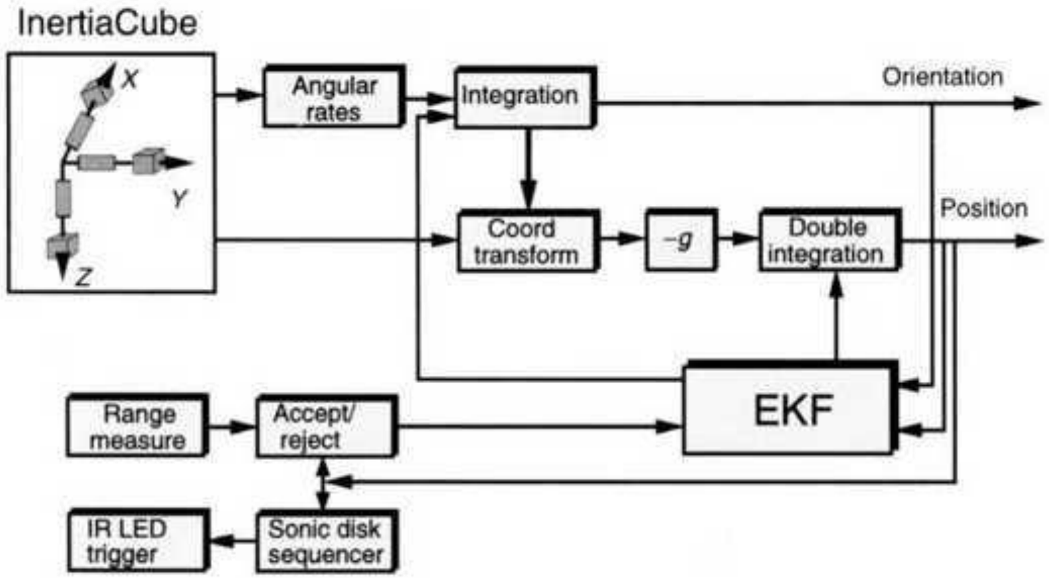
- Better than any single technology
- Ultrasonic range data are fused with the inertial gyroscopic and accelerometer data.
- The tracking algorithm first uses integration, and in the case of accelerometers, double integration, to get orientation and position data to the host computer.

InterSense IS900



InertiaCube

Ultrasonic range data fused with the inertial gyroscopic & accelerometer data



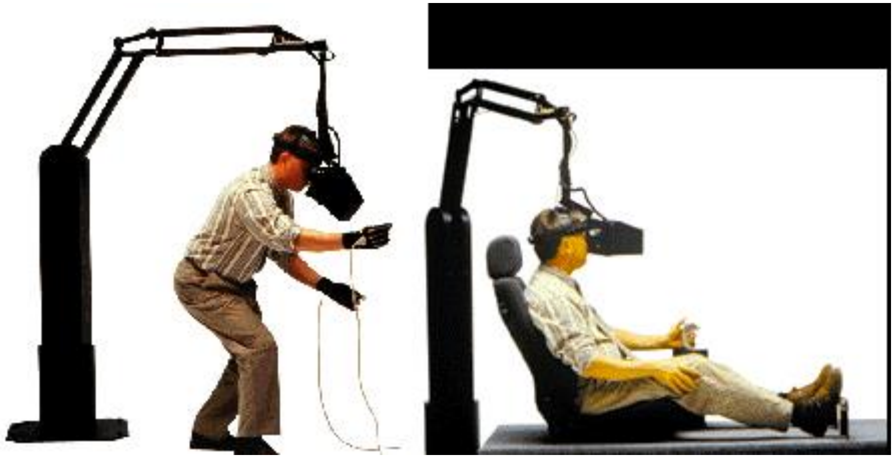
Performance Comparison of Various Trackers[a]

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.

Push – Mechanical Tracker
Fastrack; Flock of birds – Magnetic Tracker
Logitech – Ultrasound tracker
LaserBird; Hiball – Optical Tracker
3D bird; InterTrax2 – Inertial Tracker
IS-900 – Hybrid Tracker(Ultrasonic – Inertial)

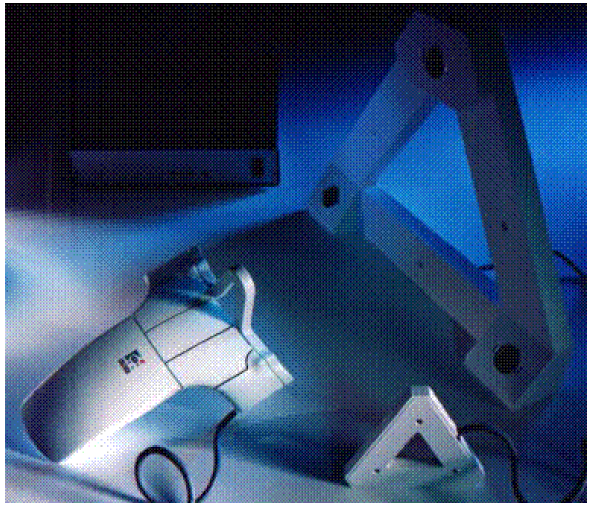
Tracker Devices



Mechanical Tracker

Magnetic Tracker - Fastrak;

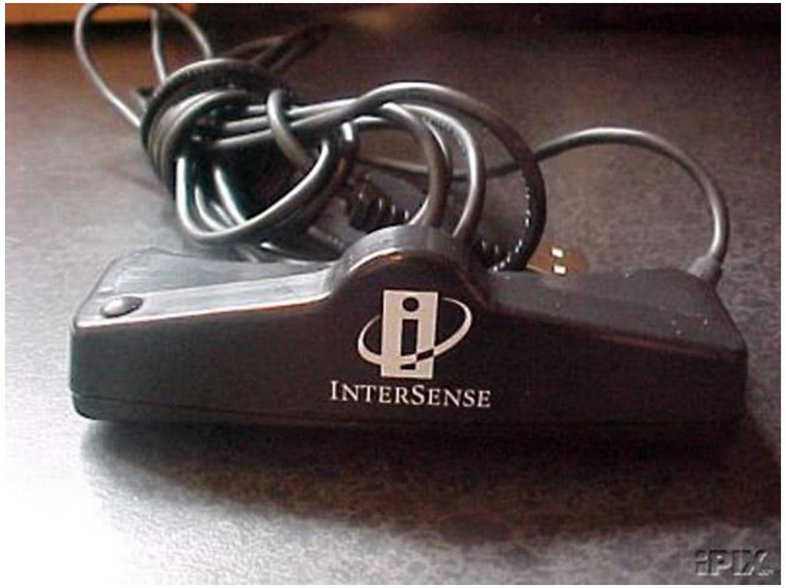
Flock of birds



Ultrasonic tracker - Logitech

Optical Tracker - LaserBird;

Hiball



Inertial Tracker - InterTrax2

Hybrid Tracker - IS-900

S. No.	Tracker Type	Idea	Advantage	Disadvantage
1.	Mechanical	Mechanical arms with joint sensors	Low jitter and Latency	Expensive
2.	Magnetic	Uses a magnetic field produced by a stationary transmitter to determine the real time position of a moving receiver element.	Robust	Wired sensible to metal, noisy
3.	Ultrasonic	Uses an ultrasonic signal produced by a stationary transmitter to determine the real time position of a moving receiver element	Doesn’t suffer from metal interface	Direct line of sight required between the transmitter and receiver
4.	Optical	Optical sensing to determine the real-time position/orientation of an object	Best accuracy	Visual occlusion of the tracked object.
5.	Inertial	Self-contained sensors that measure the rate of change in an object orientation and position velocity	No line of sight; Jitters are filtered	Latency and Drift;
6.	Hybrid	System that utilizes two or more position measurement technologies to track objects	No line of sight	

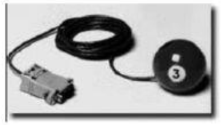
Navigation/manipulation interface - a device that allows the interactive change of the view to the virtual environment and exploration through the selection and manipulation of a virtual object of interest.

