Optic Array and Optic Flow

Michael Wang

What you should get out of this session

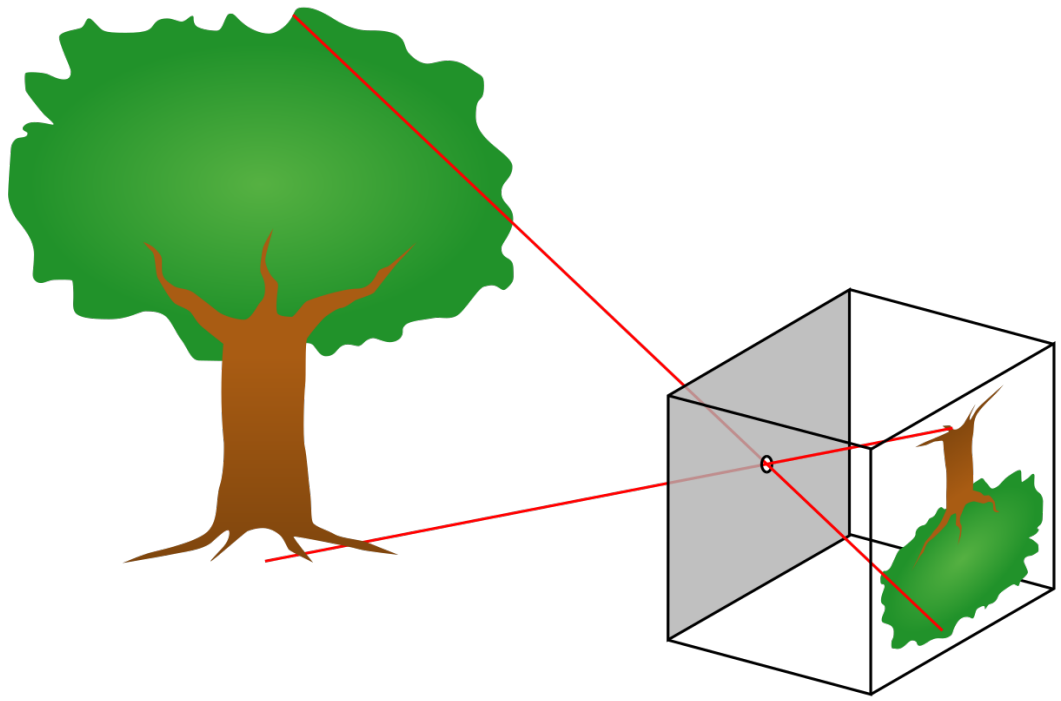
- How does the organism-environment relationship manifest in how we perceive light?
- How does the way we perceive light reflect the principle of invariant over transformation?

We need light to perceive

- “Black is the absence of light”.
- But how does light enable visual perception?

By similarity

- Similarity between patterns of light and retinal images
- Light is casted onto our retina, stimulate sensory neurons, and form retinal images.
- Like a camera



http://commons.wikimedia.org/wiki/Image:Pinhole-camera.png

But things don’t always match up

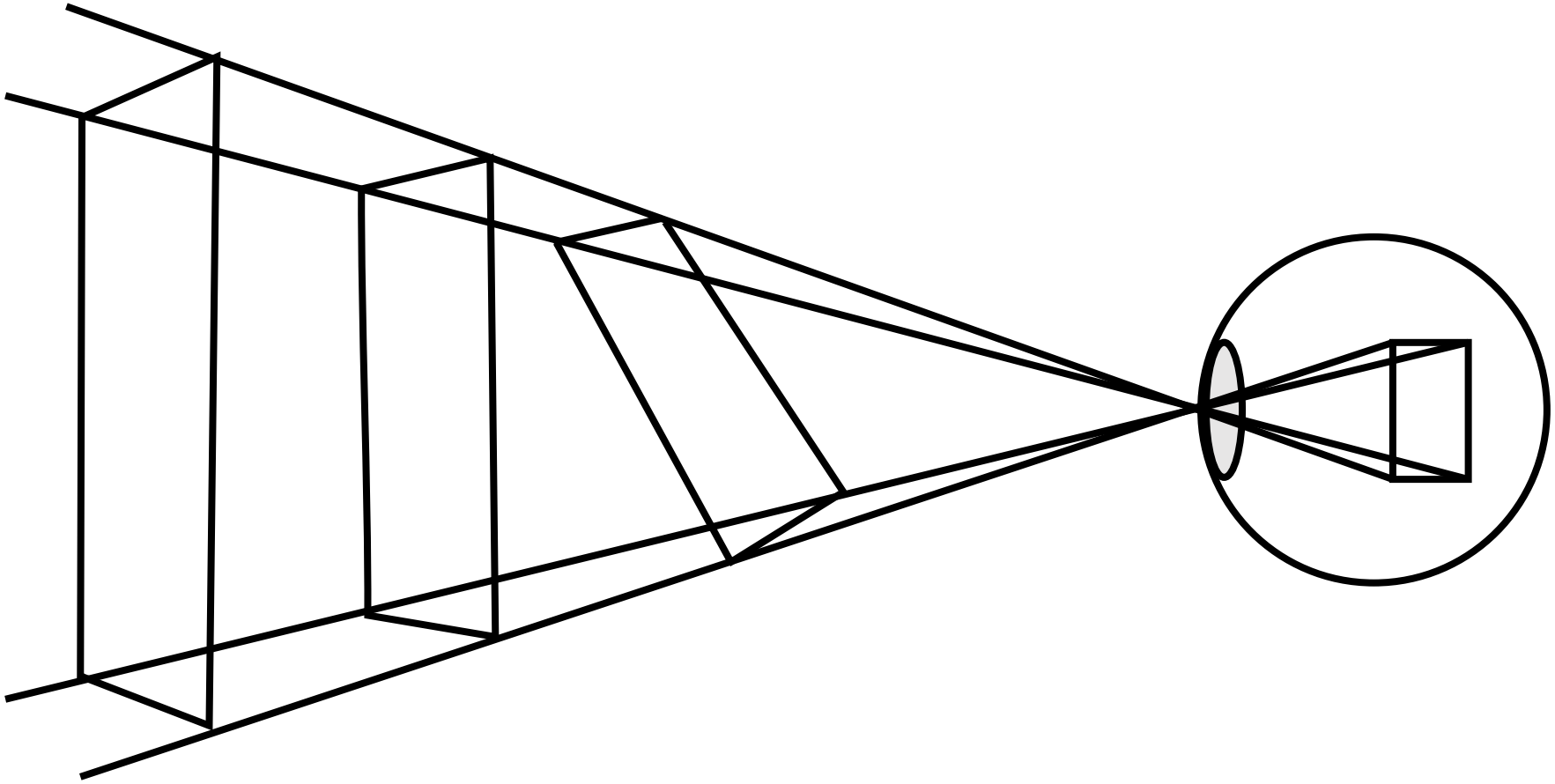
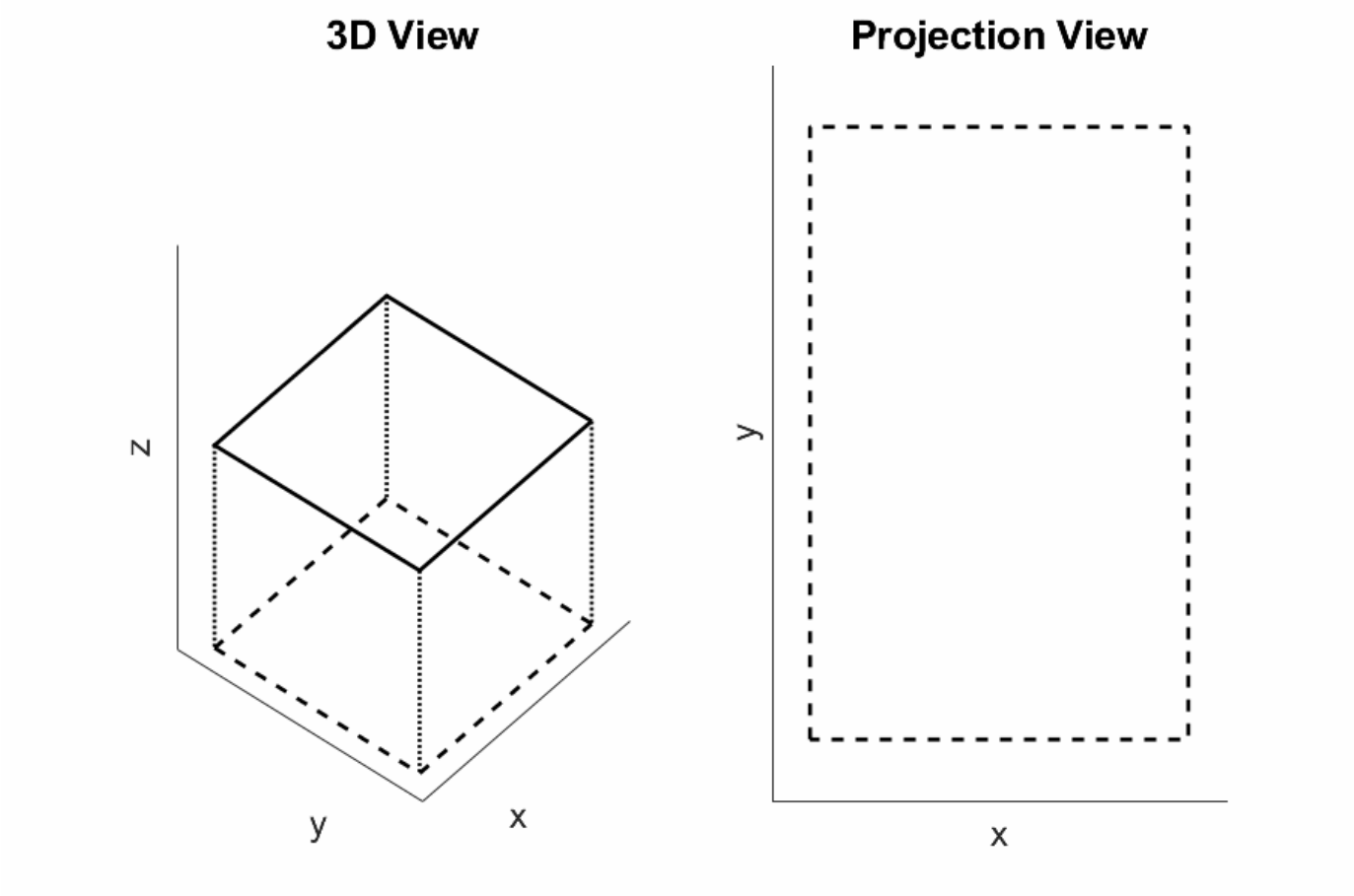


