VR Hardware II

Recall from earlier lectures:
Immersive computer-generated, user-centered environments that provide multi-modal displays and support multi-modal user interactions in “real” time for one or more simultaneous users.

How do we allow users to interact with the virtual world, and how do we make it user-centered?

Tracking & Input Devices!
Tracking for VR is usually 6 degrees-of-freedom (DOF):
- 3 degrees for location (x,y,z)
- 3 degrees for orientation (yaw, pitch, roll)

• Tracking a user’s head makes VR user-centered by providing information used to create graphics (or audio, or other displays) that are correct from the user’s current perspective.

• Tracking a user’s hand (or other body parts) allows a user to interact directly with the environment.

Considerations
➢ Size/shape of tracked area
➢ Accuracy (difference between actual and measured position/orientation, static/dynamic)
➢ Resolution (minimum detectable change)
➢ Latency (rate at which new data is acquired)

More Considerations
➢ Update rate (rate at which data is output to the port)
➢ Lag (time from when an action is performed until when it is available to the port)
➢ Update rate + latency = phase lag
➢ Number of parts tracked (tradeoff with update rate)
➢ Robustness (noise/jitter) - sources of interference
**More Considerations**

- line-of-sight
- price
- wired/wireless
- scalable
- size & weight of sensors/emitters
- filtering and prediction

**Methods/Technologies**

- Magnetic (EM)
- Mechanical
- Ultrasound
- Inertial
- Optical
- Image Based

**Magnetic (EM)**

- size/shape of tracked area: sphere of approx 5-8' radius
- accuracy and resolution: varies, but generally poorer than other methods
- number of parts tracked: approx 100
- robustness: generally poorer than other methods. Metal interference.
- line-of-sight: no problems

**EM Continued**

- price: approx $55,000
- wired/wireless: both are available
- scalable: to an extent
- size & weight of sensors: small (approx 1” cubic), light. Users can easily and comfortably wear many
- size & weight of emitters: usually large & heavy

![Image from Ascension Technology www.ascension-tech.com](image from Ascension Technology www.ascension-tech.com)
**Mechanical**
- size/shape of tracked area: generally small (think BOOM and Phantom), some areas may be difficult to access
- accuracy and resolution: very good
- number of parts tracked: limited
- robustness: very good

**More Mechanical**
- line-of-sight: no problems
- price: varies. Phantom about $57,000
- scalable: not really
- size & weight: depends on device, but may be heavy and unsuitable for extended use, some may have inertia problems

**Ultrasound**
- size/shape of tracked area: varies widely, many configurations are possible, scalable
- accuracy and resolution: generally good
- number of parts tracked: fewer than EM, more than mechanical (4 current)
- robustness: varies, some interference possible

**More Ultrasound**
- line-of-sight: issues here!
- price: approx $20-40k
- wired/wireless: wireless available
- size & weight of sensors: slightly larger and heavier than for EM because of packaging
- size & weight of emitters: generally small and lightweight, often packaged
Inertial

- size/shape of tracked area: theoretically limitless
- accuracy/resolution/robustness: issues with drift
- number of parts tracked: currently 4
- line-of-sight: no problems

More Inertial

- wired/wireless: wireless available
- size & weight of sensors: small & light alone, but usually packaged with other tech
- Currently inertial tracking is used in combination with other methods to correct for drift.

Optical

- Outside-in: Fixed sensor (camera), tracked objects have markers on them
  - passive markers: reflect light
  - active markers: emit light
- Inside-out: Fixed markers, tracked objects have sensors on them

More Optical

- size/shape of tracked area: can be large, scalable
- accuracy and resolution: varies, but generally quite good
- number of parts tracked: varies, depends on processing power and $.
- robustness: depends on number of markers/cameras, and interference

More Optical

- line-of-sight: some problems
- price: comparable to other methods, can be expensive with many cameras and markers
- wired/wireless: both are available
- size & weight of cameras: varies
- size & weight of markers: usually small and light, users can wear many

HiBall-3000™

Ceiling mounted, infrared LED strips, scalable

Smallish sensor

(images from 3rd Tech www.3rtdtech.com)
Image Based
- size/shape of tracked area: varies, generally only a few feet. Also often not 6-DOF
- accuracy and resolution: varies, but generally poorer than other methods
- number of parts tracked: varies, but generally small
- price: cameras fairly inexpensive

More Image Based
- wired/wireless: wireless
- scalable: to an extent
- robustness: software dependent
- line-of-sight: problems here, also possible interference from light sources

