Introduction to Virtual Reality

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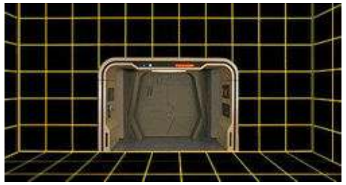
What is Virtual Reality?

- **Possible definition:**
  - Immersion into an alternate reality or point of view, e.g. book, movie
- **Popular conception of VR**
  - Star Trek Holodeck
  - The Matrix
- **A better definition of VR**
  - Medium composed of interactive computer simulations that sense the participant's position and replace or augment the feedback to one or more senses



Characteristics of VR

Characteristics of VR

- **Computer generated 3D world & real-time graphics**
- **Immersion (i.e., viewer-centered perspective)**
- **Interactivity (i.e., user controls)**
- **Sensory feedback (e.g. visual, audio, haptic feedback)**

Virtual World

- The contents conveyed by a medium
- An imaginary space often manifested through a medium
- A description of a collection of objects in a space, and the rules and relationships governing those objects

Immersion

- Also called presence (being mentally immersed)
- Sense of "being there" perspective
- To enhance immersion:
  - First-person view
  - Wide field-of-view
  - Stereo vision
  - Head tracking
  - Auditory, haptic or tactile feedback

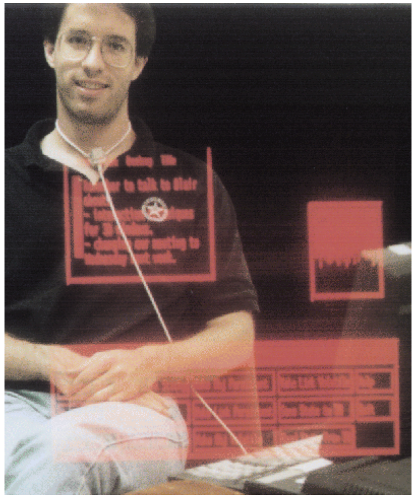
Interactivity

- The viewer controls interactively in the environment
- Tracking is the key to interactivity. The movement of the participant is being tracked and monitored as to yaw, pitch, roll and the position in x, y, z.
- The participants interact with objects, characters, places in a virtual world – i.e., manipulation and navigation.
- Collaborative environment refers to multiple users interacting within the shared virtual space or simulation. The user are represented as their avatars.

Sensory Feedback

- VR provides direct sensory feedback to the participants
- Mainly rely on visual sense
- Immediate interactive feedback requires the use of a high-performance computer
- To provide sensory output of the VR system on the position of the participants, the system must track their movement.

Other forms of VR

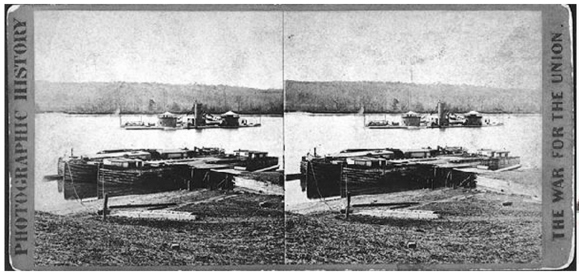


- ❖ **Artificial Reality**
- ❖ **Virtual Environment**
- ❖ **Cyberspace**
- ❖ **Augmented Reality**
- ❖ **Tele-presence**
  - ➢ Controlling a probe in a deep ocean area
  - ➢ Working with dangerous chemicals

VR History

VR History

- ❖ **1838 – Stereoscope, by Charles Wheatstone**
- ❖ **1849 – Lenticular Stereoscope, by Brewster**
- ❖ **1903 – Parallax Barrier, by Ives**
- ❖ **1908 – Integral Photography, by Lippmann**
- ❖ **1948 – Holography, by Gabor**



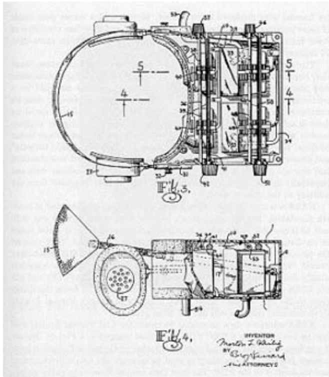
Holmes Stereoscope

VR History

- ❖ **1956 - Morton Heilig's Sensorama**
  - ➢ Cinematographer
  - ➢ Wanted to expand on 'cinerama' which had 90 degree field of view (FOV) by shooting with 3 cameras simultaneously and then synchronized when projected. Academy ratio films typically had 18 degree FOV, and Cinemascope 55 degree (depending on where you sat in the theatre)
  - ➢ Designed and patented 'the experience theatre'; - 180 degree horizontal and 155 degree vertical. 30 speakers, smell, wind, seats that moved.
  - ➢ Couldn't get funding so he made the scaled down '**sensorama**' - arcade setup with a vibrating motorcycle seat and handlebars and 2 35mm projectors for stereo and wind and aromas and stereo sound as viewer moved through prerecorded experiences – for multi-sensory virtual experience
  - ➢ Patented first head mounted display (1960) - used slides - couldn't get funding.

