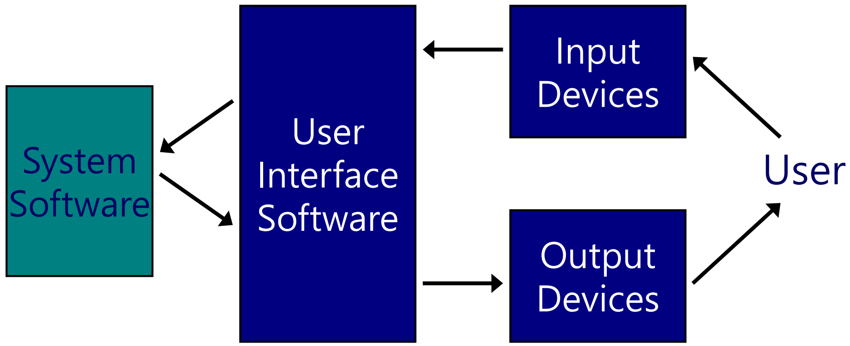
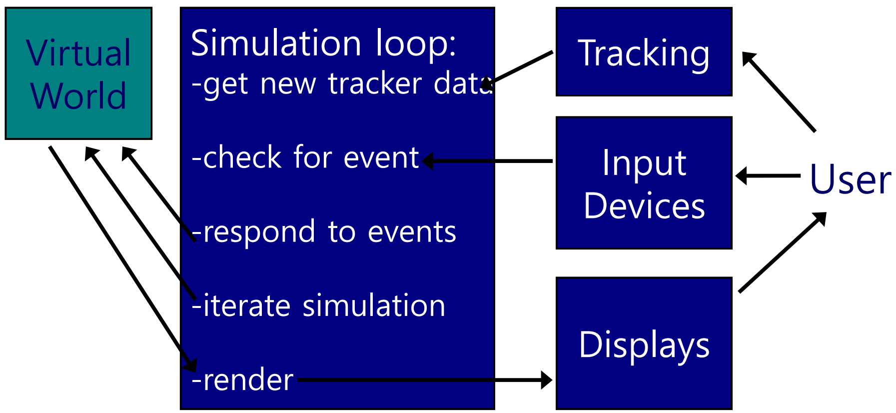
VR System Input & Tracking

071011-1
2017년 가을학기
9/13/2017
박경신

Human-Computer Interface



Human-Virtual Reality Interface



User Monitoring (User Input to VE)

- Real-time monitoring of the participant's actions in a VR experience
- Continuous tracking of user movement (tracking)
  - Allows the system to render and display the virtual world from the user's egocentric perspective.
  - Providing the effect of physical immersion.
- Discrete user-initiated inputs
  - Allows the user to indicate to the system that an action should be taken.
  - Pressing a button or speaking a command to the system

Tracking

Full-body motion tracking

Facial motion tracking

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.

Body Tracking

- Sense position and actions of the participants
- Depends on the body part and how the system is implemented
  - May track head movement in 3-DOF location & 3-DOF orientation
  - Tracking finger movement with a glove device
    - May measure multiple joins of finger flexion
    - Measure just contacts between fingertips
- Body Posture and Gesture
  - Posture: static position of a body part or group of parts
  - Gesture: a specific user movement that occurs over time
  - Posture and gestures can be derived as input commands

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

Glove Interface

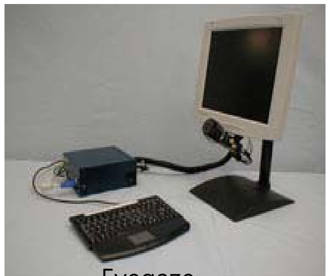
Virtual Technologies Inc, CyberGlove – tactile feedback, gesture, position & orientation tracking

Glove Interface

- Advantage
  - can provide a great amount of information about a key interactive part of the user's body
- Disadvantages:
  - Difficulty in wearing and taking it off – problematic if the world needs to be shared with others
  - Hard to calibrate so that the system has an accurate measure of the user's current hand posture
  - Calibration routine consists of striking a number of hand poses and having the computer take data with each new pose

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, head-mounted eye tracking

Eye Tracking

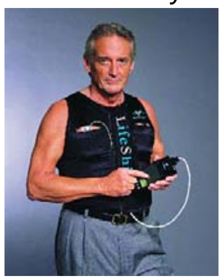
Seeing Machines, Facelab version 4

Brain-wave Tracking

StimTracker Tobii Pro TX300 EEG tracking

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.



