Output Devices

- Graphics
- 3D Sound
- Haptic Displays
Output Devices

The human senses need specialized interfaces:

- **Graphics displays for visual feedback**
- **3D audio hardware for localized sound**
- **Haptic interfaces for force and touch feedback**
- **Smell and taste feedback?**
Output Devices

A graphics display is a computer interface that presents synthetic world images to one or several users interacting with the virtual world.
Graphics Displays

- Human stereo viewing
- Personal displays
- Large volume displays
- Active glasses
  - Workbenches
  - Caves
- Walls
Human Stereo Vision

- **Vision is the dominant sensorial channel**
- **Depth perception in mono images is based on**
  - occlusion (one objects blocks another from view)
  - Shadows
  - Textures
  - motion parallax (closer images appear to move more than distant ones)
• **Depth perception in stereo is based on stereopsis when the brain registers and fuses two images**
• **Image parallax means that the two eyes register different images (horizontal shift)**
• **The amount of shift depends on the “inter-pupillary distance” (IPD) (varies for each person 53-73 mm)**
• **Works in the near field (to a few meters from the eye)**
Left/Right Stereo Pair
Stereo Viewing Devices

- Need to present two images of the same VR environment
- The two images can be presented at the same time on two displays (HMD)
- The two images can also be presented time-sequenced on one display (active glasses)
- The two images can also be presented spatially-sequenced on one display (auto-stereoscopic displays)
Personal Displays

A personal display is a graphics display that outputs a virtual scene destined to be viewed by a single user.

Such image may be monoscopic or stereoscopic, monocular (for a single eye) or binocular (displayed on both eyes).
Personal Displays

- **Head Mounted Displays**
- **3D Binoculars (hand supported)**
- **Booms (floor supported)**
- **Virtual windows (floor supported)**
- **Auto-stereoscopic displays (desk supported)**
HMD Optics Model (Simplified)
HMD integration in a VR system

Monoscopic VR System

- HMD
- HMD Controller
- RGB–NTSC Converter
- COMPUTER SYSTEM
  - graphics hardware
  - view calculation
- Ratchet for head adjustment

Stereoscopic VR System

- HMD
- HMD Controller
- HMD Tracker Control
- COMPUTER SYSTEM
  - graphics hardware
  - left–eye calculation
  - right–eye calculation
- Tracker receiver
Olympus Eye Trek *Face Mounted Display (FMD 200)*

- AMLCD display, Resolution: 267x225
- FOV: 30x23 degrees—Equivalent to 62 in at 2 m
- Weight: 100 grams
- Can be worn over glasses
Olympus Eye Trek Head Mounted Display Optics:

• Uses free-form lens to compensate for aberrations

• An eccentric optical system to reduce size (eliminate 45 degree mirror)
Olympus Eye Trek Face Mounted Display Optics
Daeyang “cy-visor” Face Mounted Display

LCOS display,
Resolution: 800x600
FOV: 60x43 degrees–
Weight: 160 grams
Can be worn over glasses

Liquid Crystal on Silicon display (LCOS)
Daeyang “cy-visor” Face Mounted Display

It is reflective – needs external lighting
Organic LEDs (OLED)

- **Active Matrix OLED display**
  - *individual pixels addressed independently*
  - *each pixel element can be selected to stay “on” during the entire frame time, or duration of the video*
  - *OLED is an emissive device: display aperture factor is not critical (unlike LCD displays, where light must pass through aperture)*
  - *No intrinsic limitations to the pixel count, resolution, or size of an active-matrix OLED display*

- **The TFT’s in the active-matrix design mean that a defective pixel produces only a dark effect - much less objectionable than a bright point defect, like found in LCD’s.**
Organic LEDs (OLED)
Organic LEDs (OLED)

- Robust Design - OLED's are tough enough to use in portable devices such as cellular phones, digital video cameras, DVD players, car audio equipment and PDA's.

- Viewing Angles – Can be viewed up to 160 degrees, OLED screens provide a clear and distinct image, even in bright light.

- High Resolution – High information applications including videos and graphics, active-matrix OLED provides the solution. Each pixel can be turned on or off independently to create multiple colors in a fluid and smooth edged display.

- “Electronic Paper” – OLED’s are paper-thin. Due to the exclusion of certain hardware goods that normal LCD’s require, OLED’s are as thin as a dime.
<table>
<thead>
<tr>
<th>Production Advantages</th>
<th>Up to 20% to 50% cheaper than LCD processes. Plastics will make the OLED tougher and more rugged. The future quite possibly could consist of these OLED’s being produced like newspapers, rather than computer “chips”.</th>
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<tr>
<td>Video Capabilities</td>
<td>They hold the ability to handle streamlined video, which could revolutionize the PDA and cellular phone market.</td>
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<tr>
<td>Hardware Content</td>
<td>Lighter and faster than LCD’s. Can be produced out of plastic and is bendable. Also, OLED’s do not need lamps, polarizers, or diffusers.</td>
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<td>Power Usage</td>
<td>Takes less power to run (2 to 10 volts).</td>
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5DT Head Mounted Display

- 800x600 pixels
- 40° diagonal view
- Organic LED
- Frame sequential stereo
- 600 grams
- $4k
Samsung Emagin z800 OLED HMD

Weight 8 oz
PC connection - USB, RGB input
SVGA resolution (800x600 pixels) stereo
Tracking - 360 degrees pan
60 degrees pitch
899 USD www.3dvisor.com
Professional HMDs

Keiser ProView AMLCD display,
Resolution: 1024x768
FOV: 28x21 degrees
Weight: 992 grams
Professional HMDs

N-Vision Datavisor
CRT display,
Resolution: 1280x1024
FOV: 78x39 degrees–
Weight: 1587 grams
LCOS Virtual Binoculars
Virtual Binoculars
Floor-supported displays

![Diagram of Boom3C (courtesy of Fakespace Labs.)](image)

- Rendering
  - Left and Right viewing matrices
  - View Calculation
    - Linkage and Viewer matrices
    - Forward Kinematics
      - Floating point angles
      - Conversion
        - Raw joint values
        - STD Box
          - Analog data
          - Left and Right graphic images

Boom3C (courtesy of Fakespace Labs.)
21” LCD display, Resolution: SXGA (1600x1200)  
Weight: Counter-Balanced;  
No dead space but High latencies due to Third-party tracker.