Stereoscopy and Depth Perception

EPFL Immersive Interaction Group
Based on Dr Nan Wang course
Outline

• Stereoscopic vision (stereopsis)
• Understanding depth
• Depth cues effectiveness
• Overview of stereoscopic delivery
Stereoscopic vision (stereopsis)

- Principle identified by C. Wheatstone (1838)

2 Views Fused in the Brain = Stereovision

- Each eye captures its own field of view

- The two eye field of views are recombined (in the optic chiasm) into a right and a left visual field

- The right visual field (red pathways) is sent to the left brain hemisphere, and vice-versa.

- The small differences between the left and right source of the visual signals add up to a big difference (Depth information)
Stereoscopic vision

• Advantage of stereoscopic vision
  – Offer depth information -> moving toward or away from viewing point
  – In VR, provide the depth information by displaying different images for the right and the left eyes, matching the user's parameters.
Understanding depth

• Depth information perception:
  – Oculomotor cues: Convergence and Accommodation
  – Visual cues: Monocular and Binocular
Understanding depth

– Monocular cues:
  • Linear perspective
  • Relative Size
  • Texture Gradient
  • Occlusion
  • Shading
  • Tilt-shift
  • Motion Parallax
  • Atmospheric blur
Understanding depth

**Motion Parallax:**

- for 2 entities with the same size, located at different depths and moving perpendicularly to the view axis, the closer one moves more on the retina than distant one.

- Conversely, moving the eye in front of static entities leads to a larger movement on the retina for the closest one.

-> cheap and powerful means for providing depth cues
Understanding depth

- **Convergence**: the angle formed by your eyes and the observed object. The higher the angle value is, the nearer the observed object is to your two eyes, and vice versa.

- **Accommodation**: process of changing optical power to maintain a clear image (focus) on an object as its distance varies.

Accommodation and convergence allow us to see objects clearly both near and far without diplopia (double vision)
Understanding depth

**Parallax**: is a displacement or difference in the apparent position of an object viewed along two different lines of sight.
Understanding depth

• 3 types of parallax (1:3):
  – **Positive parallax**: The projection for the left eye is on the left and the projection for the right eye is on the right, the distance between the left and right eye projections is called the **horizontal parallax**.
Your convergence point is lead to fall behind the display.
Understanding depth

• 3 types of parallax (2:3):
  – **Negative parallax**: If an object is located in front of the projection plane then the projection for the left eye is on the right and the projection for the right eye is on the left.

The L and R images lead your convergence point to fall in front of the display.
The L and R images lead your convergence point to fall in front of the display.
Understanding depth

- **Zero parallax**: If an object lies at the projection plane then its projection onto the focal plane is coincident for both the left and right eye, hence zero parallax.

The L and R image lead your convergence point to fall on the display.
Understanding depth

The L and R image lead your convergence point to fall on the display.

Depth cues effectiveness: J. Cutting and P. Vishton
Stereoscopic delivery

• Perceive 3D image from 2 separated images
  – Perceptual effort
    • Wall-eyed or Cross-eyed
  – Individual optics
    • HMD
  – Filtering glasses
    • Anaglyph
    • Polarization
    • Shutter
Stereoscopic delivery: stereo pairs

- Wall-eyed or Cross-eyed

https://www.lhup.edu/~dsimanek/3d/view3d.htm

http://www.starosta.com/3dshowcase/ihelp.html
Stereoscopic delivery

- **Anaglyph**: Photography, cinema, TV, etc..

<table>
<thead>
<tr>
<th>scheme</th>
<th>left eye</th>
<th>L</th>
<th>R</th>
<th>right eye</th>
<th>color rendering</th>
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<td>pure red</td>
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<td>pure green</td>
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<td></td>
<td></td>
<td>pure cyan (green+blue)</td>
<td>color (poor reds, good greens)</td>
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</table>
Stereoscopic delivery

• Auto-stereoscopic display
  – **parallax barrier** is a device placed in front of an image source
  – allowing each eye to see a different set of pixels
Stereoscopic delivery

• **Polarized glasses (passive)**: two images are projected superimposed onto the same screen or displayed through different polarizing filters.
Stereoscopic delivery

- Shutter glasses (active):
  - presenting the image intended for the left eye while blocking the right eye's view
  - then presenting the right-eye image while blocking the left eye
  - repeating rapidly
Stereoscopic delivery (HMD)

• Most common 3D format
  – Side by side:
    • halving the horizontal resolution of videos to store left and right eye images in each frame
    • Provide full frame rate at the cost of image resolution
Conclusion

• Stereopsis is only one means among many others to achieve depth perception
• True stereopsis requests providing one image per eye (double computational cost)
• A powerful alternative at a cheaper cost is motion parallax as it requires a single image
  – Depth is obtained through the viewpoint movement

• Implementation details with OPEN GL will be presented together with the presentation of the CAVE display

• Perceptual conflicts will be presented with the presentation on Cybersickness