IIT Jodhpur

Biological Vision and Applications
Module 02-03: Edge Perception

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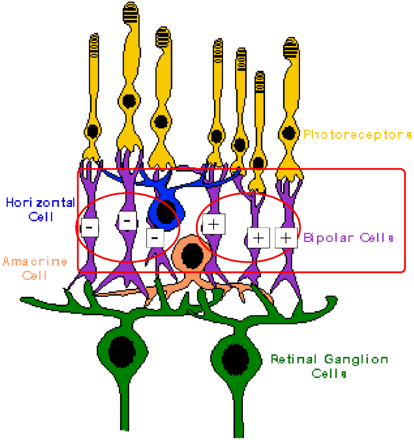
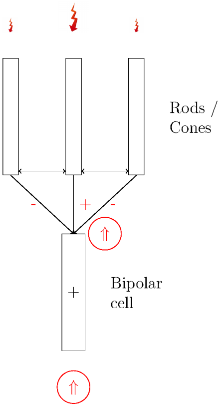
The Bipolar cells



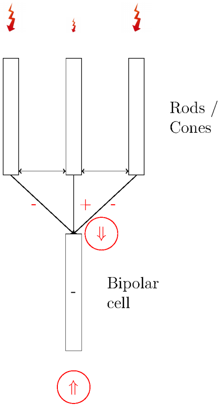
- Photoreceptors are connected to Ganglions through bipolar cells
- Some of them “invert” the signal

The Bipolar cells

On-center and off-center configurations



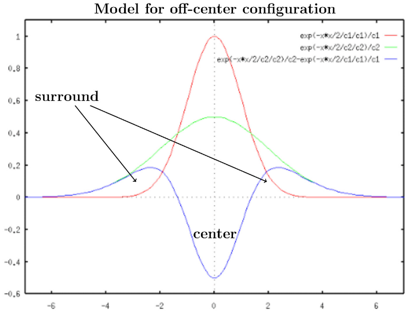
On-center configuration



Off-center configuration

Mathematical model

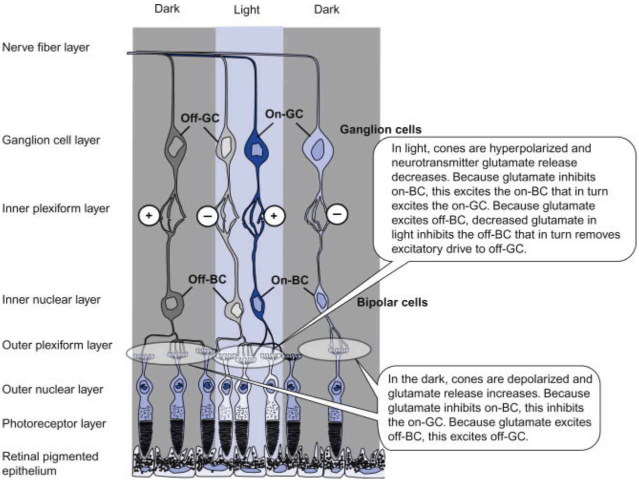
Difference of Gaussian (DoG)



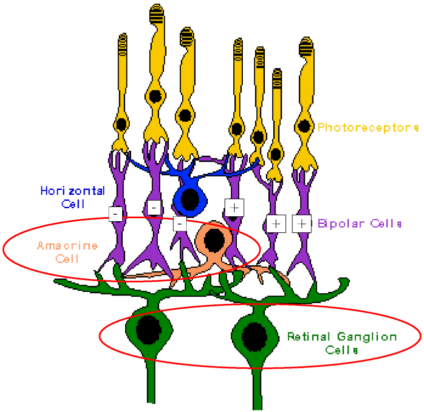
- The center-surround operation can be approximated by a Difference of Gaussian (DoG) operator