MIT Media Lab, Affective Computing Group

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

Torso, Feet, and Indirect Tracking

- Few VR applications track the torso
  - To properly render a full-body avatar requires torso tracking.
  - The torso is a good indicator of which direction the user wishes to travel.
- Very few VR applications track feet
  - Can either track the location and pressure on the bottom of the feet.
  - The feet provide an obvious means of determining the speed at which a user wishes to move through a space.
  - Most VR systems require that the user remain in a relatively small space.
- Indirect Tracking
  - Instead of tracking the body part, it tracks physical objects to estimate the position of the participant
  - Holding a **wand** indicates where their hand might be. Turning a **steering wheel**. Pressing an **accelerator pedal** for hand and feet.

Foot Interface

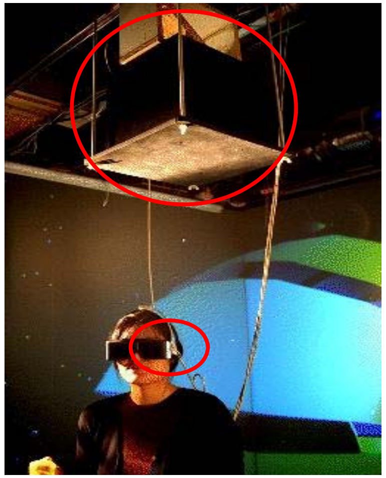
- World in Miniature (WIM) 1:1 mapping of the virtual world
- Step WIM = Step Interaction + WIM
- 3 wall + floor is a world

Brown University, Step-WIM Foot-interface

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

- Advantages
  - No line-of-sight restriction
  - Sensors are small and light
  - Multiple receivers allow tracking of several body parts
  - Technology has been around for a while
  - Generally wired. Wireless is available but needs more sensors (bulkier and more costly than necessary)
- Disadvantages
  - Affected by metal in the nearby area (magnetic interference)
  - Latency can be high (0.1 seconds)
  - Short range of generated magnetic fields → Accuracy is low in large volumes (3 – 8 feet)
  - Somewhat expensive

Electromagnetic Tracking

FASTRAK

Flock of Birds

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

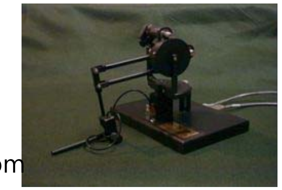
  http://www.polhemus.com/
  - **Ascension Flock of Birds**
  - Ascension MotionStar

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

Mechanical Tracking

Sarcos XOS Exoskeleton

Mechanical Tracking



Phantom

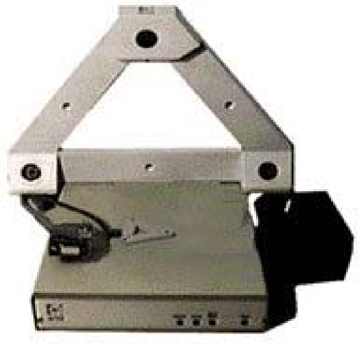
BOOM

- 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.

Mechanical Tracking

- Advantages
  - low latency
  - high accuracy and precision
  - sensors are small and light
  - technology has been around for a while
  - Force feedback can be integrated into the system
- Disadvantages
  - small volume (Mechanical linkage can prevent the user from moving to some locations)
  - only track one object at a time
- Uses
  - BOOMs, Phantom

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

Ultrasonic Tracking

- Advantages
  - High accuracy
  - Transmitters are small and light
  - Simple
  - Low cost
  - Large volume (or at least extensible)
- Disadvantages
  - Latency can be high
  - Requires line-of-sight
  - Not good in a noisy environment
  - Triangulating a position requires multiple and separate transmitters and receivers, which must be separated by a certain minimum distance → difficult for receivers

Ultrasonic Tracking

Logitech Ultrasonic Tracker

IS-900 Ultrasonic Tracker

- Examples
  - **Logitech Ultrasonic Tracking** for Fish tank VR

  http://www.vrealities.com/logitech.html
  - **InterSense Ultrasonic Tracking**

  http://www.intersense.com/

Optical Tracking

- Make use of a **video camera** that acts as an electronic eye to "watch" the tracked object or person
- In some case, light sensing-devices other than video may be used
- **Markers** may be placed on the object to be tracked
- Video cameras at fixed locations capture the scene
- **Image processing techniques** (computer vision) are used to locate the object
- With single sensing device, only 2D position of the "watched" object can be reported

Optical Tracking

- Single-source 2D optical tracking is typically used in second person VR, in which the participants watch themselves in the virtual world
- The video source is used to determine the user's position within the video picture and to add the user's image to the virtual world
- Another single-source video-tracking uses a small camera mounted near a desktop monitor. This camera can roughly calculate the user's position in front of the monitor by detecting the outline of the viewer's head (given that the distance of the user's head from the screen generally falls within some limited range)

Optical Tracking

- Watching multiple points or using multiple sensors allows the system to triangulate the location and/or orientation of the tracked entity, providing 3D position
- Multiple visual input sources can be combined to get additional position information. Using three visual inputs, such as three video cameras in different locations, a full 6 DOF position can be calculated by triangulation.

