Learning to See

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Interests: Neural Computation, Biological and Machine Learning and Perception, Multi-sensory integration
Outline

- Introduction to the vision problem and the visual system
- Sampling of some of the methods used to learn about sensory systems (——)
- Vision is not a fixed feedforward system
Which is harder for us to do?

Program a computer to play chess at the Grand Master level

or

Program a computer to have vision as good as a 2 year old
Which is harder for us to do?

Program a computer to play chess at the Grand Master level
or
Program a computer to have vision as good as a 2 year old

- Vision is hard
- Vision is much more than the eye.
Newly-sighted adults “see but don’t see” – Vision is more than the eye

“When ... the experiment was made of giving her a silver pencil case and a large key to examine with her hands; she discriminated and knew each distinctly; but when they were placed on the table, side by side, through she distinguished each with her eye, yet she could not tell which was the pencil case and which was the key.” [Wardrop 1827]
Why is vision hard?

Vision is hard because there are an infinite number of 3D scenes that could give rise to a particular 2D image.


Multiple scenes can give rise to the same 2D image.
Why is object recognition hard?

The same object can give rise to multiple 2D images
Visual Cortical Areas – Human

KEY TO FUNCTION

- **V1**: Primary visual cortex; receives all visual input. Begins processing of color, motion and shape. Cells in this area have the smallest receptive fields.
- **V2, V3 and VP**: Continue processing; cells of each area have progressively larger receptive fields.
- **V3A**: Biased for perceiving motion.
- **V4v**: Function unknown.
- **MT/V5**: Detects motion.
- **V7**: Function unknown.
- **V8**: Processes color vision.
- **LO**: Plays a role in recognizing large-scale objects.

Note: A V6 region has been identified only in monkeys.

Scientific American, November 1999 (Vision: A Window on Consciousness)
How do we study Perceptual Systems?

- Physiology
  - Single Cell Electrophysiology – what do neurons respond to?
Single Cell Electrophysiology

http://zeus.rutgers.edu/~ikovacs/SandP/prepI_3_1.html
Single Cell Electrophysiology

movie from

http://info.med.yale.edu/neurobio/mccormick/qt_movie.html
Responses of V1 neurons

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Optical Imaging
Optical Imaging

http://www.opt-imaging.com/
Optical Imaging
Optical Imaging

from Josh Trachtenberg (http://phy.ucsf.edu/joshua/postdoctoral.html)
Parallel Pathways

[Mishkin & Ungerleider 1982]
Parallel Pathways

[Van Essen & Gallant 1994]
higher-level neurons require more complex stimuli

“optimal patterns” for IT neurons (from Keiji Tanaka) are even more complex but require much less spatial precision
Neurons near the end of the Temporal pathway respond to very complex stimuli

http://zeus.rutgers.edu/~ikovacs/SandP/prepI_3_1.html
Determining Function

So we know that neurons in a particular area respond well to a particular kind of stimulation.

Does that tell us that these neurons are telling the animal about these stimuli?
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  - microstimulation – how does the animal respond when we stimulate?
Microstimulation in MT influences monkey’s decision

from Mike Shadlen and http://zeus.rutgers.edu/ikovacs/SandP/prepl_3_1.html
Visual Cortical Areas

“Feedforward and feedback connections are linked together by reciprocal connections. Much of the understanding of higher order vision rest on understanding the interactions between feedforward and feedback loops and the horizontal connections” [J Bullier, Trieste 2000]
The Visual System is not a fixed feed-forward system

It is influenced by

- prior experience
Influences from past experience

The original image was created by R.C. James. This image was taken from Andy Wilson’s home page which was scanned from David Marr’s book Vision.
Influences from past experience

This image is from Beverly Doolittle
The Visual System is not a fixed feed-forward system

It is influenced by

- prior experience
- surrounding visual scene (and not just immediate)
Simple influences from surrounding scene

http://www.cs.ubc.ca/nest/imager/contributions/flinn/Illusions/BW/bw.html
Simple influences from surrounding scene

http://www.psychology.psych.ndsu.nodak.edu/mccourt/website/htdocs/HomePage/Projects/Brightness/White
More influences from surrounding scene

devised by Ted Adelson (see http://web.mit.edu/persci/gaz/)
More involved influences from surrounding scene

http://www.olemiss.edu/courses/psy214/Readings/Illusions/ImageSizeAdjustmentTheory.htm
More involved influences from surrounding scene

Baingio Pinna’s Water Color Effect
More involved influences from surrounding scene

Baingio Pinna’s Water Color Effect
The Visual System is not a fixed feed-forward system

It is influenced by

- prior experience
- surrounding visual scene (and not just immediate)
- recent prior exposure
The McCollough Effect – short term changes in perception

taken from http://cm.bell-labs.com/who/ches/me/
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- recent prior exposure
- learned familiarity with special objects
The Thatcher Illusion – influence from learned experience with (upright) faces
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This illusion was first described by Thompson in 1980. I got this from http://www.essex.ac.uk/psychology/visual/thatcher.html
Influence from learned experience

http://www.princeton.edu/~ftong/
Influence from learned experience

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http://www.princeton.edu/~ftong/
Influence from learned experience is specific

[Sinha and Poggio Nature 1996, 384 p 404]
Influence from learned experience is specific

[Sinha and Poggio Perception 2002, 31(1) ]
http://perceptionweb.com/perc0102/sinha.html
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- learned familiarity with special objects
- concurrent input in other sensory modalities (where the relationship has been well learned)
Auditory input can influence Visual Perception


Three bars accompanied by a different number of beeps

Fixate to the cross, and press one of the buttons. You may see a different number of bars with a different number of beeps (especially with "5 beeps"), whereas the visual stimuli are physically identical.
(This demo may not work on slow computers. If the bar and beep are not synchronized with "3 beeps", you cannot observe the effect, sorry...)


demo available at http://neuro.caltech.edu/ kamitani/audiovisualRabbit
The McGurk Effect was discovered by McGurk and MacDonald in 1976. This demo is courtesy of Dr. Lawrence Rosenblum of University of California, Riverside.
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  - observe and analyze visual illusions
Visual Cortical Areas

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• Computational Modeling
  ♦ make models that do similar things and see how they work
  ♦ start with learning rules and see what happens
Computational Models

Help us understand problems the brain is solving

Force us to be specific in our theories

Motivated by biological findings but usually not enough information to fully constrain the models

1) Address what kinds of units may be useful for computations—Learn a task and look at the hidden unit representations e.g. [Zipser & Andersen 1988],[Lehky & Sejnowski 1988]

2) Address how learning occurs — Need a biologically plausible learning algorithm e.g. [Erwin & Miller 1998]
Lehky and Sejnowski trained a back-propagation network to determine information about 3-D shape from a 2-D grayscale picture [Lehky & Sejnowski 1988]
and developed oriented receptive fields
Lehky & Sejnowski’s simulations are interesting because they introduced a new view of V1 edge detectors — maybe the V1 edge detectors aren’t just edge detectors but are important in the computation of “shape from shading”.

Modeling addressing learning and development

Erwin and Miller took realistic rules for initial connectivity and a plausible (Hebbian) learning rule and determined the conditions under which they could develop a V1 map of responses similar to that observed.
Summary (What you should have learned)

Vision (particularly object recognition) is hard!

The visual system is quite plastic (over many time scales) and perception can be modified by feedback activity.

Learning about sensory systems requires work using many different techniques.