Organization of the bipolar cells

On-center and off-center configurations

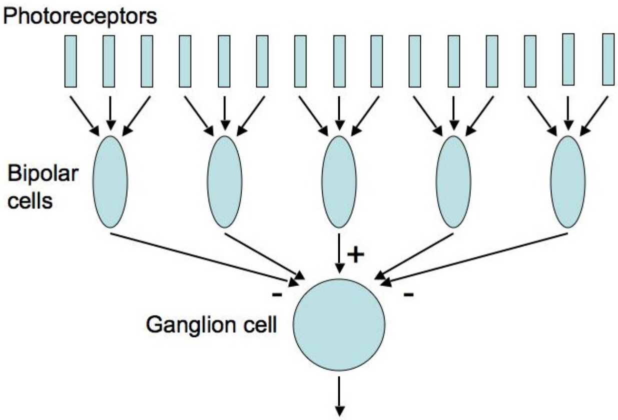


The amarcine and the ganglion cells



- Approx 126 million photosensors converge to approx 1 million optic nerves
  - Data reduction
- Amacrine cells contributes to motion detection

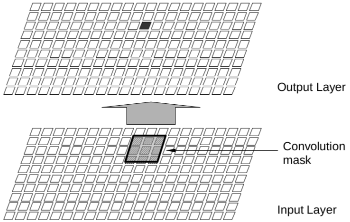
Model of receptive field



Generic model of signal processing in early vision

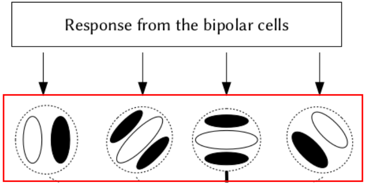
Digital Convolution (2D)

- Inputs:
  - Image $I = \{I_{xy}\}\ x = 1 : W, y = 1 : H$
  - Filter $F = \{F_{xy}\}\ x, y = -m : +m$
    - $[m \ll W, H]$
- Output: $I' = F * I = \{I'_{xy}\}$
  - $x = 1 : W, y = 1 : H$
  - where $I'_{xy} = \sum_{i=-m}^{m} \sum_{j=-m}^{m} F_{x+i,y+i}.I_{x-i,y-i}$



- Convolution is followed by a pooling layer for data reduction in CNN

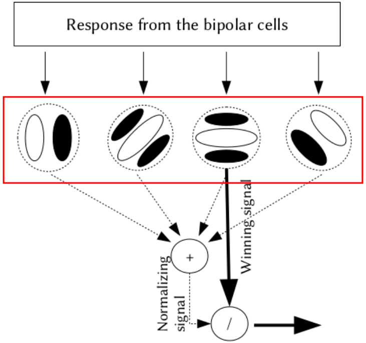
Oriented Filter Banks



- Center-surround organization of bipolar cells act like high-pass filters
- Configurations of the bipolar cells act as directional filters
  - Filters are differently oriented
  - Filters can be symmetric or asymmetric
- **Enables edge-detection in various directions**

Winner Take All (WTA) and Automatic Gain Control (AGC)

Applicable to all sensory signals



- The output of the filter with strongest output is transmitted
  - The strongest oriented edge is detected
- Output is normalized by the average response
  - Results in sublinear (logarithmic) perceptual response to a signal
  - Stronger signals are attenuated

Weber-Fechner Law

Holds good for all types of sensory signals

- Fechner's Law: Subjective sensation is proportional to the logarithm of the stimulus intensity
  - $P = K.\ln S + C$, **or**
  - $P = K.\ln(\frac{S}{S_0})$
- Weber's Law: The smallest change in stimuli that can be perceived is proportional to current signal strength
  - $\Delta S \propto S$

Weber-Fechner Law

Weber's Law can be derived from Fechner's law

- Fechner's Law: $P = K.\ln S + C$
- Differentiating:
  - $\frac{\Delta P}{\Delta S} = K.\frac{1}{S}$, **or**
  - $\Delta S = \frac{\Delta P}{K}.S$
- If $\tau = \Delta P$: the minimum change in perception that can be perceived,
  - The minimum perceivable change in stimulus $\Delta S = \frac{\tau}{K}.S$

Transformation in the eye

Retinal image

Neural image

- Human vision is sensitive to contrast, and not brightness
- There is huge data reduction in the early vision stage

Quiz

Quiz 02-03

End of Module 02-03