CS 563 Advanced Topics in Computer Graphics
Recent Advances In Augmented Reality

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Augmented Reality

- Pick A Real World Scene
- Add your Virtual Objects in it
- Delete Real World Objects
- **Not** Virtual Reality since Environment Real

http://www1.cs.columbia.edu/
What Makes Augmented Reality Work?

- **Display** (where the image forms)
- **Tracking** (get pos+orient info)
- **Environment Sensing** (see the world)
- **Visualization and Rendering** (paint a picture)
- **Applications**
- Key Idea
- Different Implementations
- Key Challenges
Display System
Idea and Types

- The image seen by user formed
- Major Types of Displays
  - Head-worn displays (HWD)
  - Handheld Displays
  - Projection Displays
Head-Worn Display (HWD)

http://www.lsi.upc.es/
Head-Worn Display (HWD)

- **Optical See-Through**
  - View real world like normal glasses
  - Virtual world images added to image formed

- **Video See-Through**
  - Real World video captured
  - Augmented with Virtual world images
  - Finally displayed

- **Virtual Retinal Display**
  - Image formed directly on retina
  - Advantage: Higher FOV
• Brightness
• Size and dimensions
• Resolution
• Parallax Error (?)
Parallax Error

- Distance between eye and lens
- Eye sees slightly different image than lens image
- When viewed straight, correct reading
- When viewed from angle, different reading
- Solution: Most meters place mirrors!!

http://www.tpub.com
Handhelds and Projection Displays

- Camera attached to handhelds to view augmented reality[ see video virtual_train ]
- Projection Display: Virtual images projected directly on real world objects
Tracking
Little Background: Imagine there is a machine (ref point) that sees the whole world.

But we need to tell the machine our position and view position for it to tell us something about world view.

Question is: Since we (wearing HWD-target) are moving, need to report position + orientation to this machine.

Forget for time being: what info machine gives us and what info we see (see later!!)
In short, Ref wants to figure pos, orientation of target!!

Identify HWD by

- **Position**
  - X, Y, Z coordinates

- **Orientation**
  - Euler angles
    - Pitch, Yaw, Roll angles
- **Accuracy**: Measure of error in position, orientation reported
- **Resolution**: Smallest change in pos, orientation detected
- **Update Rate**: Rate of updation of pos, orient info at host comp
- **Lag**: Delay b/w change in pos, orient and report to host comp
- **Working Volume**: Volume within which tracker measures pos, orient within specified accuracy and resolution.

“Position Trackers for Head Mounted Display Systems: A survey” Devesh Kumar Bhatnagar”
Magnetic Trackers

**AC**
- Transmitter (ref) has mutually perpendicular electromagnetic coils
- AC supply sets up rotating magnetic field
- Induces current in Receiver (target)
- Current at receiver is function of pos, orient of receiver

**DC**
- To avoid eddy current, transmitter excited with short DC pulses.

**Drawbacks:**
- Presence of ferro magnetic material, magnetic field causes interference.

Acoustic Trackers

- Ultrasonic waves fired at target (HWD)
- Using RADAR principle target located.
- Disadvantages: Obstructions present b/w target and ref causes distortion.
- Speed of sound in air limits “ updation rate”
- Light reflected and received by sensor
- Outside-In
  - Reflector is Target
  - Sensor is Ref
- Inside-Out:
  - Reflector is Ref
  - Sensor is Target
## Performance Analysis

<table>
<thead>
<tr>
<th></th>
<th>Magnetic Trackers</th>
<th>Acoustic Trackers</th>
<th>Optical Trackers</th>
<th>Mechanical Trackers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy &amp; Resolution</strong></td>
<td>High Adversely affected by ferromagnetic and metallic objects in the environment</td>
<td>High Adversely affected by ultrasonic noise</td>
<td>High Adversely affected by ambient infrared radiation</td>
<td>High</td>
</tr>
<tr>
<td><strong>Working Volume</strong></td>
<td>Small</td>
<td>Small</td>
<td>Practically unlimited</td>
<td>Very small</td>
</tr>
<tr>
<td><strong>Lag</strong></td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Effects of obstructions</strong></td>
<td>None if the obstructions are not metallic or ferromagnetic</td>
<td>Increase in inaccuracies; loss of tracking ability in extreme cases</td>
<td>Increase in inaccuracies; loss of tracking ability in extreme cases</td>
<td>Loss of tracking ability in areas that cannot be reached because of the obstructions</td>
</tr>
<tr>
<td><strong>Convenience of use</strong></td>
<td>Easy to use</td>
<td>Easy to use</td>
<td>Inside-out systems require special environments and are heavy. Outside-in systems are more convenient to use.</td>
<td>Very inconvenient. User motion is restricted.</td>
</tr>
</tbody>
</table>

[Devesh Bhatnagar, 1993]
Environment Sensing
Depth Information

- Occlusion of Real World Objects
  - Depth information
- Shadow Formation
  - Again requires depth information
- Therefore, Not Just sufficient to video capture world view from HWD
Occlusion

Share-Z: Client/Server Depth Sensing for See-Through Head-Mounted Displays
Shadow Formation

Share-Z: Client/Server Depth Sensing for See-Through Head-Mounted Displays
Share-Z: Client/Server Depth Sensing for See-Through Head-Mounted Displays
- Server has world depth information
- Client sees video of world
- Reads Server depth info
- Does view, depth calculation
- Client keeps track of HWD position, orientation
Visualization, Rendering
Registration Error

- AR System must “register” computer image with real world image.
- Remember parallax problem?
- Consider real world meter virtual image is arrow on the meter showing reading
- Minor tracking error can lead to wrong reading. -> **Registration Error!!**
- Solution: **Level of Error Filtering (LOE)**
- Similar to LOD (Level of Details)
- In LOD different distances, diff models
- In LOE, different registration errors, diff virtual objects.
Adapting to Dynamic Registration Errors Using Level of Error (LOE) Filtering
Rendering Requirements

- Virtual objects need to appear realistic
- Need to capture lighting and scene information of real world
- Photo realistic rendering? But Real time requirements!!
Application
- WPI project: ECE & BioMedical, Augmented Reality for Fire Fighters -> Map of Building
- Marine Navigation
- Entertainment
  [video ]