3D perception: Stereo vision

Things to do: - walk toward and away from the screen
- get (or sit) closer to see better depth
- watch your step!!

Glasses instructions: Right eye green

Make your own reverse perspective…

Pictorial depth cues

- Occlusion
- Size
- Perspective
  - Geometric perspective
  - Texture perspective
  - Aerial perspective
- Shading

Work by exploiting regularities of our environment, and provide cues about 3D shape of objects and their relative and absolute depth.

(note that motion parallax is not on this list!)

Information provided by pictorial depth cues is not always correct!
Solving the inverse problem **exactly**: Stereo vision (stereopsis)

Basis of stereoscopic vision

**Stereopsis** (literally, "seeing solid"): 3D vision resulting from slight differences in left and right eye images, arising because the two eyes view the world from slightly different perspectives

1. **Perception of stereo depth** requires two 2D images taken from slightly different positions, and presented one to each eye
2. This creates **retinal disparity**, whose magnitude increases with depth differences
3. Brain has to match images from two eyes to compute depth, i.e. solve the **correspondence problem**

Predators typically have both eyes on the front of their heads, and consequently have large binocular visual fields. In contrast, prey typically have one eye on either side of their heads, and consequently have small, if any, binocular visual fields.
Stereopsis requires two 2D images taken from slightly different positions

- Interpupillary distance (IPD)

**How do we know that having two images taken from slightly different positions is sufficient for stereopsis (i.e., 3D vision)?**

**Sir Charles Wheatstone’s Famous Invention**

Different ways of providing 2 images taken from slightly different positions

- Opening your eyes
- Stereoscope
- Anaglyph glasses
- Polarized glasses
- Active shutter glasses
- Eye crossing
- Autostereograms
- ????

Glasses instructions: Right eye green

Anaglyphs

**How they work...**

The red and blue lenses filter the two projected images, allowing only one image to enter each eye.

Anaglyph Stereograms = Blue/Red shown, Green/Red anaglyphs are used in class

Glasses instructions: Right eye green
Glasses instructions: Right eye green

Light waves involve oscillations in electric and magnetic fields

Polarized lenses only pass light whose oscillations are oriented in a particular direction

Active shutter glasses

https://www.youtube.com/watch?v=nCRyv_z-pQED
It is possible to experience stereopsis by crossing (or diverging) your eyes to make the images visually fuse.

This example is designed for convergent viewing. To see the stereo effect you must cross your eyes (i.e., converge to a point in front of the image) so that you see three equally wide panels.

(most will find this to be quite difficult or impossible)

Stereopsis requires two 2D images taken from slightly different positions

An exception (that proves the rule)

The following autostereogram (Magic Eye) is designed for divergent viewing. In order to see it correctly you must point your eyes to a point that is behind the image. If you do this correctly you will see two star shaped donuts floating in front of the background. It helps to have a visible object behind the monitor to help you focus your attention.

If instead you see a surface with spikes sticking out then you have fused it by converging your eyes rather than divergence

Different ways of providing 2 images taken from slightly different positions

- Opening your eyes
- Stereoscope
- Anaglyph glasses
- Polarized glasses
- Active shutter glasses
- Eye crossing
- Autostereograms
- ???

https://www.youtube.com/watch?v=DoAboEm4qA
Only watch from 3:27 to 6:50

Basis of stereoscopic vision

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Retinal disparity: a slight separation between retinal images of objects in left and right eyes. Retinal disparity depends on the object’s distance relative to the fixation point, and as such, it provides the geometric basis for stereopsis

The Horopter

A line connecting points (i.e., objects) that produce corresponding retinal points in the two eyes is called the horopter.

These objects are all at the same distance as the eye fixation point.

Corresponding retinal points = NO Disparity

Points at the same position on each eye correspond to one another – i.e. they have the same retinal coordinates.
Objects that are not on the horopter will be projected to non-corresponding points on the two retinas.

The direction of the disparity indicates whether an object is:
- in front of the horopter (crossed disparity)
- or behind the horopter (uncrossed disparity).

Non-corresponding retinal points = Retinal Disparity

Retinal Disparity
- Crossed Disparity – Point is in front of the fixation plane.
- Uncrossed Disparity – Point is behind the fixation plane.

Zero Disparity – right eye’s image and the left eye’s image are at the same location. Point is located on the horopter (ie., fixation plane).

Retinal Disparity = information about depth

The magnitude of disparity for any given point is defined as the difference in retinal coordinates between the optical projections of that point in the left and right eye.

Disparity - slight differences in positions of “features” in left and right eye views (Disparity is a geometric fact!)
Retinal Disparity is RELATIVE
Disparity information provides information about \textit{relative depth}

stereopsis works only within 10 - 20 ft of the observer

Bigger disparity
Smaller disparity
Same absolute depth diff
Bigger relative depth
difference

Same absolute depth diff
Smaller relative depth
difference

Retinal Disparity DEMO (optional)


Retinal Disparity is RELATIVE
Disparity depends on IPD

"ipd" = interpupillary distance (averages 6.5 cm in humans)

Basis of stereopsis

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Let’s make it hard!
Random-dot Stereograms (Julesz, 1971)

How They’re Made

Glasses instructions:
Right eye red
Let’s make one…

Glasses instructions: Right eye red

Left eye

Right eye

Both eyes

How Does the Brain “Solve” This Problem?

What dot in one eye’s view goes with which dot in the other eye’s view?

Left image

Right image

Derive the solution that maximizes the overall number of matches - i.e., that is most globally consistent.

An alternative to human correspondence matching

https://www.youtube.com/watch?v=19fahiHHToM
Basis of stereopsis

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Chromostereopsis

Chromostereopsis

Short wavelengths refract more than long wavelengths. Thus, when light is refracted through the lens of the eye, blue and red light will be focused at slightly different positions on the retina (blue light toward the nose and red light toward the temple).

This creates a disparity between each eye’s view that is perceptually interpreted as a difference in depth.
Chromostereopsis

If images in two eyes are radically different, a combined stereo cannot be found. This is a phenomenon called **binocular rivalry**.

**What Happens When Binocular Matches Cannot Be Found?**

**Binocular rivalry**

Does One Eye Dominate?

**Binocular rivalry**

Does One Eye Dominate?
Does One Eye Dominate?

Binocular rivalry

Meditation alters perceptual rivalry in Tibetan Buddhist monks

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Buddhist monks were tested at 4 monasteries in Northern India.
Methods

76 monks (5-54 years training)
including 3 "noinput" meditations
- 2/3 trials, present 2 images rivalry

1st) Familiarization

2nd) Experimental conditions
- 1 non-meditation condition & 3 different viewing conditions

- Rivalry during meditation (button-press & verbal report)
- Rivalry after meditation (button-press & verbal report)
- Rivalry during meditation (verbal report only)

Results – Switch Rate

- Compassion
  - Rivalry during meditation (n = 12)
  - Rivalry after meditation (n = 14)
  - Rivalry during meditation (n = 16)

- One point
  - Rivalry during meditation (n = 12)

Proportion of monks reporting effect (%)