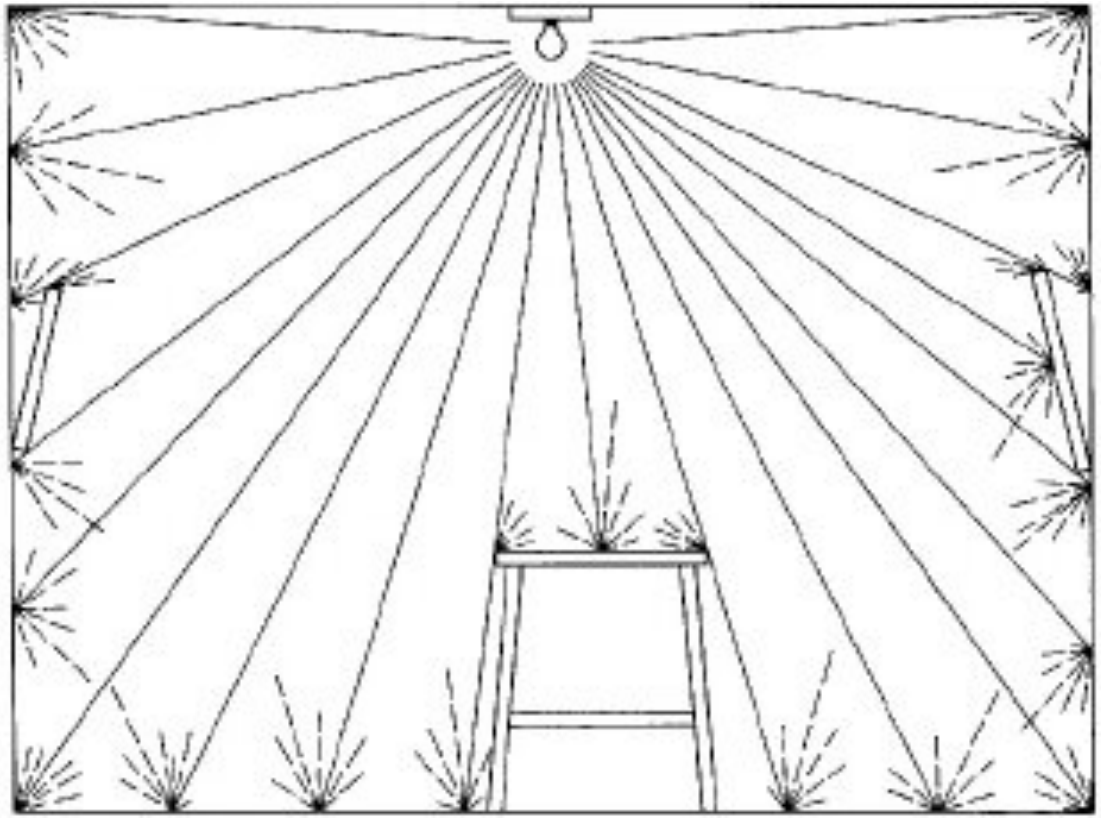
Image alone cannot uniquely determine object shape