- The navigation/manipulation can be done in either ***absolute or relative coordinates***.
- The trackers discussed 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.
- Another way to control a VR object's position is through relative sensors.
- 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.
- 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. (E.g. 3D ball, Mouse)

More Mice

More useful mouse: Polhemus 3Ball

- Provides 3(-6)DOF in a usable package

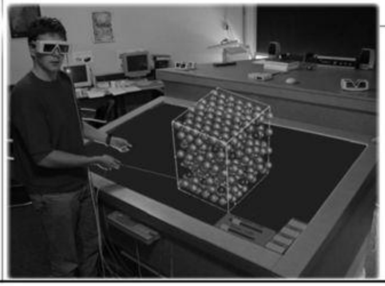


- Actually nothing like a mouse at all

3D Mouse = ‘Wand’

- Provides 5DOF (maybe 6)
- Typically used as a pointing device
- Provides buttons for selection
- The 3D equivalent of the mouse

Wand:



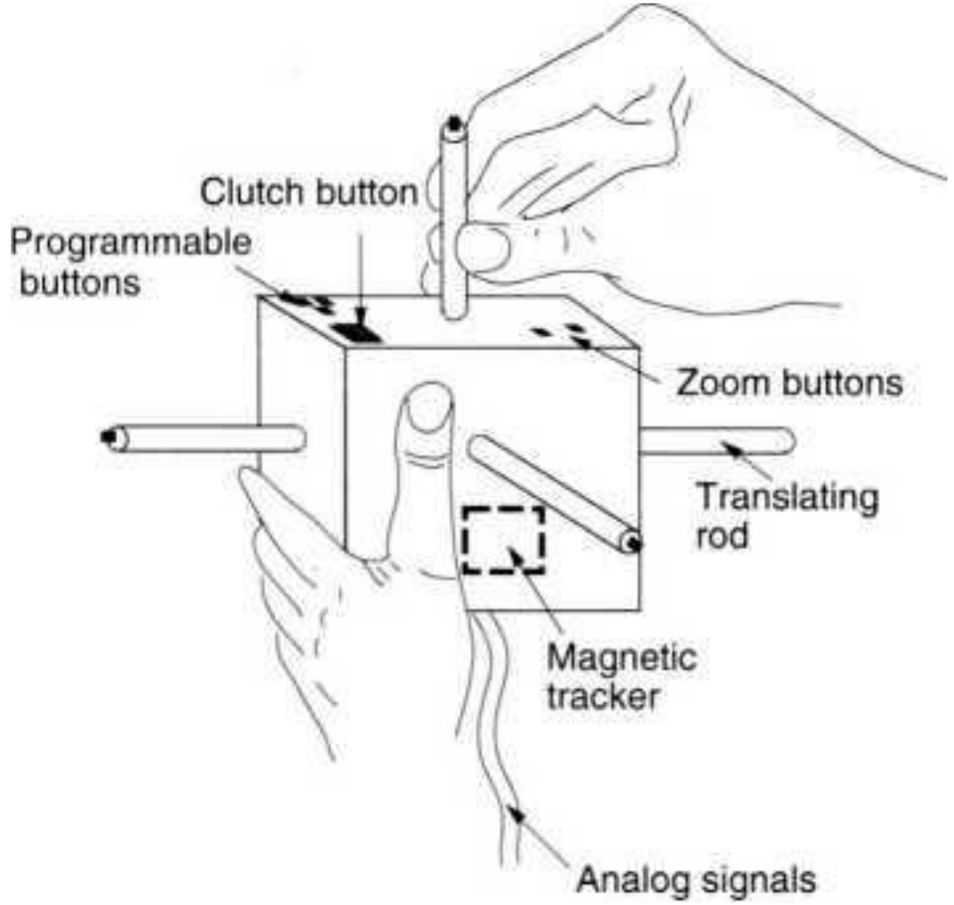
Wand: InterSense devices

Geological data analysis at Schlumberger

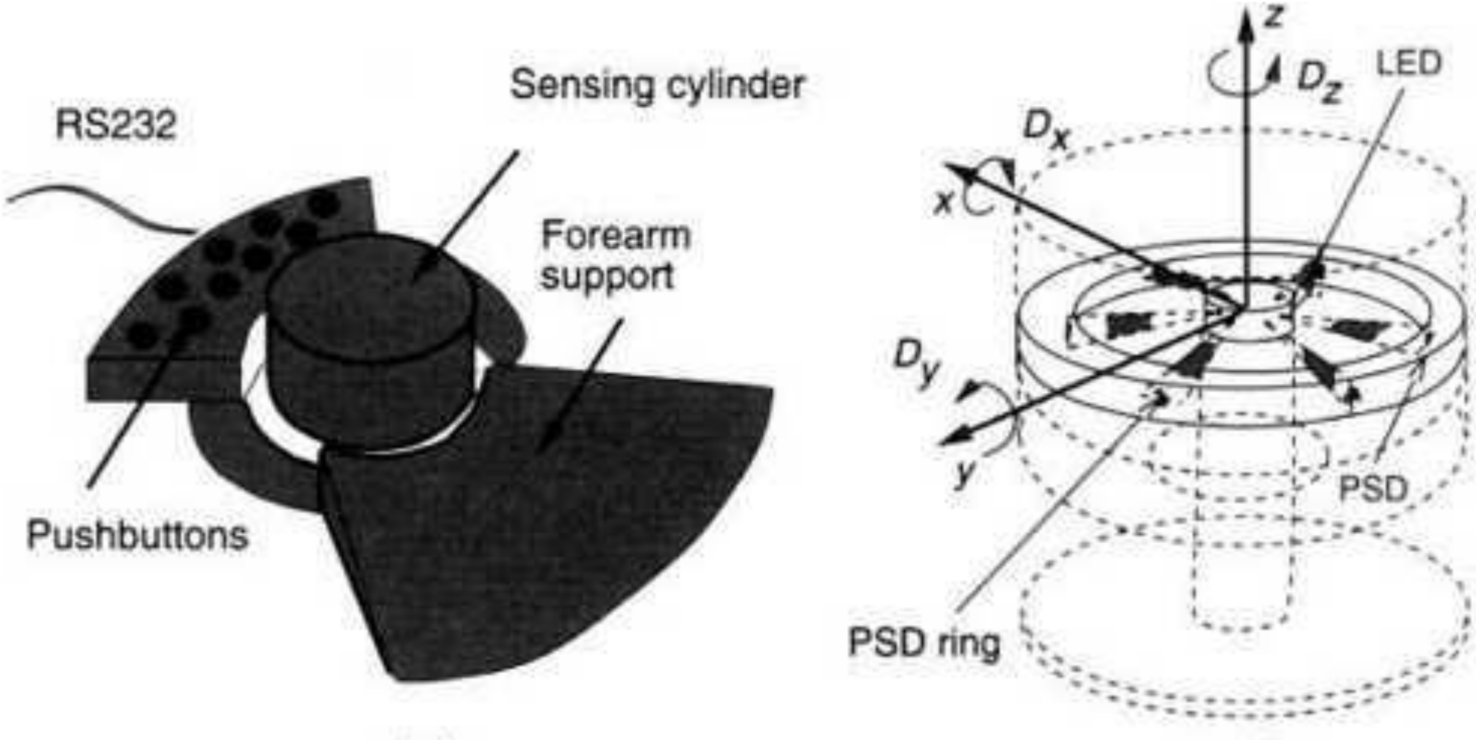
Wand = Joystick

- 6DOF makes it a joystick
  - Tracking systems used can provide 6
- Allows complex navigation
- Allows wand-like selection

