Announcements

• Read LaValle, Chapter 4,5.

• **MP4** - due on Nov 6, 11:59mp.
- focus
- optical distortion
Eye Motion and VR: 2. VOR Gain Adaptation

VOR gain under various VR stimulation + distortion
1. Pixels on the display switch their color/intensity at some non-zero rate.
2. There is RGB sub pixel structure.
3. Frames might be off (black) at particular times.
4. Asynchronous (line-by-line) display scan out.

5. Photoreceptors are slow to respond. It takes them about 0.1-0.2 seconds to respond.
6. All of the eye movements shift the image on the retina.

7. Perception
Retinal Circuitry

Source: Adapted from Dowling, J. E., and Boycott, B. B. *Proceedings of the Royal Society of London, B.*, 1966, 166, 80–111
Hierarchical Processing: Receptive Field Model

Photoreceptors -> Bipolar cells -> Ganglion cell

- Photoreceptors: ~126,000,000
- Bipolar cells: ~1,000,000

Diagram showing the connections between photoreceptors, bipolar cells, and ganglion cells, illustrating the hierarchical processing in the eye's visual system.
Ganglion Cells Response to Edges

Input image (cornea)

“Neural image” (retinal ganglion cells)

Center-surround receptive fields: emphasize edges.
Receptive Fields of Ganglion Cells

A On-center ganglion cells
- On area (center)
- Off area (surround)

B Off-center ganglion cells
- Off area (center)
- On area (surround)

1 Central spot

2 Peripheral spot

3 Central illumination

4 Surround illumination

5 Diffuse illumination

Light on

https://www.youtube.com/watch?v=8nSLz4Kx7sg

0:45
Ganglion Cells Preprocessing of an Image
Hierarchical Processing: Visual Pathways

- Visual area of the thalamus
- Optic nerve
- Optic chiasm
- Optic tract
- Visual cortex
- Retina
Single Unit Recording

stimulus presented on TV screen

visual cortex

lateral geniculate nucleus

recording electrode

Adapted from Zeki, 1993
Single Unit Recording

**Figure 4.8** Response of a single cortical cell to bars presented at various orientations.

Hubel and Wiesel experiments

https://www.youtube.com/watch?v=KE952yueVLA
https://www.youtube.com/watch?v=Cw5PKV9Rj3o
Visual Cortex Hierarchy

Nature Reviews | Neuroscience
Studying **perception** is studying how the brain makes conclusions about visual information.

**Cues** are visual features that trigger the brain to make conclusion about visual concepts.

**Two kinds of depth cues:**
- Metric (continuous)
- Ordinal (combinatorial)

**Importance to VR:** If we present enough of depth cues to the brain, the computation can be done in the brain instead of expensive GPUs and CPUs!!!

**Ex.** panoramas
Monocular Cues for Depth Perception:

SENSATION & PERCEPTION 3e, Figure 6.12
Depth Perception:

http://psych.hanover.edu/Krantz/art/rel_hgt.html
Depth Perception:

http://psych.hanover.edu/Krantz/art/rel_size.html
http://www.psypress.co.uk/mather/resources/swf/Demo10_3.swf
Depth Perception:
Depth Perception:

http://psych.hanover.edu/Krantz/art/texture.html
Depth Perception:
Have you seen VR experiences taking advantage of this? Be the first one!
Depth Perception:

http://www.psypress.co.uk/mather/resources/swf/Demo10_1.swf
Depth Perception:
Depth Perception:
Depth Perception:
Depth Perception:
Depth Perception:

http://www.psypress.co.uk/mather/resources/swf/Demo10_3.swf
Depth Perception:

https://en.wikipedia.org/wiki/Spinning_Dancer
Depth Perception:

Proprioception cues
Oculor motor cues
Depth Perception:

http://www.psypress.co.uk/mather/resources/swf/Demo10_2.swf

http://psych.hanover.edu/Krantz/MotionParallax/MotionParallax.html
Binocular Cues For Depth Perception:

- **Observer**
  - **Left-eye view**
  - **Right-eye view**

- **Daffodil**
- **Tulip**

- **Seen by left eye**
- **Seen by right eye**
Depth Perception:

Uncomfortable in VR?
Depth Perception:

- B > A

Diagram illustrating depth perception in the human eye.
<table>
<thead>
<tr>
<th>Monocular</th>
<th>Binocular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retinal image size</td>
<td>Vergence angle</td>
</tr>
<tr>
<td>Height in visual field</td>
<td>Binocular disparity</td>
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<tr>
<td>Texture gradient</td>
<td>Diplopia</td>
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<td>Atmospheric perspective</td>
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<td>Motion parallax</td>
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<td>Shadows/ shading</td>
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<td>Interposition</td>
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</tbody>
</table>

**Combination of depth cues:**
- Decision theory; machine learning
- Bayesian/probabilistic
  - Priors/Bias
  - Consistent or contradictory
  - How discriminatory is each cue in the context