Vision V
Perceiving Movement

Overview of Topics
Chapter 8 in Goldstein
(chp. 9 in 7th ed.)

- Movement is tied up with all other aspects of vision (colour, depth, shape perception...)
- Differentiating self-motion from other-motion.
- Physiology of motion perception
- Higher order motion processing

Motion is Everything

- J.J. Gibson criticized standard perception research & proposed the "ecological approach" instead.
- Gibson: Motion is tied up with all other aspects of vision. Studying reductionistic static stimuli is the wrong way to go.
- Example: We don’t stand still while looking at objects but perception researchers still use static images of objects in their research.

Motion Makes Colour
Motion Defines Shape

Motion Defines Depth (and 3D Shape)

Motion is Always There (Even When it Isn’t)
Five Ways to Perceive Movement

- Real movement
- Apparent movement
- Induced movement (a.k.a. relative movement)
- Movement aftereffect
- Movement illusions in static stimuli

Real Movement (or is it?)

Apparent Movement
Apparent Movement

Induced Motion

Movement Aftereffects

- Movement aftereffect
  - Observer looks at movement of object for 30 to 60 sec
  - Then observer looks at a stationary object
  - Movement appears to occur in the opposite direction from the original movement
  - Waterfall illusion is an example of this

Motion Aftereffects (Waterfall Illusion)
Questions

- What are five ways to perceive motion?
- What other aspects of vision does motion play a role in?
- What phenomena does the “lilac chaser” stimulus demonstrate?

Functions of Movement Perception

- Survival in the environment
- Predators use movement of prey as a primary means to location in hunting
- Prey must be able to gauge movement of predators to avoid them.
- Certain kinds of movement trigger reflexive actions
- Navigation: Flow-fields guide one’s sense of movement through the environment.
Functions of Movement Perception

- Motion aids in perceiving objects
- Movement of objects or the observer's movement through objects assists in organization of stimuli
- Example: Motion parallax and occlusion-in-motion give cues to depth of different parts of an object, revealing its structure

Motion Agnosia

- Damage to the cortex resulting in inability to perceive movement
- Extremely debilitating and dangerous for the patient
- Does the patient see “choppy” motion, or do they lose the irreducible sense of movement?

Differentiating Self-motion from Other-motion
Three Situations that Lead to Movement Perception

- An object moves, and the observer is stationary: Movement creates an image that moves on the observer's retina.
- An object moves, and the observer follows the object with his or her eyes: Movement is tracked so that the image is stationary on the retina.
- An observer moves through a stationary environment: Image of environment moves across retina but environment is perceived as stationary.

What mechanism explains all three situations?

Two Approaches to Studying Motion

- The question of how we separate self-motion from other motion has been approached from two different perspectives:
  - Behavioural Approach / Ecological Optics (Gibson)
  - Physiological Approach

Two Explanations of Movement Perception

- Behavioral approach/Ecological optics (Gibson)
  - Information is directly available in the environment for perception (why represent and process?)
- Optic array - structure created by surfaces, textures, and contours, which change as the observer moves through the environment
Behavioural Approach to Movement Perception

- Local disturbance in the optic array
- Object moves relative to background such that it is covered and uncovered
- Global optic flow
- Overall movement of optic array indicates that observer is moving and not the environment

- Maria moves her eyes (following George) producing a global optic flow.
- George is moving, producing a local disturbance in the optic array (relative)

- Maria (the observer) is still, so no global optic flow.
- But George is moving, producing a local disturbance in the optic array.

- Objects are not moving, producing no local disturbances in the optic array.
- Maria moves her eyes (walking down the hall) producing a global optic flow.
Questions

- Define optic array
- Define global optic flow
- Define local disturbance of the optic array
- Which of the above is associated with self-motion? Which with other-motion?

Corollary Discharge Theory

- Corollary discharge theory - movement perception depends on three signals
  - Motor signal (MS) - signal sent to eyes to move eye muscles
  - Corollary discharge signal (CDS) - copy of the motor signal
  - Image movement signal (IMS) - movement of image stimulating receptors across the retina

Corollary Discharge Theory

- Movement is perceived based on a summation of:
  - The Corollary discharge signal
  - The Image movement signal
- Movement is not perceived when comparator receives equal input from both corollary discharge and image movement signals at the same time
How inputs to the comparator (circle) affect movement perception. When the comparator receives either the corollary discharge signal (CDS) alone, as in (a), or the image movement signal (IMS) alone, as in (b), it sends a movement signal to the cortex, and movement is perceived. When the comparator receives both the CDS and IMS signals, a movement signal is not sent to the cortex, and no movement is perceived.

In all four examples shown in the figure, a signal is sent to the eye muscles, and a corollary discharge is generated. However, no image movement signal is generated, so other-movement is perceived.

Physiological Evidence for Corollary Discharge Theory

- Damage to the medial superior temporal area in humans leads to perception of movement of stationary environment with movement of eyes
- “Real-movement” neurones found in monkeys that respond only when a stimulus moves and do not respond when eyes move (note: V1 neurones respond to both self and other motion)

Real-Motion Neurones in Monkey Cortex

(a) RM neurone fires when bar moves left across the neurone’s receptive field (RF) as the monkey looks at the fixation point (FP)

(b) neurone does not fire when monkey moves its eye to the right, even though this also causes the bar to move to the left across the receptive field.
Questions

- What is the corollary discharge signal?
- What is an image motion signal?
- If the CDS indicates leftward self-motion and the IMS indicates rightward motion on the retina, what will be perceived in terms of motion of self and other?