Cubic Mouse

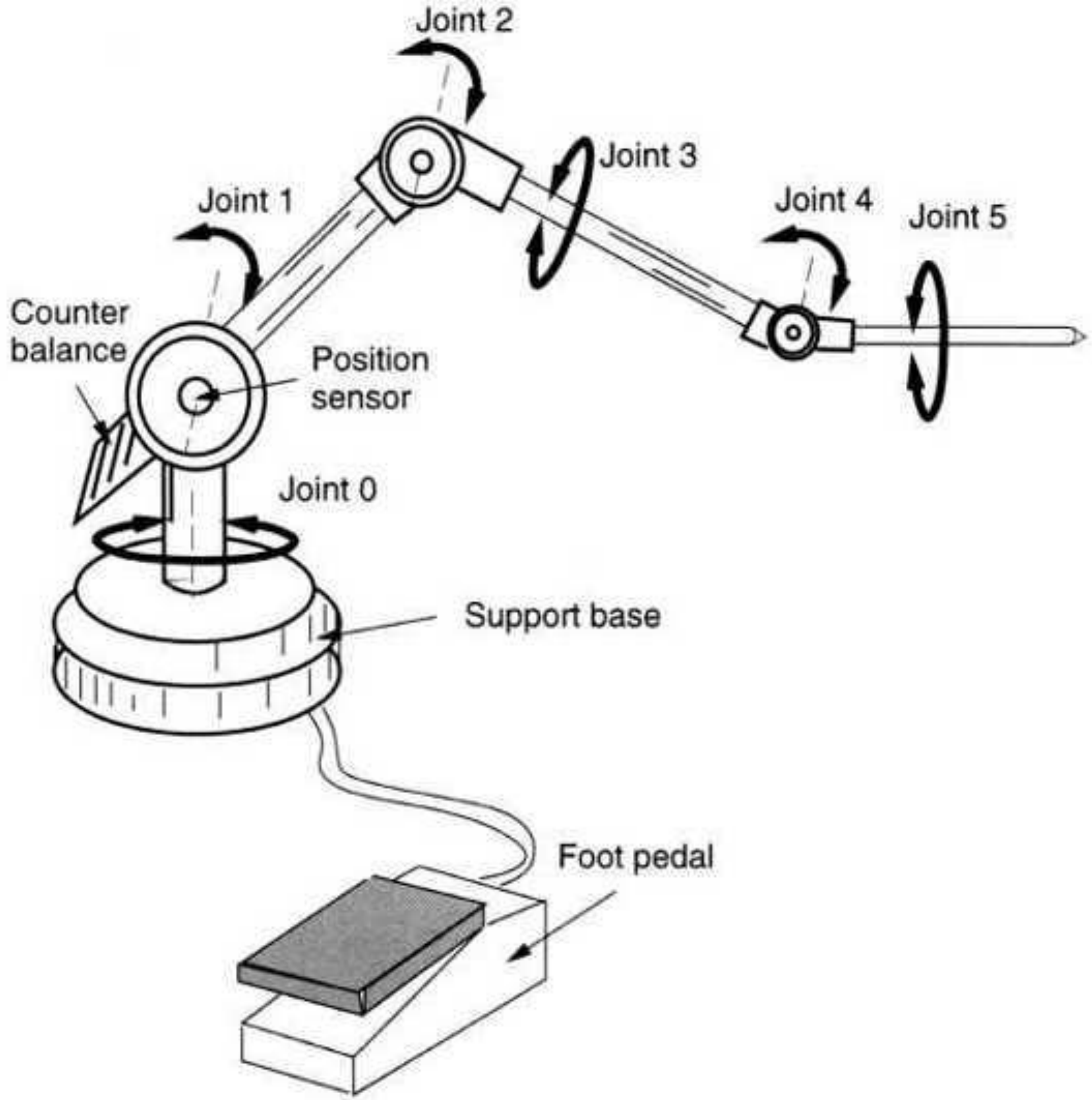

Clutch button
Programmable buttons
Zoom buttons
Translating rod
Magnetic tracker
Analog signals

Track ball - Logitech



(a) (b)

3D probes


Joint 2
Joint 3
Joint 1
Joint 4
Joint 5
Counter balance
Position sensor
Joint 0
Support base
Foot pedal

Navigation & manipulation

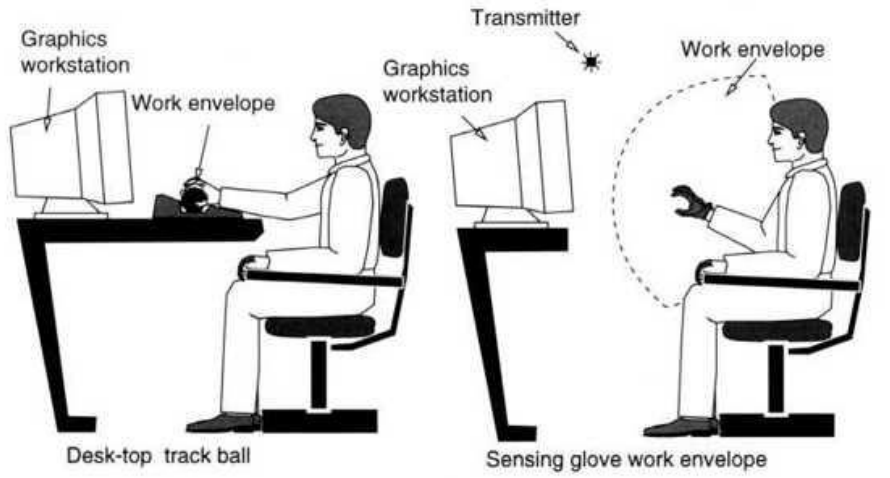
https://www.coursera.org/lecture/develop-augmented-virtual-mixed-extended-reality-applications-webxr-unity-unreal/object-selection-manipulation-in-vr-part-1-QmK4i

Gesture Interface

- 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

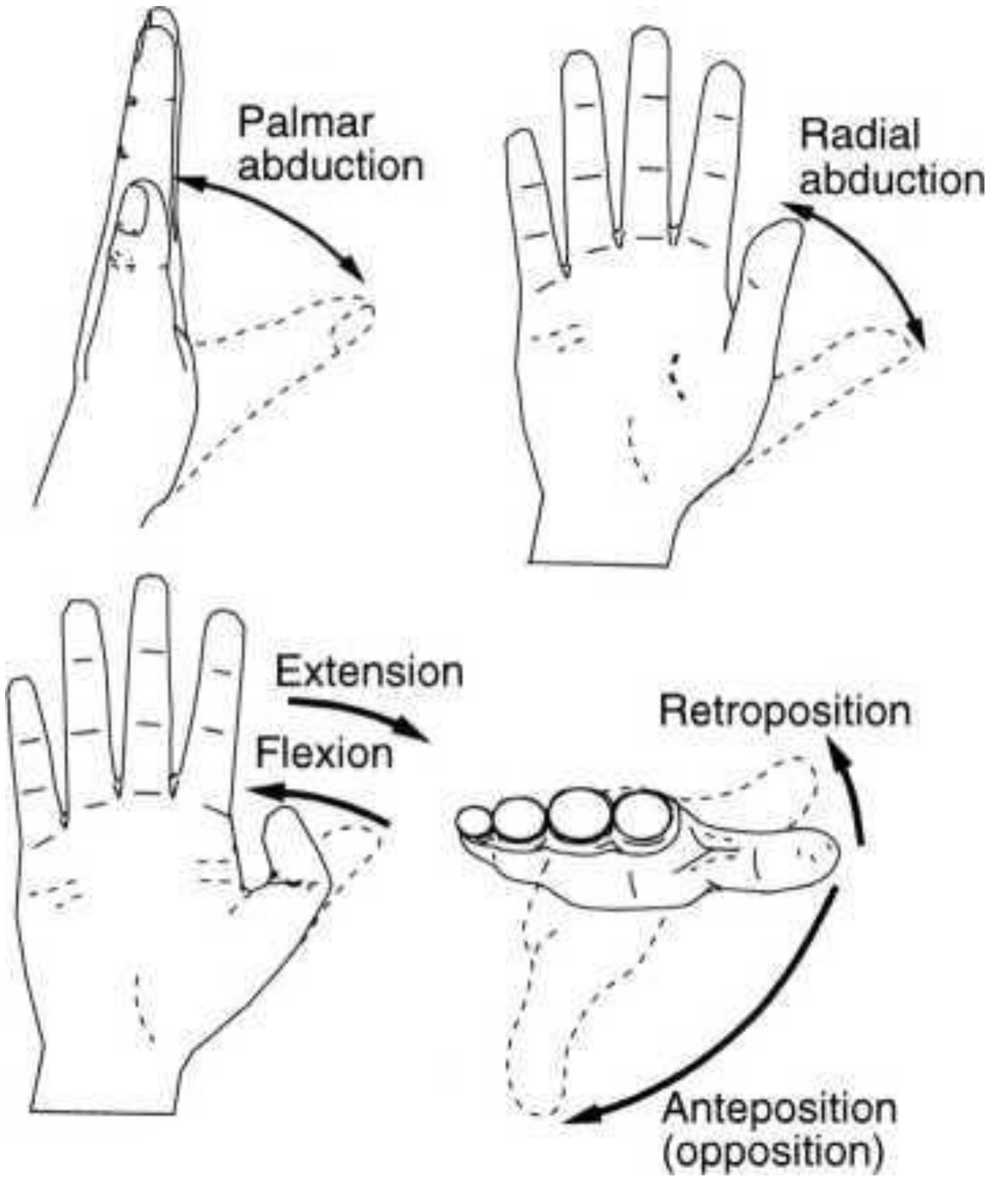
Sensing gloves - Embedded sensors which measure the position of each finger versus the palm. Sensing gloves differ in such factors as, for example, the type of sensors they use, the number of sensors for each finger (one or several), their sensor resolution, the glove sampling rate, and whether they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

E.g., Sensing gloves - Fakespace Pinch Glove, Fifth Dimension Technology (5DT) Data Glove, Didjiglove, and Immersion CyberGlove.



