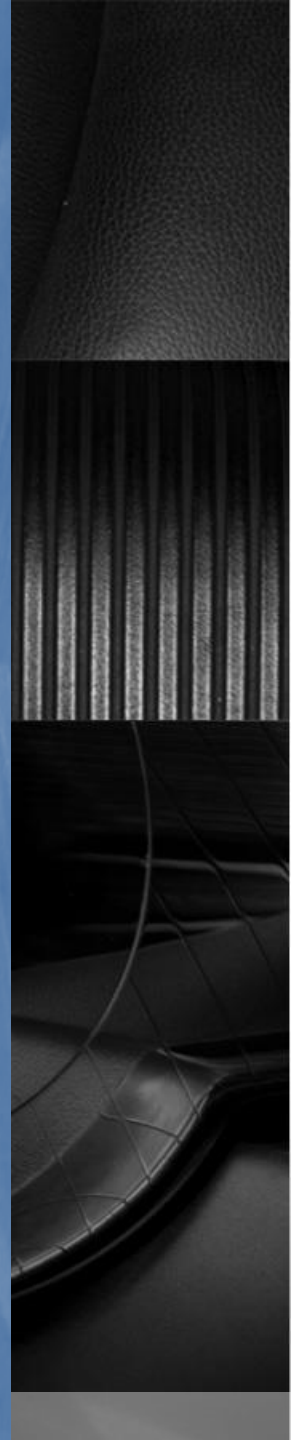
Web Based Graphics & Virtual Reality Systems

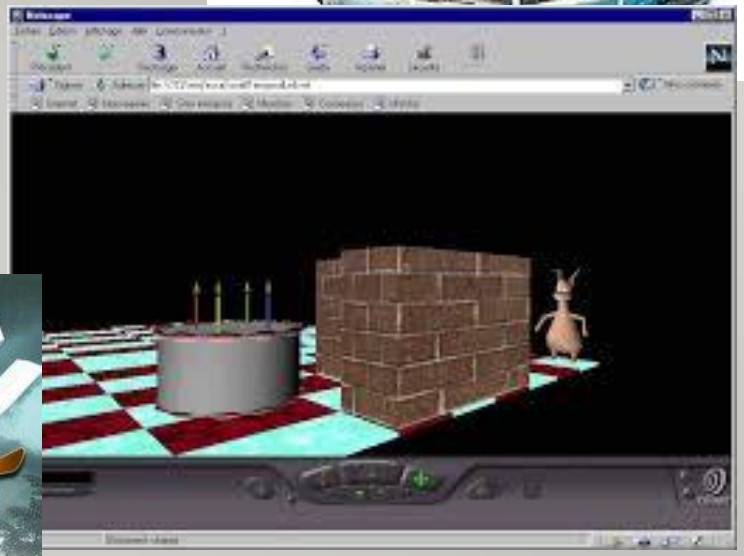
Virtual Reality

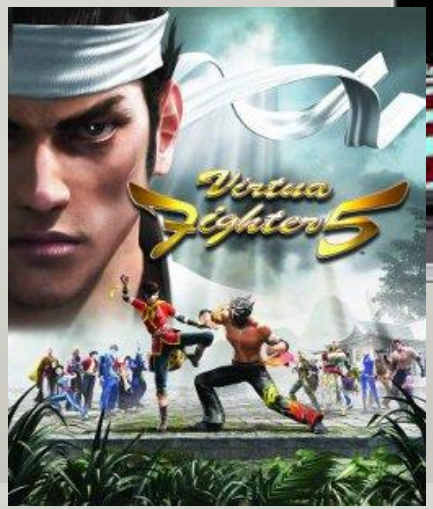


What Virtual Reality is NOT

VR is **NOT**

- QuickTime VR
- VRML
- VR Fighter





Virtual Reality

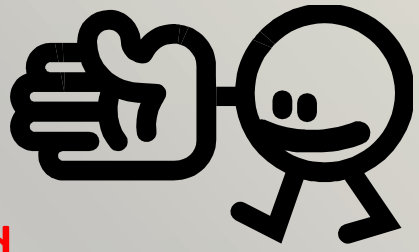
What is Virtual Reality?

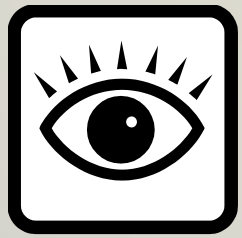
- "A high-end user-computer interface that involves real-time simulation and interaction through multiple sensorial channels." (vision, sound, touch, smell, taste)"

How we understand the reality?

- Through our five senses
  - vision,
  - sound,
  - touch,
  - smell,
  - Taste

Better supported

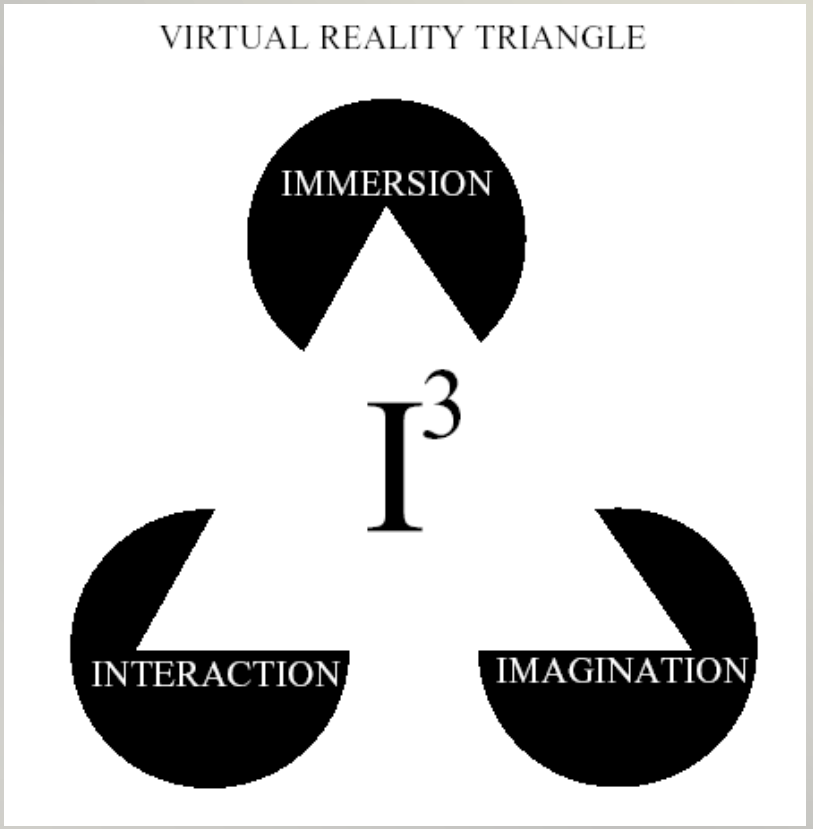




- Virtual Reality (VR) is to simulate these 5 senses with computing devices

Burdea's Three I's of VR

- Immersion
  - Feel the presence in the environment, being there
- Interactivity
  - Not merely observing
  - Environment response as in reality
- Imagination
  - Interesting idea and application

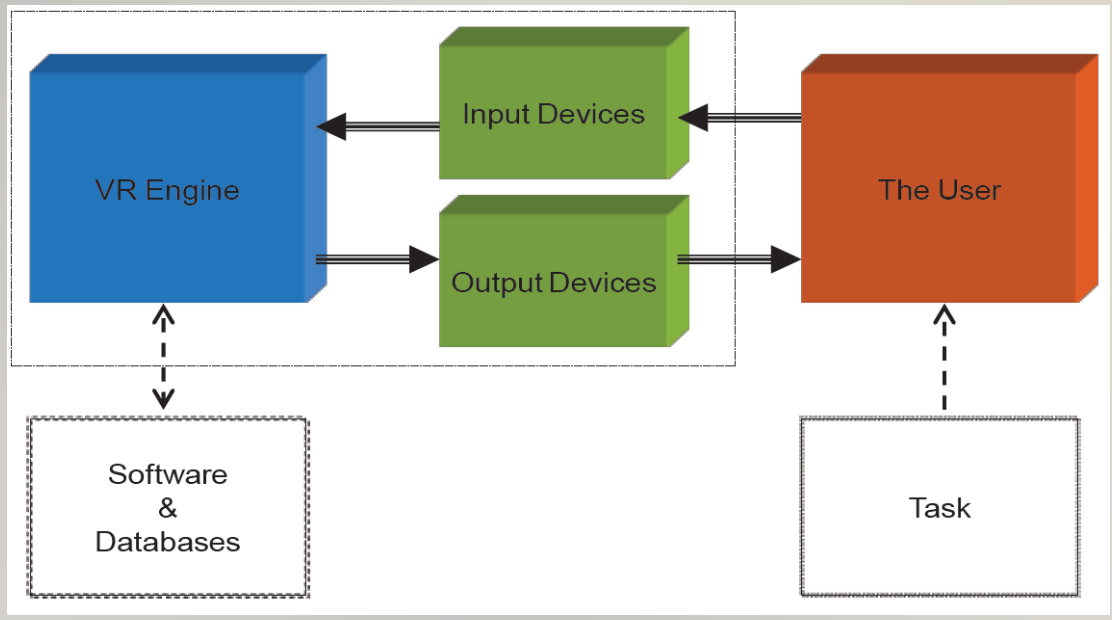


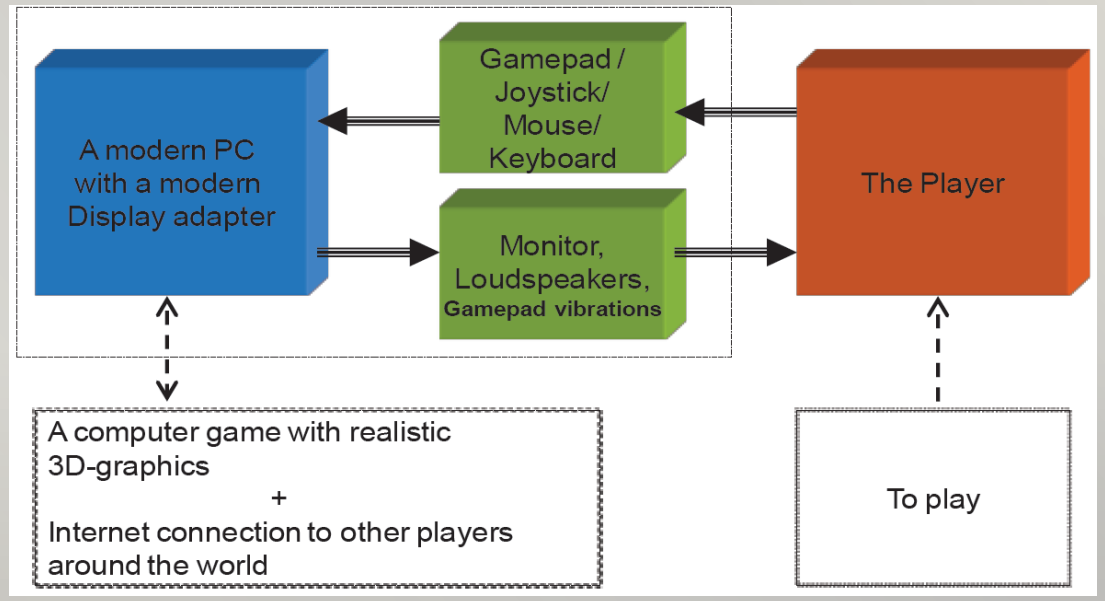
VR System

- VR System combines many advanced technologies related to HCI and CG
- HCI (Human Computer Interface)
  - Intuitive input and output devices
- CG (Computer Graphics)
  - Providing an immersive visual environment