Sensorama

Heilig's Sensorama

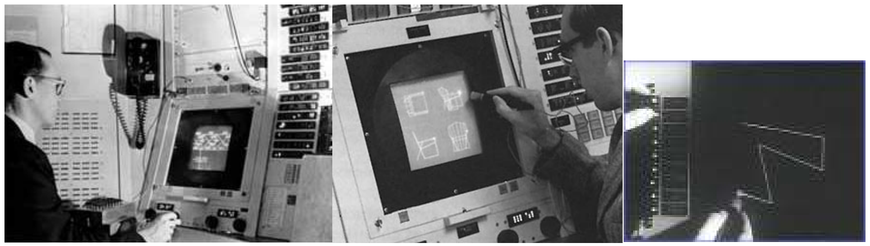


Heilig's US patent for HMD

VR History

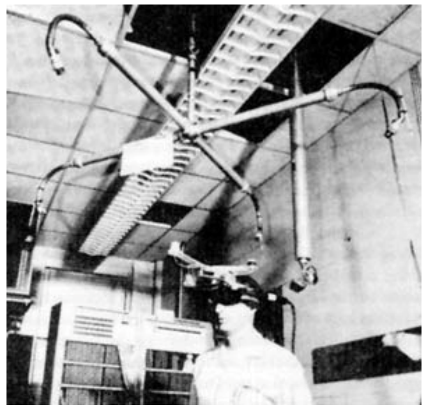
- **1963 - Ivan Sutherland @ MIT**
  - **Sketchpad**, interactive computer graphics
- **1965 - Ivan Sutherland @ University of Utah**
  - Proposes the **'ultimate display'** which is basically Star Trek's holodeck complete with the computer controlled generation of matter. "The ultimate display would, of course, be a room within which the computer can control the existence of matter. ... With appropriate programming such a display could literally be the Wonderland into which Alice walked"
- **1966 - Ivan Sutherland**
  - Created 'Sword of Damocles' - first HMD
  - Real-time computer generated display of wireframe cube with **head tracking projected onto half-silvered mirrors** so the cube floats in front of the user in the room (what we would call augmented reality today.) Two CRTs mounted by the users head along with other hardware suspended from the ceiling by a mechanical arm.

Sketchpad



Ivan Sutherland's Ph.D dissertation at MIT,
The Sketchpad: A Man-Machine Graphical Communication System (1963)
The first interactive computer graphics system with a light-pen for design and engineering.

Ultimate Display



Sutherland's "Ultimate Display"

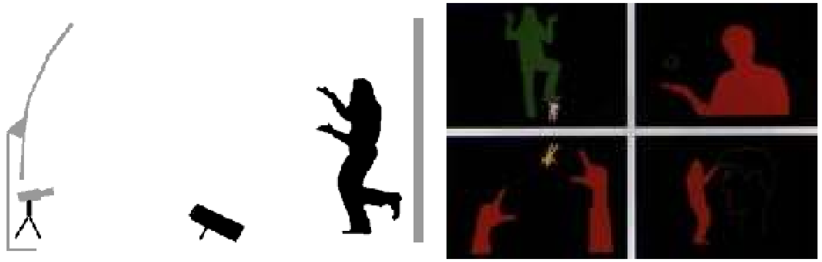
VR History

- 1967 - GROPE @ UNC
  - Force-feedback project (began in 1967)
  - GROPE-I – 2D system for continuous force feedback
  - GROUP-II – 6DOF (with 3 forces and 3 torques)
  - GROUP-III – a full 6-DOF molecular docking system
  - UNC uses a ceiling mounted ARM (Argonne Remote Manipulator) to test receptor sites for a drug molecule

UNC's GROPE II 6-DOF ceiling mounted ARM (Argonne Remote Manipulator)

VR History

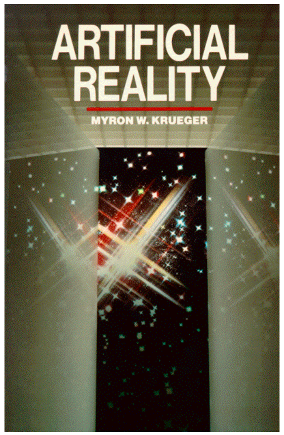
- **1970 - Myron Krueger**
  - **VIDEOPLACE** - '**artificial reality**' where cameras are used to place people into projected scenes
  - Image processing used to track the users in the 2D space



Krueger's Videoplace

Artificial Reality

- **1983 – Myron Kruger published his famous book, Artificial Reality.**



VR History

- **1977 – Sayre, DeFanti, Sandin @ EVL**
  - **The Sayre Glove** – the inexpensive, lightweight, first data glove for gesture recognition
  - This glove uses light-conductive tubes to transmit varying amounts of light proportional to the amount of finger bending.
- **1978 – Andrew Lippman, Michael Naimark, Scott Fisher @ MIT**
  - **The Aspen Movie Map**
  - The first true hypermedia system
  - It was a surrogate travel application that allowed the user to enjoy a simulated ride through the city of Aspen, Colorado

VR History

- **1979 – F.H.Raab, et al. utilized tracking systems in VR – the Polhemus (6-DOF eletromagnetic position tracking)**
  - Bill Polhemus started Polhemus Associates in 1964, working on projects related to navigation for US Dept of Transportation

Polhemus FASTrak and VISIONTrak tracking system

VR History

- **1982 – Thomas Furness III**
  - **VCASS (Visually Coupled Airborne Systems Simulator)**
  - 6 degree of freedom HMD which isolated user from the real world
- **1986 – Thomas Furness III**
  - Virtual Super Cockpit for pilots that fed 3D sensory information directly to the pilot, who could then fly by nodding and pointing his way through a simulated landscape below.
- **1989 – Thomas Furness III**
  - found HITlab (Human Interface Technology Laboratory)

VR History

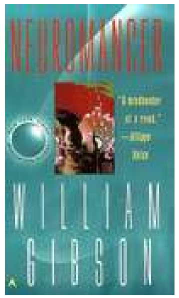
- **1984 - Michael McGreevy, et al.**
  - **VIVED (Virtual Visual Environment Display)** created inexpensive HMD with off-the-shelf components (e.g. Sony watchman, DEC PDP 11, Picture System2 graphics computer, and a Polhemus noncontact tracker)
  - Scott Fisher @ NASA Ames continues to add features: data glove, quad-sound, voice control, etc becoming VIEW (Virtual Interface Environment Workstation)

By 1988, four 3D virtual sound sources were added.

