**Virtual Reality Technology and Programming**

TNM053:
Lecture 5: Virtual Reality Displays

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**Stereo Display**

- Most common method used in virtual reality technology
- Made most use of in depth perception
- Requires different image for each eye
- Requires specialized equipment
  - Glasses:
    - Cross polarized or ‘passive’ stereo (e.g. IMAX)
    - LCD ‘shutter’ or active stereo (most systems)
  - Head mount display (HMD)

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**Stereo Rendering**

- Two camera points, slightly separated.
- Hardware may do it automatically

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**Cross Polarized glasses - ‘Passive’ stereo**

- Two lenses
- Polarized in orthogonal directions
- Two projectors produce different images
  - Polarize with filters

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**Polarized glasses**

- Cheap
- Light and comfortable
- More or less indestructible
- Continuous image in both eyes (2 projectors)
- Two projectors - alignment issues
- Non-polarizing screen required
- 50% light loss
- Can’t tilt your head more than a few degrees

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**Shutter glasses - ‘Active’ stereo**

- LCD display technology
- Two crossed, polarized layers per eye
- One permanently polarized
- One switchable
- Controlled by an IR signal
**Shutter glasses (2)**

- Expensive (~$250+)
- One display (Screen or projector)
- Heavier and more uncomfortable
  - Batteries and electronics inside
- Batteries run out - maintenance issues
- Much more fragile
- 50% light loss
  - could avoid with two active layers

**Display Hardware - Monitors**

- CRT (~200 Cd/M²)
- LCD (~300 Cd/M²)
  - Passive - Dual Scan
  - Active - TFT
- PDP - Plasma Display Panel
- ELD - electroluminescent display

**Luminance in context**

- From Ferwanda et al: SIGGRAPH '96

<table>
<thead>
<tr>
<th></th>
<th>Starlight</th>
<th>Moonlight</th>
<th>Indoor lights</th>
<th>Sunlight</th>
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<tbody>
<tr>
<td>No colour vision</td>
<td>Poor Acuity</td>
<td>Good colour vision</td>
<td>Good Acuity</td>
<td></td>
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</tbody>
</table>

Human simultaneous range ~10³

**Display Hardware - Projectors**

- CRT-based (~1000Cd/M²)
  - Phosphor produces the light
- LCD (~3000Cd/M²)
  - Light filtered through LCD makes image
- DLP (Digital Light Processor)
  - Complex new technology (TI)
  - Uses Digital Micromirror devices (DMD)

**CRT projectors**

- Optical lens system
- Phosphor layer
- Screen
**CRT projectors**

- Typically:
  - 3 CRT’s + lens per projector
  - Liquid cooled internally
- Hot
- Noisy (cooling)
- Consume a lot of power
- Fragile
- Analogue devices - need frequent calibration
- Phosphor decays - need frequent calibration
- Not Particularly Bright
- Good refresh rate (essential for stereo)
- Can distort the image as necessary to get rectangular display

**CRT - distortion**

- Flat display - rectangular image
- Curved display - distorts image
- Use CRT distortion to compensate
  - Use automatic hardware to control it
  - Complicates the configuration
  - More frequent alignment problems

**LCD projectors**

- Usually single projector
  - Brighter
  - Lower power
  - Less heat
  - Less noise
  - Lower refresh rate
  - Produce polarized light - Interfere with LCD shutter glasses
  - Harder to correct for curved screens

**DLP (DMD) projection**

- New technology becoming available
- DMD developed at T.I. Labs in 1994
- Basis for digital cinema projection
- DMD is a Digital Micromirror Device:
  - 1.3 Million mirrors on a silicon chip
  - Digitally controlled
  - Switching rate of thousands of Hz

**DMD**
DLP systems in practice

- DLP projectors becoming available
- Can buy small portable projectors - $2500-8000
- Can buy cinema projectors ~$12000
- Produce a lot more light than even LCD
- Produce very vivid colours
- Potentially no frame rate problem
- Can be used with polarized light
- Still have problems with curved screens

Laser projection systems

- Use coloured lasers to scan a projected image
- Fast mechanical scanning required.
- Zeiss Optic market ‘Tulip’
  - Multilaser display.
  - Used for planetariums.
  - Domed display.
Pros & Cons

Pros:
- Very bright
- Very high resolution
- High frame rate
- Can scan area of any shape (non-flat?)

Cons:
- *Very* expensive

Stereo Projector Hardware - Summary

- Need fast refresh rate
- Need fast 'blanking' to avoid 'shadows'
- CRT vs. LCD
  - Stereo display requires CRT or duplication of projectors
  - CRT projectors are more adjustable but need regular trimming (tuning)
  - CRT’s are not bright enough!
- DLP is improving the situation slowly...
- ...but lasers would be better

Head Mounted displays

- Original idea for VR
- Too heavy
- Too cumbersome
- Too uncomfortable
- Low update rate
  - nausea

HMD's - ‘portable’

- 1997!
- Still big and heavy
  - Note the counterweight!
- Still using CRT’s

- Changing displays doesn’t fix the updates problem

‘HMD’ - Other solutions

- ‘Boom’ (Fakespace)
  - CRT-based
  - Heavy and cumbersome
  - Supported by a counter-weighted ‘boom’
- Still hard to move

‘HMD’ - Boom (2)

- NCSA Virtual Wind Tunnel
**HMD - Today**
- LCD displays
  - Light level less of an issue
- Easy to wear
- Cheap to make
  - $1000-$10,000
- E.g. Sony Glasstron
- Others available

