Displays for VR

Derek Juba, and Amitabh Varshney

Light Polarization

- Light has an electric (E) and a magnetic field (B)
- Light is polarized if the electric field oscillates in a specific manner
- Possible polarizations: horizontal, vertical, circular (clockwise or counter-clockwise) and elliptical (clockwise or counter-clockwise)
- Sunlight is not polarized

Image from www.uwgb.edu/dutchs/petrolgy/genlight.htm
Liquid Crystal Display

- Passive Matrix: Grid of wires crossing at each pixel
- Active Matrix: Transistor-per-pixel to maintain voltage
- Color: 3 such cells per pixel, dyes for colors

Digital Micromirror Devices

- Texas Instruments DMD chip
  - has >500,000 addressable mirrors
  - 1 Mirror per Pixel
- Light beam reflected from DMD chip to screen
- Bright, better contrast ratio

Images from Fig 2.15 Computer Graphics by Hearn and Baker

Image Courtesy: Raytheon
Types of 3D Devices

• Stereoscopic Displays
  – Displays separate image in each eye
  – Special glasses or head mounted displays needed
  – Spatially multiplexed (anaglyph or polarized glasses)

Stereo Display Devices: Anaglyphs

• Red/blue or red/green glasses

• If the left eye has the red filter, the images for the right eye are drawn in shades of red

• Analogously for the other eye

• Inexpensive to produce images and to view (use cardboard glasses)
Stereo Display Devices: Polarized Glasses

- Left eye and right eye views are projected on a screen using orthogonal polarizing filters.
- Screen material reflects light while preserving the light polarization.
- Glasses have corresponding polarizing filters to view appropriate images.

Types of 3D Devices

- Stereoscopic Displays
  - Temporally multiplexed (LCD shutter glasses)
  - More expensive but better quality
  - Shuttering synchronized by RF or IR
Stereo Display Devices: LCD Shutter Glasses

- LCD panel in front of each eye
- When left eye’s view is displayed on monitor, the right eye LCD turns opaque while the left eye LCD is clear, and vice-versa
- Infrared emitter synchronizes LCD switching with displayed frames

Stereo Display Devices: Head-Mounted Displays

- Small displays in front of each eye
- Optics engineered to make the images appear several feet away
- Higher-end models are designed to block outside light, and inter-ocular distance adjustments
Stereo Display Devices: Retinal Displays

- Different colored lasers scan images directly onto retina
- Advantages: Small, lightweight, could reach very high resolution approaching human vision, very low power consumption

Image courtesy of Microvision

Stereo Display Devices: Autostereoscopic Displays

- Glasses-free Stereo Viewing
- Multiple viewing zones
- Use a lenticular screen to achieve stereo

Image Courtesy of Stereographics

Lecture 9
Autostereoscopic Displays: Parallax Barrier Method

Used since early 1900’s

Images Courtesy of Paul Bourke
Autostereoscopic Displays:
Parallax Barrier Method

Multiple Viewing Zones

Images Courtesy of Paul Bourke

Lecture 9

Autostereoscopic Displays:
Lenticular Method

Lenticular screens on LCD panels
Huge surge of interest ~2003
Stereographics displays, Sharp Electronics laptop, …

Image Courtesy of Paul Bourke

Lecture 9
Types of 3D Devices

- Autostereoscopic Displays
  - Parallax-based Displays
    - Expensive
    - Uses either lenslet arrays or parallax barriers
    - Inadvertent color degradation due to refraction in lenslet arrays
    - Cross-talk across views and color channels.

Stereo Display Devices: Direct Volume Display Devices

Holographic Princess Leia (Star Wars)
Stereo Display Devices: Direct Volume Display Devices

- Multiple infrared lasers scan glass cube at 30 – 60 Hz
- Glass cube is treated with special ions
- Laser excites the ions to higher energy states
- Ions give off light at a particular voxel (volume element) when they return to the unexcited state
- One-inch cube prototype

Image courtesy of 3D Technology Labs and Elizabeth Downing

Autostereoscopic Devices

Volumetric Displays
- Can only show transparent objects
- Uses a participating medium such as vapor or a moving (typically revolving) surface
- Can display an object at different depths so that they do not suffer from vergence-accommodation conflict
- They often fail to show monocular depth cues such as shading, texture gradients, and occlusion
Holograms

