3D User Interface Hardware

Lecture #5: Visual Displays
Spring 2017
Joseph J. LaViola Jr.

Interaction Workflow
Introduction To Displays

- **Display**: device which presents perceptual information
- Often ‘display’ used to mean ‘visual display’
- Goal: display devices which accurately represent perceptions in simulated world

Lecture Outline

- Visual System
- Depth Cues
- Visual Display Characteristics
- Visual Display Examples
  - single screen displays
  - surround and multi-screen displays
  - workbenches and tabletop displays
  - head mounted displays
  - anywhere displays
  - autostereoscopic displays
Vision

- Stimulus: light of wavelengths \( \sim 350-750 \) nm

- Visual dominance: 50% of brain involved in processing!

Eye Physiology

- Camera metaphor:
  - lens (can change)
  - film (retina)
  - amount of exposure (pupil)
Retina

- Photoreceptors: rods & cones
- Distinction of function
  - rods: periphery, motion, B&W, sensitivity
  - cones: fovea, static, color, acuity

Rod/cone Distribution

# rods/cones

position on retina

“blind spot”

cones

rods
Depth Cues – How Do We See 3D?

- Monocular/static cues
- Occulomotor cues
- Motion Parallax
- Binocular Disparity and Stereopsis

Monocular/Static Cues

- Relative Size
- Height relative to horizon
Monocular/Static Cues

- Occlusion and Linear Perspective

Monocular/Static Cues

- Shading, Lighting, and Texture
Oculomotor Cues

- Accommodation - physical stretching and relaxing of eye lens
- Convergence - rotation of viewer's eyes so images can be fused together at varying distances

Motion Parallax

- Stationary viewer vs. moving viewer
Binocular Disparity and Stereopsis

- Each eye gets a slightly different image
- Only effective within a few feet of viewer
- Many implementation schemes

Accommodation-Convergence Mismatch

- Standard stereo displays confuse the brain based on oculomotor cues
- Only “true 3D” displays can provide these correctly
Visual Display Characteristics

- Field of View (FOV) and Field of Regard (FOR)
  - FOR - amount of physical space surrounding viewer in which visual images appear
  - FOV - maximum visual angle seen instantaneously
- Spatial Resolution
  - number of pixels and screen size
- Screen Geometry
  - rectangular, hemispherical, etc...
- Light Transfer Mechanism
  - front projection, rear projection, laser light, etc...
- Refresh Rate
  - not the same as frame rate
- Ergonomics

Single Screen Displays

- Ordinary monitor, TV, tablet equipped with emitter and shutter glasses
Stereo Monitor – Advantages

- Least expensive in terms of additional hardware over other output devices
- Allows usage of virtually any input device
- Good resolution
- User can take advantage of keyboard and mouse

Stereo Monitor – Disadvantages

- Not very immersive
- User really cannot move around
- Does not take advantage of peripheral vision
- Stereo can be problematic
- Occlusion from physical objects can be problematic
Surround and Multi-Screen Displays

- Has many screens and projectors (often planar at 90 degree angles)
- Surround user for visual immersion
- Usually driven by a single or group of powerful graphics engines
Surround and Multi-Screen Displays

Display with screens at 120 degree angles

Surround and Multi-Screen Displays

Multi-screen surround displays where the screens are at nonorthogonal angles.
Surround and Multi-Screen Displays

Non-planar surround screen displays (cylindrical and hemispherical)

SS Displays – Advantages

- Provides high resolution and large FOV
- User only needs a pair of light weight shutter glasses for stereo viewing
- User has freedom to move about the device
- Environment is not evasive
- Real and virtual objects can be mixed in the environment
- A group of people can inhabit the space simultaneously
SS Displays – Disadvantages

- Can be expensive (6-7 figures)
- Requires a large amount of physical space
- Calibration must be maintained
- Non-planar displays require nonstandard projection
- No more that two users can be head tracked
- Stereo viewing can be problematic
- Physical objects can get in the way of graphical objects

SS Displays – Interface Design

- Do not need to represent physical objects (i.e. hands) as graphical objects
- Can take advantage of the user’s peripheral vision
- Do not want the user to get too close to the screens
- Developer can take advantage of the space for using physical props (i.e. car, motion platform)
Workbenches and Table Top Displays

- Similar to SS Displays but one display (two at most)
- Traditionally a tabletop metaphor
- Considered a smaller version of SS Display
Workbenches and Table Top Displays

Workbench Displays - Advantages

- High resolution
- For certain applications, makes for an intuitive display
- Can be shared by several users
Workbench Displays - Disadvantages

- Limited movement
- At most two users can be head tracked
- No surrounding screens
- Physical objects can get in the way of graphical objects
- Stereo can be problematic

Workbench Displays - Interface Design

- Ergonomics are important especially when designing interfaces for table displays
- User can take advantage of direct pen-based input if display surface permits
- No need to make graphical representations of physical objects
Head Mounted Displays

- Device has two CRT, OLED, or LCD screens plus special optics in front of the users eyes
- User cannot naturally see the real world
- Provides a stereoscopic view that moves relative to the user

Variants
- Virtual Retinal display
- Arm mounted display
Head Mounted Displays

- Used for Augmented Reality
  - video see through
  - optical see through

HMDs - Advantages

- Provides an immersive experience by blocking out the real world (except for AR)
- Fairly easy to set up
- Does not restrict user from moving around in the real world
- Good quality HMD is relatively inexpensive
- Can achieve good stereo quality
HMDs – Disadvantages

- Often have reduced field of view (FOV)
- Does not take advantage of peripheral vision
- Isolation and fear of real world events
- Devices can cost in the 100,000 dollar range
- Sometimes do not fit well

HMDs – Interface Design

- Physical objects require a graphical representation
- Limits the types of input devices that can be used
Anywhere Displays

- Goal is to use anything as a display screen
  - objects
  - non planar surfaces
- Projection mapping
- Spatial augmented reality
AutoStereo displays

- Lenticular
- Volumetric
- Holographic

Simulated Autostereo - pCube

University of British Columbia
http://hct.ece.ubc.ca/research/pcube/
Other Display Technologies

SidebySide/Motion Beam
Disney Research, Pittsburgh

Compressive Displays
Ramesh Raskar, Camera Culture Group, MIT
Which Visual Display to Use?

- Consider lists of pros and cons
- Consider depth cues supported
- Consider level of visual immersion
- But this is a very hard question to answer empirically

Next Class

- Audio and Haptic displays
- Readings
  - 3DUI Book - Chapter 3, pages 29-59