VIVED evolved into VIEW (Virtual Interface Environment Workstation)

VR History

- **1984 – William Gibson**
  - In **Neuromancer**, he added the word "**cyberspace**" – the implications of a wired, digital culture, and have had tremendous influence on the scientists, researchers, theorists, and artists working with virtual reality.
  - Cyborgian, cyber-habitats, virtual communities, online chat spaces



VR History

- **1985 - Jaron Lanier, Thomas Zimmerman & VPL Research**
  - **Term: Virtual Reality**
  - First company focused on VR products
  - Sold **VPL data gloves** in 1985 and eye phones in 1988

VPL Data Glove

VIEW system, NASA Ames Research Center

VR History

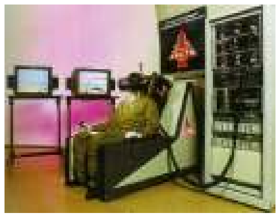
- **1986 – Ascension Technologies founded from former Polhemus employees, Ernie Blood and Jack Scully**
  - Develop a wide range of electromagnetic tracking systems for various applications, such as animation, medical imaging, biomechanics, virtual reality, simulation, military

Ascension Flock of Birds motion tracker

Puma helicopter repair training system

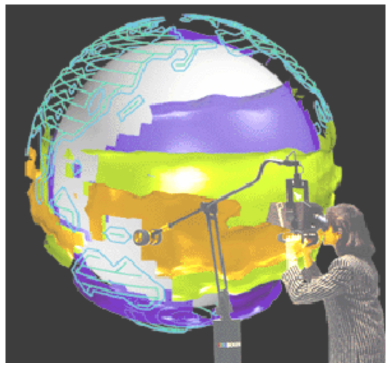
VR History

- **1987 – Virtual Cockpit (British Aerospace)**
  - Head and hand tracking, eye tracking, 3D visuals, 3D audio, speech recognition, vibro tactile feedback
- **1989 - Autodesk**
  - First PC based VR system
- **1989 - Fakespace Lab**
  - Development of the **BOOM (Binocular Omni-Orientation Monitor)**



Virtual Cockpit

BOOM

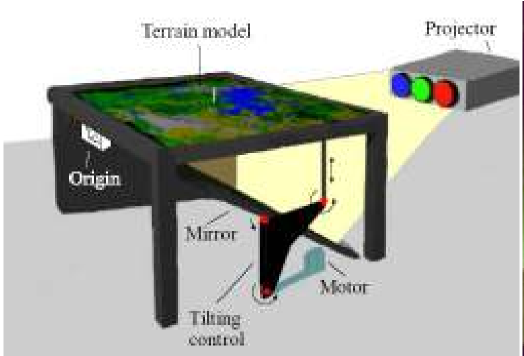


BOOM commercialized by Fakespace

VR History

- 1991 – ICAT (International Conference on Artificial Reality and Telexistence)
- 1992 – Development of the CAVE @EVL
- 1993 – Silicon Graphics Reality Engine
  - Hardware-supported Gouraud shading, texture mapping, z-buffering, anti-aliasing
- 1993 – OpenGL standard
- 1993 – Development of the Immersive Workbench,
  - by GMD (German National Research Center for Information Tech)
- 1993 – Development of PHANTOM by SensAble Technology
- 1993 – Development of Virtual Retinal Display by HIT lab
- 1995 – IEEE Virtual Reality Annual International Symposium

Immersive Workbench



Immersive Workbench

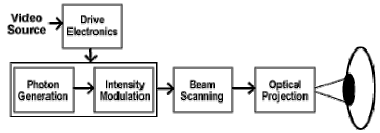
Phantom

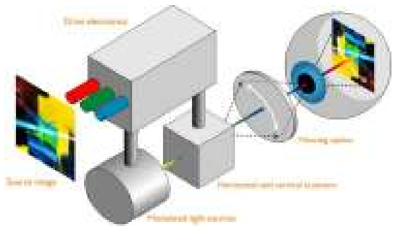
Phantom Desktop

Phantom Omni

Virtual Retinal Display

Figure 3: Virtual retinal display technology is being incorporated in helmet-mounted displays for military applications. (Photo courtesy of Microvision).

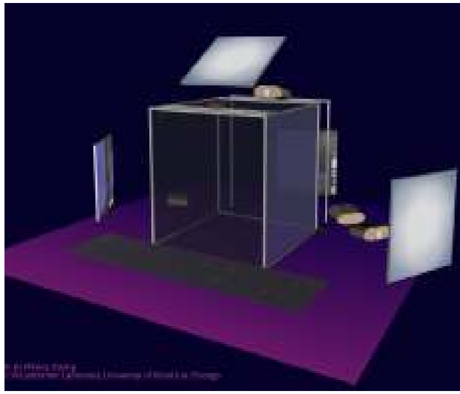




VR History

- 1995 – Development of the ImmersaDesk @ EVL
- 1996 – Intersense founded
  - Create a wide range of ultrasonic/inertial motion trackers
- 1998
  - Disney opens the first of their DisneyQuest family arcade centers, which features numerous VR attractions using both HMD and projection-based visual displays
  - The first six-sided CAVE installed at the Swedish Royal Institute of Technology
- 2000 – Development of Geowall @ EVL
- 2002 – PC graphics & PC clusters
- 2003 – University of Arizona
  - Development of SCAPE and the Head Mounted Projective Display
- 2003 – Development of PARIS and Varrier @ EVL

CAVE



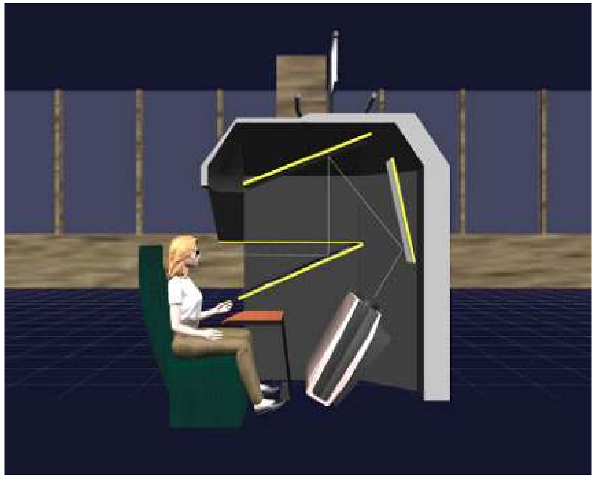
ImmersaDesk

- 1992 – 1 CAVE
- 2001 – at least 50 CAVEs & at least 100 ImmersaDesks around the world
- Now available from Silicon Graphics Inc. and FakeSpace Systems Inc.

