Virtual Reality & Interaction

Virtual Reality
Input Devices
Output Devices
Augmented Reality
Applications

What is Virtual Reality?

narrow:

- immersive environment with head tracking, head-mounted display, glove or wand

broad:

- interactive computer graphics

our definition:

- an *immersive interactive* system

Fooling the Mind

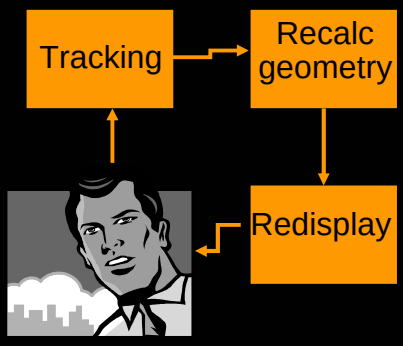
The mind has a strong desire to believe that the world it perceives is real. -Jaron Lanier

- Illusion of depth:
  - Stereo parallax
  - Head motion parallax
  - Object motion parallax
  - Texture scale
- Interaction: grab and move an object
- Proprioceptive cues: when you reach out and see a hand where you believe your hand to be, you accept the hand as your own
- Often you will accept what you see as “real” even if graphics are poor

Interactive Cycle

Display must be continuously redrawn (usually in stereo).

1. User is constantly moving. Positions are tracked (head, hands, or whole body).
2. Position of objects in the environment is updated.
3. Display is redrawn with new view position, new user body configuration (if tracking head, hands, or whole body), new object locations.
4. And back to step one.



Low Latency is Key

- *latency*: time lag between sensing a change and updating the picture
- 1 msec latency leads to 1 mm error
  - at common head/hand speeds
- 50 msec (1/20 sec.) is common and generally seen as acceptable

- Otherwise user feels nausea
  - if inner ear says you've moved but your eyes say otherwise
  - effect is strongest for peripheral vision
  - nausea is a serious problem for motion platforms (simulator sickness)
  - filmmakers know to pan slowly
- Our system for full body tracking has 100ms latency—not so good.
  - Measured with a record player…
  - Blame assignment is hard and the path from user action -> display is complicated.

Input: Tracking Head/Hand

- Magnetic
  - Transmitters stationary, receiver in hand / on hat
  - Oldest, most common
  - Fast (4 ms latency, 120Hz for Polhemus Fasttrak)
  - Metal objects, magnetic fields cause interference (e.g. CRT's)
- Acoustic
  - Works well over small areas
  - Background noise interferes
- Optical (1): Camera on head looks at LEDs on ceiling (UNC HiBall)
  - Very accurate (.2 mm position), fast (1 ms latency, 1500 Hz)
  - Recently currently available, and not terribly expensive
- Optical (2): Camera on head looks at markers in environment
  - Vision system calculates camera position
  - Very simple, quite inexpensive
  - Slow (may fall a whole frame behind - 30 ms)

Input: Tracking Head/Hand 2

- Optical (3): Cameras in world look at markers on user
  - Expensive
  - 120Hz
  - Can do whole body with some IK, disambiguation problems
- Inertial
  - Tiny accelerometers
  - Subject to drift (add gyros)
- Hybrids
  - Intersense combines inertial for speed, ultrasound to prevent drift
  - 150 Hz updates, extremely low latency
  - http://www.isense.com

UNC HiBall Tracker

- Camera looks through six lenses at pulsed LED's in ceiling
- Very accurate (.2 mm position error)
- Fast (1 ms latency, 1500 Hz)
- http://www.3rdTech.com/HiBall.htm (commercial version)
- http://www.cs.unc.edu/~tracker/

Input: Sensing the Hand

- Primitive technologies:
  - mouse
    - » ok for 2-D positioning, poor for drawing/orienting
  - joystick, trackball
    - » good for small/slow movement
  - pressure-sensitive stylus
    - » good for drawing
- Wand
  - tracker with buttons attached
  - may also include a joystick/joybutton or trackball
  - a simple way of grasping virtual objects
  - rotating object in your “hand” provides some sense of reality but no force feedback
- Data glove
  - measures joint angles of each knuckle in each finger
  - more degrees of freedom than needed
  - low accuracy

Input: Whole Body Tracking

- Realtime whole body tracking with Vicon System

Input: Whole Body Tracking

Getting good data in realtime is hard—no filtering

Input: Whole Body Tracking

- Low pass filter

Input: Whole Body Tracking

- Kalman filter

Example Application: Tai Chi Training

- How best to present feedback to the user?
  - Visually or otherwise?
  - Orientation, overlay, number of copies?

