Stereoscopy

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Stereoscopy

• a large part of our brain is devoted to understanding visual cues
• depth information can help us to understand spatial relationships in a complex data set
Binocular Vision

• our two eyes produce a single image in the brain – a “Cyclopean image”
• creatures with binocular vision generally have forward-facing eyes that move together

Binocular Vision

• animals that tend to get chased find it useful to have a **panoramic** view of the world
  – rabbits have almost 360 field of vision
• animals that do the chasing need to be able to judge distance to their prey accurately
  – predators tend to move fast, if they are inaccurate in distance estimates they will starve or injure themselves
• tree apes need to be able to judge the distance to the next branch accurately
Binocular Vision

Human Interpupillary Distance (IPD)

- need separation between our eyes to see in stereo
- different sources provide different values for this number
- mean adult IPD is around 63 mm
- the vast majority of adults have IPDs in the range 50–75 mm
- the wider range of 45–80 mm is likely to include (almost) all adults
- and the minimum IPD for children (down to five years old) is around 40 mm

Binocular Vision

- our eyes are separated by about 6.5 cm so our retinas each get a slightly different view of the world
- the right actually sees more distance between the objects (as well as slightly different parts of the surfaces)

Binocular Vision

- components of stereo vision:
  - convergence of the eyes (achieved by the eye muscles)
  - accommodation (focus) of the lens to provide sharp images on the retinas
Binocular Vision

• Convergence angles for different distances given 6.3 cm for the eye separation
• as the convergence angle decreases the difference between images on the retina becomes smaller and the stereo effect is reduced

<table>
<thead>
<tr>
<th>Distance</th>
<th>Convergence Angle (deg)</th>
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<tbody>
<tr>
<td>10 cm</td>
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<tr>
<td>30 cm</td>
<td>12.0</td>
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<td>60 cm</td>
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<tr>
<td>200 cm</td>
<td>1.8</td>
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<tr>
<td>500 cm</td>
<td>0.72</td>
</tr>
<tr>
<td>1000 cm</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Binocular Vision

• if retinal images are very different the eyes try to adjust to make them more similar
• once the brain has fused the images into one object, the small differences on the retina are interpreted as the 3rd dimension
• our brains interpret the two views as a scene with depth and does a great job of judging distances from us, up to about 20 feet (diminishes but works up to ~200 m)
Binocular Vision

• image from left eye is sent to the right half of the brain
• the brain deciphers retinal differences and interprets them as 3D information
• the interpretation can take time
• with practice the computations can go faster (they get “hardwired”)
• Image from “Eye Brain and Vision” by David H. Hubel

Non-stereo Depth Cues

• occlusion – near objects block the view of distant objects
• apparent size – if two objects are actually the same size, but one appears smaller, then the small one is farther away than the larger
• motion parallax – near objects appear move faster than distant objects
• perspective – parallel lines converge in the distance

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Non-stereo Depth Cues

- texture - becomes finer with distance
- colour change – colour becomes more blue with distance
- haze – objects become fuzzy in the distance
- accommodation – our brain knows how hard our eyes are working to focus

What is Stereoscopy?

- a technique to create the illusion of depth in a photograph, movie, or other two-dimensional image
- need to present a slightly different image to each eye
- stereoscopic viewer invented by Sir Charles Wheatstone (1838)
What is Stereoscopy?

- no photography yet
- stereo pairs were created by hand: drawing and painting

Salvador Dali – The Chair (1975)
What is Stereoscopy?

- a 1905 stereoscope can be upgraded with a couple of IPod-Photos

Cross-eyed Stereo

- look at the stereo pair by crossing your eyes.
- left eye sees the right image and right eye sees the left image
Stereoscopy

• to create depth perception in the brain provide to the eyes of the viewer with two different images
• two perspectives of the same object
• minor deviation similar to the perspectives that both eyes naturally receive in binocular vision

Stereoscopy

• simple test for stereo:
• hold a pencil in front of your nose and look into the distance
• do you see 2 pencils?
• some people don’t see 2 pencils because their brains suppress information from one eye
• the suppressed eye can shift from left to right
• there might be permanent suppression of one eye
• people with one eye suppressed won’t be able to see in 3D
Active Stereo

- requires shutter glasses and a monitor or projector with a fast refresh rate
- the image for the left eye is alternated with the image for the right and the shutters are timed to allow the appropriate eye to see the image

