Computational Color Final Project Proposals

Nithin Raghavan
Navneedh Maudgalya
Rishi Upadhyay

Overview

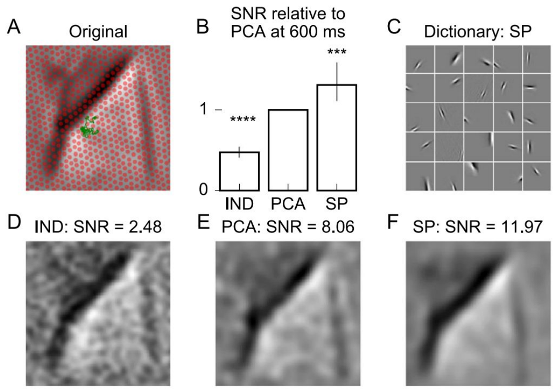
Extend the mathematical model presented in “High-acuity vision from retinal image motion” [1] and work done by previous year’s Anderson project group to understand how fixational drift in the retina …

1. Can perceive natural stimuli
2. Affects peripheral color vision
3. Effectively utilizes a distribution of achromatic and chromatic cones

Project Idea 1 - Motivation

Big Question: How effective are the brain's mechanisms that infer retina location and stimuli shape for perceiving complex natural images?

- Experiments of [1] primarily rely on projecting "E" in different orientations onto cone lattice
- Natural stimuli tested in [1] limited to images in Figure 4
- Stimulus shape, ERS position inferred jointly with online EM algorithm
- [6] conjectures that brain efficiently represents natural images



Project Idea 1 - Our Approach

How can we extend the experiments of [1] to better represent the spectrum of natural images?

- Measure different priors to see which gives best results with [1]'s EM algorithm
  - 1/f noise, deep learning priors, and others
- Conditioning on a particular metric
  - eg. condition on high LPIPS score, or only use images that look natural to the human eye
- Possibly jointly infer chromatic information
  - ie. jointly infer multiple colors in addition to position and stimulus shape
- Results would indicate how useful [1]'s algorithm is with natural/strange images
  - Could possibly support the idea that two separate populations of cortical neurons contribute to higher quality representation of natural high-acuity targets.
- Twofold motivation
  - how can we construct better priors in joint inference algorithm
  - seeing how well it does with better priors

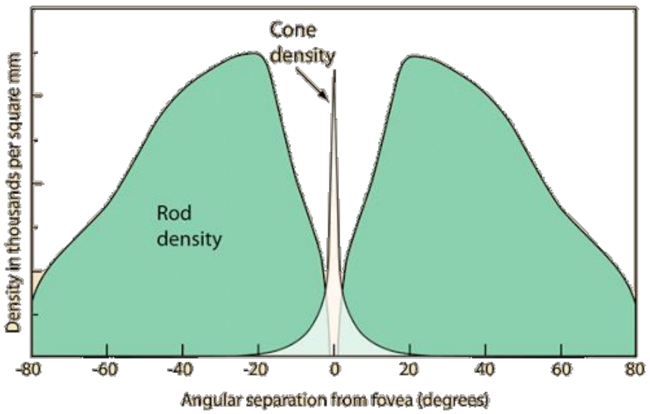
Project Idea 2 - Motivation

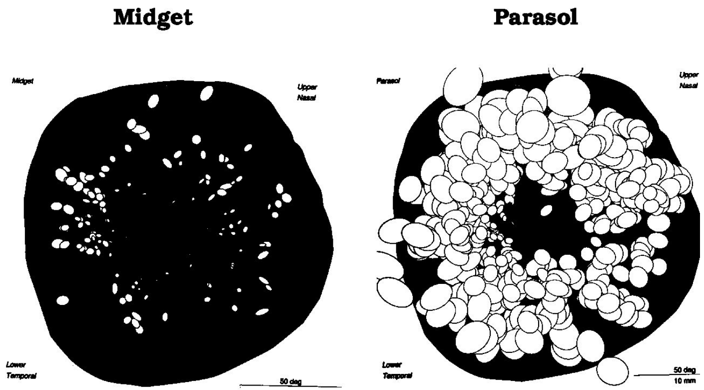
Big Question: How does color vision deteriorate further from the fovea?