Input and Output: Haptics

- *Haptic* means relating to the sense of touch
- input: sense hand/finger position/orientation
- output: force-feedback

examples:

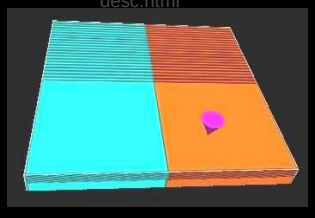
- mechanical force-feedback joystick: 2 or 3 degree of freedom (DOF): x,y,(twist)
- robot arm, e.g. Phantom

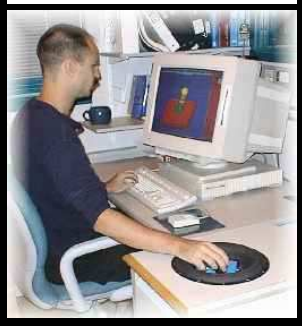
Phantom

Input and Output: Haptics

Another example:

- magnetic levitation 6 DOF haptic device
  - Ralph Hollis at CMU
  - http://www.cs.cmu.edu/afs/cs/project/msl/www/haptic/haptic_desc.html





UNC NanoManipulator

http://www.cs.unc.edu/Research/nano/

feeling carbon nanotubes with an Atomic Force Microscope

Input: Presence Measure

- Sense user's immersion:
  - Heart rate
  - Palm sweat
- Can then vary frame rate, latency, etc. and see how it affects immersion
- Use of passive haptics

UNC

Input: Affective Computing

- Sense user's attention and *emotions*:
  - gesture
  - posture
  - voice
  - eye gaze
  - breathing
  - pulse & blood pressure
  - electrical activity of muscles
  - skin conductance

  http://www.media.mit.edu/affect/
- Alter system behavior accordingly (how exactly?)

Output: Rendering Pictures

- Historically, big SGIs
- Now PCs are in the range, except:
  - Some issues with stereo
  - Internal bandwidth
- System Demands
  - At least 30 frames/sec; 60 is better
  - times 2 for stereo
  - at as much resolution as you can get
  - 1 K to 40K displayed polygons per frame (more would be nice)

Output: Display Technologies

- Projection displays
  - CAVE-type
  - IDesk/IScreen
  - Fishbowl VR
- Head mounts
  - Immersive
  - Non-immersive (augmented reality)
- To do stereo, you must get a different image to each eye
  - trivial for head mounts
  - shutter glasses
    - » left & right images temporally interleaved
  - polarized glasses or red/blue glasses
    - » left & right images optically superimposed

CAVEs

- A room with walls and/or floor formed by rear projection screens.

CAVE Details

- Typical size: 10’ x 10’ x 10’ room
- 2 or 3 walls are rear projection screens
- Floor is projected from above

- One user is tracked (usually magnetically)
- He/she also wears stereo shutter goggles…
- And carries a wand to manipulate or move through the scene
- Computer projects 3D scenes for that viewer’s point of view on walls
- Presto! Walls vanish, user perceives a full 3D scene
  - Turning head doesn’t necessitate redraw, so latency problems are reduced

- But, view is only correct for that viewer!
- cost is fairly high

CAVE Painting

http://www.cs.brown.edu/~dfk/cavepainting/index.html

CAVE Painting

http://www.cs.brown.edu/~dfk/cavepainting/index.html

Video Walls

- IDesks and their relatives
  - (This is the Pittsburgh Supercomputing Center's IScreen)
- Fishbowl VR is also in this category