GeoWall

- Originally designed & developed by EVL in 2001
- Now widespread adoption by GeoWall Consortium for research & education in the Geosciences (at least 70 GeoWall)
- www.geowall.org

PARIS



PARIS (Projected Augmented Reality Immersive System)) Projection-based "augmented" virtual reality system Half-silver mirror superimposes the displayed image over user's hands

half-silvered mirror display

Varrier

- Varrier Tiled Auto-Stereoscopic LCD Display
- Use barrier strip material in front of LCD to create autostereoscopic image.
- 4 horizontal pixels to create 1 stereoscopic pixel- oversampling to reduce aliasing.
- Use low-latency tracking to eliminate pseudo-stereo.

Current Uses of VR

Current Uses of VR

- **Demos**
- **Vehicle Design and Architectural Walkthroughs**
- **Education and Training**
- **Therapy and Rehabilitation**
- **Scientific Visualization**
- **Cultural Heritage**
- **Art and Entertainment**

Vehicle Design & Manufacturing

- Visual Eyes developed by General Motors Research, Hughes Research Lab & EVL
- Rapid prototypes for reviewing computer generated 3D CAD models

Vehicle Design & Manufacturing

- The Virtual Backhoe project by NCSA & Caterpillar Inc.
- VR manufacturing system that allows engineers to quickly prototype wheel loader and backhoe loader design
- Engineers can operate the equipment and evaluate visual obstructions in a natural manner without having to build a physical prototype.

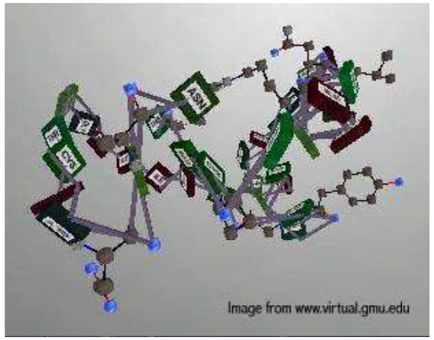
Architectural Walkthroughs

- Architectural Linked Immersive Environment (ALIVE) by SARA, The Netherlands & EVL
- Dutch architect Rem Koolhaas' design of the new Campus Center at the Illinois Institute of Technology in Chicago
- ALIVE lets viewers navigate through 3D CAD models

Architectural Walkthroughs

- CALVIN (Collaborative Architectural Layout Via Immersive Navigation)
- Persistent networked virtual environment
- Multi-perspective (Mortals and Deities) collaborative design

Education



- Science Space for high school or college students, using HMD by George Mason University & University of Houston
- Newton World allows students to experience Newton's three laws where they control the environment
- Maxell World examines Gauss's Law by examining the nature of electrostatic forces and fields
- Pauling World studies chemical structure of molecules

Education

- For middle school students, by GVU, Geogia Tech
- The Virtual Gorilla Exhibit project which is based on actual data from the Zoo Atlanta gorilla exhibit (gorilla behavior data & terrain data)
- Children can "be a gorilla" and experience first-hand what it is like to join a gorilla family group

Education

- For elementary students, by EVL
- NICE (Narrative Immersive Constructionist Environments) Per sistent garden
- Round Earth Project is intended to teach young children the concept of a spherical Earth
- Virtual Ambients is designed to help students improve early stages of students' scientific inquiry skills

Medical Training

- Virtual Temporal Bone, developed by UIC's VR Medicine Lab lets physician teach medical students about 3D structure and function of the inner ear
- External view of the human ear
- Human temporal bone to reveal the delicate anatomic structures imbedded within bone
- Closeup view of the sturcture within the bone

Medical Training

- Virtual Reality Dental Training System (VRDTS), developed by School of Dental Medicine at Harvard University, to train medical students

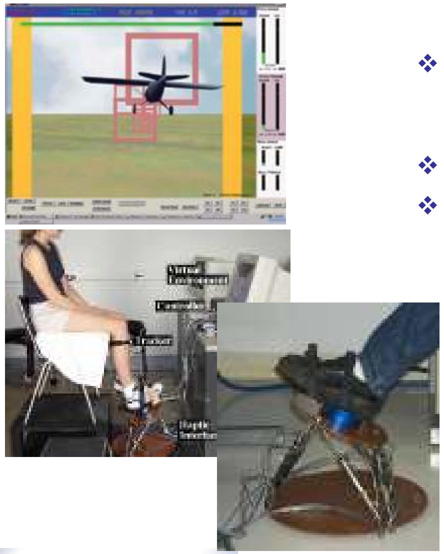
Military Training

- NPSNET – Large Scale Virtual Environment Technology Testbed
- NPSNet is a real-time, interactive distribution simulation system, developed by Naval Postgraduate School
- To implement a large-scale networked virtual environment
- IEEE 1278 Distributed Interactive Simulation (DIS) application protocol

VR Therapy

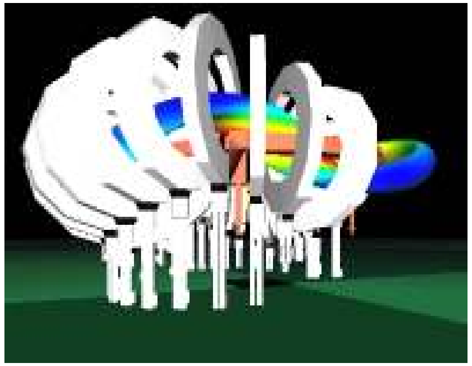
- Spider phobia, developed by HIT lab at University of Washington – VR exposure therapy for treating spider phobia
- Acrophobia (the fear of heights), developed by GVU at Georgia Tech – VR exposure therapy that involves exposing the subject to anxiety producing stimuli while allowing the anxiety to attenuate

