What you should be reading…

- For today: Chapter 9 (on motion)
- For Thursday: Chapter 6 pp 219-242, on object recognition
- For Tuesday 4/13: Ch 6 pp 243-246, on attention

One way to think about detecting image motion:

PROBLEM: Local motion detectors cannot determine true direction of motion:

Detector will respond as long as perpendicular component of velocity matches the space-time offset.

These local computations are incapable of determining the specific motion direction and speed of a 2D signal. They can only “see” the component at their orientation. How, then, does the visual system detect the motion of 2D features?

The local detectors give a constraint line in velocity space…
Suggests a **two stage model** of motion processing:

First, the stimulus is decomposed into a set of 1D components ("wavelet", Gabor, or Fourier components).

These **1D components** are combined during a subsequent stage of processing using a form of intersection of constraints. This implies that 2D features (like points, corners, etc.) are derived.

Physiological experiments have since confirmed that this occurs...

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Neurons in area V1 respond only to 1D motion.

Area MT (V5) has neurons that respond to 2D motion.

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Why might it make sense for the magno system to provide most of the input to area MT, which seems to be dedicated to motion analysis?

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When direction selective neurons are adapted, a motion aftereffect is induced.

Last time we saw an MAE demo. (Spiral umbrella).

How does this relate to population codes?
So, MT cells seem to be able to detect 2D motion signals.

Problem: Many things that move in the world, e.g. edges, are 1D and therefore are inherently ambiguous, independent of how they are measured.

Given the ambiguity of edge motions, how does the visual system determine their velocity?

Two main answers:

- Use “unambiguous” 2D signals to disambiguate edge motion.
- Integrate multiple edge motions across space.

Resolving motion ambiguity with 2D features: The barberpole illusion suggests such features are important.

However, there’s a problem with using 2D motion signals to resolve ambiguous 1D edge motions: not all 2D motion signals are “real” motion signals!

Question: When is a 2D motion not a motion?

Answer: When it’s caused by occlusion.

(Image removed due to copyright considerations.)
Given the ambiguity of edge motions, how does the visual system determine their velocity?

Two main answers:

• Use “unambiguous” 2D signals to disambiguate edge motion.
• Integrate multiple edge motions across space.

PROBLEM: some local motions may arise from different objects.

• Form info is needed to decide what goes with what.

So, motion analysis is evidently informed by information about depth and occlusion.

Motions that occur at points of occlusion tend to be discounted, and the feature motions that are left can be used to disambiguate edge motions.

Individual edges are insufficient to determine motion, but can be used to generate a constraint line along which the velocity must lie.

Multiple edges provide multiple constraint lines (if they are at different orientations), and these can be combined to yield a single unambiguous estimate of velocity.

Show single square demo

The Diamond Stimulus
(Lorenceau and Shiffrar, 1992)

No feature moves in circle, so motion must be derived from integrating the bar motions.

Static occluders drastically alter perceived motion.

Form analysis is constraining motion integration.
Both thick and thin occluders produce T-junctions:

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But if completion constrains motion integration, thin occluders should cohere much less.

Thin occluders produce far less coherence than thick ones.

(Image removed due to copyright considerations.)

Closing the outlines restores coherence.
Amodal completion appears to constrains integration.

Another factor influencing completion is whether contours are positioned so that they can complete:

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If completion constrains integration, non-relatable stimulus should cohere much less.

Non-relatable contours almost never cohere, even though motion and junctions are unchanged.

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Adding dots reinstates coherence.

What about when moving edges overlap?
Is motion integration affected by depth layering?

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Plaid coheres much less when components are separated in depth.

(Image removed due to copyright considerations.)
Despite the existence of two streams of visual processing, motion and form are inextricably linked.

"Biological" motion - motion can define form

Motion is also intimately linked to depth perception...

Motion also plays a key role in helping us figure out where we are going.

Show Kersten motion in depth demo

Show stereokinetic effect.

Mention Necker cube effect.

(Image removed due to copyright considerations.)
Neurons selective for optic flow patterns can be found in area MST of the monkey brain.

Eye Movements

Eye movements are necessary to direct the fovea to image regions of interest.

But making eye movements causes massive retinal image motion. How do we distinguish retinal motion induced by eye movements from motion of stuff in the world?
Eye movements come in several flavors:

Saccades - fast movements from one image location to another
- we make 3-4 of these each second

Microsaccades - small eye movements that occur when we try to fixate a point

Smooth pursuit eye movements
- track moving image features
- can only make these if something in image is moving

Each time we make an eye movement, huge amount of motion are induced on the retina.

How do we discount this motion?

Several theories:
- proprioceptive signals from eye muscles
- efference copy from motor system to visual system

We can test the proprioceptive theory by poking our eye.
And the efference copy theory by paralyzing the eye muscles.

Efference copies seem to be an important part of the story.