- Introduced by Dennis Gabor in 1948
- Provides depth cues through binocular disparity, motion parallax, accommodation, and convergence much like an object in the real world
- Can be very thin and produce images in full natural color

![Dynamic hologram updated every 2 sec [Blanche et al. 2010]](image)

Holographic Devices

- The acquisition of data for holographic display is difficult
- The amount of computation that is required to compute a hologram is high
- Dynamic updates on the polymers used in holograms are still very slow (0.5Hz)
- The depth of field that can be shown by a hologram is limited
Other Recent Displays

- OLED (organic LEDs)
- E-Ink
- Pico Projectors

OLED

- Place a series of organic thin films between two conductors
- Electrical current causes bright light to be emitted
- First developed in early 50’s in France by Bernanose *et al.*
OLED

$h^+ & e^{-}$ meet to form an exciton on a molecule or same conjugated segment of polymer

- The four layers are collectively 100 to 500 nm thick
- OLED emits light

OLED Features

- Thin
- Sony XEL-1: OLED TV
  - 11” screen, 3mm thin, 1.9kg, 178 deg viewing angle, 1:1,000,000 contrast ratio
OLED Features

- Flexible

http://www.crunchgear.com/wp-content/photos/oled_01.jpg

OLED Features

- Transparent

Slide 27  Lecture 9

Slide 28  Lecture 9
OLED Features

- Top-Emitting

OLED Summary

- **Pros**: Consume much less power than LCD, brighter than LCDs, organic layers can be multi-layered, emit light, thin, …

- **Cons**: Expensive to manufacture (water destroys organic layer – need to use complex sealing/ manufacturing processes)

- OLED material from talks by Joe Shinar (Iowa State), Grant Warfield (Harding Univ), & other sources on the web
Electrophoretic Displays: E-Ink

R G B R G B

E-Ink

1 2 3 4 5 6 7 8 9 10 11
E-Ink

- Spun-off in 1997 from MIT Media Lab
- E-ink: Single company that makes extremely low-power, grayscale, non-illuminated displays on *most popular* e-book readers
  - Amazon Kindle, Sony Reader, Barnes and Noble nook, CyBook Gen3, iLiad, etc..
  - Esquire magazine
    http://www.esquire.com/the-side/video/e-ink-cover-video
- The Daily Prophet from Harry Potter
  http://www.youtube.com/watch?v=oq_2LiTxhls
  http://www.youtube.com/watch?v=3n2xxqMQyfY

Pico Projectors
Inside a Pico Projector (Optoma)

http://www.memsindustrygroup.org/i4a/pages/index.cfm?pageID=3675
Projector-Camera Opportunities (Ramesh Raskar)

- Aware Projectors
  - Decoupled display size

- Image Overlay on Real Objects
  - Decoupled device
  - Non-planar surfaces

- Machine Projection
  - Projector for non-display apps

RFID ↔ RFIG
(Radio Frequency Id & Geometry)

Find tag location using Pocket Projector

Interactive stabilized projection
Many geometric ops

Siggraph 2004
Using Projector to Interact with Tagged Books in a Library

With RFID, get list of books in RF range

• With Precise Location Data
• Find which books are out of sorted order!

Support for handheld projection + RF Reader

Camera  RF Transponder  Inertial Sensor
Projector  Laser Ptr
Directions for PocketProjector

• ‘Personal’ display
  - Shrinking portable devices that carry more data
  - Opportunity to switch between personal and public

• Modular
  - Low cost mass market product
  - Will become building block
    • Platforms: TV, Stereoscopic, Advertising, VideoWalls etc
    • Process: Tiling, Jittering, Superposition, Steering

http://www.ted.com/index.php/talks/pattie_maes_demos_the_sixth_sense.html

Vergence-Accommodation Conflict

Scientific Literature has identified vergence-accommodation conflict causes a variety of psychophysical problems including:
  - induced binocular stress
  - difficulty in fusing the two images into a stereo pair
  - the perception of scene geometry
  - discomfort

(Image is from [Kroeker 2010]).
The Challenge

- Popular press has reported a number of viewers complaining about 3D movies giving them headaches, nausea, blurred vision, and other symptoms of visually-induced motion sickness.
- A principal suspect is widely believed to be the vergence-accommodation conflict.