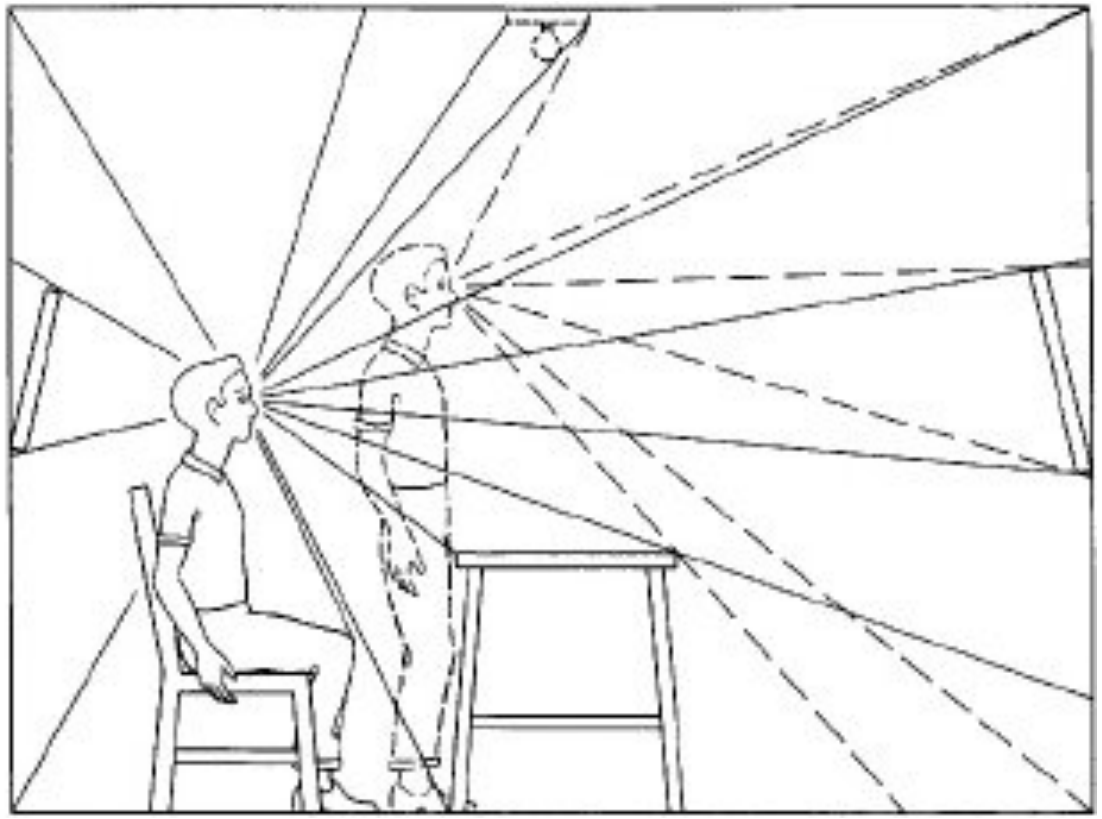


Let’s talk about light

- Radiant light
  - Diverges from a source of illumination: the sun, a lightbulb, etc.
  - Homogeneous, i.e. not structured
  - Light as energy
- Ambient light
  - AKA ambient optic array
  - Converges to a potential point of observation: the observer.
  - Heterogeneous, i.e. structured
  - Light as information

James J. Gibson (1979/1986)





Optic Array

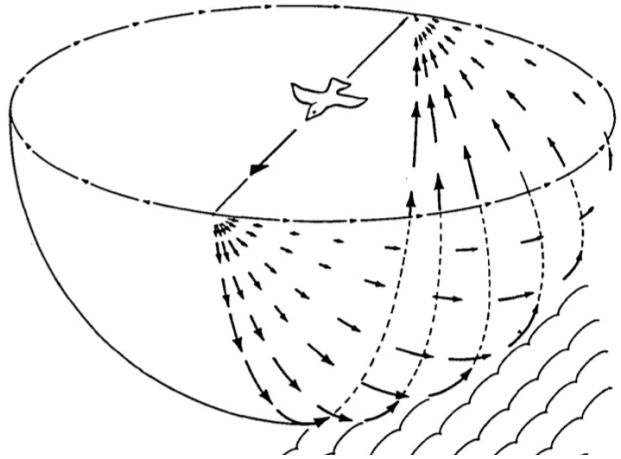
- Optic array = patterns of light, can be described using visual solid angles.
  - “Permanent possibilities of vision” (p. 191, Gibson, 1966).
- Structure in ambient light is contrasts in intensity (brightness) and quality (hue). It is determined by:
  - Surface orientation with respect to the eye, light source, other surfaces.
  - Surface texture (wood, granite, metal)
  - Surface reflectance
- Ambient optic array is 360°
  - Visual field – head-centric sample of the ambient optic array
  - Retinal image – eye-centric sample of the ambient optic array
    - Chambered eye only, not compound eye.
    - Compound eyes do not form images.

What is missing?

- Time
  - The **spatiotemporal** patterns in light provides us (human observers) with information regarding the world.
- Optic flow
  - Invariant over transformation.
  - Track identifiable points in the optical structure