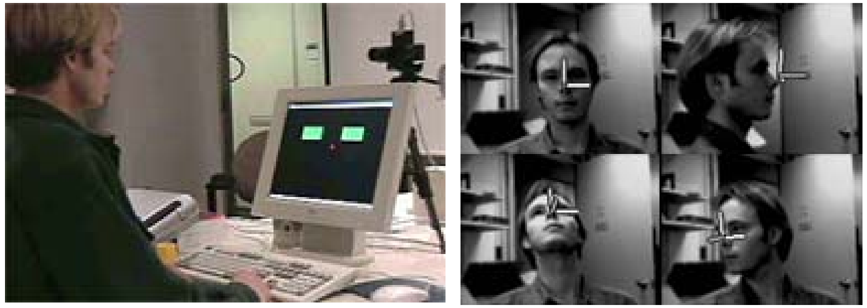
Optical Tracking

- Advantages
  - Accurate
  - Can capture a large volume
  - Allow for un-tethered tracking
- Disadvantages
  - May require light emitting diodes (LEDs) or retro-reflective material marker
  - Image processing techniques
  - Occlusion problem (line of sight required)
  - Limit the participant's range of movement, but expanding the tracking area is done by adding more cameras

Optical Tracking – Marker-based

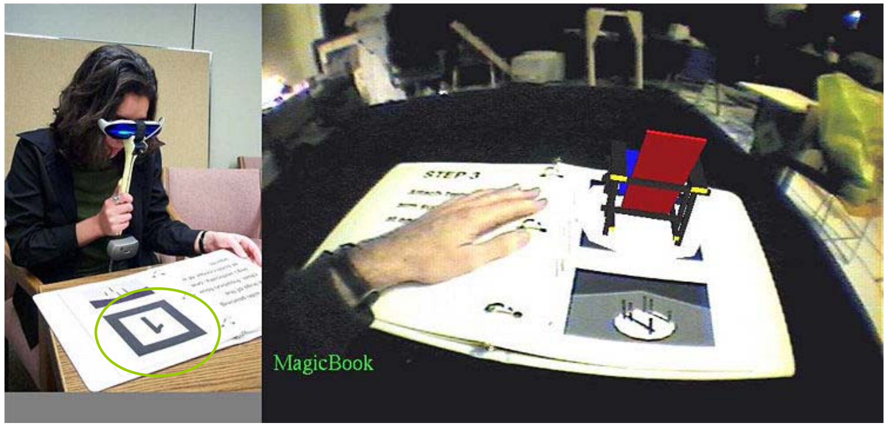
Vicon optical camera tracking system used in CAVE2

Optical Tracking – Stereo-vision based



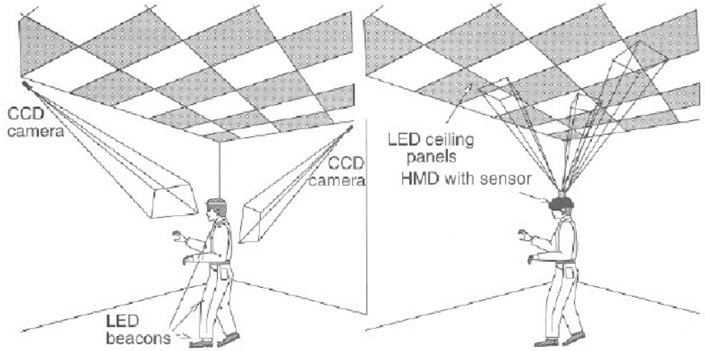
WATSON @AI Lab, MIT: Real-time head pose estimation using a stereo camera to recover the 3D rotation and translation of objects, or of the camera itself.