Acoustic emitter for head tracker

Emitters for stereo glasses

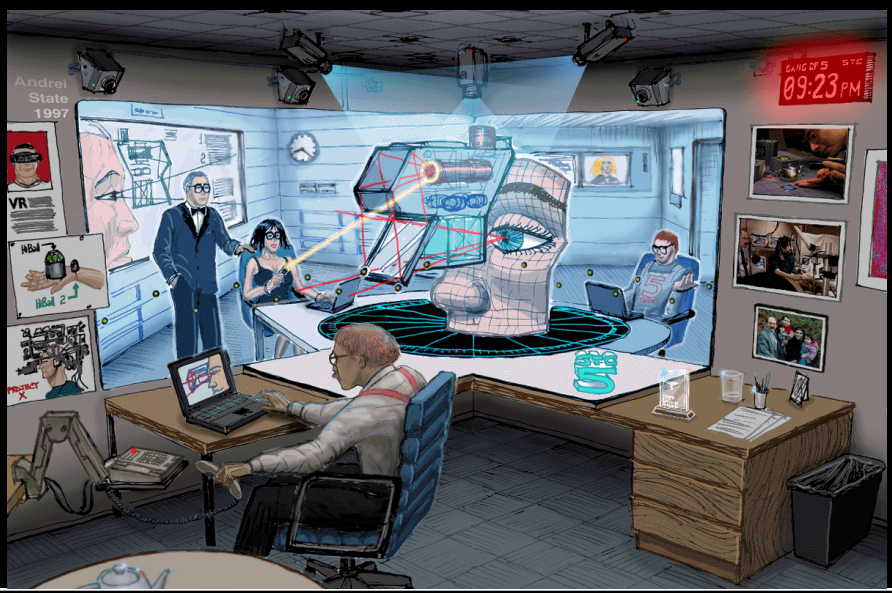
Rear projection screen

SGI Onyx with "Infinite Reality" Graphics & 4 Processors

Video Walls

- Princeton video wall
- Behind the curtain are n PC's and n projectors
- Calibration is a (nearly solved) research issue

Office of the Future



Classic Immersive Headmounts

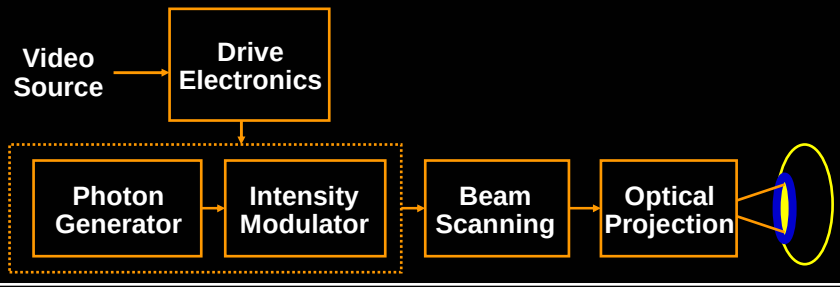
- Typical: small LCDs, one per eye
- Higher resolution: tiny little CRTs
- Flat panel displays are pushing this technology
- Can get 1Kx1K or more, but heavy and expensive (>$10K)
  - Good for the military
- Serious problems with latency and tracking errors
  - Leads to nausea
- Field of view is pretty limited, maybe 35º
  - Serious problem for some applications
  - Prevents seeing your body in a natural way even with full body tracking
- Can now be wireless

head-mounted display
Bell Helicopter, 1967

IO Systems I-glasses
640x480 resolution stereo
~$4K, 1999

Virtual Retinal Display

- Eric Seibel, U. Washington Human Interface Technology Lab
  - http://www.hitl.washington.edu/research/vrd/
  - www.mvis.com (commercial version)
- Simple enough: shine a laser in your eye and modulate it *real fast*.
- Potential for wearable very high resolution virtual reality



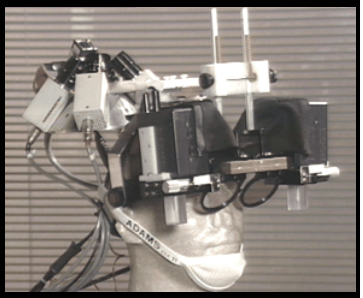
Virtual Retinal Display In Use

Tom Furness of HITL
Uses a prototype

Microvision's "Nomad" Product

Augmented Reality Headmount Systems

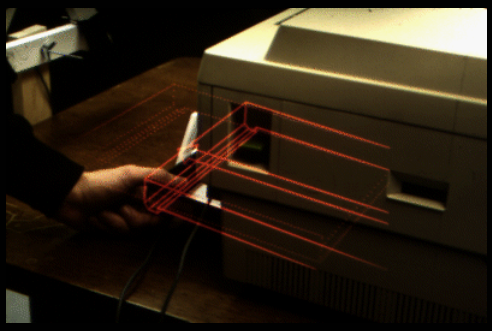
- *Augmented Reality* means augmenting the image of real environment with virtual one, rather than replacing
  - "heads-up display"
- One approach is to look through prisms or semi-transparent LCDs
- Alternatively, video see-through
  - Cameras are cheap and fast
  - Image-based tracking
  - Allows virtual objects to hide real objects
- Augmented VR is *very* sensitive to latency!
- But the user is comfortable and stays oriented, and can still see office / lab



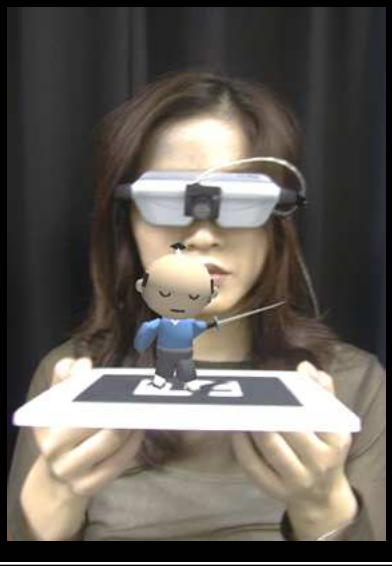
http://www.cs.unc.edu/~azuma/azuma_AR.html
note: many AR devices are small & lightweight!