VR Therapy



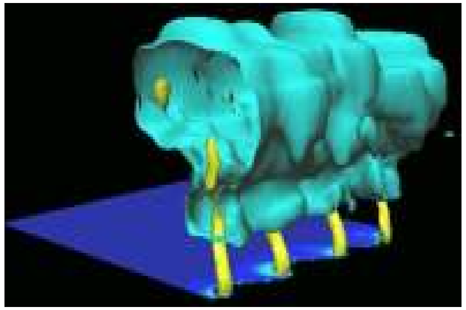
- ‘Rutgers Ankle’ Rehabilitation Interface, developed by Rutgers University
- Pilot the virtual plane
- The "Rutgers Ankle" Rehabilitation Interface is a robotic ankle rehabilitation device designed for at-home use and Internet-based remote monitoring by therapists

Scientific Visualization



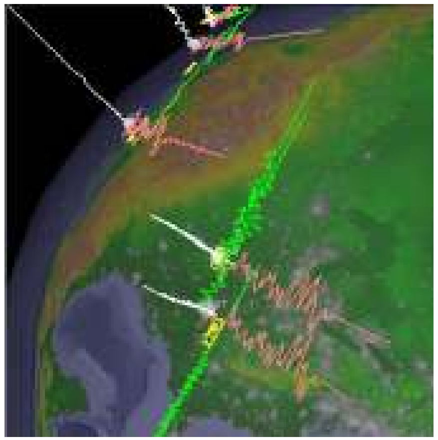
- Heliac Plasma Coil, developed by Cooperative Research Center for Advanced Computational Systems at Australian National University
- Main magnetic coil set and a magnetic “flux surface” of the H-1HF Heliac fusion plasma physics experiment

Scientific Visualization



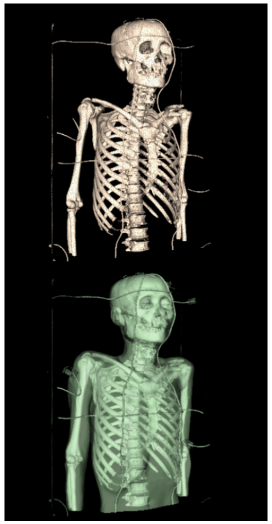
- Non-Supercell Tornado Simulation developed by UIUC Dept. of Atmospheric Sciences & NCSA
- Viewers can immerse themselves with the digital storm and understand how they form and develop

Scientific Visualization



- Wiggleview, developed by EVL
- Traditionally seismologists look at 2D X-Y plots of a time-series of the displacement of a seismometer in the North-South, East-West, and Up-Down directions
- Wiggleview allows to visualize the simultaneous recording of three channels of seismic data in response to an event

Scientific Visualization



- Visible Korean Human, developed by Computer Graphics Lab at Sogang U. & KISTI
- Volume visualization using image-based rending technique
- CT, MRI, RGB datasets of a Korean senior, created by KISTI and Ajou Univ.
- allows users to investigate skin and bone of the human

Scientific Visualization

- Development of Typhoon Maemi landed on the southern coastal area of Korea during Sep 2003, developed by Digital Ocean & Virtual Environment Center at Korea Ocean Research and Development Institute
- Low-saline water in Yellow Sea due to spreading of Changjiang Diluted water toward Jeju Island, developed by DOVE at KORDI
- Scientific visualization to display multi-dimensional numerical data (e.g. atmospheric, oceanographic), 8

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KIPO

Cultural Heritage

- Virtual Harlem allows people at remotely located CAVEs to tour 1920-40 Harlem, and listen to African American artists, writers and intellectuals of that time - notably Langston Hughes, Marcus Garvey and others.
- Collaborative effort between Central Missouri State University, Advanced Technology Center at University of Missouri, and EVL at UIC.

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KIPO

Cultural Heritage

- Silk Road Cave Shrine is a virtual cultural and artistic exhibit of the Mogoa Grottoes of Dunhuang (built on 300 to 1300 A.D.)
- Collaboration among historians, artists, and computer scientists at Northwestern University & EVL

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KIPO

Cultural Heritage

- Hellenistic Miletus, by Foundation of Hellenic World (FHW) & EVL
- A cultural heritage demonstration which takes visitors on a shared virtual voyage through the ancient Greek city of Miletus as it existed 2000 years ago

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KIPO

Cultural Heritage

- Digital restoration of Koguryo mural painting tomb, Anak No. 3 Tumulus, in virtual reality
- Allows children and adults to experience the life and times of Koguryo people and details custom to Korea
- In collaboration with Jeonju University, ICU Digital Media Lab, Sangmyung University, ATEC

Cultural Heritage

Interactive Art

- Crayoland created by Dave Pape, EVL – 2D crayon drawings placed in a 3D world
- Synesthesia by Rita Addison & Marcus Thiebaux, EVL – a sensory input (e.g. music) is perceived as a different sensory mode
- CAVE Quake by Paul Rajlich, NCSA

Interactive Art

- CITYCLUSTER "From the Renaissance to the Gigabits Networking Age", EVL & Fabricat
- Florence representing " Renaissance Age" & Chicago representing the "Gigabits Age" are interconnected by high speed network, enabling remote participants to interact and collaborate in shared environments

Interactive Art

- ID Illusion
- Exploration into the artist's subconscious as a metaphorical journey: maze, topiary garden, family photograph, falling away of the floorboards, ultimately dropping into a space fills with memories, abstract world, magic mirror reflecting identity, liberate from the bird cage, hanging butterfly, tree growing out of the ground