- Changes in cone/rod distributions
- RGCs integrate cone signals over larger spatial resolutions

Previous research indicates color blindness at 50 degrees [3]

Quality of color vision between 20-50 deg remains uncertain [2]





Project Idea 2 - Our Approach

What is the role of ocular fixational drift motion, if any, on periphery color vision?

The cone sampling lattice in Anderson model is representative of the fovea

- Cones on average are 1.09 arcmin apart and one-to-one connection with RGC

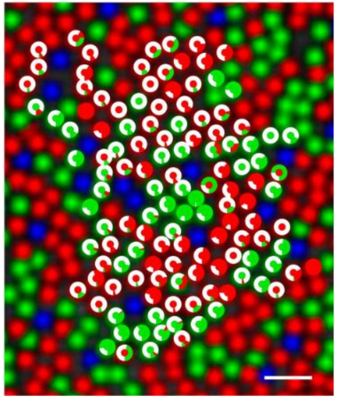
To better understand <u>when</u>, <u>why</u> and <u>to what extent</u> intermediate regions of the periphery retina encode chromatic information, we plan to modify the experimental setup and model in [1] in the following ways:

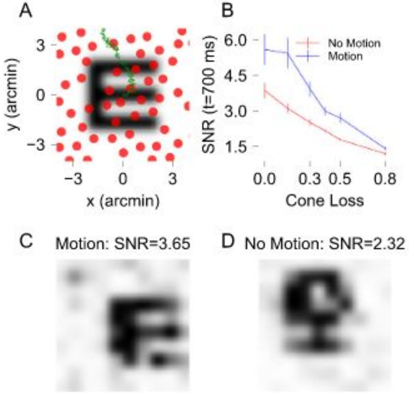
1. Vary the distances between cones
2. Integrate over many cone signals
3. Change the size of the visual stimuli

Project Idea 3 - Motivation

Sabesan 2016 paper raised possibility of chromatic and achromatic cones

Anderson 2020 paper developed an achromatic model of human vision





Can we combine these two?

- Can the model reproduce pattern of cone types?
- Does having both types of cones lead to better SNR?

Want to explore Sabesan hypothesis by investigating benefits to having two populations of cones and causes for the natural pattern to arise

- Potentially large impact on understanding of vision

Project Idea 3 - Our Approach

1. Add chromatic cones to the currently achromatic only model
    a. Use very similar ON/OFF bipolar cell structure with slight changes for L, M, S
    b. Might already be implemented by last semester’s Anderson project group
2. Test various stimuli with just chromatic + achromatic and chromatic cones
    a. Simple stimuli (like E in original paper)
    b. Natural images
3. Work on adding optimization over various values to the model
    a. Change achromatic/chromatic % of individual cones to maximize SNR
4. (If time) Add support for horizontal cells
    a. Allow us to optimize over location of cells and see if same pattern emerges
        i. Test similar arrangements (opponent neighborhoods)

Next Steps

1. Select one of the three outlined project ideas
2. Reach out to Prof. Olshausen and last year’s Anderson Project Group
3. Familiarize ourselves with Anderson model and related code
4. Make relevant changes to Anderson Model

Bibliography

1. Anderson, A.G., Ratnam, K., Roorda, A., and Olshausen, B.A. (2020). High-acuity vision from retinal image motion. J. Vis. 20, 34.
2. Hansen, T., Pracejus, L., Gegenfurtner, K. (2009). Color perception in the intermediate periphery of the visual field.
3. Johnson, M. (1986). Color vision in the peripheral retina.
4. Callaway, E. (2005) Structure and function of parallel pathways in the primate early visual cortex.
5. R. Sabesan, B. P. Schmidt, W. S. Tuten, A. Roorda, The elementary representation of spatial and color vision in the human retina.Sci. Adv.2, e1600797 (2016).
6. Olshausen, B. A., & Field, D. J. (1997). Sparse coding with an overcomplete basis set: A strategy employed by V1? Vision Research, 37(23), 3311–3325.