Depth Perception, part II

Lecture 13
(Chapter 6)

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Depth and scale estimation from accommodation

“tilt shift photography”

Keith Loutit (artist):

tilt shift + time-lapse photography

https://vimeo.com/10792824

http://vimeo.com/keithloutit/videos
nice illusions video - car ad (2013)
(anamorphosis, linear perspective, accidental viewpoints, shadows, depth/size illusions)

https://www.youtube.com/watch?v=dNC0X76-QRI
countering the depth-from-focus cue
Monocular depth cues:

Pictorial
- occlusion
- relative size
- shadow
- texture gradient
- height in plane
- linear perspective

Non-Pictorial
- motion parallax
- accommodation ("depth from focus")
• **Binocular depth cue**: A depth cue that relies on information from both eyes.
Two Retinas Capture Different images

(a)

(b)

Right retinal image

Left retinal image
Finger-Sausage Illusion:
Pen Test:

Hold a pen out at half arm’s length

With the other hand, see how rapidly you can place the cap on the pen.

First using two eyes, then with one eye closed
Binocular depth cues:

1. **Vergence angle** - angle between the eyes

   If you know the angles, you can deduce the distance

   ![Diagram showing convergence and divergence](image)
Binocular depth cues:

2. **Binocular Disparity** - difference between two retinal images

**Stereopsis** - depth perception that results from binocular disparity information

(This is what they’re offering in 3D movies…)
Retinal images in left & right eyes

Figuring out the depth from these two images is a challenging computational problem. (Can you reason it out?)
Disparity: difference between points in L and R eye images

- Zero disparity
- Big disparity
- Zero disparity
- Small disparity
Horopter: circle of points that fall at zero disparity (i.e., they land on corresponding parts of the two retinas)

A bit of geometric reasoning will convince you that this surface is a circle containing the fixation point and the two eyes
(a) Crossed disparity

(point with crossed disparity)

appears closer

(b) Uncrossed disparity

(point with uncrossed disparity)

appears further
Is this a simple picture or a complicated computational problem?
Interpreting the visual information from three circles

Known as the “correspondence problem” - which points in the left eye go with which points in the right eye?
Wheatstone’s stereoscope

• device for presenting one different images to the two eyes
**Free fusing** - focusing the eyes either nearer or farther than this image so that each eye sees a different image
Free fusing - focusing the eyes either nearer or farther than this image so that each eye sees a different image

“Crossed-fusion”
Free fusing - focusing the eyes either nearer or farther than this image so that each eye sees a different image

“uncrossed fusion”
Random Dot Stereogram - same concept, but no detectable “features” in either image. Details of dot pattern allow brain to solve the correspondence problem.
“Magic Eye” images use same principle
If you were designing a visual system, how might you go about designing neurons tuned for different disparity?
The brain solves this problem with disparity-tuned neurons.
Binocular Vision and Stereopsis

How is stereopsis implemented in the human brain?

• Input from two eyes must converge onto the same cell

• Many neurons: respond best when the same image falls on corresponding points in the two retinas (this is the neural basis for the horopter)

• However: many neurons respond best when similar images occupy slightly different positions on the two retinas

• i.e., these neurons are “tuned to a particular disparity”
Panum’s fusional area: only certain range of disparities that the brain can fuse
- comes from distribution of disparity-tuned neurons
Depth Illusions

Müller-Lyer Illusion

https://michaelbach.de/ot/sze-muelue/
In which image are the two horizontal lines the same length?

(Ans: second from left)
Two figures are the same size
“Terror Subterra”
“Terror Subterra”
red lines are all the same length
Depth / Size illusion

• all 3 cars take up the same space in the image + on your retina!
**Defects in Stereopsis**

**Strabismus**
- eyes are not aligned, so different images fall on the fovea
- If not corrected at an early age, stereopsis will not develop

**stereoblindness**: inability to use binocular disparity as a depth cue.
Binocular Rivalry
Two stimuli battle for dominance of the percept
Chapter 6 Summary:

- monocular depth cues
- binocular depth cues (vergence, disparity)
- horopter
- crossed / uncrossed disparities
- free fusing
- random dot stereogram
- stereoscope
- “correspondence problem”
- panum’s fusional area
- strabismus / stereoblindness
- binocular rivalry (in book)