Physiological Basis of Motion Perception

The Aperture Problem

- As we saw in Chapter 3, complex cortical cells respond to an oriented bar moving in a specific direction. Is this the basis of motion perception?
- Problem: observation of small portion of larger stimulus leads to misleading/incomplete information about direction of movement
- Thus, activity of a single complex cell (which intercepts only a small portion of the image) does not provide accurate information about direction of movement
The Aperture Problem

- Solution to aperture problem
- Responses of a number of V1 complex cells with different direction sensitivities are pooled
- This may occur in the medial temporal (MT) cortex, which is part of the where/how stream
- Evidence for this has been found in the MT cortex of monkeys
An illustration of how several V1 complex cells can solve the aperture problem by pooling their responses.
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From Chapter 4:
M vs. P Pathway...

The m pathway feeds into the where/how pathway via motion-processing areas V3 and MT.
Is MT a Motion Processor?

- Evidence that MT is a higher-order motion processing area (compared to V1) comes from coherence experiments by Newsome et al.
- Coherence of movement of dot patterns was varied
- Monkeys were taught to judge direction of dot movement and measurements were taken from MT neurons
- Results showed that as coherence of dot movement increased, so did the firing of the MT neurons and the judgment of movement accuracy

Is MT a Motion Processor?

- Lesioning experiment by Newsome and Paré
  - Normal monkeys can detect motion with coherence of 1 or 2% (i.e., motion coherence threshold)
  - Monkeys with lesions in MT cortex cannot detect motion until the coherence is 10 to 20%

Is MT a Motion Processor?

- Microstimulation experiment by Movshon and Newsome
  - Monkey trained to indicate direction of fields of moving dots
  - Neurons in MT cortex that respond to specific direction were activated by this process
  - Experimenter used microstimulation to activate different direction sensitive neurones
  - Monkey shifted judgment to the artificially stimulated direction

Coherent Motion Stimuli

- 75% Coherence
- 10% Coherence
Questions

• What is the aperture problem? How is it solved by the visual system?
• MT ultimately gets most of its input from the _____ layers of the LGN.
• Describe some evidence that MT is a motion-processing centre.

Higher-Level Motion Processing

STS: A Higher-Order Motion Processor?

• Neurological studies show biological motion is processed in the superior temporal sulcus (STS)
• Biological motion movement of person or other living organism
• Biological motion can be isolated in a point-light stimulus - motion made by placing lights in specific places on a person
• A form of structure-from-motion takes place with point-light walkers, but it involves a varying structure

Apparent Motion: The Occlusion Heuristic

• Exp by Ramachandran and Anstis
• Question: How does the visual system interpret ambiguous apparent motion situations?
  • Answer 1: In the most ecologically plausible way.
  • Objects do not simply appear or disappear
  • But objects can occlude one another
  • Answer 2: In the most economical way
  • If two interpretations are possible, take the one that implies the least motion (shortest path constraint)
Stimulus:

Possible Visual Interpretations:
- Two objects fuse
- Triangle disappears
- Triangle occluded
Stimulus:
The two figures are seen as occluding one another if no other interpretation is available.

If an occluding object is included in the display, then the shortest-path constraint takes over, and changes the interpretation.
Questions

- Define biological motion.
- What are some heuristics used by the visual/cognitive system to resolve ambiguous motion stimuli?

Apparent Motion & Biological Plausibility

- Shortest-path constraint can be over-ridden by biological plausibility constraints
- Experiment by Shiffar and Freyd
  - Stimuli were pictures of person with hand on sides of head
  - Pictures were presented rapidly to evoke apparent motion
Experiment by Shiffar and Freyd

- Results showed that
  - When stimuli presented at stimulus onset asynchronies (SOA) greater than 200ms, observers perceived the hand going around the head
  - When stimuli presented at SOAs less than 200 ms, observers perceived hand moving through the head (shortest path)
  - If other stimuli are used, such as boards, the shortest-path constraint always applied

Implied Motion

- Pictures that are stationary that depict an action that involves motion
- Representational momentum - observers show that the implied motion is carried out in the observer’s mind
- Experiment by Reed and Vinson
  - Observers saw a series of still pictures
  - Third picture was called the memory picture
Experiment by Reed and Vinson

- Fourth picture was the test picture and was slightly lower or higher than the memory picture
- Observers were to indicate whether the memory and the test pictures were in the same position
- Results showed the tendency for representational momentum was affected by expectations about the object
Kourtzi and Kanwisher

- fMRI response was measured in MT and MST to pictures with
  - Implied motion
  - No-implied motion
  - At rest
  - Houses
- Results showed MT/MST fire in response to pictures of implied motion
Questions

• What is the shortest-path constraint?
• How does it interact with biological plausibility constraints?
• What was the point of the demo with the rocket and the dumbell?