Optical Tracking – Visual Marker



Magic Book @ NZ HIT lab

Optical Tracking - Looking-In or Out



Outside Looking-in

Inside Looking-out

Videometric (Looking-Out) Optical Tracking

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

- The tracking device carries the camera that tracks markers in the environment
- Infrared LED 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

Inertial Tracking

- Advantage
  - Self-contained
  - Doesn't require a reference point
  - No range limitation
  - Little latency (lag time)
  - Fairly inexpensive
  - Used in some HBDs (Head-Based Displays)
  - Works well in combination with other tracking systems
- Disadvantage
  - **The degradation of accuracy over time (drift)**
  - Occasionally need manual realignment
  - Typically limited to orientation-only measurements

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

Hybrids Tracking: InterSense IS-1200

InterSense IS-1200, 6DOF Inertial-Optical
Self-Tracking System for Mobile Applications
http://cb.nowan.net/blog/tag/vrpack/

Hybrids Tracking: InterSense IS-1500

InterSense IS-1500, 6DOF Inertial-Optical
Self-Tracking System for mixed reality and GPS denied navigation
http://www.intersense.com/pages/70/255

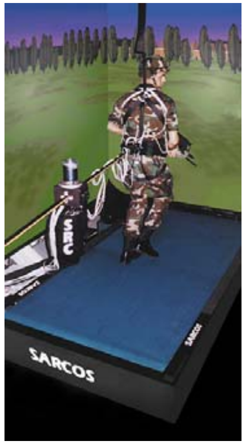
Specialized Tracking

- Specialized VR applications are usually better served using specialized tracking hardware
- GM and Caterpillar testing of their driver designs they place the actual hardware into the VR system so the driver controls the virtual loader in the same way the actual loader would be controlled
- A treadmill can be used to allow walking and running within a confined space
- A bicycle with handlebars allows the user to pedal and turn, driving through a virtual environment

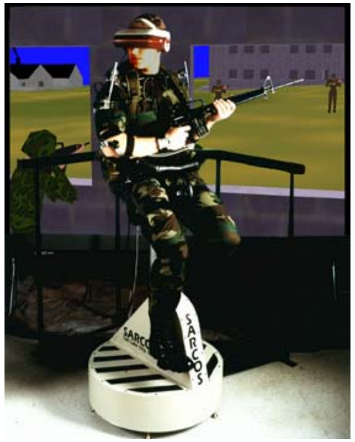
Specialized Tracking

Backhoe Design Prototyping @ Caterpillar

Specialized Tracking



Treadmill



UNIPORT

Specialized Tracking

Tracker Issues

- Resolution
- Accuracy/Registration
- Latency
- Update rate
- Range
- Interference/Noise
- Mass, Inertia and Encumbrance

Noise and low accuracy in the position sensor reports and lag time (<50ms) decreases the realism or immersiveness of the experience and can lead to nausea.

Tracker Issues

- Resolution
  - Fineness with which the tracking system can distinguish individual points or orientations in space
  - Measurement resolution – the ability of the tracker to measure different point
- Accuracy (registration)
  - Represents the difference between an object's actual 3D position and the position reported by the tracker
  - Calibration processes are used to measure and adjust for the differences between reported and actual position
  - Crucial for Augmented Reality applications
- Jitter: Change in reported position of a stationary object
- Drift: Steady increase in tracker error with time

Tracker Issues

- Latency
  - Difference between when a sensor first arrives at a point and when the tracking system first reports that the sensor is at that point.
  - **Latency (Data generation):** The rate (or time delay) at which the acquisition portion of the system can acquire new data.
  - **Transmission Lag:** Time needed to send bits of information that define position to the computer or graphics engine.
- Update rate
  - Number of tracker position/orientation samples per second that are transmitted to the receiving computer.
  - Fast update rate is not the same thing as accurate position information.
  - Poor use of update information may result in more inaccuracy.
  - Upper bound is determined by the communications rate between tracker and computer and the number of bits it takes to encode position and orientation.

Tracker Issues

- Range
  - Position range or working volume
  - Sphere (or hemisphere) around the transmitter
  - Accuracy decreases with distance
  - Position range is inversely related to accuracy.
  - Orientation range: set of sensor orientations that the tracking system can report with a given resolution.
- Interference/Noise
  - The action of some external phenomenon on the tracking system that causes the system's performance to degrade in some way.
  - Noise: random variation in an otherwise constant reading. (Static position resolution)
  - Inaccuracies due to environmental objects (e.g. metals, opaque objects)

Tracker Issues

- Mass, Inertia and Encumbrance
  - Tethering (e.g. wires, mechanical linkages)
  - Things with no weight on your head can have inertia
- Multiple Tracked Points
  - Ability to track multiple sensors within the same working volume
  - Interference between the sensors
  - Time multiplexing: Update rate of S samples per second and N sensors results in S/N samples per sensor per second
  - Frequency multiplexing: Each sensor broadcasts on a different frequency