VR System Architecture

- VR Engine
- Input and Output Device





Some History

- The first complete system was developed by NASA “Virtual Visual Environmental Display” in early 80s;
- Prototyped with the LCD HMD;

Virtual Environments

- Augmented Reality (Mixed Reality)
  - Closely related to VR
- Allow real object also exists
- Embed virtual object in a real environment

Augmented Reality

- Marker-based AR
  - Identify special markers from camera
    - b&w in old days, now can support arbitrary images
  - Estimate orientation and position
  - Place virtual object with same orientation and position

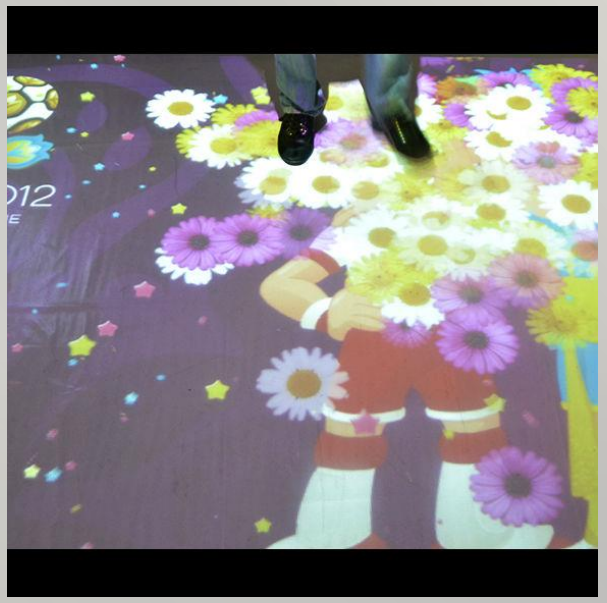
Augmented Reality

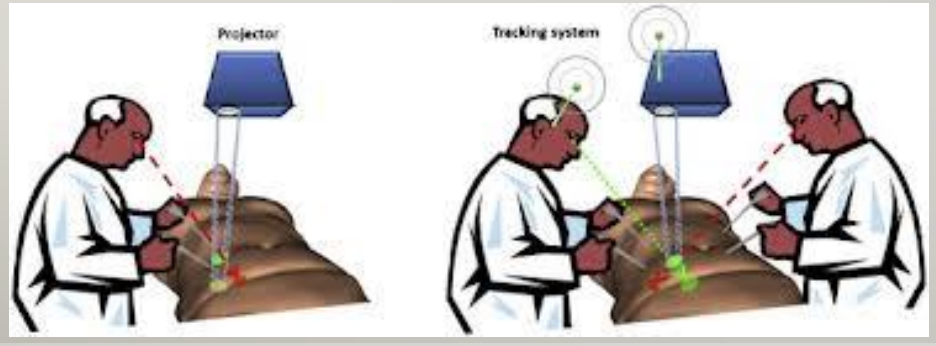
- Feature-based AR
  - An extension of marker-based AR
- Based on features in environment
  - Face detection
  - Buildings
  - Accelerometer and GPS

Augmented Reality

- Projector-based AR
  - Project image on real object
  - Track user action within the projected region

    e.g. hand motions
  - Update projected image according to actions





Vision

Visual Technology

- 70% of our sensory comes from vision
- Most commonly used display devices:
  - Monitor
  - Projector
- True Color (24 bit RGB)
- Refresh rate must > 30 fps
  - Avoid flicker

Stereo Vision

- Vision with two eyes
- Due to disparity of two eyes
- Depth cues

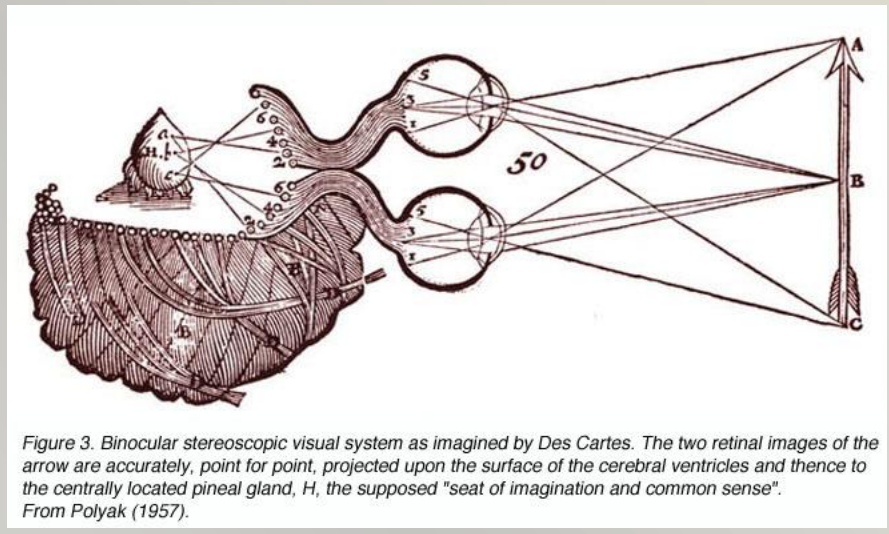
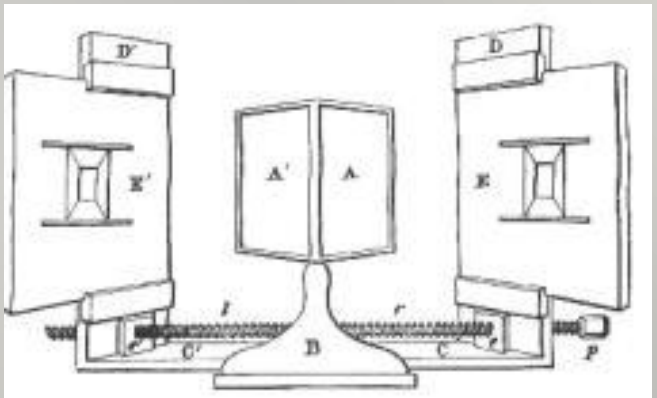


Figure 3. Binocular stereoscopic visual system as imagined by Des Cartes. The two retinal images of the arrow are accurately, point for point, projected upon the surface of the cerebral ventricles and thence to the centrally located pineal gland, H, the supposed "seat of imagination and common sense". From Polyak (1957).

- First stereo system
  - Stereo viewer by Sir Charles Wheatstone's reflecting stereoscope in 1838



The Wheatstone stereoscope used angled mirrors (A) to reflect the stereoscopic drawings (E) toward the viewer's eyes.

Stereo Vision (cont'd)

- Things seen from left and right eyes have a little difference
- Render twice in virtual environment

Stereo Vision Equipment

- Stereo/3D Monitors
- Stereo/3D Projectors
- Graphics Card special for stereo vision
  - Quadro series

    4 frame buffers : double buffer for left & right

Stereo Systems

Critical issue:

How to present two different images to two eye separately at the same time?

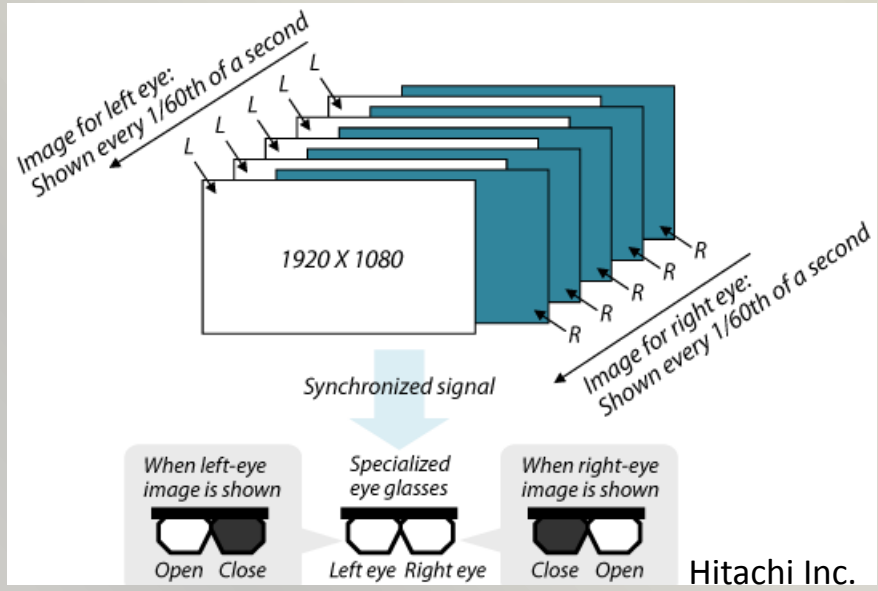
- Five major kinds of stereo systems
  - Anaglyph
  - Active
  - Passive
  - HMD
  - Naked-Eye

Anaglyph

- Color Multiplex
  - Use colored lens to separate images get into different eyes
- Early stereo system
- Can use normal monitors and projectors
- Use of special glasses with red and blue lens
- Images seen lost its original color

Active Stereo System

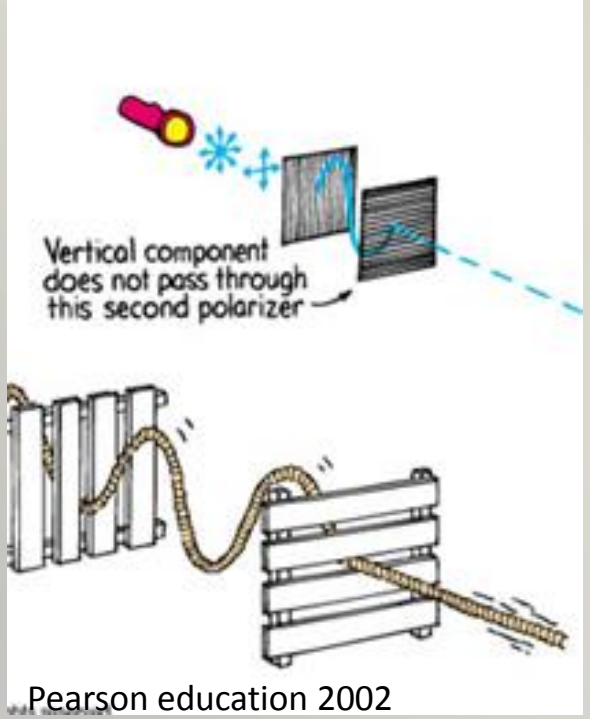
- Temporal multiplex
- Shutter glasses is used
  - Occlude one eye at a time
  - Synchronized with the frame displayed (via IR or etc)
- Advantages
  - Lower crosstalk
  - Normal but hi speed display
  - Expensive glasses



Hitachi Inc.

