Early processing in human vision

Rods vs. cones

In the night sky:
- Why do stars appear to disappear when you look directly at them?
- Why do all stars look white?

Cones:
- Sensitive to color
- Operate in daylight
- Adapt quickly to changing light

Rods:
- Not sensitive to color
- Operate at low light levels
- Adapt slowly to changing light

Retinal ganglion cells

Emergence of center-surround receptive field
Analyzing intensity changes in a 2D image

image after smoothing & second derivative convolution with $V^2G$ operator

~ convolution of the retinal image is passed up the optic nerve
- on-center cells carry positive part
- off-center cells carry negative part

Detecting intensity changes at multiple scales

human vision:
- multiple receptive field sizes in the same region of the visual field
- receptive field sizes increase with eccentricity (distance from the center of the eye)

Spatial frequency decomposition

Any real signal, such as $I(x)$, can be described as the sum of sinusoidal waves of different frequency, amplitude, and phase

firing rate = (number of spikes)/time

excitation: higher firing rate    inhibition: lower firing rate
Spatial frequency channels

‘Low’ spatial frequency filters encode coarse luminance variations in the world (e.g. large objects, overall shape)

‘High’ spatial frequency filters respond to the fine spatial structure of the world (e.g. small objects, detail)

Hybrid images combine the low spatial frequencies of one picture with the high spatial frequencies of another

Oliva, Torralba & Schyns, 2006
Hybrid Images @ MIT Gallery: http://olivalab.mit.edu/hybrid_gallery/gallery.html

Orientation tuning curves

Single neuron:

Many neurons: