MATLAB Modeling of Retina Structure and Function

Abstract
Research at the intersection of neuroscience and engineering offers the promise of neuro-mechanical prostheses. The success of cochlear implants and interest in brain function, robotics, and quality of life issues has motivated a search for an ocular prosthesis. Recently retinal implants have successfully offered low-resolution sight to the blind, but an incomplete understanding of the structure and function of the retina is preventing a prosthesis from “plugging” into the optic nerve. Our goal is to model the structure and function of the retina given our current knowledge. Validating the model with clinical data will support that our current understanding is accurate. The model can then be used to test hypotheses of structure and function, which will motivate new clinical investigations. New clinical knowledge will lead to a better model. Synergy between the two approaches has the potential of accelerating our understanding of how the eye processes images of our physical world.

Contrast Detection Enabled by Center Surround Structure
Connecting neighboring photoreceptors in a bulls eye arrangement and allows local comparisons of color and contrast. Center of bulls eye is directly connected to a bipolar cell. Signals from photoreceptors in the outer annulus are integrated by horizontal cells that connect to bipolar cells via negative feedback, resulting in a comparison of stimulus received by the center and the surround.

Results
Currently, the system detects only contrast and light levels. Gray scale output is presented for each bipolar cell, where darker represents a stronger response. Purple actually represents non-information and just serves to fill empty places. The black and white checkerboard was “shown” to the eye; the purple checkerboard is the result. White squares result in light output and black squares dark output because the default bipolar cells in the model are excited by darkness. The wide, light gray lines around the borders of the squares indicate regions of strong contrast.

Image Processing
A digital image serves as the stimulus and is “shown” to the photoreceptors. Their responses are calculated and passed onto the horizontal cells, which aggregates them and passes on the information to the bipolar cells. The bipolar cells integrate direct signals from photoreceptors and indirect signals from the horizontal cells, resulting in a measure of contrast and light levels.