Passive Stereo System

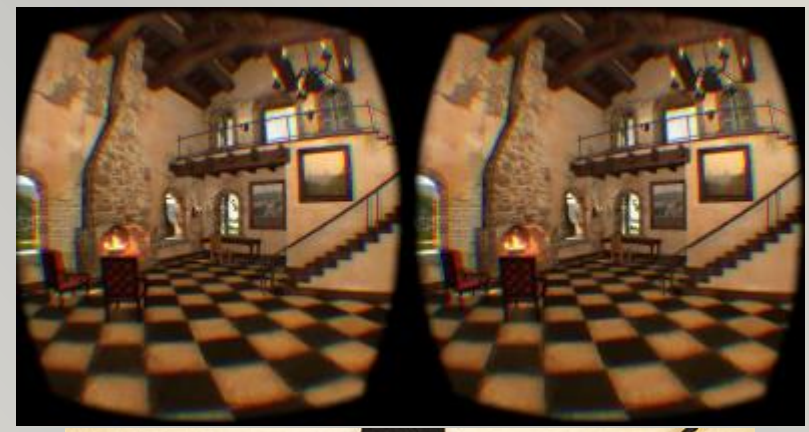
- Polarization Multiplex
- Left frame and right frame are polarized differently
  - Linear : horizontal & vertical
  - Circular : clockwise and anticlockwise
- May have crosstalk, about 20~30%
- Tailored screen may be needed
- Glasses is less expensive
- Images seen will be dimmer



Pearson education 2002

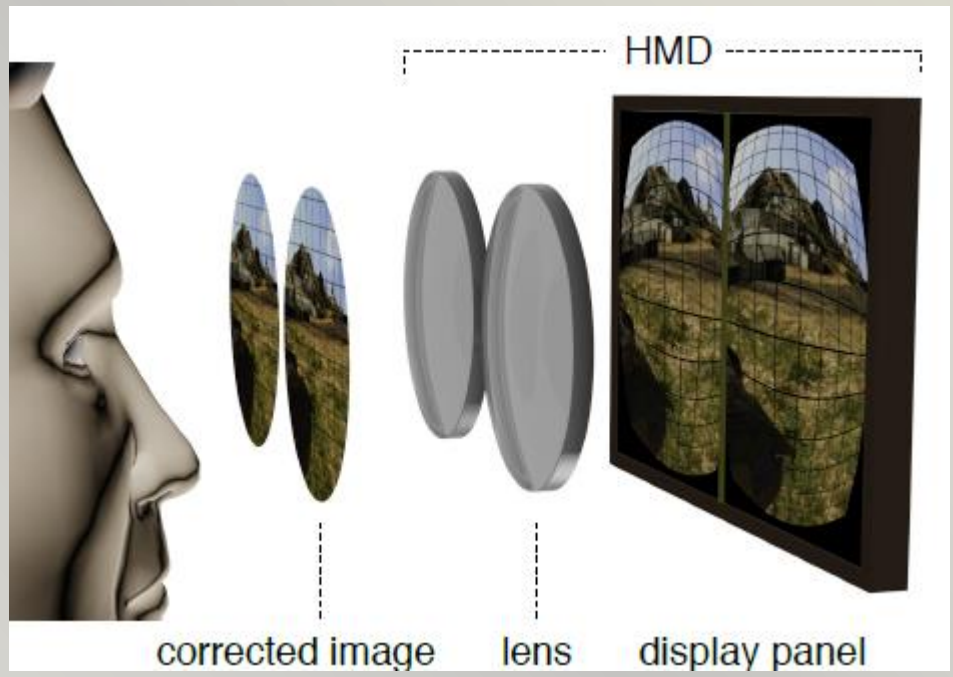
Head Mount Display (HMD)

- VR eyewear/ headset
- Affordable solution
  - Just separate chambers of display
- More bulky than a normal eye glass
- Convex Lens Distortion



Head Mount Display (HMD)

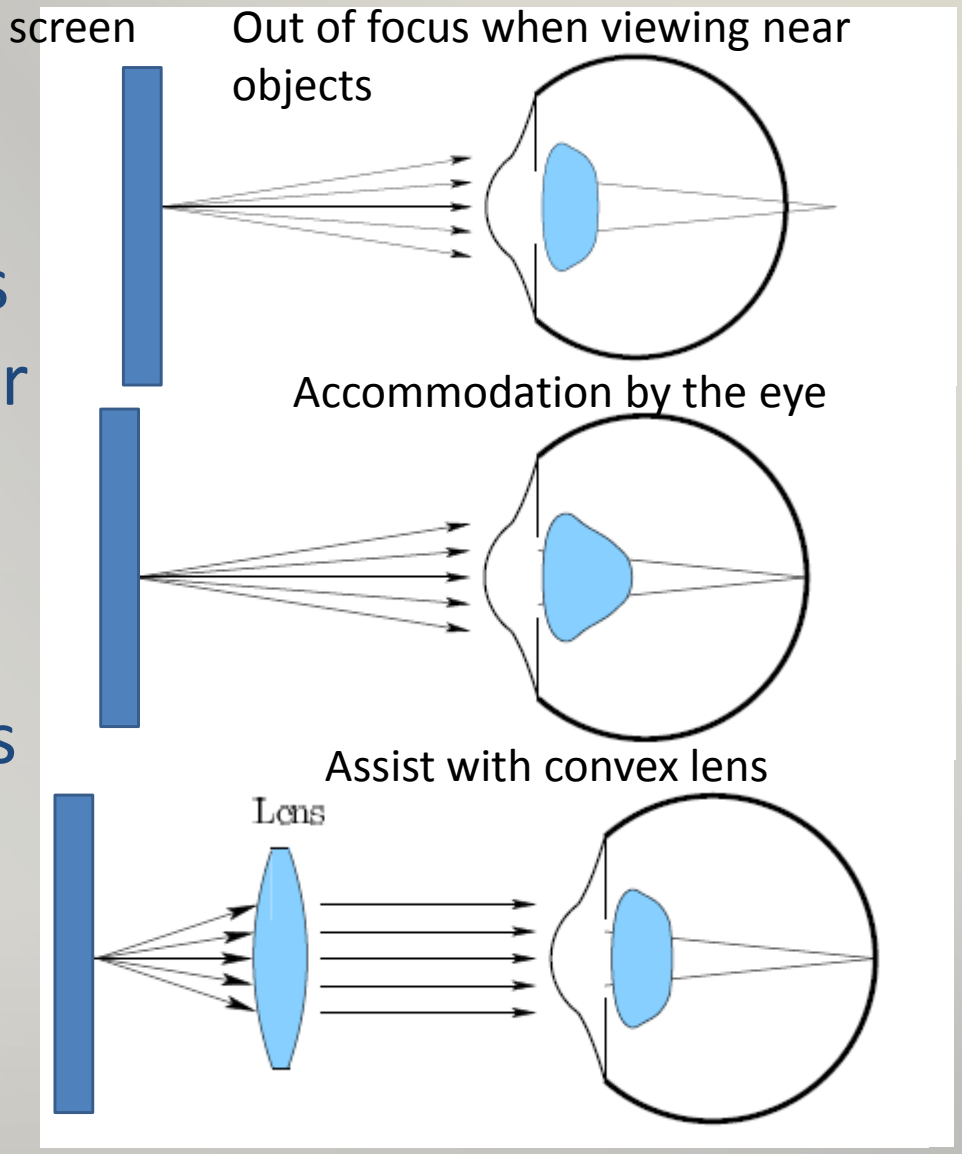
- Commodity display panel is placed close to user
- Convex lens
- Display a barrel distorted image pair
- But user can see a corrected one



Pohl et. al.

Why Convex Lens ?

- Commodity display (screen) in VR headset is placed closed to the user
- Out of focus /
- Lens adopt to focus causes eye muscle stress
- Convex lens helps to bring near object into focus



Post-render Warping

- Pincushion distortion is introduced
- Compensate by barrel distortion warping
- Post-render screen warping (in rasterized viewport)

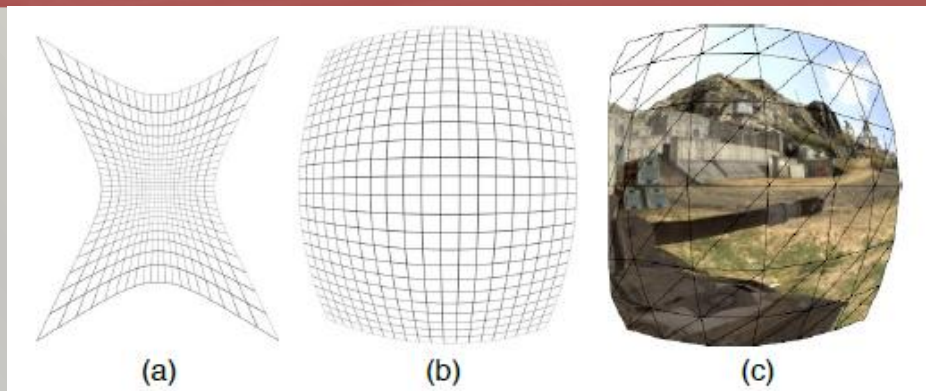
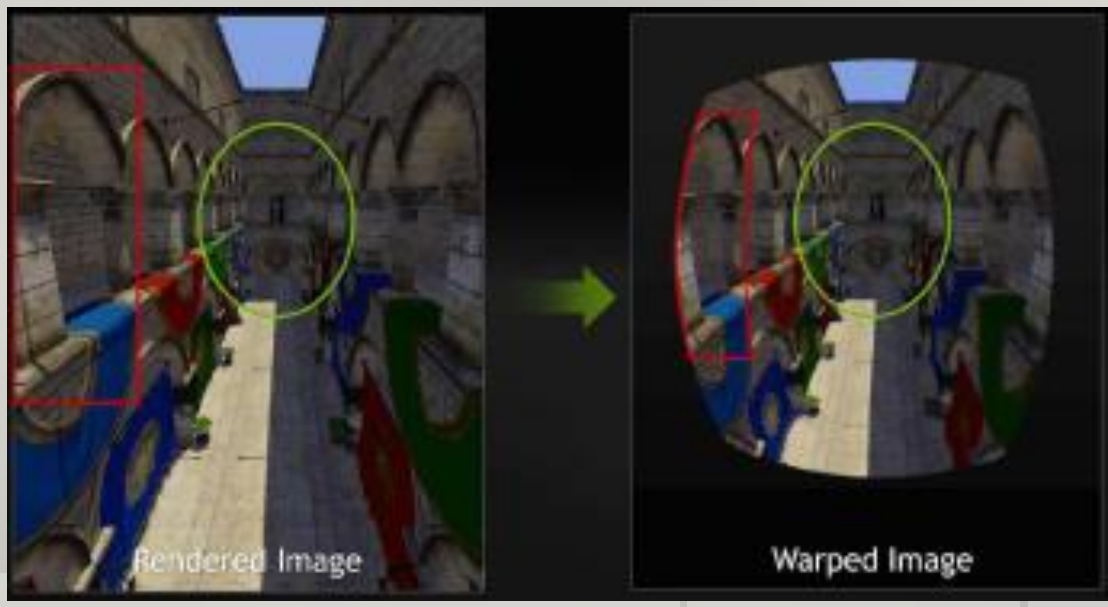


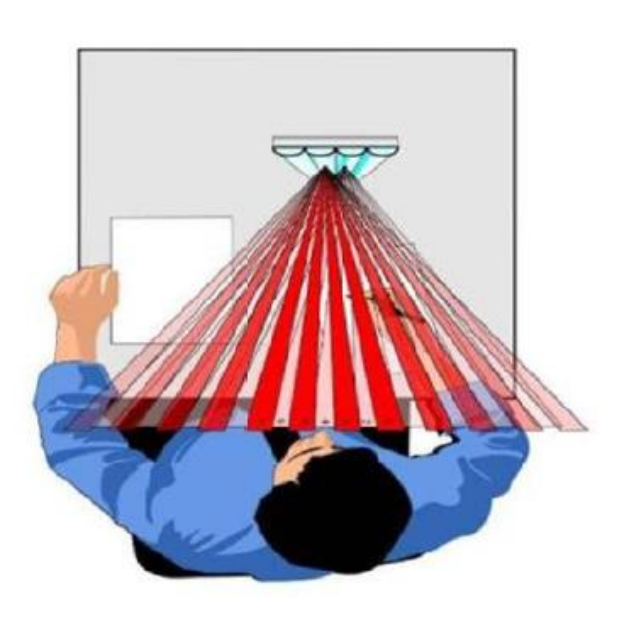
Figure 2: *Wide angle lenses used in modern HMDs produce a pincushion effect (a) which can be canceled by applying the corresponding barrel distortion (b) to images presented on the display panel. This correction can be applied in image space by resampling the image according to Equation 1 or by texture mapping the image onto a mesh in which the vertices have been displaced according to the same equation.*

Pohl et. al.