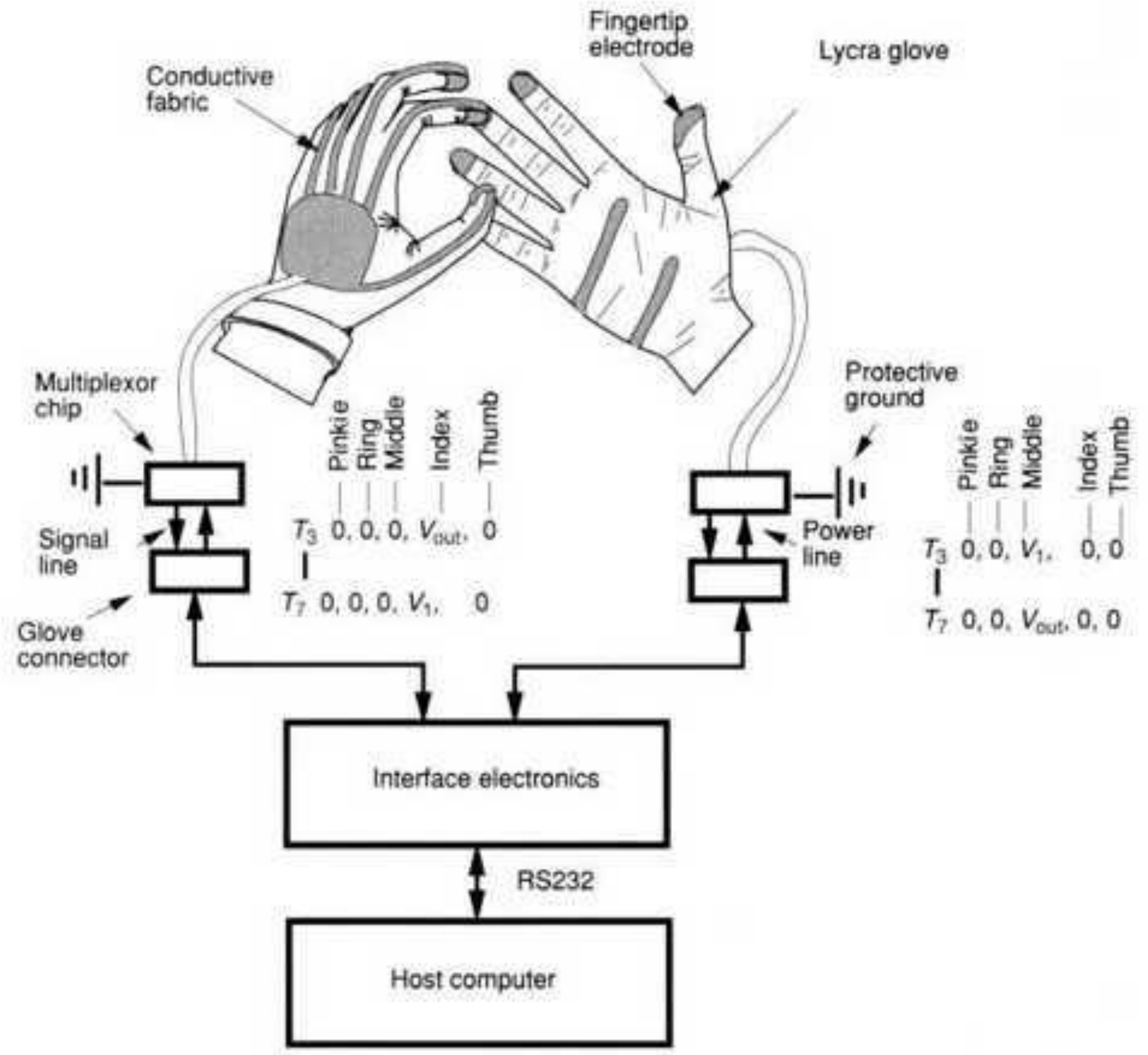
Comparison of trackball work envelope and sensing glove work envelope and

Hand Gesture Terminology



https://www.youtube.com/watch?v=UBakV63xi64

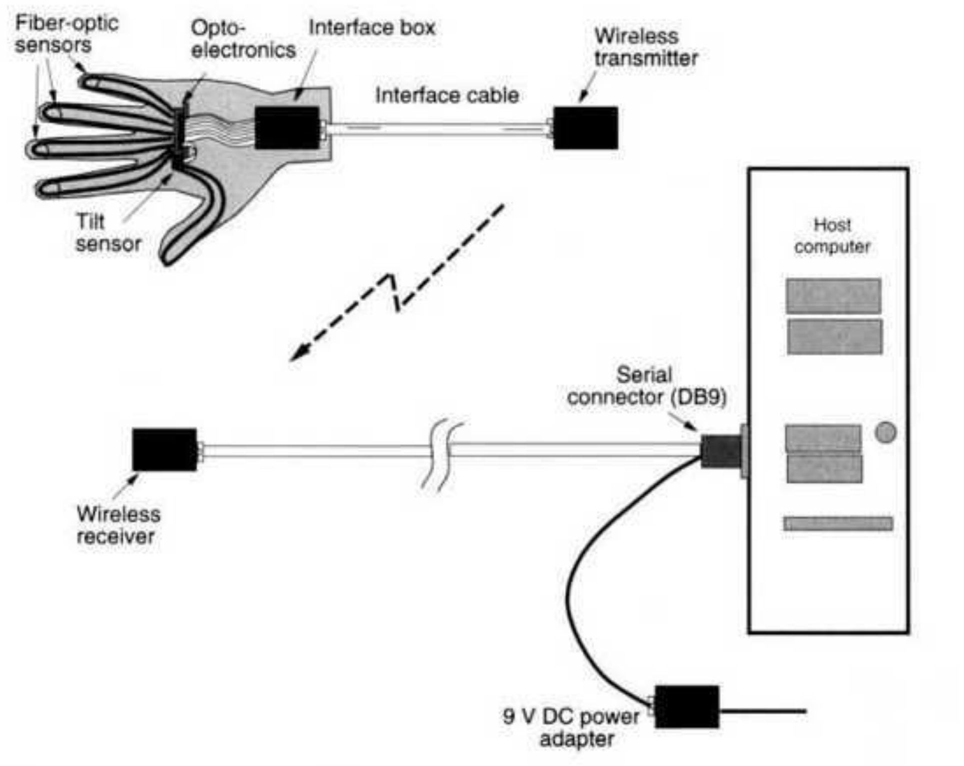
Pinch Glove



Fingertip electrode
Lycra glove
Conductive fabric
Multiplexor chip
Signal line
Glove connector
Pinkie
Ring
Middle
Index
Thumb
T_3 0, 0, 0, V_{out}, 0
T_7 0, 0, 0, V_1, 0
Protective ground
Power line
Pinkie
Ring
Middle
Index
Thumb
T_3 0, 0, V_1, 0, 0
T_7 0, 0, V_{out}, 0, 0
Interface electronics
RS232
Host computer

5 DT Data Glove

https://www.youtube.com/watch?v=YTQqkpwCZvA



Gesture library

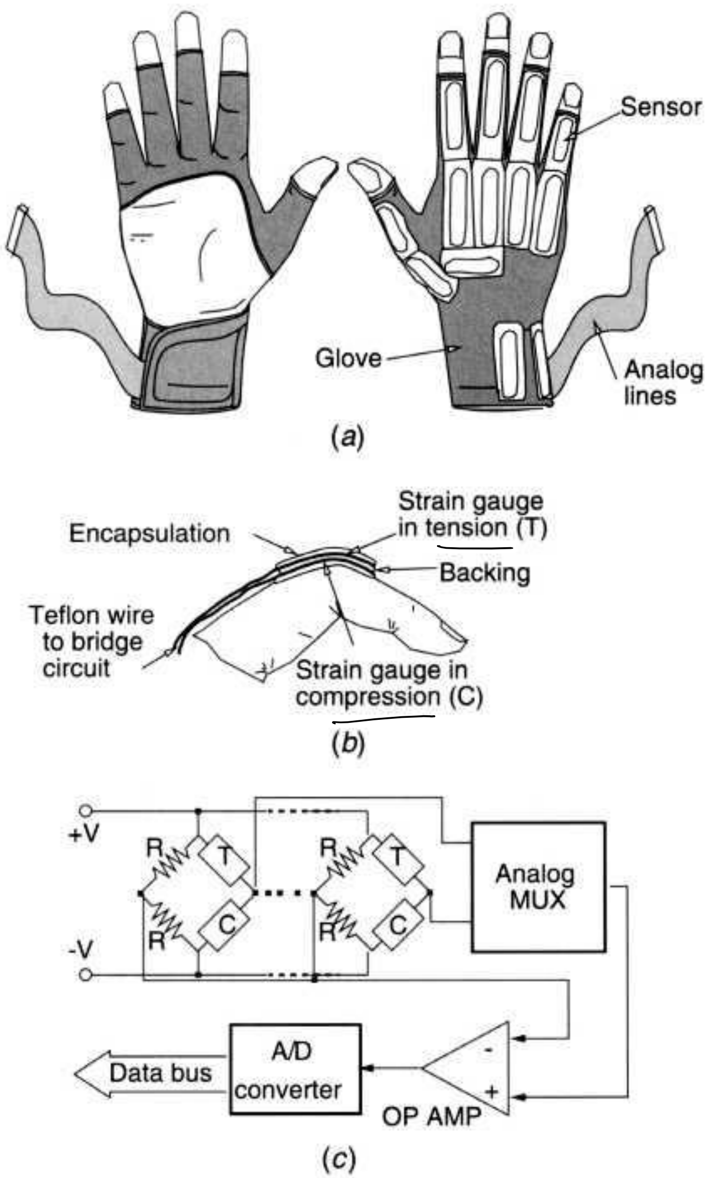
https://www.youtube.com/watch?v=W9YzGSUlVMI

Didjiglove

- Uses 10 capacitive bend sensors to measure the position of the user’s finger.
- Capacitive sensors consist of 2 layers of conductive polymer separated by a dielectric
- Each conductive layer is arranged in a comblike fashion, such that the overlapping electrode surface is proportional to the amount of sensor bending.
- Has A/D convertor, multiplexer, processor and RS232.

Cyber glove

https://www.youtube.com/watch?v=4aMCJDOEi0k



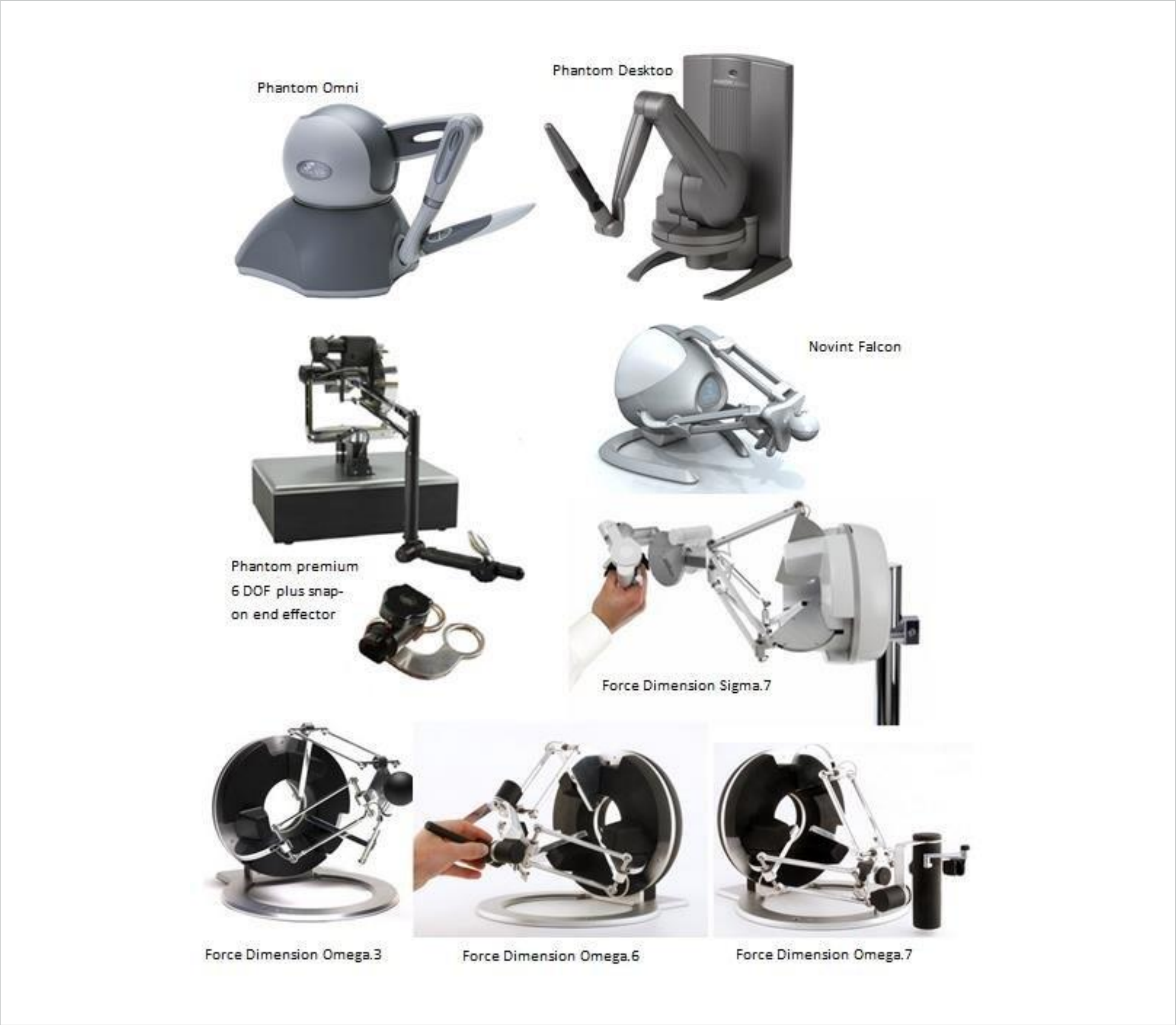
Objectgrasp

- CyberGlove CyberGrasp system is an innovative force feedback system for fingers and hand. It lets you “reach into your computer” and grasp computer-generated or tele-manipulated objects.
- Eg: https://youtu.be/xp9Bh8efC0E

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

Haptic display



Haptics - the technology of adding the sensation of touch and feeling to computers

- When virtual objects are touched, they seem real and tangible.
- Derived from greek word haptikos" meaning "ABLE TO COME INTO CONTACT WITH"

 Haptics = Touch = Connection

 Touch is at the core of personal experience.

 Of the five senses, touch is the most proficient, the only one capable of simultaneous input and output Haptic senses links to the brain's sensing position and movement of the body by means of sensory nerves within the muscles and joints.

Components:

- Tactile – Input through skin
- Proprioceptic – Input through the muscular and skeletal systems

- The 3D trackers, trackballs, and sensing gloves, which are devices used to mediate the user's input into the VR simulation.
- 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).

Haptic feedback

- *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.
- *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).

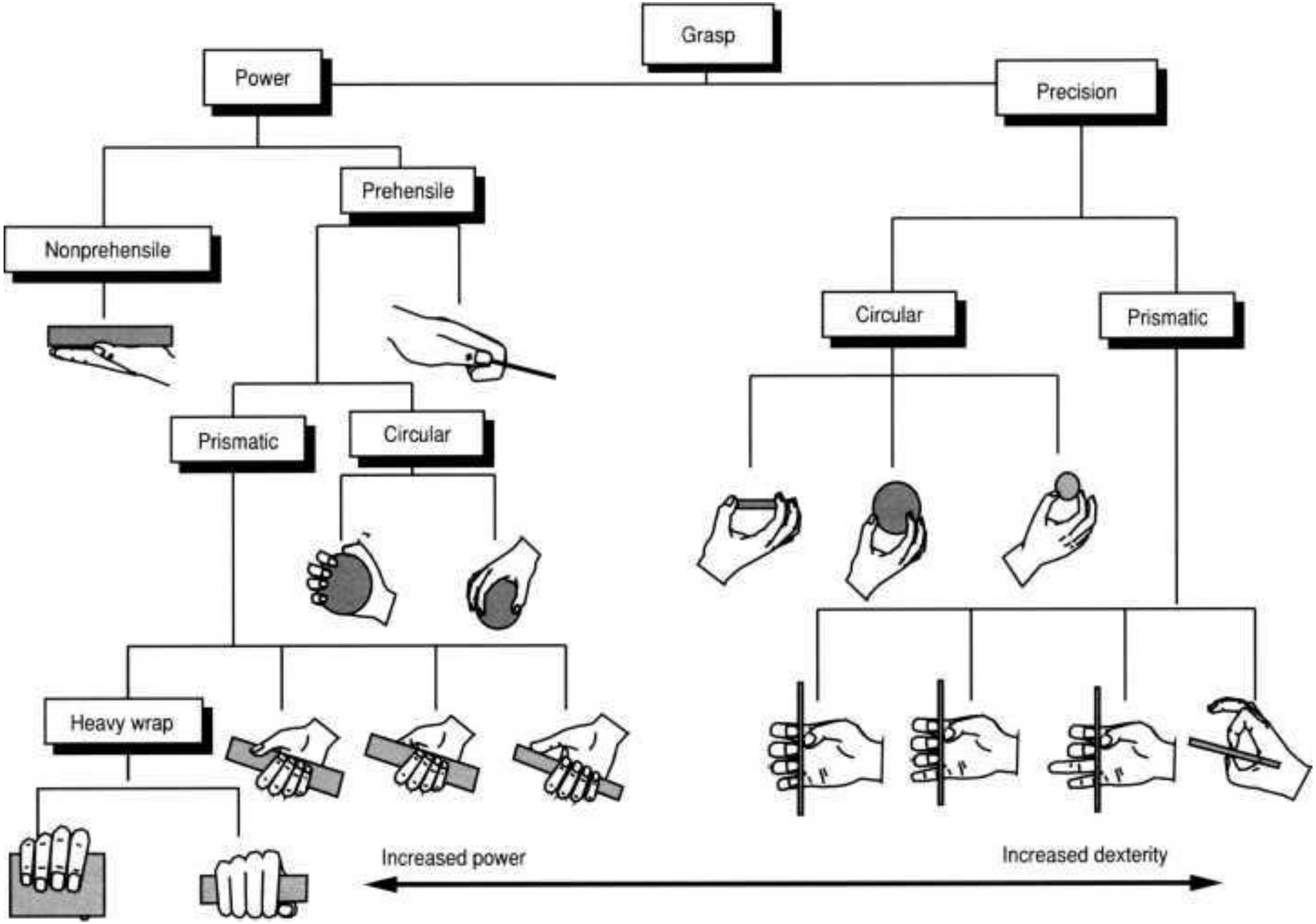
Designing good haptic feedback interfaces

- *User safety and comfort* : While the user interacts with virtual objects, the forces he or she feels are real. These contact forces need to be large (in the simulation of rigid objects), but not large enough to harm the user. In this context a good design is also fail-safe, so that users are not subject to accidents in case of computer failure.
- *Portability and user comfort:* The difficulty with force-feedback actuators is the need to provide sufficient force while still keeping the feedback hardware light and unintrusive. If haptic interfaces are too heavy and bulky, then the user will get tired easily and will prefer a less cumbersome open-loop control. Heavy feedback structures can be gravity counterbalanced, but this further increases complexity and cost. Portability also relates to ease of use and installation at the simulation site.
- Haptic feedback interfaces should be *self-contained*, without requiring special supporting construction, piping, or wiring.

- Human Haptic System
- Tactile feedback interface
- Force Feedback interface

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 (means humans perceive hapticly much faster than they can respond).

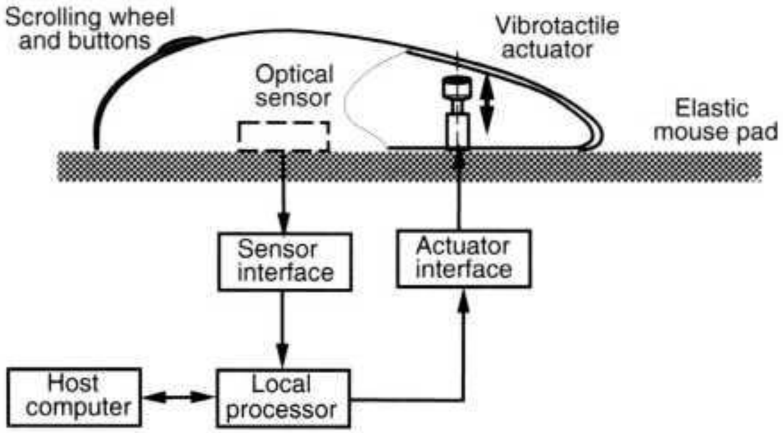


Grasp
Power
Precision
Prehensile
Nonprehensile
Circular
Prismatic
Prismatic
Circular
Heavy wrap
Increased power
Increased dexterity

iFeelTM tactile feedback mouse

(a)

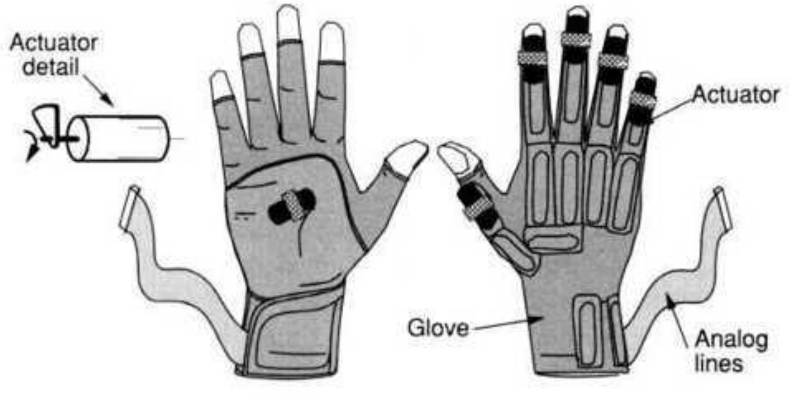
(a) Outside appearance.



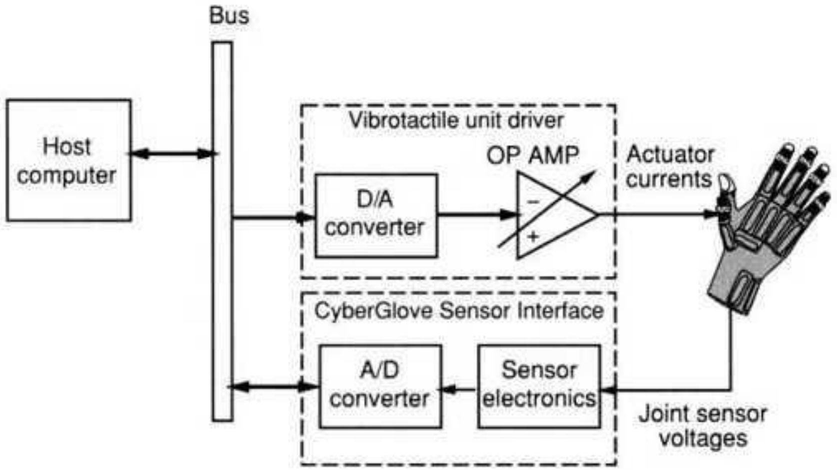
(b)

(b) Tactile feedback system

CyberTouch Glove

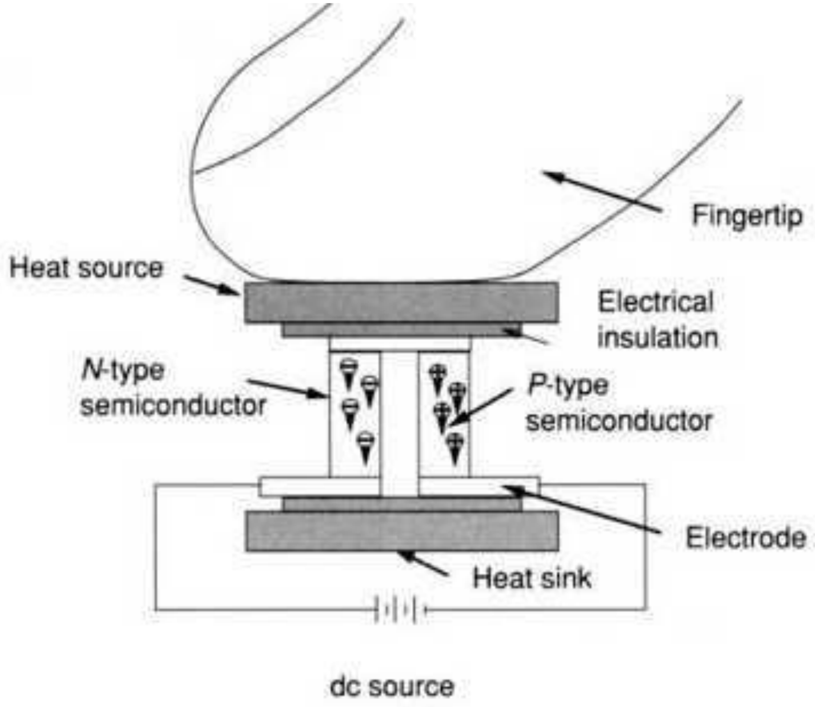


(a)

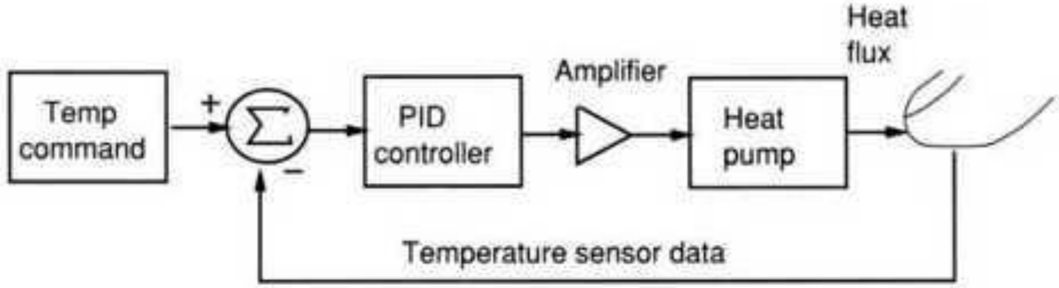


(b)

Temperature feedback glove : (a) Thermoelectric heat pump element (b) Thermode control diagram



(a)



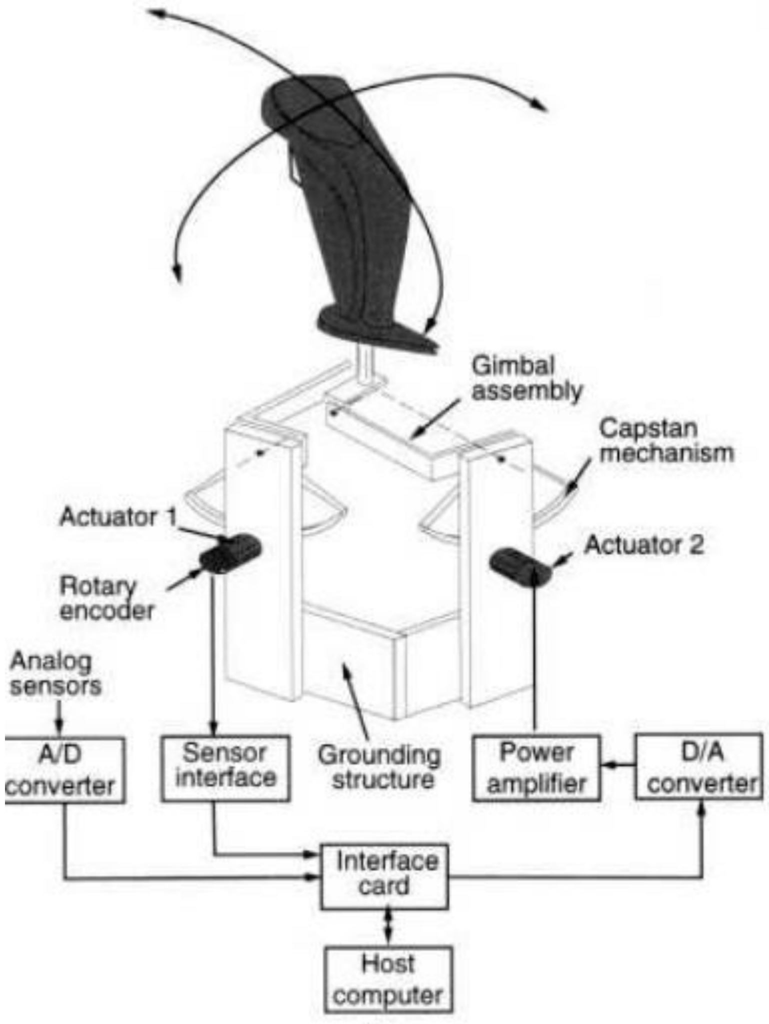
(b)

Force Feedback Interfaces

- Force feedback joysticks
- Phantom arm
- Haptic master arm
- Cybergrasp glove
- Cyberforce

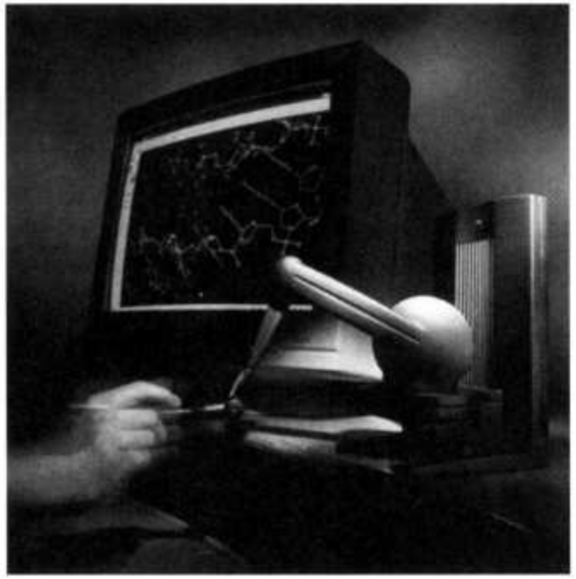
Joystick

(a)

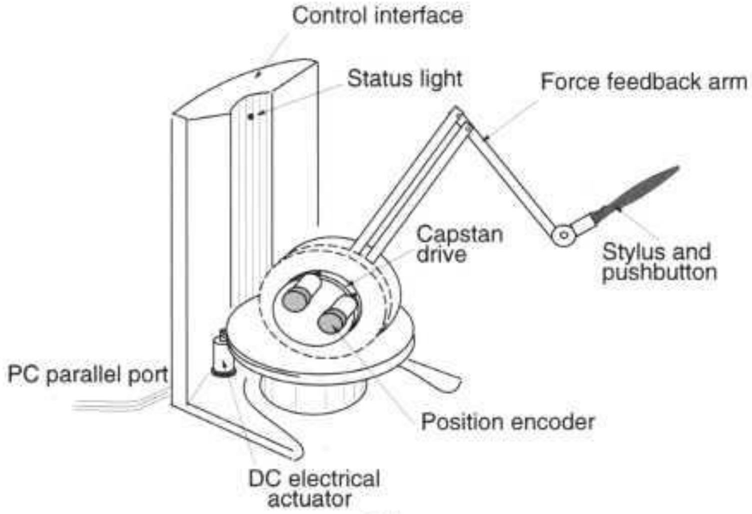

Gimbal assembly
Capstan mechanism
Actuator 1
Actuator 2
Rotary encoder
Analog sensors
A/D converter
Sensor interface
Grounding structure
Power amplifier
D/A converter
Interface card
Host computer

(b)

Phantom force feedback arm

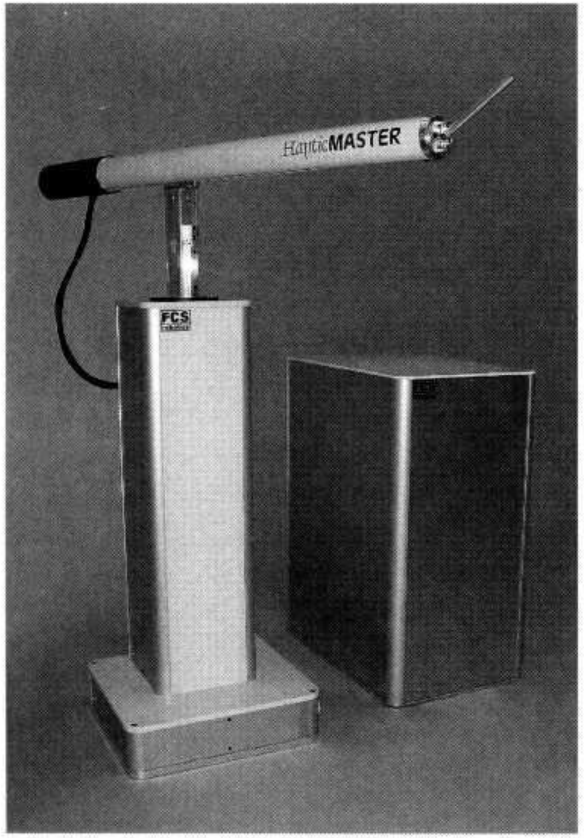


(a)

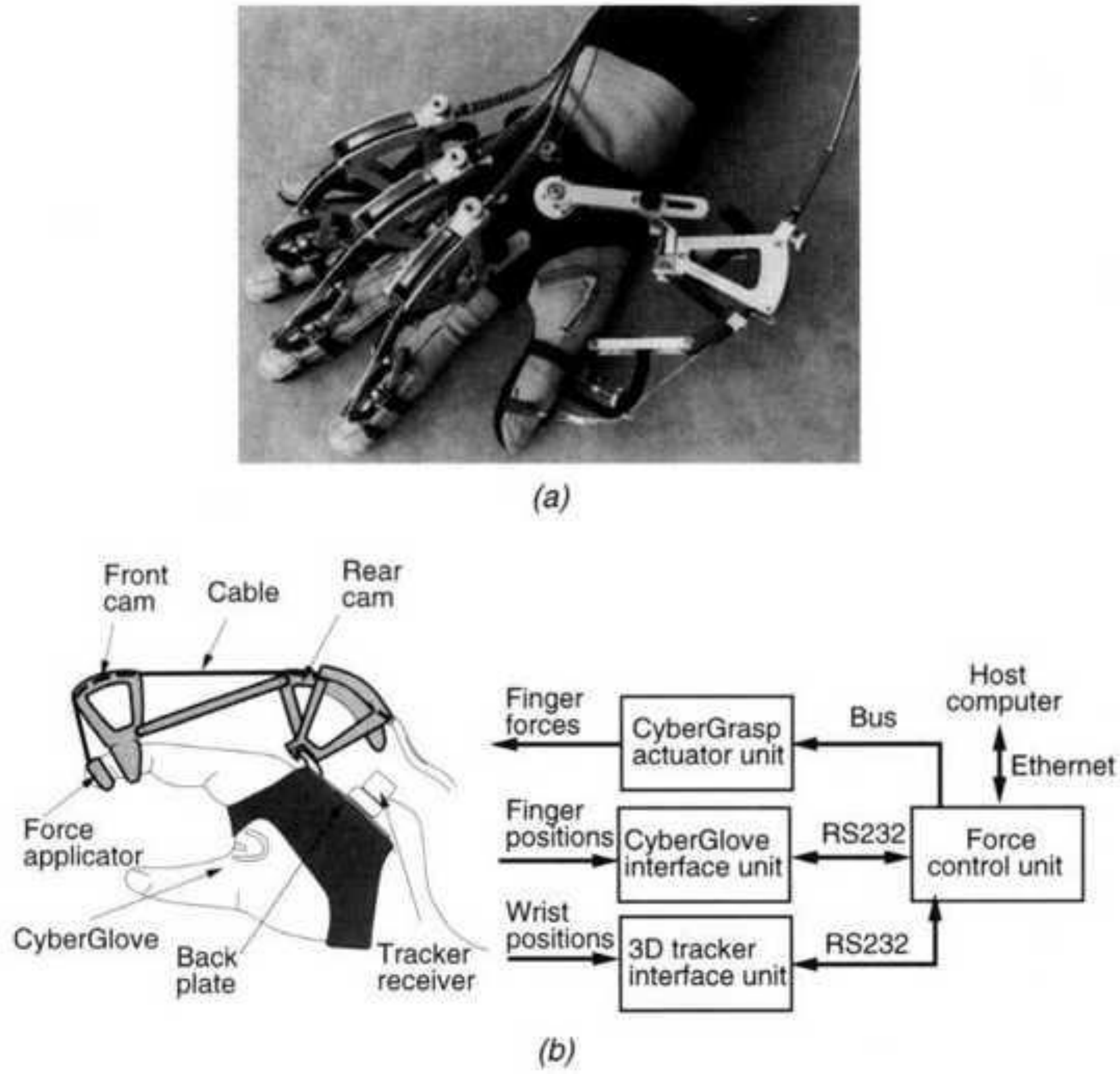


(b)

