ISTA 352

Lecture 7

Human Vision System (HVS)

Light Capture and First Level Processing

The HVS

Administrivia

- HW1 due in 68 hours
- Homework questions
  - Email mail list or Kyle (and CC me if you like)
  - Kyle Simek <ksimek@email.arizona.edu>
- Friday bonus lecture 1pm (sharp) in GS 906
  - Demo on “color constancy”
  - Monitor gamma (time permitting)
The human eye

- The amount of light entering the eye is a function of the pupil size (controlled by the iris)
  - Camera analog is aperture
  - The range of brightness in nature is huge
    - The ability to handle this is referred to as dynamic range
    - The eye has higher effective dynamic range than most cameras because at a fixed aperture the range is higher, and their range adjusts as a function of what they are looking at.
- Light is sensed on the retina
  - Camera analog is CCD (or other sensor type) chip
  - The flat sensor in a camera has some disadvantages to the spherical one
- The lens accommodates to focus what is being looked at on the retina.

The Retina

- The retina is an information processing machine
- Sensors (rods and cones) feed into other cells
  - Around 7 million cones
  - 75 to 150 million rods
  - “only” one million nerves in optic nerve bundle
Sensory elements (rods and cones)

- Rods are sensitive to low light
  - Pegged at max and non-informative when it is bright
- Cones only work when there is enough light
  - Night vision is black and white (only one kind of rod)
- Cones carry color
  - People with normal human vision have three types
    - L (long), M (medium), and S (short)
    - Is this fundamental?
      - Consider that cats have 2, most birds have 4, some turtles have 6, ...

Color vision is linear

- Cone response to photon capture can be modeled in the same way we did for camera sensors
  - At the capture level it is linear
  - It is confusing because the automatically adjusting aperture, and downstream processing makes the overall “brightness” response more like a logarithmic function.
- We can use the cone sensitivities to predict whether two spectra will be seen as the same color
- We will learn more about color vision when we study color reproduction

Distribution of rods and cones

- A small central part of the eye (the fovea) is especially densely populated with L and M cones (no rods)
  - To see detail when it bright, look straight ahead
  - To see a dim star, don’t look directly at it
    - Foveal vision is black and white
- The S cones (blue sensitive) are relatively rare
  - True color vision is fuzzy and inferred
  - Interesting tidbit --- if there were more S cones, the “chromatic aberration” in the eye would be a problem.
The relative acuity of the eye across the field of view

- Fovea
- Blind Spot

3. 1 4 5 9 2 6 5 3 5 8
3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9
3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6
3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6 4 3 3 8 3 2 7
3. 1 4 1 5 9 2 6 5 3 5 8 9 7 9 3 2 3 8 4 6 2 6 4 3 3 8 3 2 7 9 5 0 2 8 8 4 1 9
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The high resolution illusion

- Despite blind spots, low resolution outside the fovea, very low resolution, we see the world in high resolution!
  - Our brain constructs a high resolution illusion
  - When we need to know a detail, we can look there
  - The eye naturally moves to a new fixation point many times a second ("saccades").
  - Motion sensitive cells detect change
  - We still miss a lot more than we think!

From capture to optic nerve

- Recall that there are many more sensors than nerve fibers going from the eye to the back of the brain
- Initial computations aggregate signals and detect change
- Three kinds of differencing operations
  - Center surround cells (respond to edges)
  - Opponent color cells (reduce correlation between color channels)
  - Motion sensitive cells detect temporal differences

Neural organization of the retina

- A basic arrangement is central cells surrounded by others
- The neuron output is the difference between the signals
  - If the input corresponds to a spatial arrangement, then we have a dot detector
    - e.g. a bipolar cell with surround connections to horizontal cells, center connections to cone
  - If the input corresponds to cone types, then we have color opponent cells
    - implemented in ganglion cells

Center surround and opponency
Basic detection is based on correlating current signal with delayed signal from nearby sensors.

More when we study movies

Motion detection

Fix your eyes on the black spot