Autostereoscopic Display

- Also called Naked-eye display
- View angle multiplex
- Cast several images simultaneously but at different angles

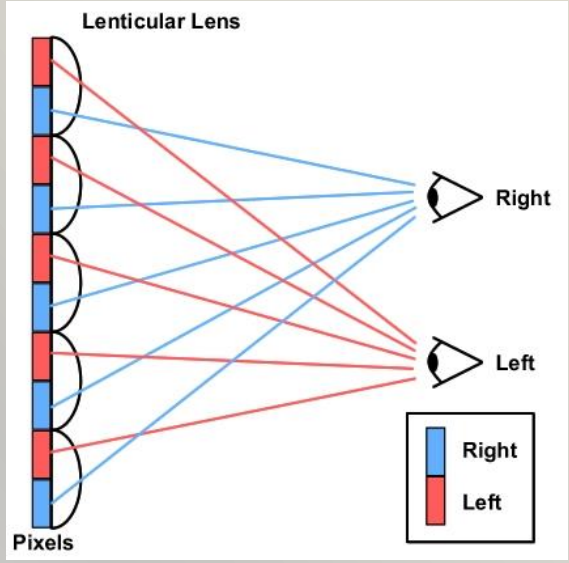


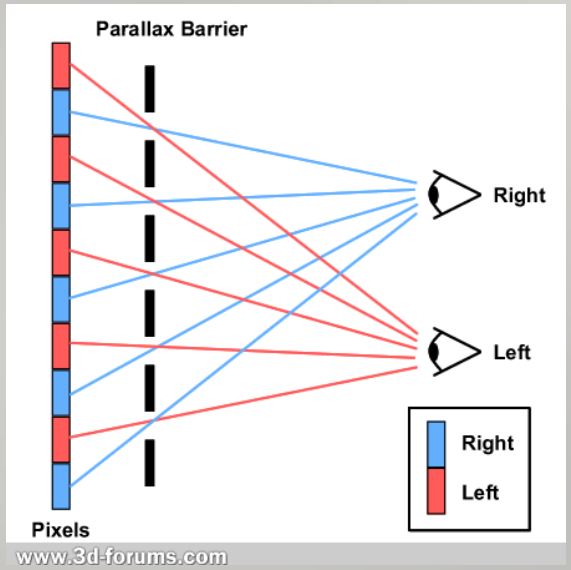
Nintendo 3DS

Toshiba Naked-eye TV

Autostereoscopic Display

- Technologies
  - Leticular sheet
    - Refract light to different directions
    - Like 3D postcard
  - Parallax barrier
    - Block to allow certain light transmit
    - Most common
    - Low cost
    - Diminished brightness
- Always have an effective/ optimal viewing distance





Comparison of Stereo Systems

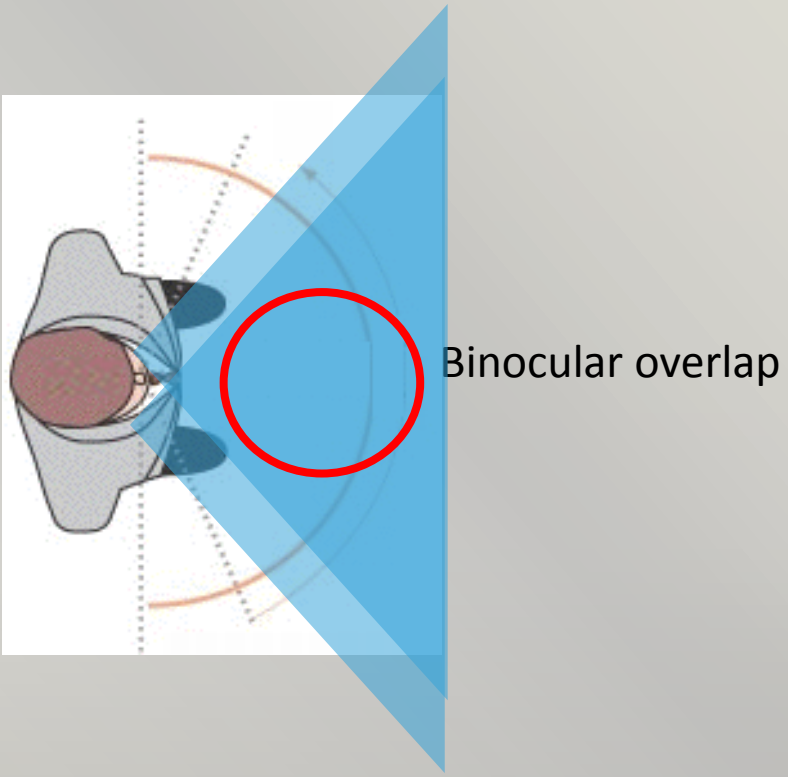
	Anaglyph	Active Stereo	Passive Stereo	HMD	Naked Eye
Cost	Low	High	Medium	Low-Medium	High
Projector / Display	Normal	Normal with synchronizer	Polarize preserving	Normal	Specially designed
Glasses	Yes	Yes	Yes	Yes	No
Multiplex	Color	Temporal	Polarization	Spatial	View angle
Crosstalk	Medium	Low	Medium	Low	High

Application of Stereo Vision

- Improve sense of depth
- Improve reality
- Applications include entertainment, medical visualization, education and training

Immersion and FoV (Field of View)

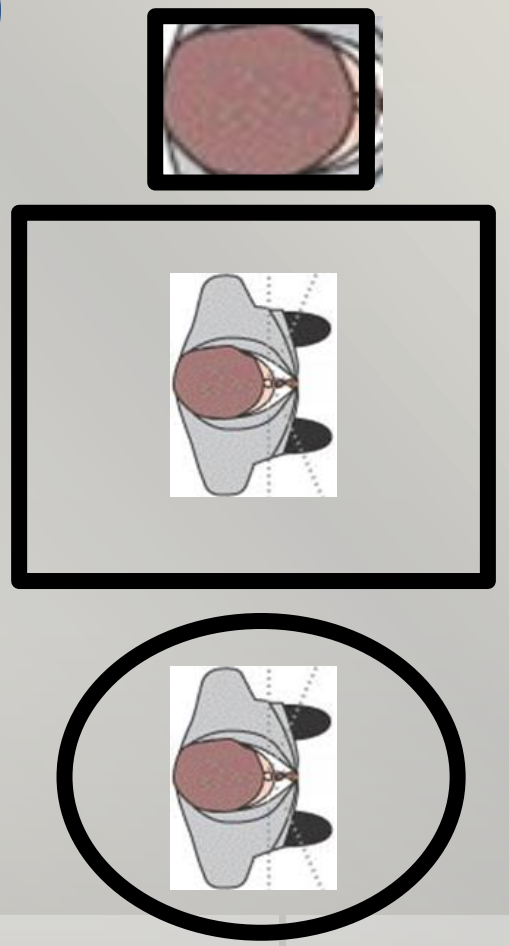
- One will feel immersed in another environment when his FoV is full covered
- FoV in Human
  - 200 degrees in horizontal
  - 130 degrees in vertical
  - 120 degrees binocular overlap



Immersion in VR

Devices to cover the user's field of view

- Head Mount Device (HMD)
  - Covered by wearable glasses
- CAVE
  - Covered by 6 walls
- Spherical Display
  - Covered in a spherical wall



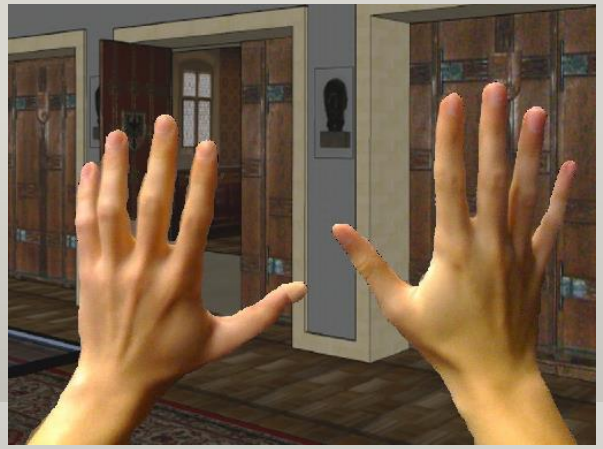
Head Mount Display (HMD)

- Integration of
  - Dual eye display (optical or videomix)

    Fully cover user's view
  - Head tracker

    Track head orientation so as to update view in virtual environment
  - Audio display

    3D sound

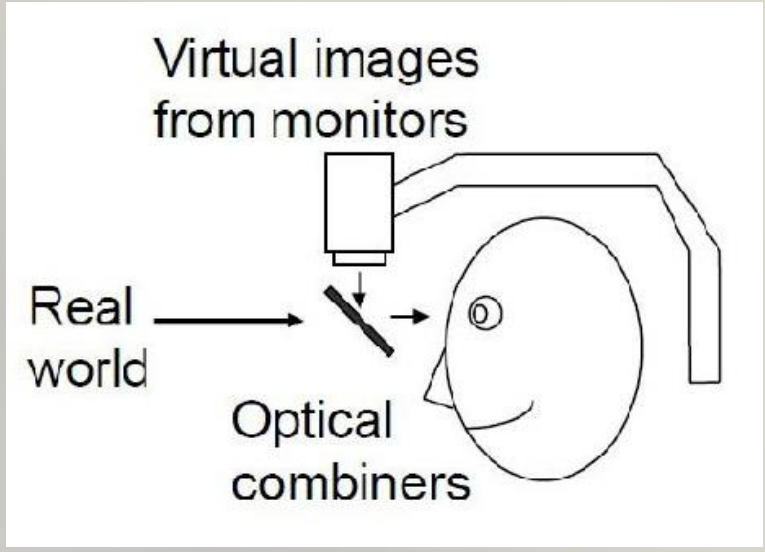


Head Mount Display (HMD)