Entertainment

- Disney Quest - Aladdin

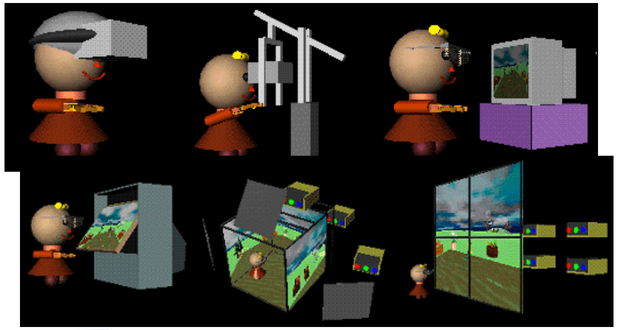
VR Components

VR Components

- Display: Visual, Aural, Haptic
- Tracking, Input Devices
- Networking
- Computer Hardware, Software

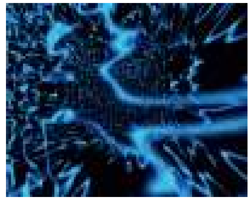
Visual Display

- Head-mounted Display (including See-through VR)
- BOOM
- Fish tank VR
- Projection-based VR



Visual Display



- It is important to note that although the field is called ‘virtual reality’, the goal is not always to create reality.
- Want to see things that can’t be easily seen
- Want to create worlds that are more interesting or exotic than reality
- Want to create worlds that are simpler than real life for teaching

Visual Display

- **Computers are capable of creating very realistic images, but it takes a lot of time to render these.**
- **In VR we want to at least 15 frames per second in stereo**
- **For comparison:**
  - Film is 24 frames per second monoscopic (with roughly 10-20 million pixels per frame)
  - Television is 30 frames per second monoscopic (with roughly 0.4 million pixels per frame)
  - HD Television is 24 or 30 frames per second monoscopic (with roughly 1 million pixels per frame)
- **The tradeoff is image quality (especially in the area of smoothness of polygons, antialiasing, lighting effects, transparency) vs. speed**

Stereoscopy

Stereoscopy

- If we want stereo visuals, we need a way to show a slightly different image to each eye simultaneously. The human brain then fuses these two images into a stereo image.
- One way is to isolate the users eye (As in a HMD or BOOM). Each eye watches its own independent TV.
- Another way is to use color – this has been done in 3D theatrical films since the 50s with red and blue glasses
- We can use polarization (linear or circular) – linear polarization was used in 3D theatrical films in the 80s
- We can use time – this was common in VR in the 90s and continues today where we show the left image then the right image and the user wears LCD shutter glasses which ensure that only the correct eye sees the correct image.

Audio

- Ambient sounds are useful to increase the believability of a VR space (Important for Immersion)
- Sounds are useful as a feedback mechanism
- Important in collaborative applications to relay voice between the various participants
- Spatialized sound can be useful

Tracking

- 6 degrees of freedom (DOF) tracking the position (x,y,z) and orientation (yaw, pith, roll) of the user's head, hands, or devices
- Important for immersion and interactivity
- A common tracker for low-cost systems is the Ascension SpacePad
- A separate PC maybe used for tracking

Input Devices

- Input devices are perhaps the most interesting area in VR research.
- While the user can move their head 'naturally' to look around, how does the user navigate through the environment or interact with the things found there?
- Input Devices:
  - 3D mice
  - Data glove
  - Voice
  - Treadmill or bicycle locomotion system
  - Haptic
  - Tracking for gesture recognition

Input Devices

Wand

Wanda

Input Device - Treadmill

Input Device - Data Gloves

cyberglove

Networking

- **Often useful to network a VR world to other computers, such as supercomputers for computation and other VR devices for collaborative work**
- **Need high bandwidth networking for moving large amounts of data around**
- **Need network Quality of Service, especially latency and jitter**

Computer Hardware

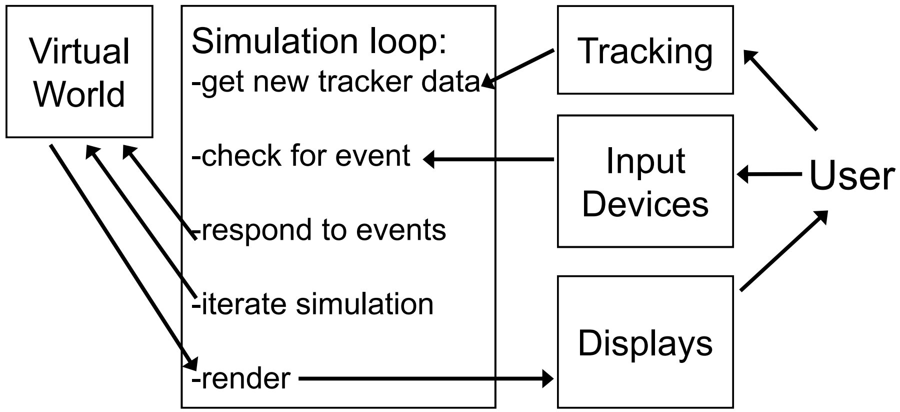
- Simulates virtual world, generates images and audio
- Should have fast processor, large memory, and fast graphics card
- Need a computer capable of driving the display device at a fast enough rate to maintain the illusion
- Needs two video outputs for passive stereo VR system
- Need multiple graphics engines are pretty much required if you have multiple display surfaces.

Software

- Most VR programming is done ‘from scratch’ or using lab-based software.
- 3D graphics library, such as OpenGL, Performer, Open Inventor
- VR system library, such as VRCO’s CAVElib, VREC’s VR Juggler, Virginia Tech DIVERSE
- VR authoring tool, such as Sense8 WorldToolkit and WorldUP

VR Input & Tracking

Human-VR Interaction



Tracking

- Measure the real-time changes in 3D position & orientation.
- The primary purpose of tracking is to update the visual display based on the viewers head/eye position & orientation.
- May also be tracking the user's hands, fingers, feet, or other interface devices.
- Want the user to be able to move freely with few encumbrances.
- Want to track as many people/objects as possible.
- Want tracking to be accurate (1mm and 1 degree).
- Want to have minimal delay between movement of an object and the detection of the objects new position & orientation.