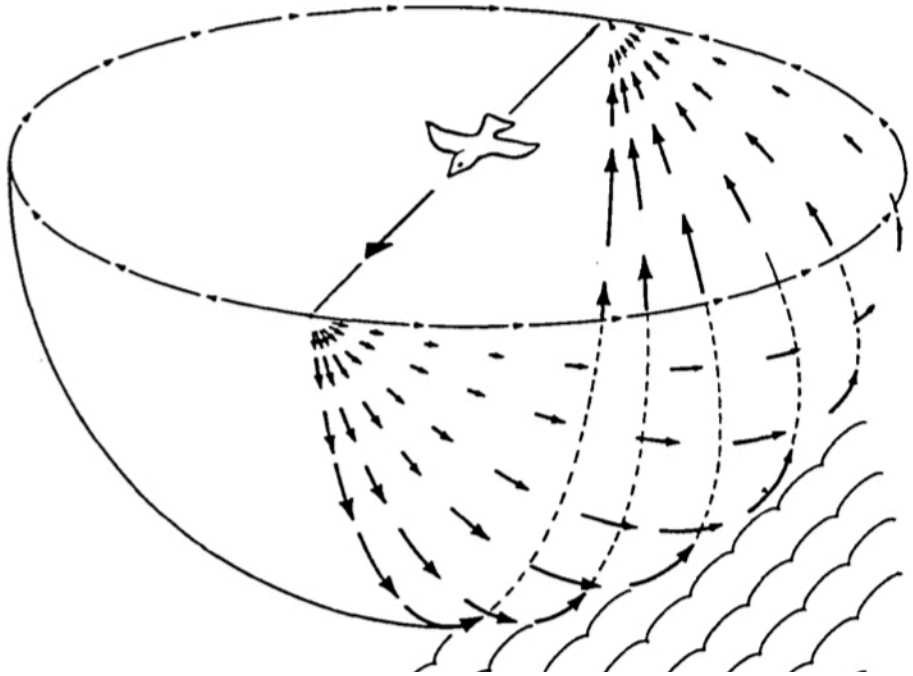
Optic Flow

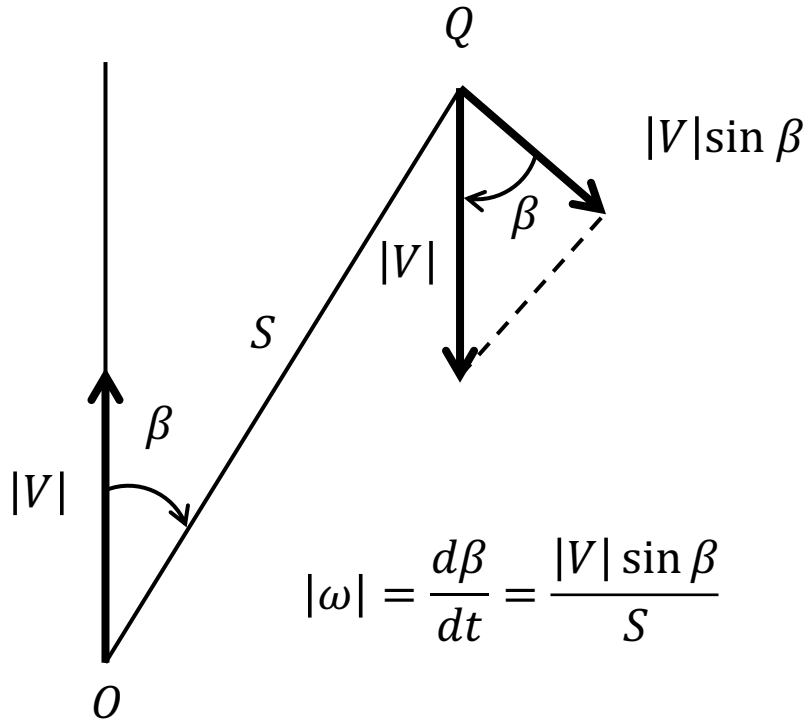
- Instantaneous velocity field
- We use a spherical representation to describe optic array.
  - Ancillary line: a line that passes through the center of the sphere.
    - Vanishing points: intersections between the ancillary line and the surface of the sphere.
  - Meridians: the great circles that connects the two poles of the sphere.
  - Eccentricity: the angular position of a point along a certain meridian.



Gibson (1966)