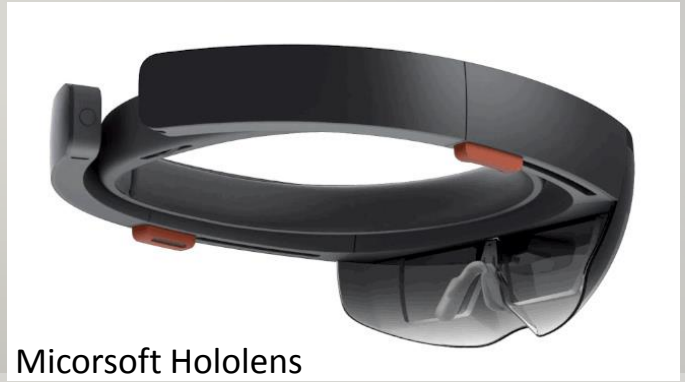
- See-through and nonsee-through
  - Whether mix with the real world scene is needed
- Optical see-through
  - Project virtual scene on lens to mix
- VideoMix see-through
  - Capture real world scene with camera
  - Mix digitally with virtual objects

See-through HMD

- Optical see-through
  - Direct view of real world
  - Virtual image is combined optically
  - Less clear of virtual scene
  - Safe when moving in environment

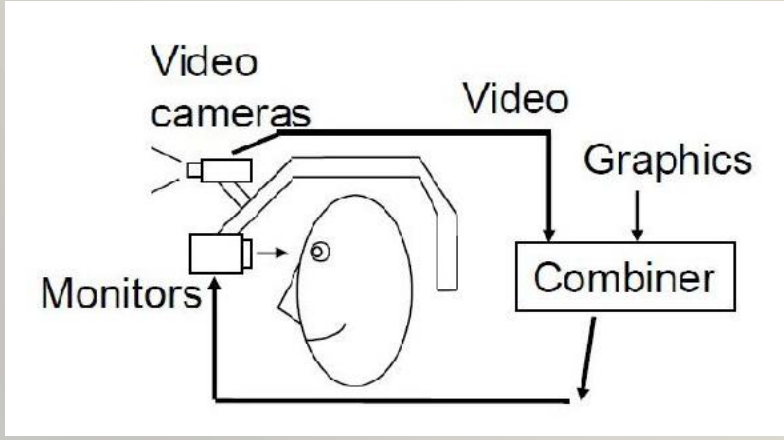



Epson's Moverio glasses


Micorsoft Hololens

See-through HMD

- Videomix see-through
  - Digitized real world image
  - Clear virtual and real scene
  - Small time delay
  - Full occlusion may cause danger when moving in environment



Components and Capability of HMD

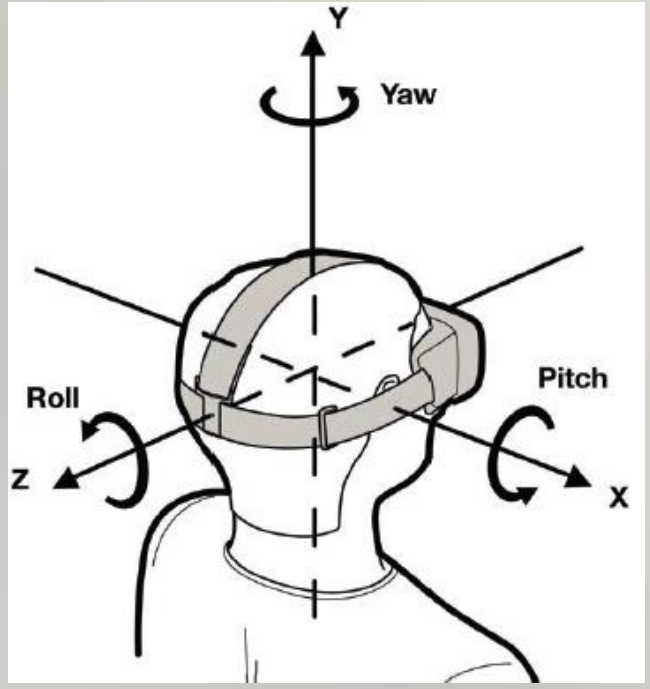
- Stereo display
- Orientation tracking
  - IMU sensors
- Positional tracking (optional)

IMU Sensor

- Inertial Measurement Unit (IMU)
- Appear in most mobile devices nowadays
- Mainly track orientation of head
  - Accelerometer

    Measure linear acceleration
  - Gyroscope

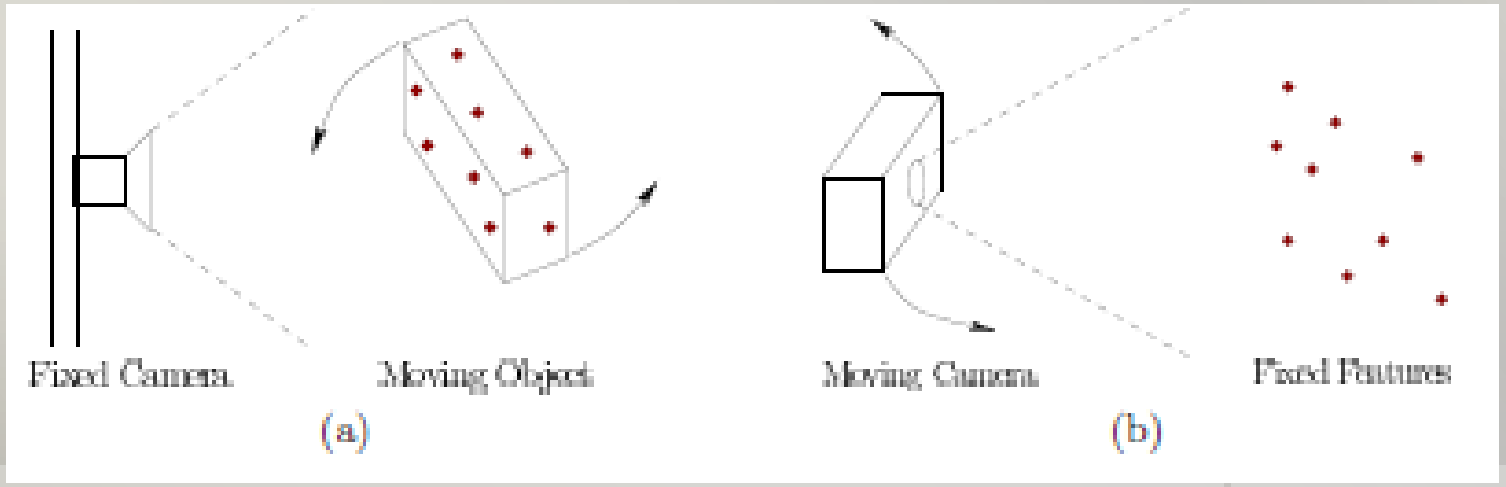
    Measure angular velocity



- Contain error/noise when integrating head orientation

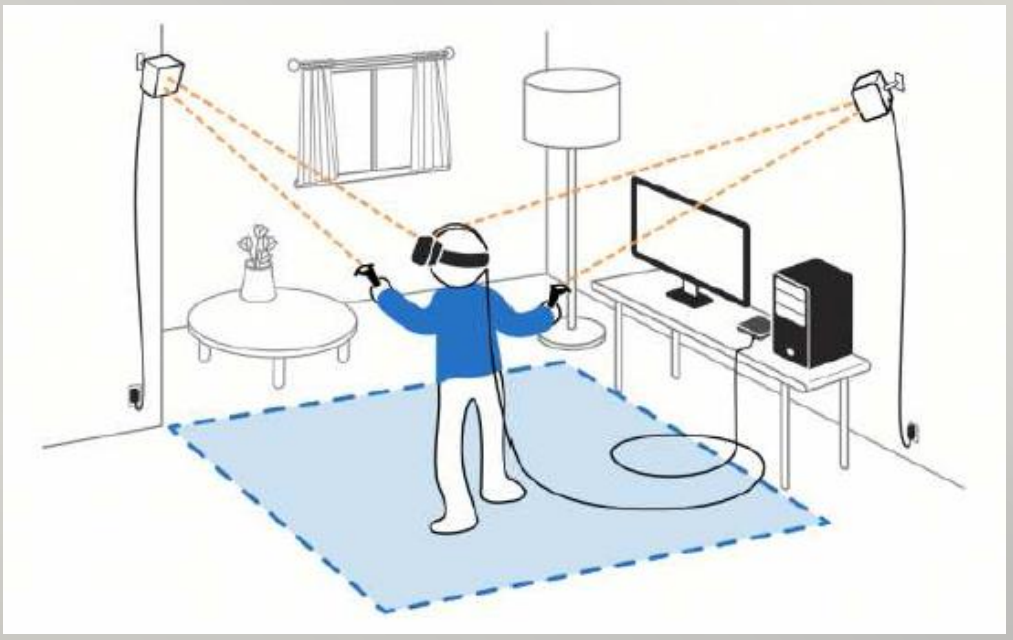
Orientation & Positional Tracking

- Apart from IMU, vision-based tracking is also a common solution
- Fixed camera
  - Require base stations and features on headset
- Moving camera
  - Need to mount camera on headset
  - Fixed features in environment(e.g. wall)



Positional Tracking

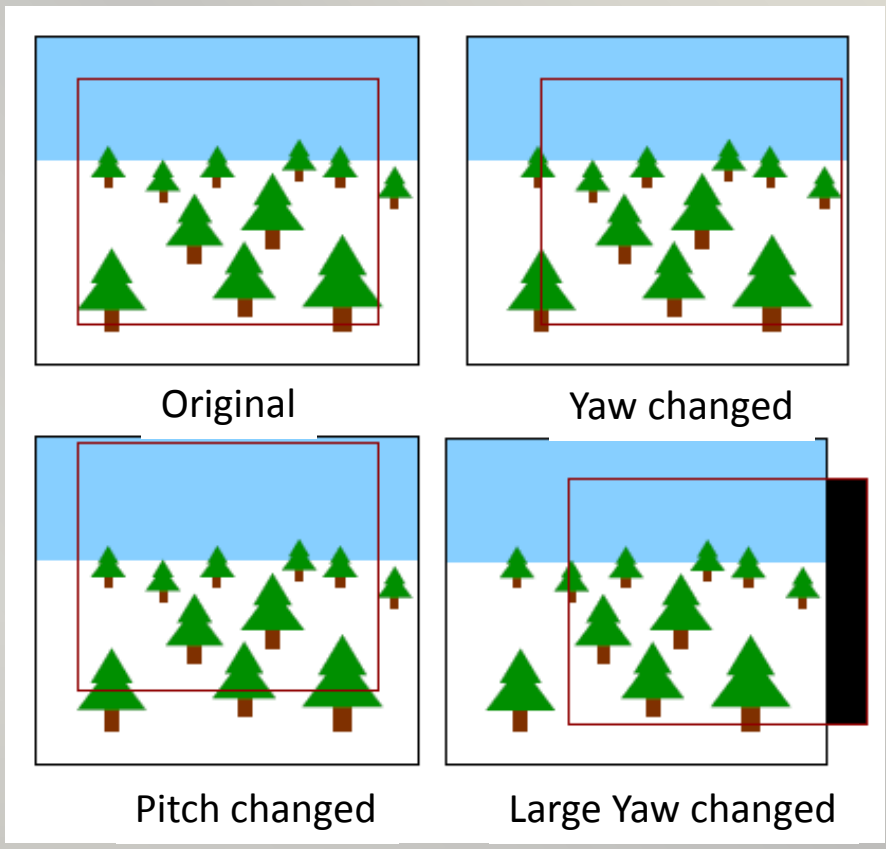
- Vision-based tracking
  - A number of base station setup in the environment
  - Usually use invisible light / Laser
- Multiple camera setup to avoid occlusion and achieve multi-view vision