Head Tracking

- **Head is tracked in many VR systems**
- **Head-based displays require head orientation to be tracked**
  - As users rotate their heads, the scenery must adapt and be appropriately rendered in accordance with the direction of view
  - Needed for physical immersion
- **Stationary VR visual displays (a computer monitor or a projection screen) needs to determine the relative position between the eyes of the user and the screen**
  - Requires head location
  - The direction from the head to the screen is often enough information about the head's orientation
- **Head location tracking**
  - Helps provide the sense of *motion parallax*, which is important for objects that are near the viewer

Hand and Fingers Tracking

- Generally to support user interaction with the virtual world
- Usually tracked by putting a sensor to the user's hand near the wrist or through the use of a tracked handheld device
- A glove input device is often used if detailed information about the shape and movement of the hand is needed

Eye Tracking

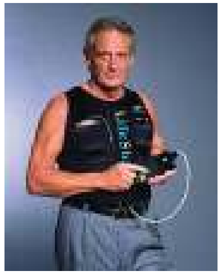
- Tracking eyes recently become practical for use with VR.
- Eye tracking systems provide applications with knowledge of the user's gaze direction.
- May be used to select or move objects based on the movement of the eyes.


Eyegaze


iView

Physiological Tracking

- Other aspects of a participant's situation can be measured – temperature, heart rate, respiration, brain waves, etc
- Perhaps useful for medical/athletic evaluation or training.
- May monitor user's emotional state using physiological sensors to dynamically modify an application's interface.



Muscular Tracking

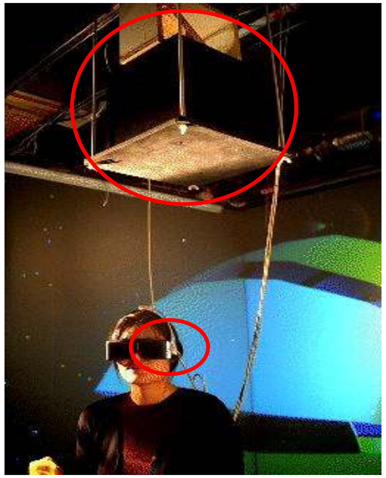
- Means of sensing body part movement relative to other body parts (e.g. curling the hand into a fist)
- Has not been explored to a large degree in VR systems.


NASA Ames Research Center, Bioelectric input device

Tracking Methods

- Electromagnetic
- Mechanical
- Acoustic (Ultrasonic)
- Optical
- Inertial
- Hybrid
- Specialized

Electromagnetic Tracking



- **Large transmitter and one or more small sensors.**
- Transmitter **emits an electromagnetic field.**
- Receiver **sensors report the strength of that field at their location to a computer.**
- **By analyzing the strength of the signal, 6 DOF of the receiver is calculated**
- **Sensors can be *polled* specifically by the computer or transmit *continuously*.**

Electromagnetic Tracking

FASTRAK

Flock of Birds

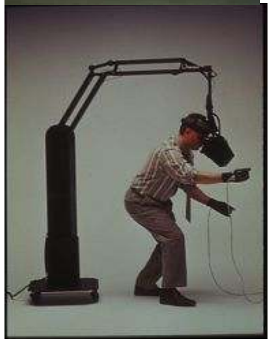
- **Uses**
  - Projection-based VR system (CAVE, ImmersaDesk)
  - HMDs
- **Examples**
  - **Polhemus FASTRAK**

    http://www.polhemus.com/
  - **Ascension Flock of Birds**
  - Ascension MotionStar

    http://www.ascension-tech.com/

Mechanical Tracking

Phantom



BOOM

- **Rigid structure with multiple joints**
- **One end is fixed, the other is the object being tracked**
- **Can be tracking user head or hand**
- **Physically measure the rotation about joints in the armature to compute position and orientation**
- **Structure is counter-weighted - movements are slow and smooth**
- **Knowing the length of each joint and the rotation at each joint, location and orientation of the end point is easy to compute.**

Ultrasonic Tracking

- **Small transmitter and one medium sized receiver**
- **Each transmitter (speaker) emits high-pitch sounds (ultrasonic pulses) at timed interval, which are received by receiver (microphones) on the sensor (usually arranged in a triangle)**
- **As the pulses will reach the different microphones at slightly different times, the position and orientation of the transmitter can be determined**

Optical Tracking – Stereo-vision based

Louis-

WATSON: Real-time head pose estimation using a stereo camera to recover the 3D rotation and translation of objects, or of the camera itself.

Optical Tracking - Looking-In or Out

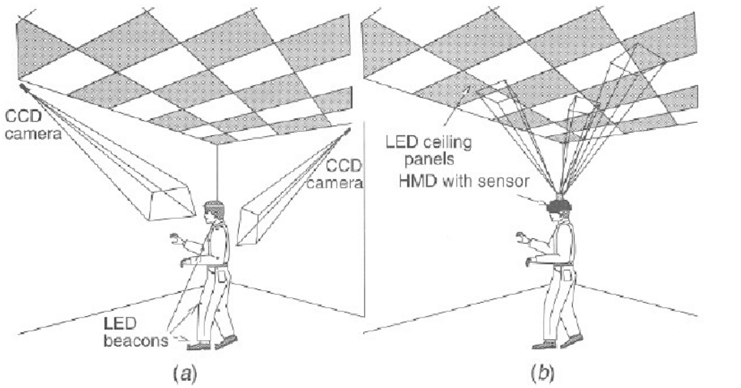


Fig. 2.16 Optical tracker arrangement: (*a*) outside-looking-in; (*b*) inside-looking-out. Adapted from Welch et al. [2001]. © 2001 Massachusetts Institute of Technology. Reprinted by permission.