Improving Tracking Techniques

- Predictive Analysis
  - Computational process that increases precision effectively while reducing latency
  - Predict the path it is likely to take by analyzing the motion of the tracking unit, and supply values for where it is expected to soon be
  - Effectiveness relies on the tracked object moving in a predictable fashion
  - When the object is moving unpredictably, the system will not be able to return accurate and timely results

Improving Tracking Techniques

- Calibration
  - Calibrating the system for operation within a specific environment can help reduce errors
    - E.g. Metals near a magnetic tracking system causes errors
  - Basically all tracking system requires some kinds of calibration
    - Tell the tracking system where it is
  - Can be corrected or altered in computer code
  - Correction (lookup) table for a magnetic tracking system

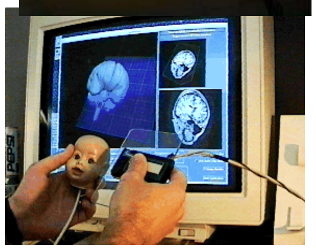
Other Means of Input to VR

- User initiated inputs, rather than data from tracking the user
- Physical control
  - Direct physical inputs
  - **Props**
  - **Platforms**
- Speech control

Physical Controls

- Direct physical inputs into the system
- Buttons, switches, valuators
- Generally mounted on a "prop" or a "platform"

Props



- A physical object used as an interface to a virtual world to represent some manipulable object in a virtual world
- May be generic or specific
- The physical properties (shape, weight, texture, center of gravity, solidity) give a limited amount of haptic feedback
- Real nature of props allows user to easily manipulate the object
- Realness of the prop may make the entire world seem more real

Props

CavePainting @ Brown University

Platforms

- A larger physical structure used to interface with virtual world (the place where the user sits or stands)
- Can themselves represent some portion of the virtual world
- Can be generic or specific
- Several common platform types
- CAVEs, ImmersaDesks are stationary VR display platform

Props

HTC VIVE Controller

Oculus Touch

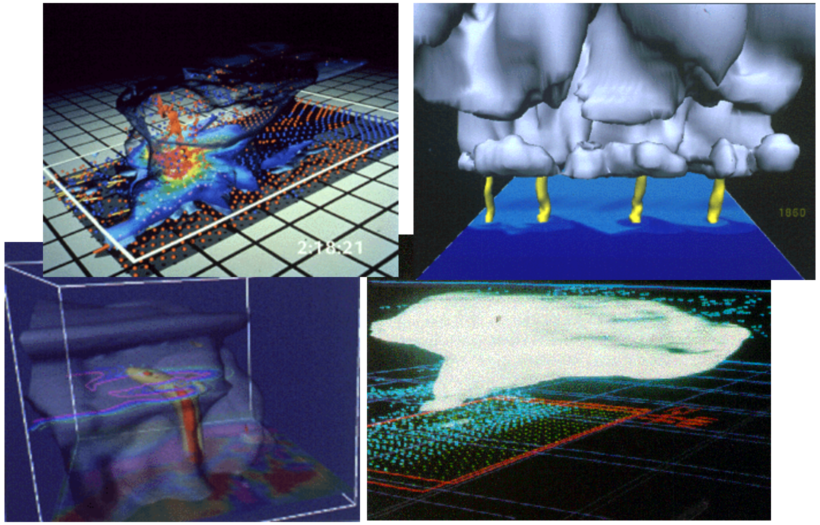
Audio Input Speech Control

- A natural means of communicating information
- Not good when instantaneous response is required
- Not good when speaking can interfere with other operations
- Very good when hands are occupied with other tasks
- How does computer know you're talking to it?
  - Push-to-talk
  - Name-to-talk
  - Look-to-talk

World Monitoring (input to VE)

- Information gathering and brought into the experience from sources not related to the participants
- Applies to both real world and persistent virtual world.
- Bring real world into VE
  - Useful for scientist/engineers to monitor some phenomenon of the real world.
  - E.g. a simulated weather-monitoring station that gathers information from the real world.
- Persistent virtual world
  - World that exists and evolves whether or not a user is there.
  - User manipulations in a persistent world can remain intact until another user (or agent) comes along and changes them.
  - Allows asynchronous communication

Bring Real World into VE



http://access.ncsa.uiuc.edu/Archive/backissues/96.2/Tornadoes.html

Persistent Virtual World

NICE @ Electronic Visualization Laboratory, University of Illinois at Chicago

Reference

- http://www.evl.uic.edu/aej/528/
- http://en.wikipedia.org/wiki/Motion_capture