Optic Flow

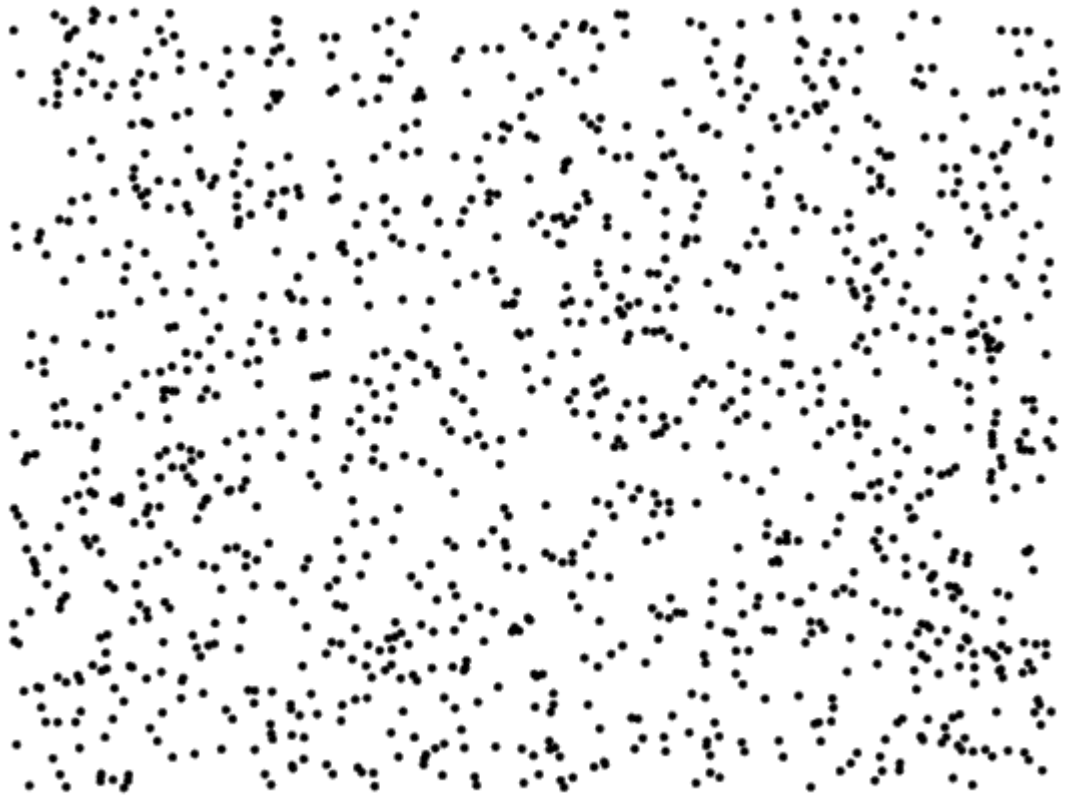


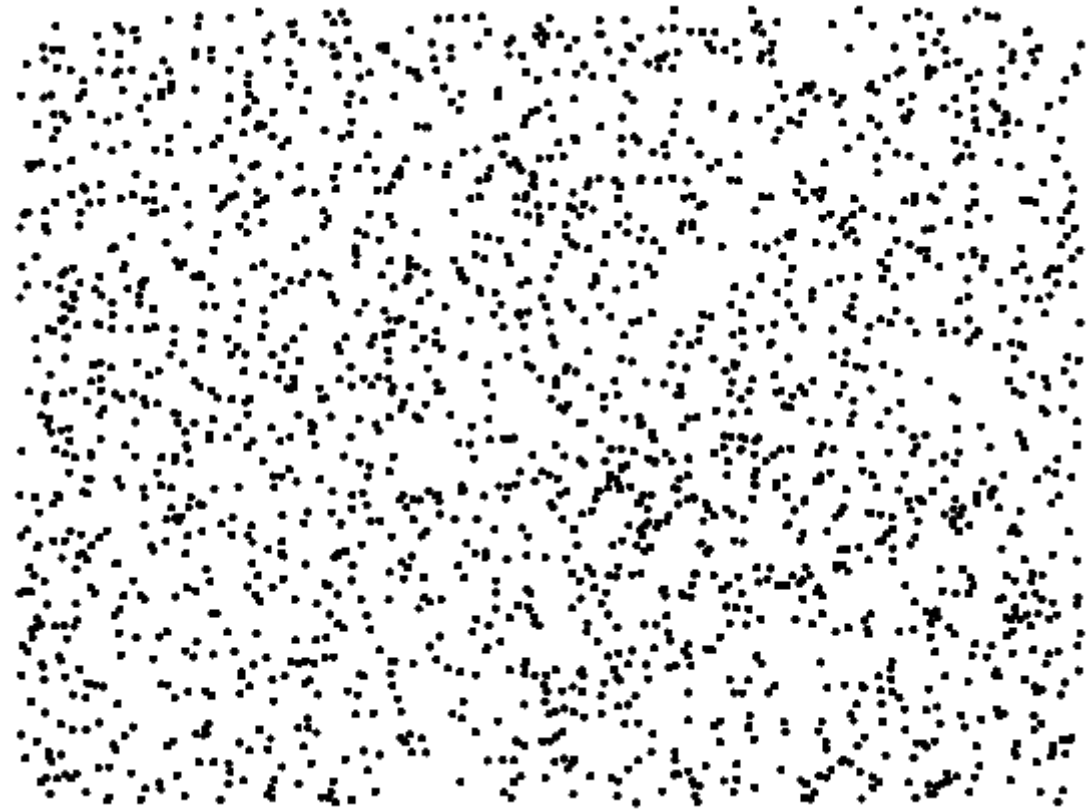


$$|\omega| = \frac{d\beta}{dt} = \frac{|V|\sin\beta}{S}$$

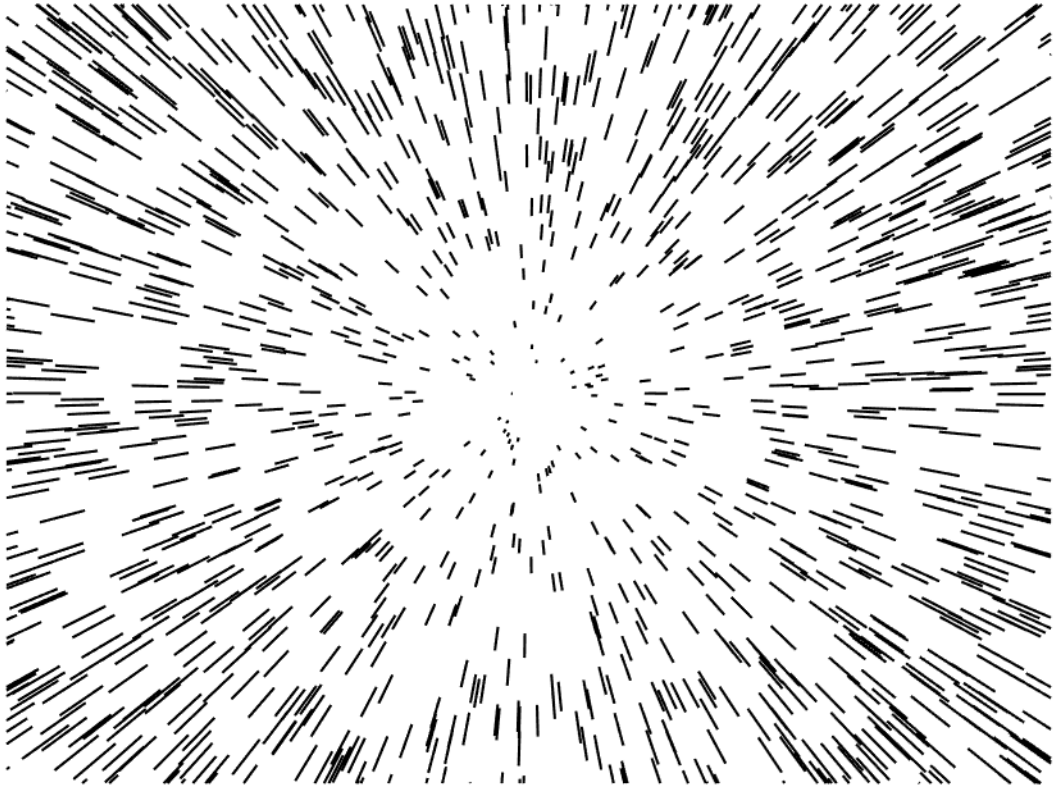
Nakayama & Loomis (1974)

Optic Flow





Optic flow, visualize (vectors)



(Arrows going in)

(Arrows going right)

Global Optic Flow

- Corresponds to a moving observer, where everything in the visual field is moving.
- Direction of the flow specifies the direction of movement.
  - Radial outflow (flows are going out) – approach (the observer is moving towards something).
    - Focus of expansion (FOE)
  - Radial inflow (flows are going in) – retreat (the observer is moving away from something).
    - Focus of contraction (FOC)
  - Parallel flow (flows are parallel to each other) – passing (the observer is passing through something)