**Sony Glasstron for VR/AR**
- UNC-Chapel Hill
- Added cameras
- Added tracking
- Merged displays

**HMD's - The bad points**
- Still expensive per person:
  - Display now costs hundreds (thousands?) of dollars
  - Computing costs thousands
  - Resolution is poor (~1024x768 or less)
  - Field of view is very small
- No collaborative display
- Update rates are much too low:
  - Cybersickness still a big issue
  - Hardware solutions coming for that
- Hence projected displays still popular

**Projected displays**
- Front projection
  - Casts shadows
  - Makes best use of available light
- Back projection:
  - Expensive translucent screen
  - More space (lots of it!).
  - Lose light - brighter displays needed

**CAVE**
- Small room theatre
- Back-projected screens:
  - Walls
  - Floor
  - Ceiling
- Any combination from 2-6 sides of box
- Designed to avoid HMD limitations on update rate
Typical CAVE Footprint

CAVE - Update rates
- Head turning no longer a problem
- Needs more computing power
- Head movement through the space still a problem:
  - Incorporating tracking allows updates
  - Can still move the head quickly
  - System has problems keeping up
- The problems are significantly less than HMD's, however.

HMD - hardware updates
Ronald Pose et al
- Render onto six ‘cave’-like virtual walls
- Hardware projection to eye-cone
- Update rate vastly improved

Cave attributes
- Completely immersive display
- Tracking allows for parallax
  - (for one person only)
- Can be used by more than one person
- Needs *lots* of space
- Costs *lots* of money
  - ~$1000000

Non-Immersive displays: ‘PowerWalls’
- Originally a multi-monitor display
- Large display
- Used by one person
- Stereo and tracking possible
- Other systems: e.g. ‘Infinitywall’

Non-immersive theatres: ‘Reality Centre’
- Reality Centre
  - Cylindrical display (typically 120°+)
  - Front projected (has to be!)
- 1-3 (or more) projectors
- Overlap zones with hardware blending
RC - Configuration

- Overlap Zones
- Projectors

RC - Configuration (2)

RC - Benefits

- Relatively low cost
- Very wide field of view
- Good for collaborative audience
- Popular in oil industry
- We use it for:
  - Collaborative projects (VizClim)
  - Air Traffic Management

RC - Drawbacks

- No tracking
  - Not with large audience
  - No parallax - no head tracking
- Projector ‘blending’ can be a problem
  - Often visible
  - Projectors need frequent tuning to hide it
- Curvature of the screen
  - Requires compensation
  - Usually best done with CRT displays – less bright

Dome displays

- Multiple projector system
- Project onto domed surface overhead
- Can cover as much as 180° or more
- 180°x180°:
  - Hayden Planetarium (Trimension)
Non-Immersive theatres

- Much cheaper than a cave
- Needs less space (Front Projection)
- Collaborative
- Wide field of view
- Non-immersive
  - Wide field of view gives immersive effect?
  - Can include parallax (for one person)

Non-Immersive: Benches

- ‘Workbench’
  - Similar to a wall display
  - Tilttable?
  - Possibly can be made flat
  - Usually used with tracking
  - Usually used by one person
  - Used as a wide screen monitor

FakeSpace ImmersaDesk

- A “portable” semi-immersive environment:

VR ‘Responsive’ Workbench
### Specialist displays

- ‘Microscopes’
- ‘Telescopes’
- Any other ‘scope’ you can think of

### Specialist displays: Microscope

- Medical simulation
- Drilling into the petrous bone
- First step in cochlea implant surgery
- Uses stereo
- Uses force feedback

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### ‘True’ 3D display

- Not stereo display
- Uses alternative technologies to create 3D objects which can be seen with the naked eye
- Still quite new and primitive

### Depthcube 3D display

- Lightspace Technology
- Based on DLP and LCD
- Displays volumes as volumes!
- No glasses
  - 3D display of 3D ‘data’
- No head tracking required
  - Perspective and parallax from the display

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### Display

- DLP projector
- Mirrors to increase optical path
  - 4m!
  - Collimates light to (almost) parallel
- 20 layers of LCD spaced over ~15cm
- Use each layer as a projection screen

### How does it display a volume?
Full set-up

- 4m path!
- Large box!

Projection

- DLP – No fixed frame rate
- Drive display at 50fps
- 1000 frames per second needed!
  - 20 image frames per volume frame
- Custom hardware built around 3colour DLP projection system

The box...

Driving the display

- Works with any standard OpenGL app.
- Hardware in PC intercepts GL calls from any application
- Renders them for the 3D display
- Also has API for writing specific applications
  - Allows for 3D interaction etc.
- Uses ‘antialiasing’ for virtual depth layers
  - 32 per physical plane
  - Done in hardware

Cons

- Big box – small display
- 1024x768 plane resolution
- Only 20 physical planes
- Good for opaque objects
  - Not so good for transparency
- $65000 price tag!

Helix 3D

Helix (1) rotates in transparent cylinder (3) while an image beam (4) emits tiny light points, “voxels”, (5) at x,y,z.

Rotating helix invisible to the viewer.
The spatial ‘picture’ – composed of hundreds of voxels – floats in an apparently empty space...

...like fish in an aquarium.

Can be viewed from any angle
Common Problems with VR display hardware

- Projectors
  - Convergence
  - Fast phosphor – stereo ‘shadows’
  - Frame Synchronization
  - Edge matching or blending

- Light Spillage
  - ExTRANeous light source
  - Seen in both eyes
  - Destroys stereo effect. Confuses viewer