Videometric Optical Tracking

HiBall Tracker @ UNC uses image-sensing devices mounted on user's head

- **Looking-out optical tracking**
- **The tracking device carries the camera that tracks markers in the environment**
- **Infrared LDE placed on the ceiling**
- **Multiple infrared-sensitive cameras mounted on the tracked object**
- **Can use reference points in the real world to determine the location of the camera(s)**
- **Some AR systems already use a camera for input, so no added hardware required on the user**

Inertial Tracking

- **Use electromechanical instruments to detect the *relative motion of sensors* by measuring change in gyroscopic forces, acceleration, and inclination**
- Gyroscopes **measure angular velocity**
- Accelerometers **measure the rate of changes in linear velocity (acceleration)**
- Inclinometer **measures inclination relative to some level position**
- **Knowing where the object was and its change in position and orientation the device and 'know' where it now is**
- **Could be used in wired or wireless mode**
- **Works well in combination with other tracking systems**

Hybrids Tracking: InterSense IS-900

InterSense IS-900 Controller

- **InertiaCube (for orientation)**
  - 3 accelerometers
  - 3 gyroscopes
- **Ultrasonic Rangefinder Module (for position)**
  - Sends IR and receives ultrasonic signal
  - Determines distance from sonic disks
- **Sonic Disk**
  - Responds to an IR signal with an ultrasonic signal with ID

Specialized Tracking

UNIPORT

VR Displays

Human Perception System

- **Obtain information about environment through senses:**
  - Vision: primary form of perception in most VR
  - Audition: second most common in VR
  - Haptic/Touch: perceptible on through direct contact
  - Olfaction
  - Gustation
  - Vestibular/kinesthetic sense
- **VR systems mimics the senses by output of computer-generated stimuli rather than natural stimuli to one or more of these sense.**

Monitor-based or Fishtank VR

- **Use standard computer monitor**
- **Differ from generic interactive 3D graphics displayed on a monitor because render scenes based on the user's head tracking data**
- **Fewer components & lower cost**
- **Standard interface devices available (keyboard, mouse)**
- **Limited FOV & FOR**
- **Generally less mentally immersive**

Projection-based VR

- Mostly rear-projected to avoid the participants casting shadows on the screen
- Larger more costly displays
- Longer range tracking systems
- Greater FOV & FOR
- Not isolated from the real world
- Multi-viewers friendly
- Not very encumbering
- Less eye strain
- More space required
- More graphics power required
- Occlusion problem

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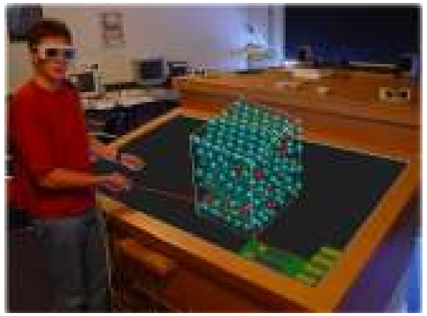
Projection-based VR: Table-type



- Direct manipulation
- Good for god's eye view
- Good for changing orientation
- Less immersion than surrounded VR displays

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Projection-based VR: Wall displays

- 3D movie-like VR displays
- Larger tiled or curved wall displays are suited for larger audiences – larger pixel, need more projectors
- Less immersion than surrounded VR displays
- Problem of seamless integration

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Head-based Display

- Small, lightweight screens
- More portable than stationary VR displays
- More encumbering than stationary VR displays
- Tethering to computer
- 100% FOR
- Limited FOV
- No peripheral vision
- Lag in tracking is detrimental
- Eye fatigue

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Head-Mounted Display

- e.g. Sony Glasstron
- HMD Vendors at http://www.faqs.org/faqs/virtual-worlds/visual-faq/section-2.html

Augmented Reality: See-thru HMD

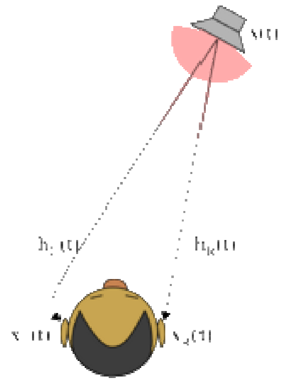
- Optical see-through vs. video see-through
- Require 6-DOF tracking
- Registration of tracking with the real world
- Application must live within the restriction of the real world
- Proper rendering of object occlusion is difficult

Handheld VR

- Limited example of handheld VR – e.g. Chameleon, Virtual binoculars
- Used as a magic lens
- Need to track both the screen and the head
- Registration of tracking with the real world
- Can be used in conjunction with projection-based VR displays

Auditory Display

- 3D Sound Spatialization
- Works well in plane of ears
- Based on:
  - Interaural intensity differences (IID)
  - Interaural time differences (ITD)
- Head-Related Transfer Function (HRTF)



Tactile Display

Teletact Glove

- Sensed by the skin – the largest single organ of the human body
- Actuators mounted generally on the fingers and hand
- Generally no need for world grounding
- Bladder actuators
- Vibrator actuators
- Pin actuators
- Thermo actuators
- Helps in the fine manipulation of virtual objects
- Less expensive & portable

Tactile Displays using Vibrator

Cyberglove

Cricket Prob

End-effector Display

Rutgers Dextrous Master

- A mechanical device that provides a force to the participant's extremities
- Generally linked to mechanical tracking sensors
- Generally world grounded (exoskeleton method is body-grounded)
- Often operate with respect to a single point in the virtual world
- Fast and accurate tracking is usually built into display

Robotically Operated Shape Display

Cybernetic Systems

- Use robots to place a representation of the virtual world where the user is reaching
- May be generic (corners and edges) – e.g. Cybernetic Systems
- May be specific (selection of switches) – e.g. Boeing
- Usually uses a finger surrogate for fast tracking
- Can provide a very realistic haptic display
- World-grounded display
- Works with HMDs

Vestibular Display

- Physically move the user – e.g. motion platform
- Sense of body movements or acceleration
- Virtual body representation
- Can "display" to these senses by stimulating the proper parts of the brain

Olfactory Display

- Very little research is done in olfaction
- Lack of effective displays and difficulty in producing broad range of stimuli
- Smell synthesis
- Require chemicals
- Olfactometer

Gustatory Display

Food Simulator

- Affected by other senses – strong influence of smell on taste
- Need more than flavor – e.g. texture
- Basic elements of taste – sweet, sour, bitter, salty, smell, umami

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