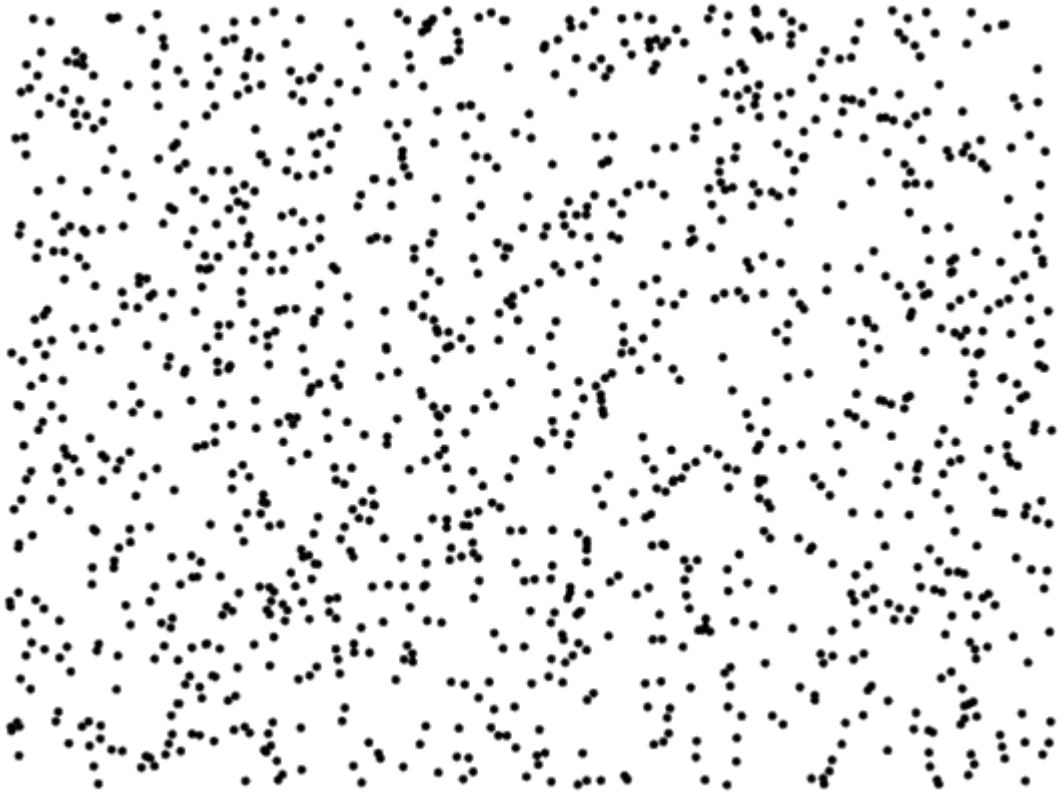
Local Optic Flow

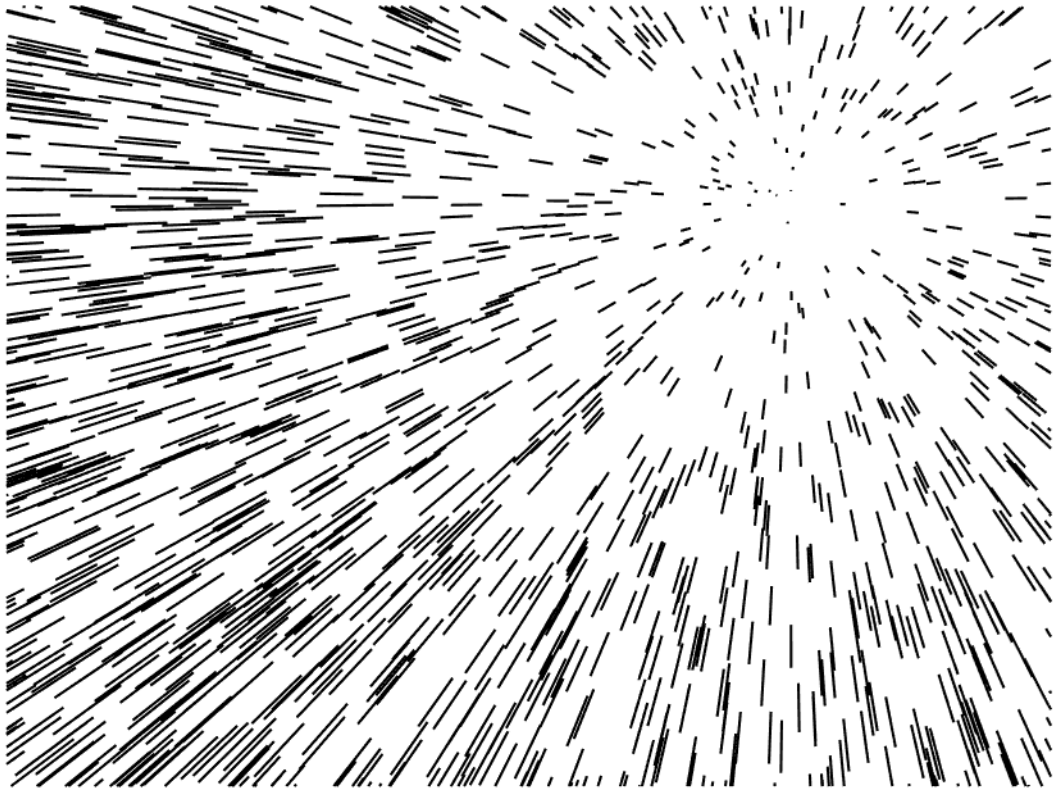
- Corresponding to object motion, where only a portion of the visual field is moving.
- Structure-from-motion
  - We will cover this in a later session.

What does it matter?

- Optic flow as information for heading direction
  - Warren, Morris, & Kalish (1988)

Optic flow as information for heading direction





What does it matter?

- Optic flow as information for heading.
  - Warren, Morris, & Kalish (1988)
- Maintaining an upright posture.
  - The moving room experiment (Lee & Aronson, 1974)
  - Visual information is more sensitive than vestibular information in helping to maintain an upright posture.

(Lee & Aronson, 1974)

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- Optic flow as information for heading.
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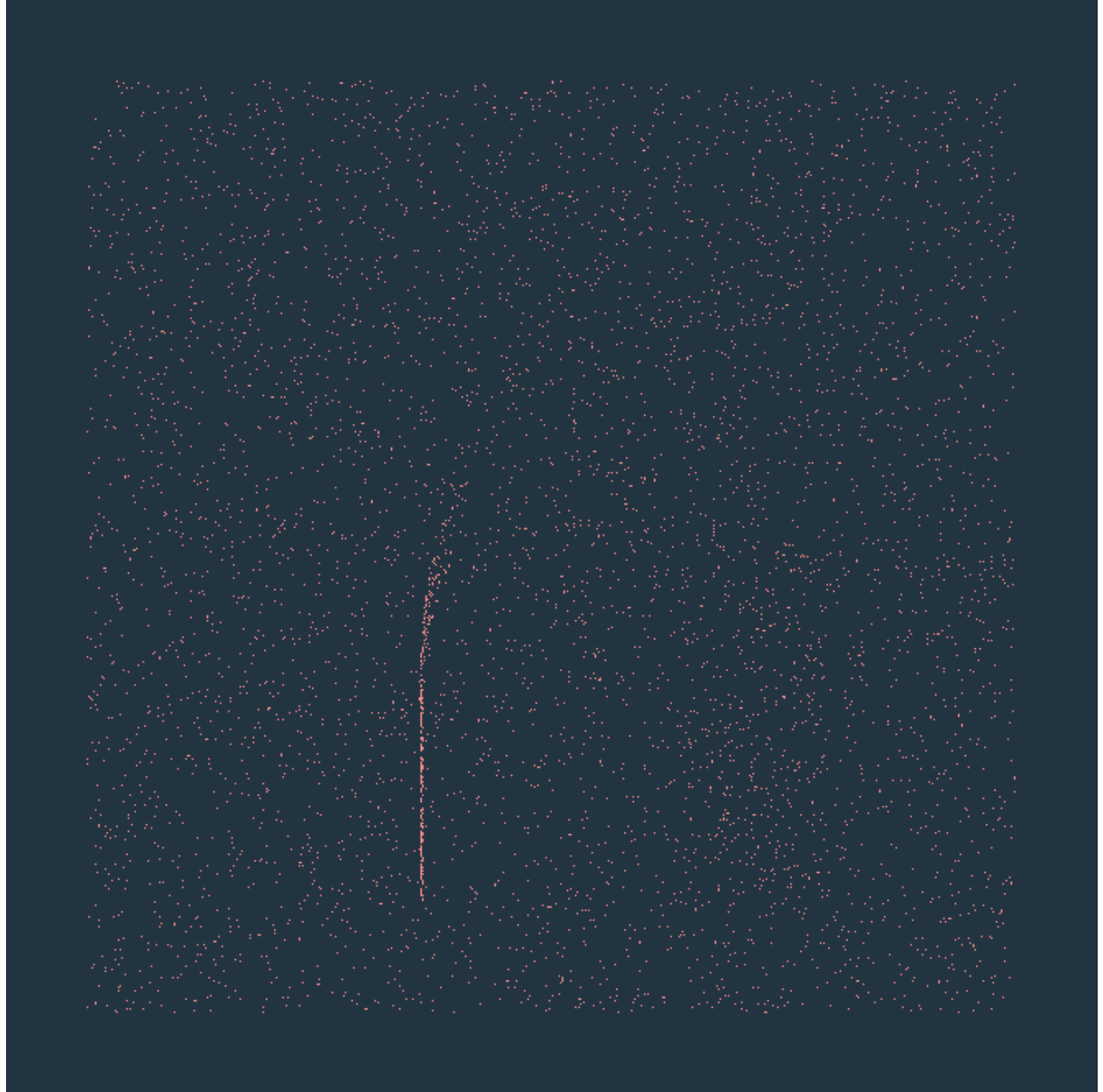
- Maintaining an upright posture.
  - The moving room experiment (Lee & Aronson, 1974)
  - Visual information is more sensitive than vestibular information in helping to maintain an upright posture.
- Visual event perception
  - Low vision, when image structure is not informative (Pan & Bingham, 2013)
  - (Make sure you are looking at this from a larger display)

How about now?

What does it matter?

- Optic flow as information for heading.
  - Warren, Morris, & Kalish (1988)
- Maintaining an upright posture.
  - The moving room experiment (Lee & Aronson, 1974)
  - Visual information is more sensitive than vestibular information in helping to maintain an upright posture.
- Visual event perception
  - Low vision, when image structure is not informative (Pan & Bingham, 2013)
- 3D shape perception
  - Structure-from-motion



What you should get out of this session

- How does the organism-environment relationship manifest in how we perceive light?
  - The light that we receive from the environment reflects our position/relationship with the environment.
- How does the way we perceive light reflect the principle of invariant over transformation?
  - Although the ambient optic array is always changing based on the environment and our position therein, it always truthfully reflects the relationship between the two.