Time Warping

- Also called “Reprojection”
- To avoid time delay in rendering to head motions
- Before send image to HMD, change image according to perturbation

Perturbation	Image effect
$\Delta\alpha$ (yaw)	Horizontal shift
$\Delta\beta$ (pitch)	Vertical shift
$\Delta\gamma$ (roll)	Rotation about image center
Δx	Horizontal shift
Δy	Vertical shift
Δz	Contraction or expansion

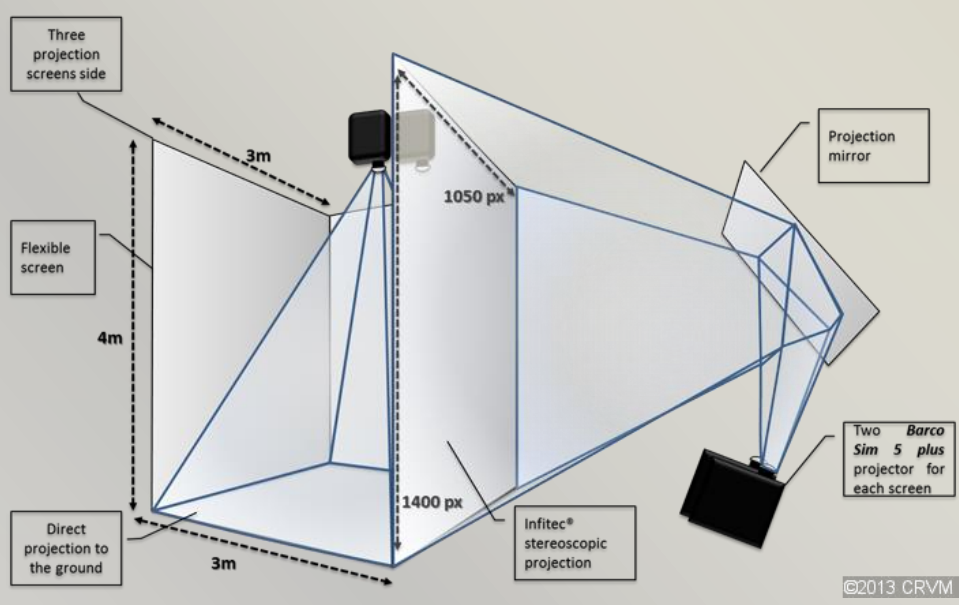


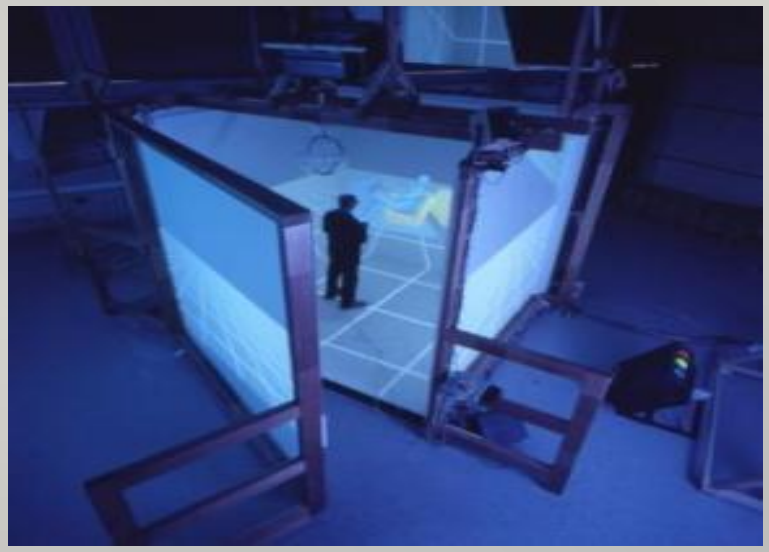
CAVE

- Cave Automatic Virtual Environment (C.A.V.E.)
  - 4-6 walls surrounding the user
  - Scene is seamlessly projected onto the wall
- No wearing required
- Require large space to setup

CAVE

- Projector images are reflected onto wall of cave
  - More easy to adjust size of the projection
- Except the bottom one is from top projector directly
- Usually top wall is missed out





Spherical Display

- Cover with spherical wall and projected scene
  - E.g. VisionStation
- Project from inner of a spherical screen

VisionStation

Spherical Display

- Special designed lens in projector
  - To project in 180 degrees
  - To minimize distortion
- Like fisheye lens having a wide projection angle
  - But require small distortion

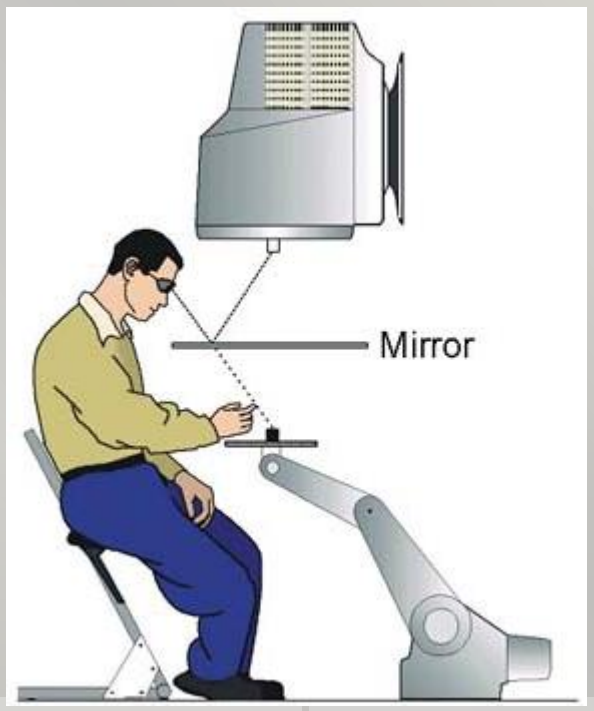
Imaging devices to capture wider viewing angles

- Wide angle or Panoramic imaging devices
- Composes of multiple cameras
  - Multiple
  - 2 cameras + fish eye lens

    E.g. Ricoh theta

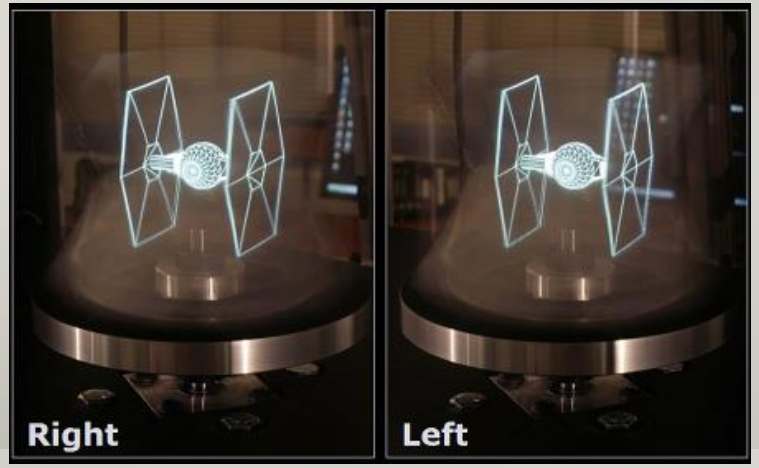
Virtual Workbench

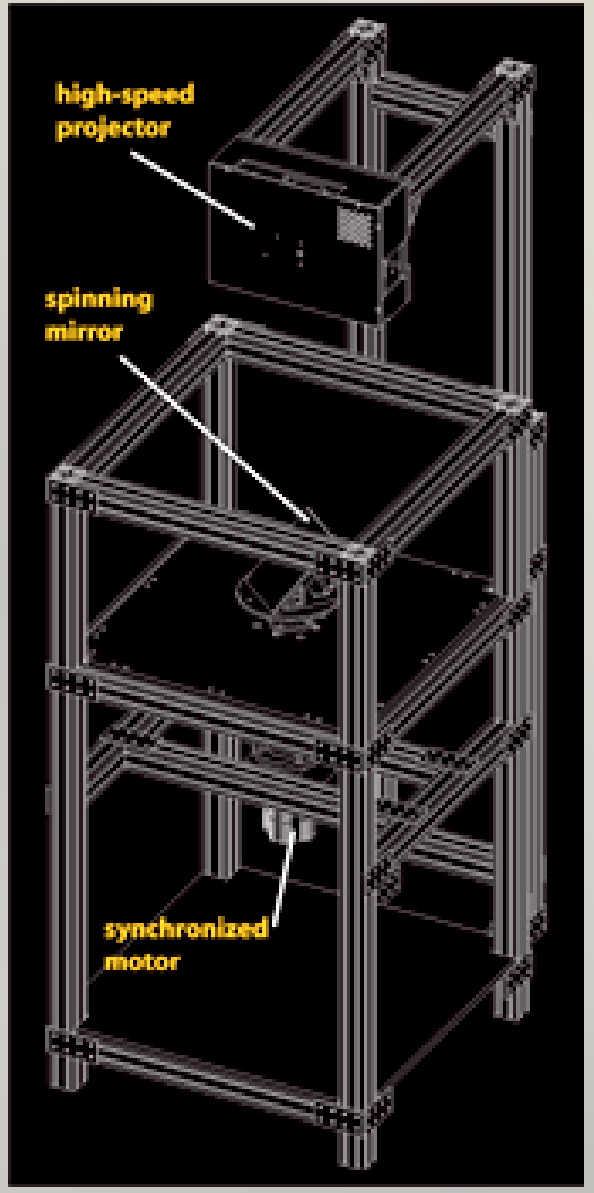
- A specially designed workbench
- Mirror reflection of inverted scene image
- Hand operations under the mirror
- The virtual and real space can be nicely aligned



Volumetric Display

- A 360 degrees display
- Still an emerging technology
- Can present different views from different angles
- High speed spinning mirror to reflect synchronized views

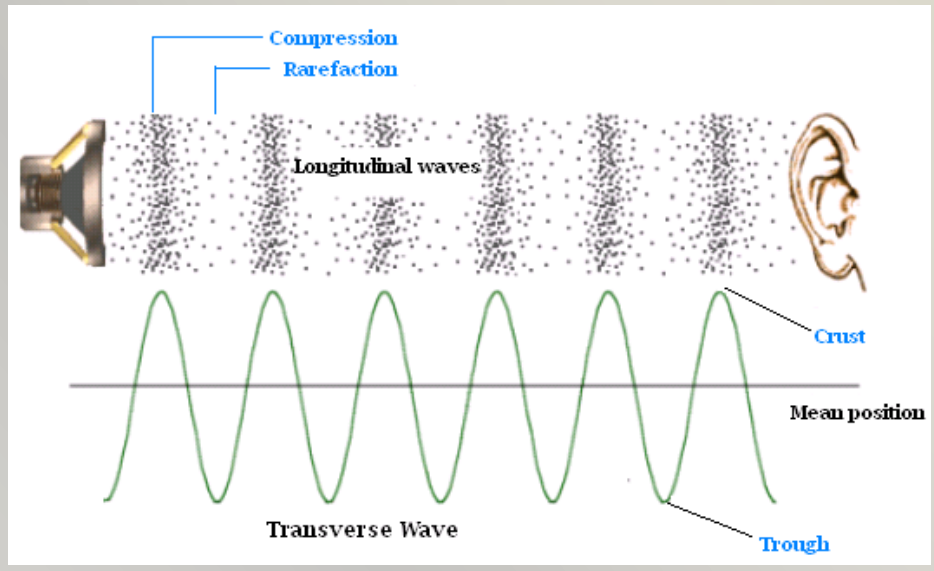




USC Institute for Creative Technologies

Sound

Audio Technology



- audible frequency
  - 20-20,000 Hz
  - Speech: 50-10,000Hz
- Sampling rate
  - CD-DA, the standard audio CD: 44.1 kHz
  - MP3