Active Stereo

- DepthQ by InFocus
- announced March 2005
- low cost ~$3500USD
- 120 Hz refresh rate
- 800x600 native resolution
- DLP technology
- http://www.depthq.com
Active Stereo

- NuVision 60GX wireless stereoscopic LCD glasses and emitter
- infrared emitter is synchronized with the video output to control the shutters in the glasses

Passive Stereo

- relies on two projectors or overlaid display surfaces
- wear glasses that separate the images for the left and right eyes
  - anaglyph
  - polarizers
  - ChromaDepth (one image)
  - Pulfrich lenses (one image)
Anaglyph Stereo

• the image for one eye is red and the image for the other eye is blue
• need to be aware of the orientation of the images: left-eye-red and right-eye-blue or vice versa
• view with inexpensive red/blue 3D glasses
• this is especially useful for stereo viewing of games on flat panel LCD monitors, which cannot be used to view page flip stereo

Anaglyph Stereo

• NASA recommends Reel3D red/cyan glasses for viewing the Mars Pathfinder anaglyphs

http://www.nasm.si.edu/research/ceps/etp/mars/pathfinder/MPF3D.html
http://www.stereoscopy.com/reel3d/anaglyph-glasses.html#7026
ChromaDepth

• left lens is ordinary plastic film
• right lens is in essence a prism – light is deflected according to its colour
  – yellow is bent to the left
  – blue is bent to the right
• yellow objects look closer than blue objects
• glasses were originally made by Chromatek Inc.
  – now American Paper Optics, Inc.
ChromaDepth

- the stereo effect comes from color only – there is only one image in this system
- with a black background:
  - dark blue for the most background object
  - green for the middle-ground
  - red for the most foreground object
  - other colors fall in between according to the colors of the rainbow
- images by Mike Bailey from the San Diego Supercomputing Center
Auto-stereo Devices

- the "Holy Grail" of virtual reality
- a display device which displays 3D stereo without glasses
- DTI 2018XLC Virtual Window
- left and right images are shown simultaneously
- light for the different images goes in slightly different directions because of a hardware "barrier"
- this provides each eye with the correct image
Virtual Reality

- we can surround ourselves with 6 walls rendering stereo images
- huge amounts of visual data available but this isn’t Virtual Reality
- even though you are viewing data that your brain is interpreting as having depth, in fact you are viewing flat images and if you move your head from side to side you don’t get a different view of the objects

Virtual Reality

- in the real world, if you move your head around an object you get to different views of that object ... this is what gives you the sense that the object is 'present' in front of you.
Virtual Reality

• to enable this sort of change of view the user must tell the computer where he is in relation to the objects in the virtual world at all times
• some portion of the users body be tracked
• i.e. information is somehow gathered and supplied to the computer continuously so the view of the world can be updated as the user changes position

Virtual Reality

• this sort of feedback now makes it easy to believe that you are in a “virtual world”
• if you are deeply engaged in this world to the point that you can accept that you are present you have achieved “mental immersion” – suspension of disbelief
• one requirement (possibly the strongest) for VR has been described as “presence”
Virtual Reality

- other senses can be included to enhance the effect of the environment
- add a force feedback game controller for tactile feedback (haptics)

Virtual Reality

- a complete virtual world should incorporate a three dimensional sound field that reflects the conditions modeled in the virtual environment
- this sound field has to react to walls, multiple sound sources, and background noise, as well as the absence of them
Virtual Reality

• requires massive computational power and speed because hearing is a complex system which uses the shape of the outer ear and microsecond delays in the arrival of sound to the two ears to determine position and location of the source of the sound

Safety Issues

• A small percentage of the population may experience epileptic seizures when viewing certain types of TV images or video games that contain flashing patterns of light.

• The following people should consult a physician before viewing in stereo:
  – Children under 5 years of age
  – Anyone with a history of epilepsy, or who has a family member with a history of epilepsy
  – Anyone who has ever experienced epileptic seizures or sensory disturbances triggered by flashing light effects.
Safety Issues

• Some light patterns may induce seizures in persons with no prior history of epilepsy.
• Discontinue stereo use if you experience any of the following symptoms while viewing stereo images:
  – Involuntary movements, eye or muscle twitching
  – Muscle cramps
  – Nausea, dizziness, or queasiness
  – Convulsions
  – Disorientation, confusion, or loss of awareness of your surroundings

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