Example – Vivid Group

<table>
<thead>
<tr>
<th>Approximate Price</th>
<th>Accuracy</th>
<th>Resolution</th>
<th>Update Rate/ Latency</th>
<th># parts tracked – base/max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ascension Motion Star®</td>
<td>$55K</td>
<td>0.76cm, 0.5°</td>
<td>0.08cm, 0.1°</td>
<td>144Hz/ 20ms</td>
</tr>
<tr>
<td>InterSense IS-900</td>
<td>$30K</td>
<td>4mm, 2...4°</td>
<td>1.5mm, .05°</td>
<td>180Hz/ 4-10 msec</td>
</tr>
<tr>
<td>UNC/ 3rd Tech Hi-ball, 3000+</td>
<td>$28K</td>
<td>0.5mm, 0.03°</td>
<td>.2 mm, .03 °</td>
<td>2000Hz/ &lt;1 ms</td>
</tr>
<tr>
<td>Phantom</td>
<td>$57K</td>
<td>?</td>
<td>0.03 mm, 0.00008 on one &amp; 0.00023 on other 2</td>
<td>15Hz (rots)</td>
</tr>
</tbody>
</table>

Eye Tracking
(images from http://www.smi.de)

Input Devices
- Hardware that allows the user to communicate with the system
- Input device vs. interaction technique
  - A single device can be used for many different techniques
- Issues
  - Degrees of freedom
  - Data: discrete vs continuous
  - Number of limbs involved
  - Task to be performed
  - Cost
### Traditional/Fishtank Devices

- [Image from www.rhino3d.com]
- [Image from www.fakespacelabs.com]

### Novel Keyboard Devices

- [KITTY (Keyboard Independent Touch Typing) image from HITLab]
- [Image from http://halfkeyboard.com]

### Wands

- [Image from evl.uic.edu]
- [Image from www.isense.com]
- [Image from www.wandavr.com]

### Gloves

- **Pinch**
  - Conductive cloth at fingertips and palm.
  - "pinching" gestures of 2 to 10 fingers, also combinations. Good recognition.
  - >115,000 gestures
  - Other devices can be built using the conductive cloth
  - Relatively inexpensive
  - Easy on/off
  - [Image from www.fakespacelabs.com]

- **CyberGloves / 5DT gloves**
  - Senses flex/bend at each joint
  - Uses this to determine postures/gestures
  - "infinite" possibilities
  - Calibration
  - Cost
  - [Image truth www.immersion.com]
  - [Image from www.immersion.com]

### Vehicles & Simulators (mockups)

- [Image from www.immersion.com]
**Speech/Voice Input**

- Advantages:
  - Hands-free
  - Familiar
- Limitations:
  - Ambiguity possible
  - Noise and interference
  - “training” needed, both for system and user

**Locomotion Devices**

**Novel Input Devices**

- “Biofeedback”
- Galvanic skin response
- Pulse rate
- Respiration rate

**ShapeTape/ShapeWrap**

**Haptic Devices**

- Tactile displays
  - Give a sense of touch
  - Vibration
  - Pneumatic
  - Electrotactile
- Force displays
  - Convey larger scale forces to a user

**More Haptics**

- Issues:
  - Duration – adaptation, decreased sensitivity
  - Density, sensitivity of human touch
  - Strength
  - Durability
  - Fit and calibration to different users
  - Friction - Fatigue
  - Sensitivity
  - Update rate
  - Pain/injury threshold
  - Noise
  - Inertia
  - Space requirements
  - Cleanliness
  - Portability
Audio Display

- What does the user need?
- What does the user want?
- What does the user expect?
- These issues may be in conflict with each other
  - "Realistic" sound may not always be best
    - realistic sound in movies is often perceived as "flat"
  - Document the audio just as for visual

Audio Hardware

- PC sound card may be adequate, but multiple sound sources, multiuser interface, spatialized audio, high fidelity may require more sophisticated audio server.
- Headphones
  - Better ability to give the user detailed and specific info and localization
  - Difficult for group use
- Speakers
  - Easy for groups
  - More difficult to transmit specific information

Audio Production Methods

- Live transmission (ex: speech in a distributed app)
- Playback of recordings
- Synthesis using samples
- Synthesis using pure waveforms
  - Most often used for sonification of data
- Issues:
  - Acquisition time
  - Processing time
  - Storage requirements
  - Audio quality (realistic, understandable)
Olfactory Displays

- Attempts to produce olfactory displays
  - Scratch-n-Sniff
  - Sensorama
  - Smell-O-Vision
  - Trisenx (www.trisenx.com)
  - ScentAir Technologies
  - DigiScents
  - AromaSys

- Still searching for the “RGB of scent”

Taste Displays

- Issues
  - Intrusive
  - Safety
  - Human variability
  - Learning
  - Affected by other senses
  - Need more than flavor, ex: texture

- Basic elements of taste
  - Sweet
  - Sour
  - Bitter
  - Salty
  - Smell

Partial client list:
- Bellagio
- Caesars Palace
- MGM Grand
- Marriott
- Ritz Carlton
- Victoria’s Secret