    96 kbit/s - for speech or low-quality streaming

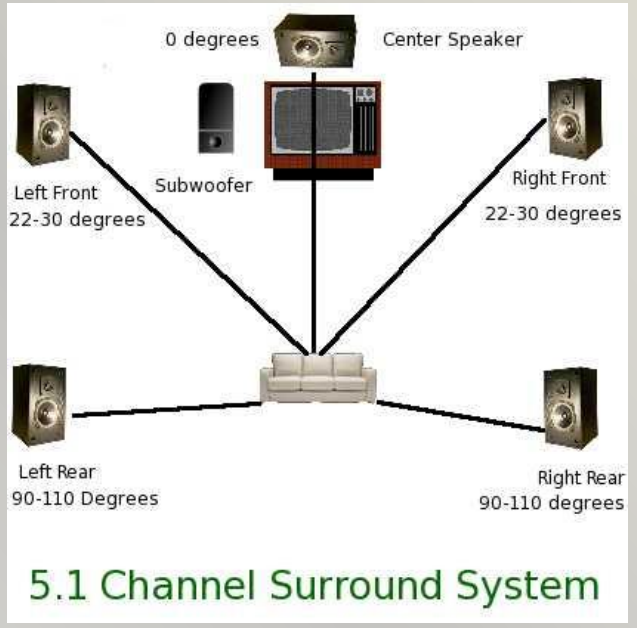
    128 or 160 kbit/s – mid-range bitrate quality

    192 kbit/s - a commonly used high-quality bitrate

    320 kbit/s - highest level supported by the standard

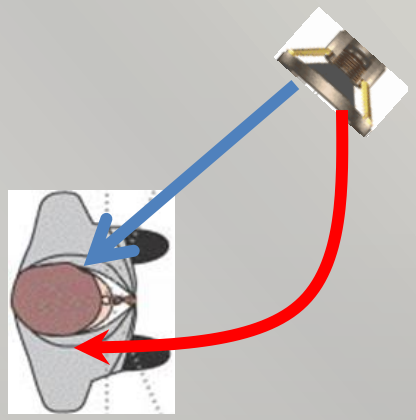
Multichannels speaker

- At least 2-channel (stereo) in most systems
- 2.1 system
  - stereo pair + subwoofer
- 5.1 system
  - front: L+C+R, back: L+R, subwoofer
- 7.1 system
  - 5.1 plus center L+R
- Surround sound is not interactive 3D audio



Locating Sound

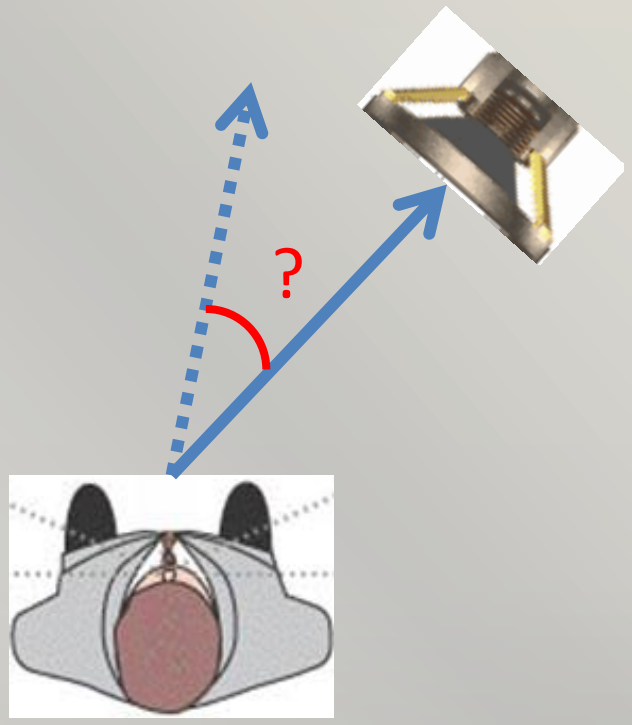
- Similar to two eyes, two ears can help locating sound source
  - binaural cue
- Amplitude difference between ears
  - Stronger sound with ear nearer
- Time difference between ears
  - Minor difference in milliseconds can also benoticed



Locating Sound

Precision of locating sound by human ears

- Front : 3.5°
- back : 5.5°
- On the sides : 10°
- Elevation : 10-25°



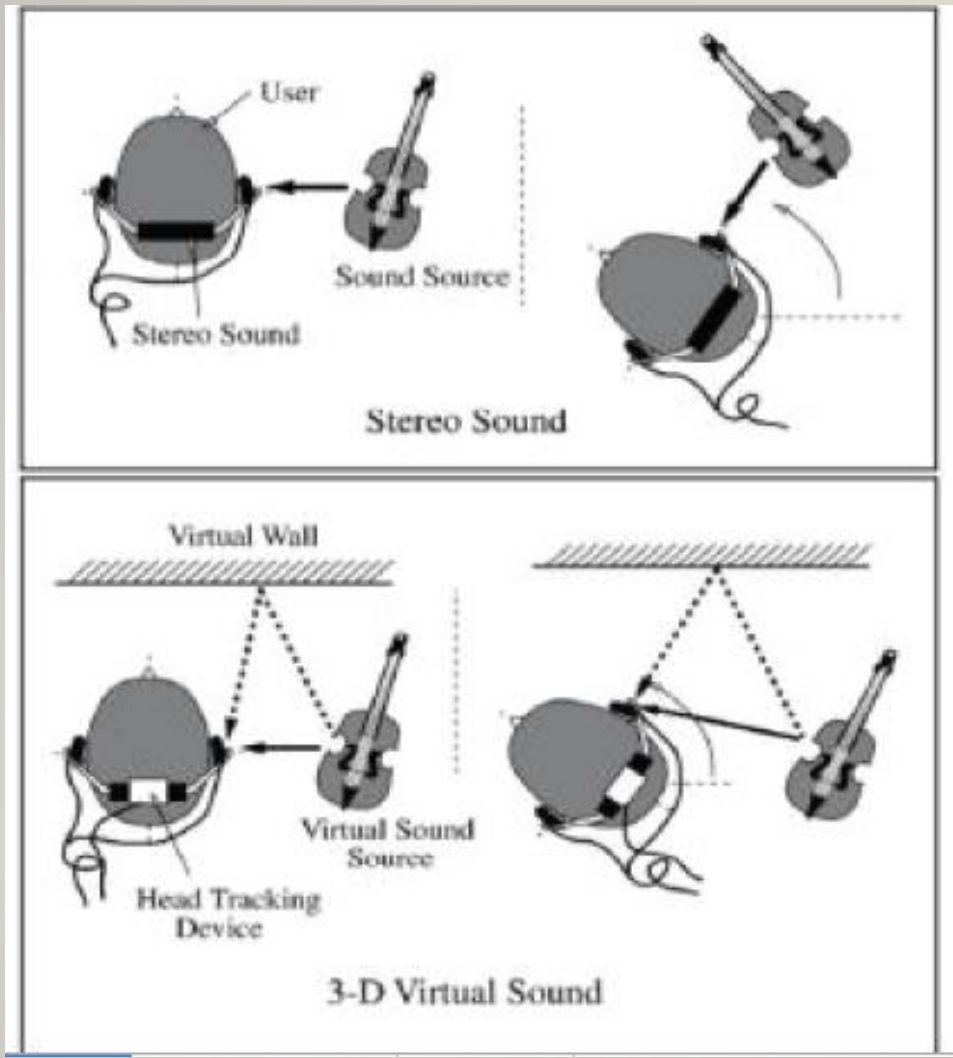
3D Sound

- Spatialized binaural audio
- Emulate sound effects in virtual environment
- Artificial sound composition
  - Direction
  - Volume
  - Reflections and etc. of sounds

3D Sound

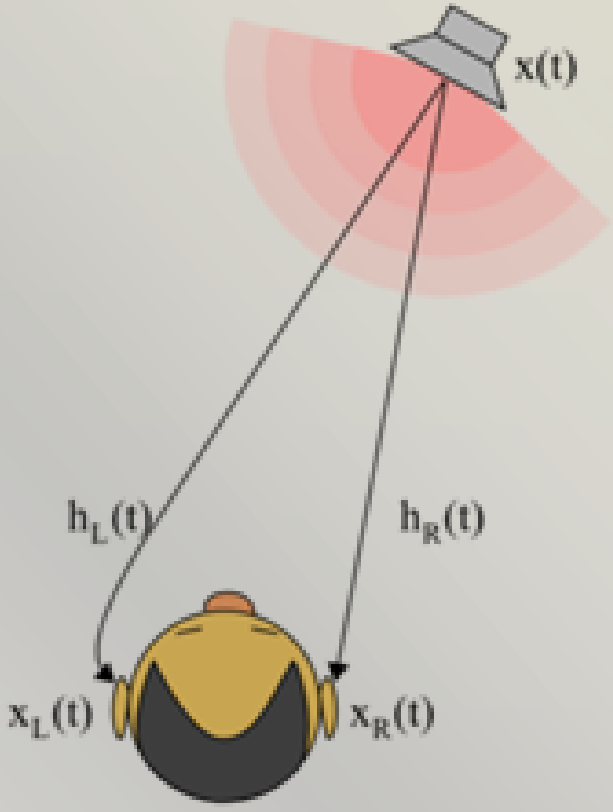
- Not the same as Stereo or surround sound
  - Source do not move with head in 3D sound
  - Virtual acoustics in 3D sound

    e.g. reflection or echo



3D Sound

- HRTF (Head-related transfer function)
  - a personal transform function of a sound based on the forms of ears, shoulders, etc.
  - Filtering of a sound source (x(t)) before it is perceived at the left and right ears as $x_L(t)$ and $x_R(t)$, respectively.
  - Tracking of head orientation and position is needed
- Fairly low-cost to implement



Touch (Haptics)