One more thing…

- In case we still have time

Stereopsis

- Stereopsis
  - AKA binocular vision, stereovision.
- Our eyes are separated by a certain distance, and therefore they produce slightly different images.
  - Try the two-thumb trick with me.
  - This also tells you about your dominant eye.

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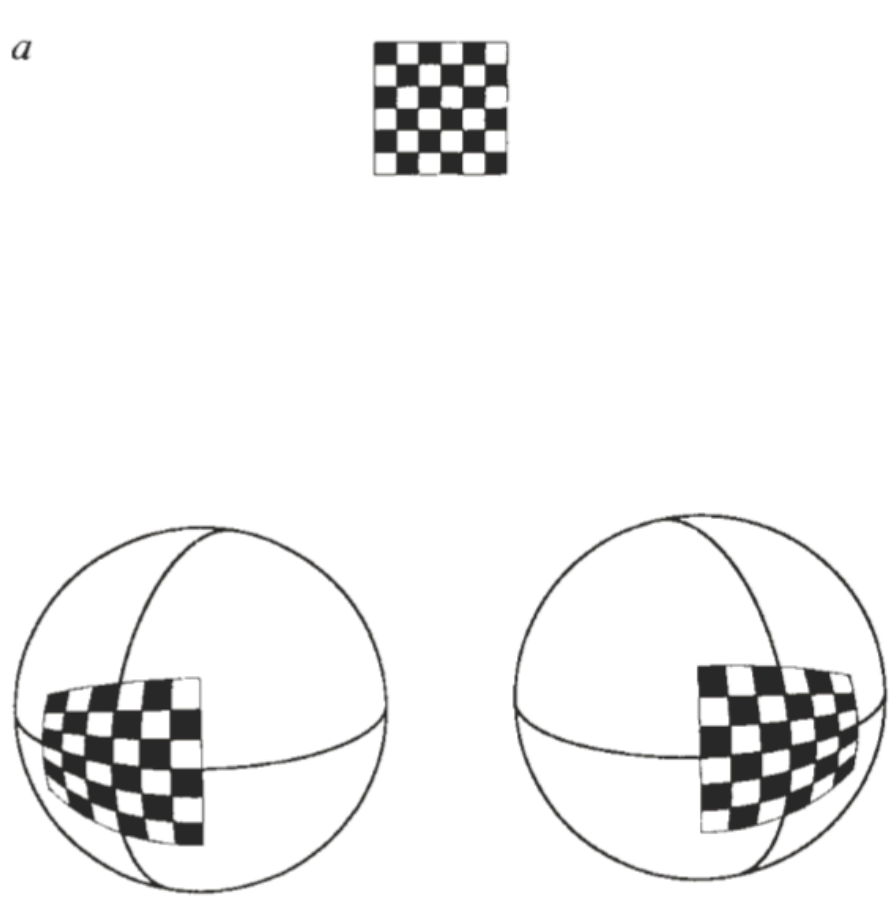
- Our eyes are separated by a certain distance, and therefore they produce slightly different images.
  - Try the two-thumb trick with me.
  - This also tells you about your dominant eye.
- The distance between our eyes is called the interpupillary distance (IPD).
- The separation between the two eyes' image is called disparity.

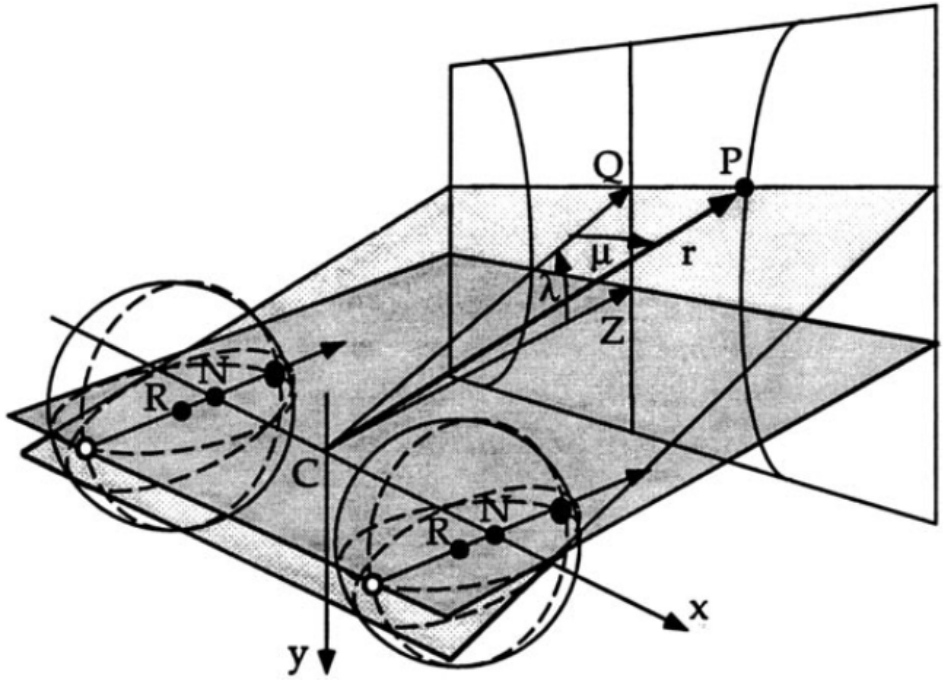


Rogers & Bradshaw (1993)

Stereopsis

- If IPD is known, we can uniquely determine distance based on disparity.
- Some variables:
  - r: head-centric distance to point P.
  - μ: azimuth
  - λ: elevation
  - $\delta_\mu = \mu_L - \mu_R, \delta_\lambda = \lambda_L - \lambda_R = 0$

$$\tan \delta_\mu = \frac{IPD \cos \mu}{r^2 - \frac{IPD^2}{4}}$$



Erkelens & van Ee (1998)

Stereomotion

- Two types of stereomotion
  - Change of disparity over time (CDOT)
  - Interocular velocity difference (IOVD)

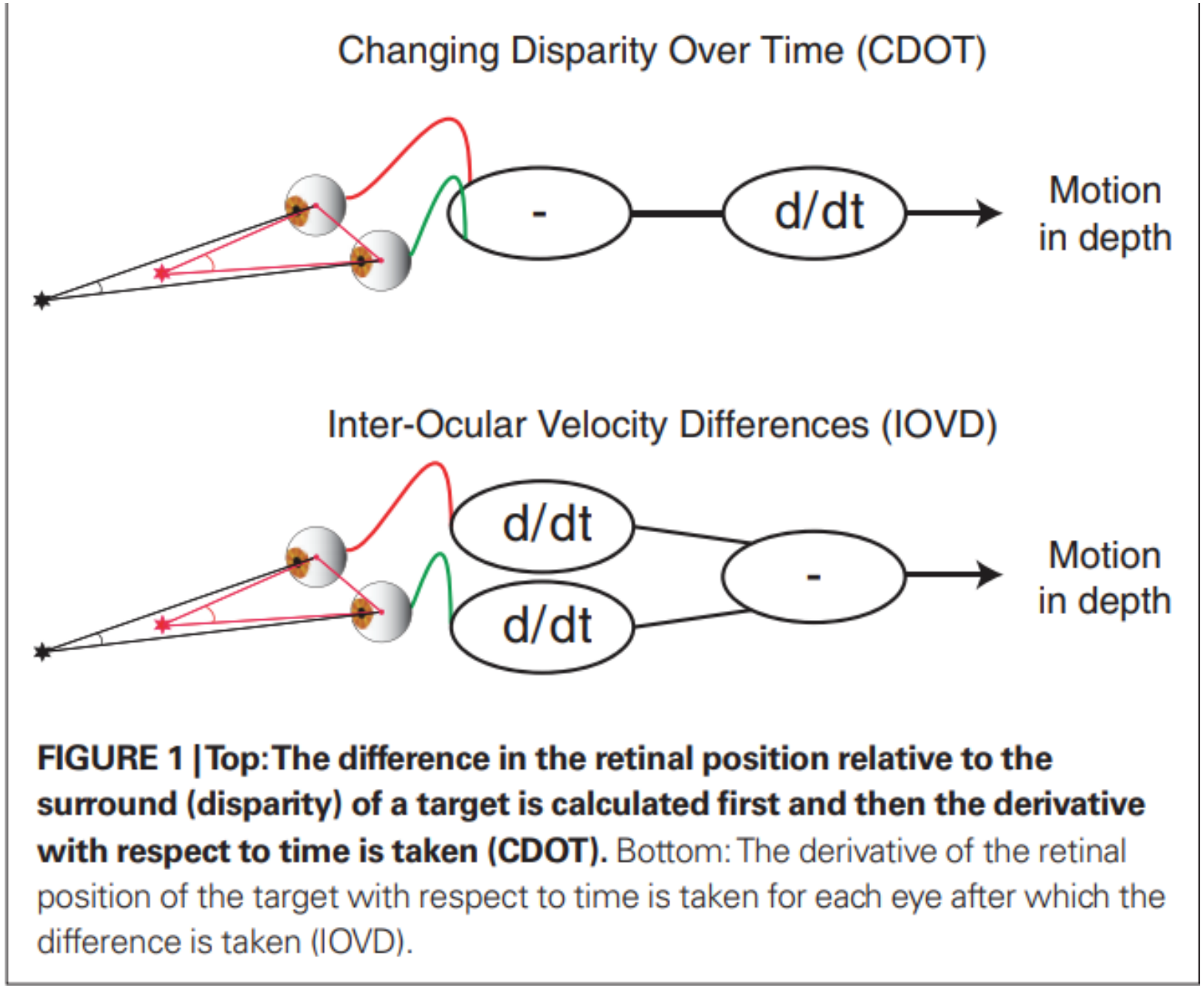
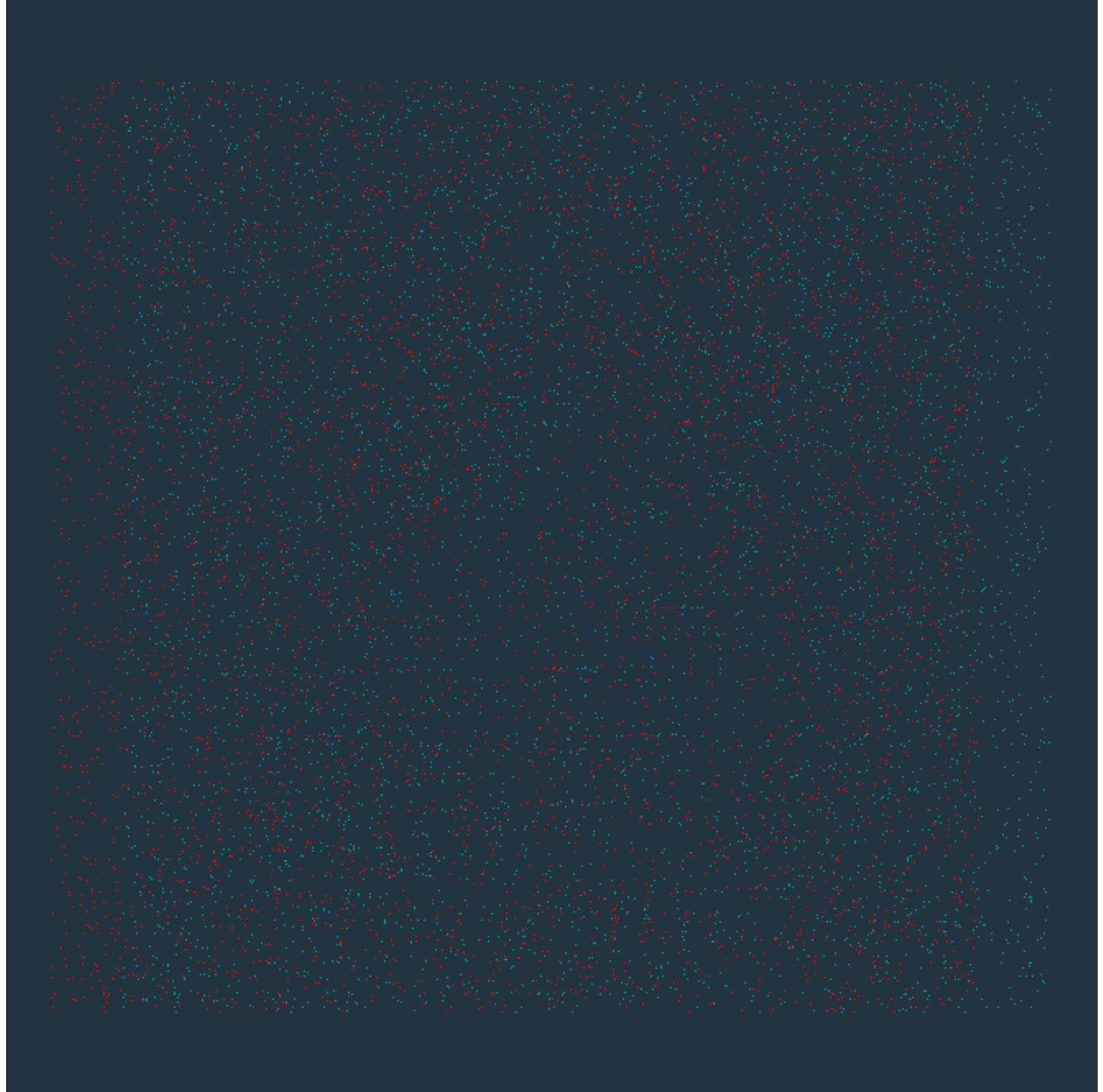


FIGURE 1 | Top: The difference in the retinal position relative to the surround (disparity) of a target is calculated first and then the derivative with respect to time is taken (CDOT). Bottom: The derivative of the retinal position of the target with respect to time is taken for each eye after which the difference is taken (IOVD).

Nefs, O'Hare, & Harris (2010)

Stereomotion

- Two types of stereomotion
  - Change of disparity over time (CDOT)
  - Interocular velocity difference (IOVD)
- How do you separate them?
  - CDOT is easy



Stereomotion

- Two types of stereomotion
  - Change of disparity over time (CDOT)
  - Interocular velocity difference (IOVD)
- How do you separate them?
  - CDOT is easy
  - Disentangling IOVD from SFM is difficult, if not impossible
    - We must only use disparity information, presenting different random dots to different eyes.
    - This may lead to binocular rivalry: If each of your eyes were shown different images, what you perceive would alternate between different images.

See you next time!