Augmented Reality Headmount Systems

- http://www.cs.columbia.edu/graphics/
- Applications in assembly and maintenance
- Also in navigation



A Nice Little Augmented Reality System



- This project is from HITL
- Video see-through
  - Inexpensive but low-res
- Video-based tracking
  - Tracker recognizes the glyph on the card
  - Inexpensive but high latency
- Multiple cards with different characters
- Characters interact when you get them close to each other

Output: Audio

- Audio is important!
- Synthesis techniques
  - library of canned samples
    - » one at a time
    - » mixed (compositing)
    - » MP3 digital audio compression format
  - parametric model
    - » engine sound as a function of speed, incline, gear, throttle
      www.staccatosys.com
    - » human voice driven by phonemes, inflection, emphasis, etc.
- Spatialized sound
  - make sound seem to come from any point in space (not the loudspeaker)
  - need several loudspeakers, carefully phased
  - might need model of listener's head shape

Moving Through the Environment

- Best way is to walk—study at UNC comparing flying, walking in place, walking showed that walking gave a greater sense of presence
- With a wand, you can grab the environment and pull it past yourself…
  - This feels surprisingly natural
- Or you can fly through the environment.
  - Sounds like fun...
  - But your vision says you are moving while your inner ear says you are standing still
  - Surprise! Nausea is common
  - Less severe if the image doesn't cover your peripheral vision
- More clever:
  - move a little doll replica of yourself through a little dollhouse replica of the environment.
  - You then shrink down into the dollhouse, and a new dollhouse appears.
  - (All this pushing context bothers programmers, but not lay people).

Perceptual Issues Really Matter

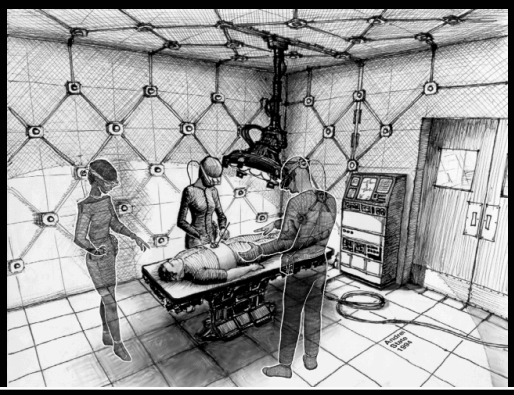
- Re-directed walking – UNC

movie

movie

Shared Virtual Environments

- Simple idea: two or more people look at the same geometry
- They can be widely separated; just draw *avatars* for those that aren't present locally.
- Have to avoid getting network latency into the loop
- What do you do if one person throws a virtual ball to the other?



Applications

- Flight simulators
- Architectural walk-throughs
- Design - interference testing (e.g. engine assembly)
- Teleoperation of robots in dangerous (Chernobyl) or distant (Mars) locations
- Medical X-ray vision (e.g. ultrasound)
- Remote surgery
- Psychotherapy (e.g. fear of heights)
- Interactive microscopy

More Applications

- Video Games
- Location-Based Entertainment
  - DisneyQuest
  - Sony Metreon
  - www.xulu.com
- Entertainment Technology (CMU)
  - http://www.etc.cmu.edu/
- Virtualized Reality (CMU)
  - http://www.ri.cmu.edu/projects/project_144.html
- Office of the Future (UNC)
  - use walls / desktops as displays
  - http://www.cs.unc.edu/Research/stc/office/
- Ubiquitous computing and wearable computers
  - information superimposed on the environment

Other Graphics Courses

- Fall 2004
  - 15-463 Advanced Rendering and Image Processing (Efros)
  - 15-869 Physically Based Character Animation (Pollard)
- Spring 2005
  - 15-493 Computer Game Programming (Kuffner)
  - 15-505 / 60-414 Animation Art and Technology (Hodgins / Duesing)
  - 15-864 Advanced Computer Graphics (James)
  - Grad seminar (James)
  - Grad seminar (Efros, tentative)

Announcements

- Grades for prog. project #3 and HW #3 out tonight
- Office hour 2-3 Friday to pick up homeworks, other questions
  - NSH 4207
- No class Tuesday, April 27
- Thursday, April 29 (last class) – course review
- Course surveys