Haptics Technology

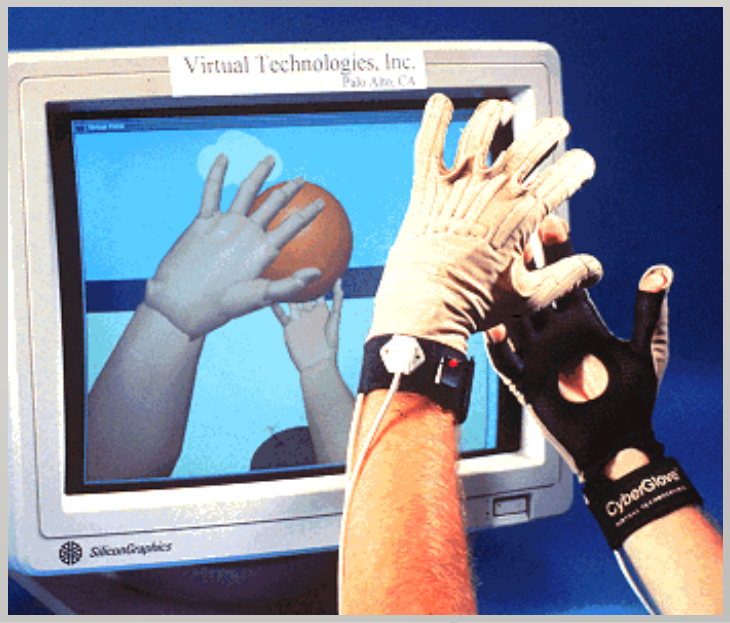
- Force Feedback
  - Give the feeling of touch
- 1000 Hz refresh rate is required
  - Oppose to 30Hz for vision
- Current technology focuses on sense of touch with the hands
  - Cyber glove
  - Phantom haptic device (force feedback stylus)

Cyber/ Virtual Glove

- Tracking gesture of hand
- Feedback with vibration
  - Vibrator on each finger
- Feedback with electromechanical parts

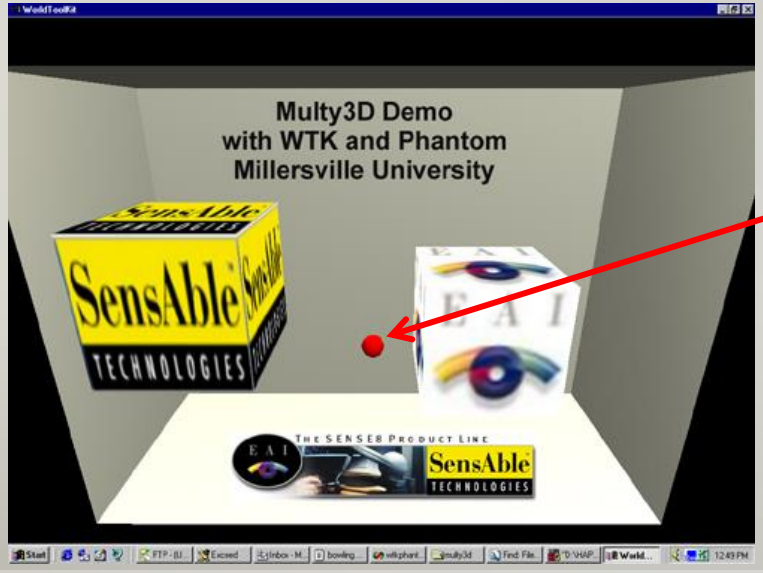
Cyber / Virtual Glove

- Work as both input and output
- Interact and touch virtual objects
- Control of robot

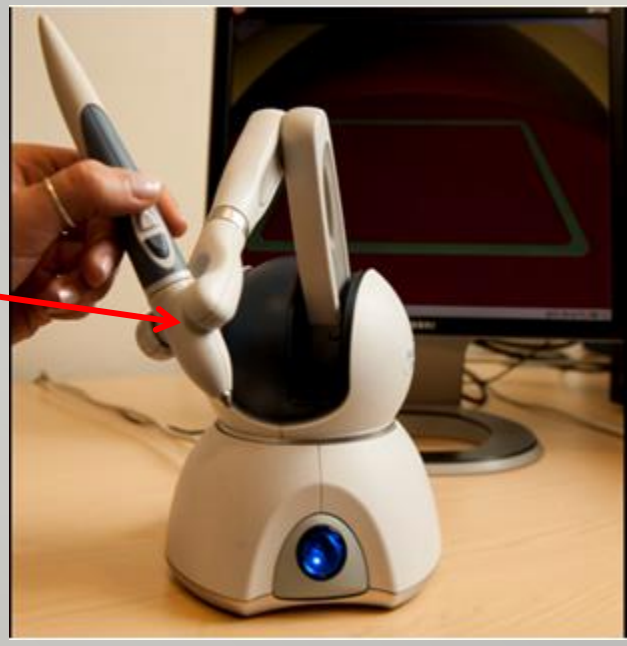


Phantom

- A commercialized and standard device for haptic user interface
  - Development with OpenHaptics SDK
- Single point of touch



point of touch



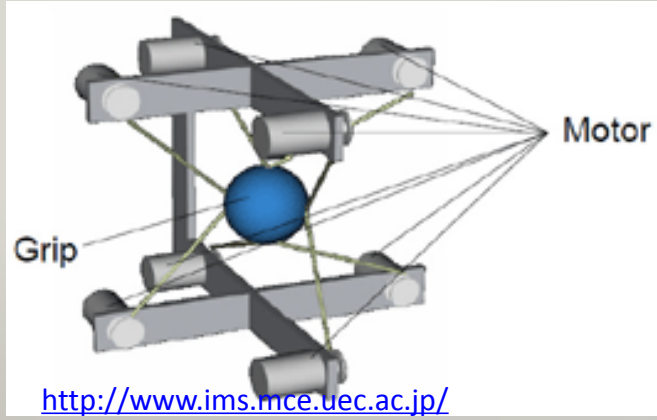
Phantom

- Versions with difference in DoF (Degrees of Freedom) that provide force feedback
- 3DoF
  - X,Y,Z Positions
- 6DoF
  - 3 for Position + 3 for rotation

Some Other Haptics Devices

- Gamepads with Vibration
- Tailored devices
  - Laparoscopy (FLS) box trainer
  - Multiaxis control machining

FLS Box Trainer



http://www.ims.mce.uec.ac.jp/

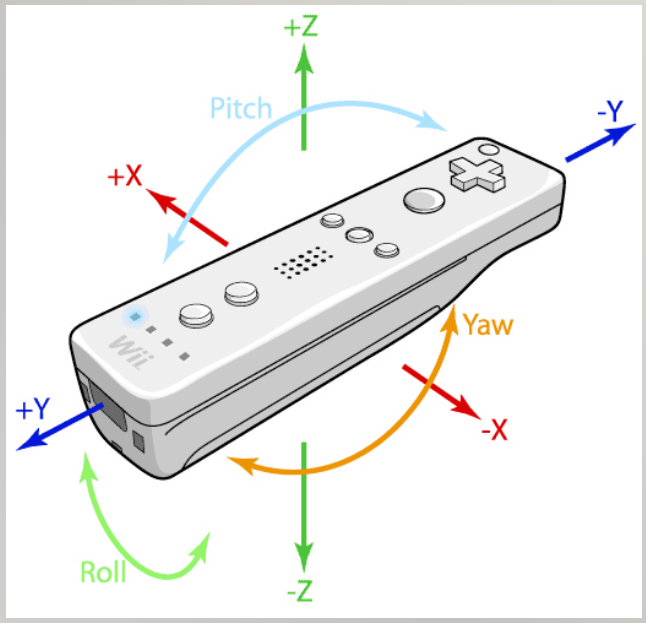
Motion Tracking for Interactivity

Motion Tracking User Interface

- A recent trend in HCI
- Use motion sensing technologies to obtain chains of movements
- Examples in game industry
  - Wiimote
  - PlayStation Move
  - Kinect

Wiimote and PlayStation Move

- Accelerometer and optical sensor to track motion
  - X,Y,Z position data
  - Yaw, Pitch, Roll Orientation data
- Bluetooth to send back to base machine
- Combine gesture recognition and use in games



Oculus Touch and HTC Vive Controller

- Wireless hand controllers tailored for VR applications
  - Track 3d positions and orientation

Kinect

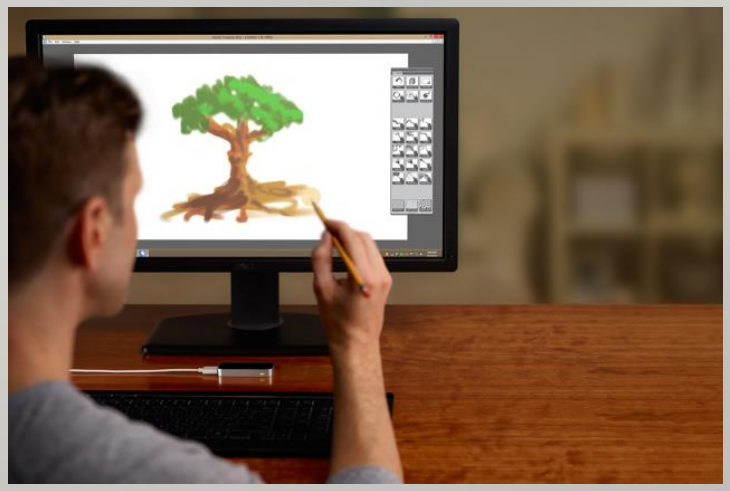
- Infrared and dual camera
- Real-time recovery of scene depth
  - Special purpose hardware

Kinect

- Software algorithms to recognize human body and parts
- Extract skeleton and estimate current posture
- Related SDK : MS Kinect SDK and OpenNI

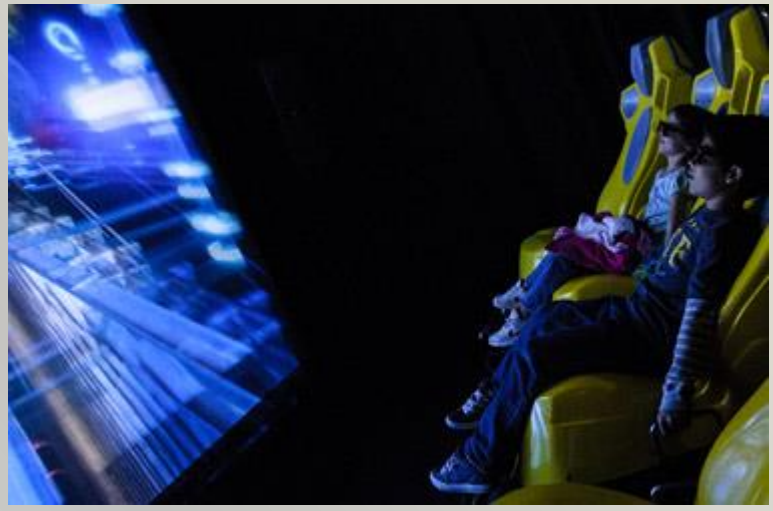
Hand tracking

- Leap motion
- Dual camera system
- High precision hand tracking



Applications

Entertainment



- Motion or 4D theater
  - Enhance excitement when watching movies
- VR is commonly seen in games
  - Special designed devices like guns or joysticks

Design and Communication

- Tele-conference
- Design
  - Provide navigation of design (e.g interior design)
  - Fusion with real environment

Education and Training

Flight Simulation

- Real cockpit with real motion
- Virtual environment
- Standard procedure in pilot training

Education and Training

Surgical Training

- Surgical procedures
- Haptics feedback devices
- Real time human tissues deformation

Summary

- An overview of virtual reality
- An integration of HCI and CG
- Introduced technologies involved ranging from vision, audition, haptics and motion sensing
- Improve immersion, interaction and reality
- Wide applications including entertainment, education and training