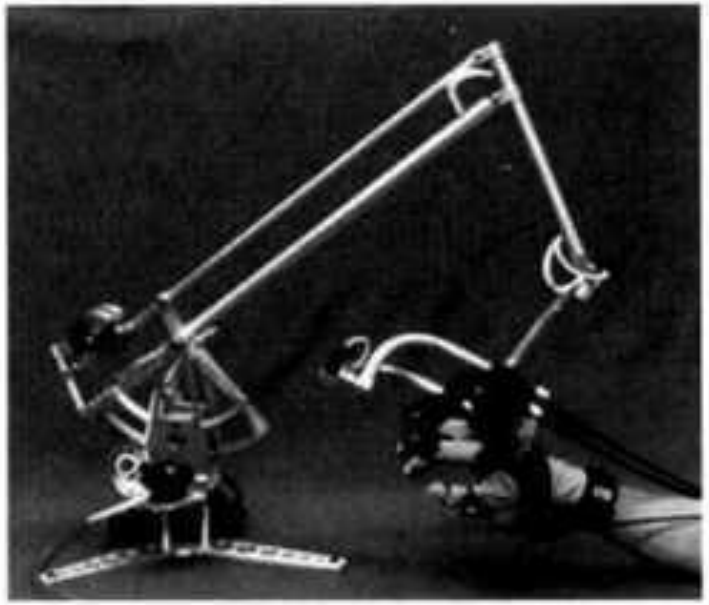
Haptic master arm



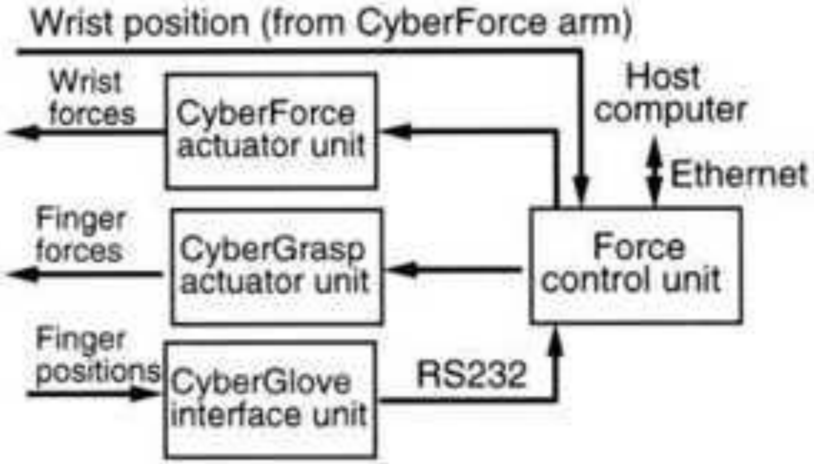
Cybergrasp glove



Cyberforce



(a)



(b)

. Haptic Interfaces for the Hand

Product Name	Type of Feedback	Number of Actuators	Maximum Force (N)	Weight (g)	Bandwidth (Hz)	Price ($10^3$$)
iFeel Mouse	Vibrotactile	1	1.18 @30 Hz	132	0–500	0.04
CyberTouch glove	Vibrotactile	6	1.2 N @125 Hz	142	0–125	15
DTSS X10	Temperature	≤8	NA	340	NA	20
WingMan 3D joystick	Force	2	3.3	NA	0–333	0.06
PHANToM Desktop	Force	3	6.4	75 (aparent)	NA	16
PHANToM 1.5/6.0	Force	6	8.5	90–108	15 (rotation)	57
Haptic Master	Force	3	250	NA	10	34
CyberGrasp glove	Force	5	16	539	40	39
CyberForce arm	Force	8	8.8 (translation)	NA	NA	56

3D Manus

- https://www.youtube.com/watch?v=8vupvT_XdNQ&t=8s

FlyJacket: An Upper Body Soft Exoskeleton for Immersive Drone Control

https://www.youtube.com/watch?v=L0FTPYkLKHI&t=88s

Tools for VR:

https://www.lullabot.com/articles/11-tools-for-vr-developers

Development Tools &
Frameworks in Virtual Reality

1. Unity

It is famous for game development, however, it helps you to build VR solutions for many other sectors too. E.g., you can create VR solutions for automotive, transportation, manufacturing, media & entertainment, engineering, construction, etc. with Unity.

- A powerful editor to create Unity 3D VR assets;
- Artist and designer tools;
- CAD tools;
- Collaboration tools.

2. Amazon Sumerian

It is the VR engine from AWS, and you don't need 3D graphics or VR programming skills to use it. Sumerian works with all popular VR platforms like Oculus Go, Oculus Rift, HTC Vive, HTC Vive Pro, Google Daydream, and Lenovo Mirage, moreover, it works with Android and iOS mobile devices too.

Amazon Sumerian supports various VR use cases like employee education, training simulation, field services productivity, retail & sales, and virtual concierge.

It has powerful features, e.g.:

- Sumerian editor;
- Sumerian hosts;
- Asset management;
- An ability to script the logic in the scenes you create.

3. Unreal Engine 4 (UE4)

It offers a powerful set of VR development tools. With UE4, you can build VR apps that will work on a variety of VR platforms, e.g., Oculus, Sony, Samsung Gear VR, Android, iOS, Google VR, etc.

- The UE4 platform has many features, e.g.:
- It offers access to its C++ source code and Python scripts, therefore, any VR developer in your team can study the engine in detail and learn how to use it.
- UE4 has a multiplayer framework, real-time rendering of visuals, and a flexible editor.
- With the Blueprint visual scripting tool offered by UE4, you can create prototypes quickly.
- It's easy to add animation, sequence, audio, simulation, effects, etc.

4. CRYENGINE

CRYENGINE is a robust choice for a VR software development tool. You can build virtual reality apps with it that will work with popular VR platforms like Oculus Rift, PlayStation 4, Xbox One, etc.

- CRYENGINE offers various features, e.g.:
- You can incorporate excellent visuals in your app.
- Creating a VR app or VR game is easy with CRYENGINE since it offers sandbox and other relevant tools.
- You can easily create characters.
- There are built-in audio solutions.
- You can build real-time visualization and interaction with CRYENGINE, which provides an immersive experience to your stakeholders.

5. Blender

- Blender is an open-source 3D creation suite, and it's free.
- Blender offers the following features and capabilities:
- You can create your 3D pipeline with modeling, rigging, animation, simulation, rendering, composing, and motion tracking.
- Blender supports video editing and the creation of VR video games.
- If you have an experienced VR developer in your team, then he/she can use its API for Python scripting to customize the application. This allows you to create specialized tools.

6. 3ds Max

It is a popular 3D modeling and rendering software from Autodesk, and you can use it for design visualization, creation of video games, etc. This powerful software offers a wide range of features, for example:

- You can create professional-quality 3D animations with it.
- 3ds Max offers an efficient and flexible toolset to produce high-quality 3D models.
- There are various options to create textures and effectsYou get an impressive array of 3D rendering, UI, workflow, pipeline, 3D animation, and other capabilities with 3ds Max.

7. Maya

It is yet VR software development tool from Autodesk. With Maya, you can create 3D animations, motion graphics, and VFX software.

- Maya is a powerful software that offers tools for dynamics, effects, 3D animation, 3D rendering, 3D shading, 3D modeling, pipeline integration, motion graphics, etc.

8. Oculus Medium

- Oculus, the well-known provider of VR platforms like Oculus Rift S, Oculus Quest, and Oculus Go also offers powerful VR development software, named Medium. It’s a comprehensive tool, which allows you to create 3D assets.

9. Google VR for everyone

- Google, the technology giant offers a wide range of VR development tools, and you can use them to create immersive VR experience for your stakeholders. You can access these tools on the Google VR developer portal.
- You can use these tools to develop VR apps for multiple platforms, e.g., Unity, Unreal, Android, iOS, and web. To access the guides to develop VR apps for each of these platforms, first navigate to “Choose your development environment” on the Google VR developer portal.

- The Google VR developer platform has software development kits (SDKs) for all VR platforms it supports, e.g., Unity, Android, iOS, etc. You can navigate to the download page on the Google VR developer portal to access them. You can read “Google VR API reference” to understand the Google VR APIs and plugins that covers all SDKs that the Google VR development platform offers

Video

How to create architectural VR walkthroughs with online tools (Lumion)

https://www.youtube.com/watch?v=OkB-mtkVrHg

Unity basics

- https://www.youtube.com/watch?v=pwZpJzpE2lQ

- VR in unity
- https://www.youtube.com/watch?v=gGYtahQjmWQ

- C# Script
- https://docs.unity3d.com/ScriptReference/

References

- Burdea, G. C., P. Coffet., “Virtual Reality Technology”, Second Edition, Wiley-IEEE Press, 2003/2006.
- Images and videos are taken from internet sources.