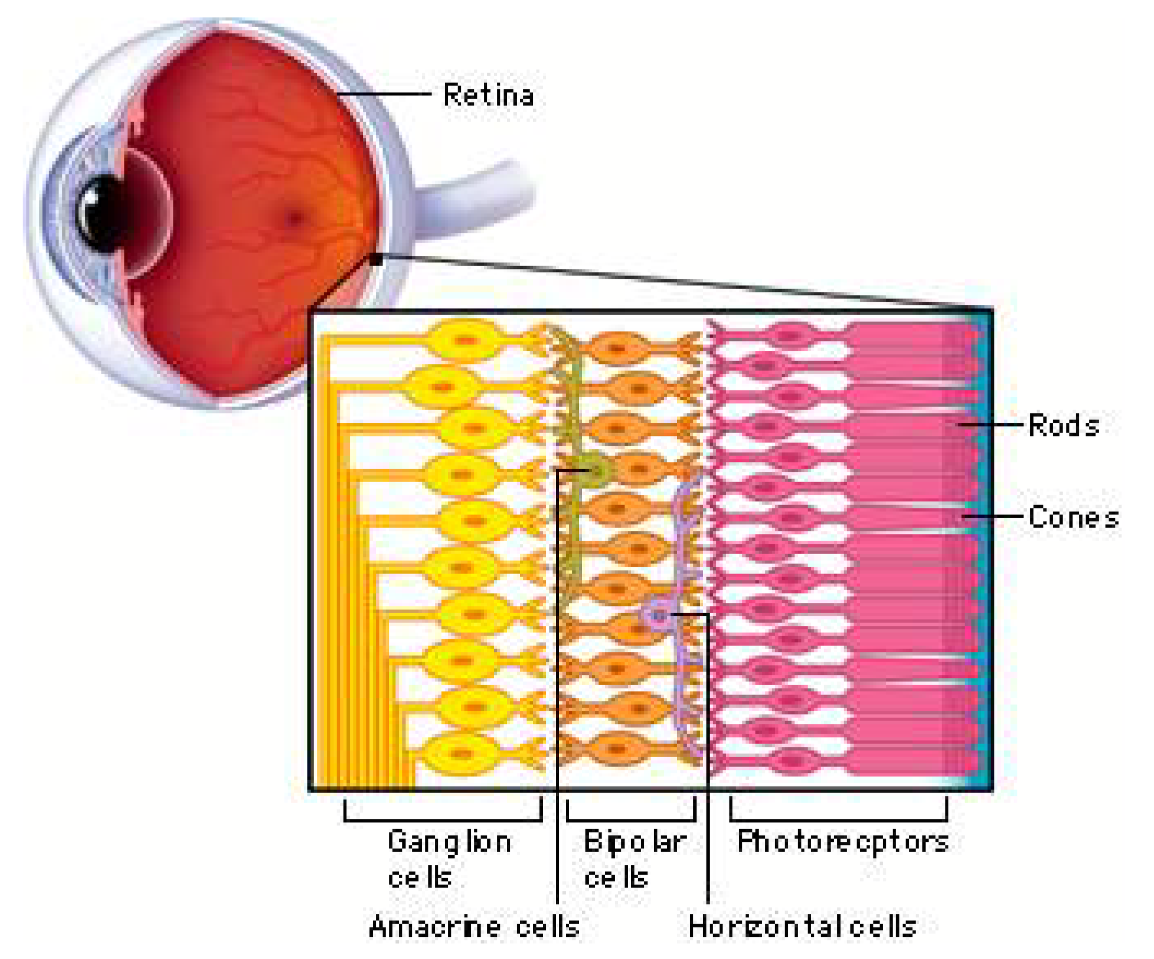
POLYTECHNIC INSTITUTE OF NYU

Department of Mechanical and Aerospace Engineering
Jason Farina, Eric Hogle, Janelle Corderro, and Adenibi Curry. Dr. Vikram Kapila, Principal Investigator

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.

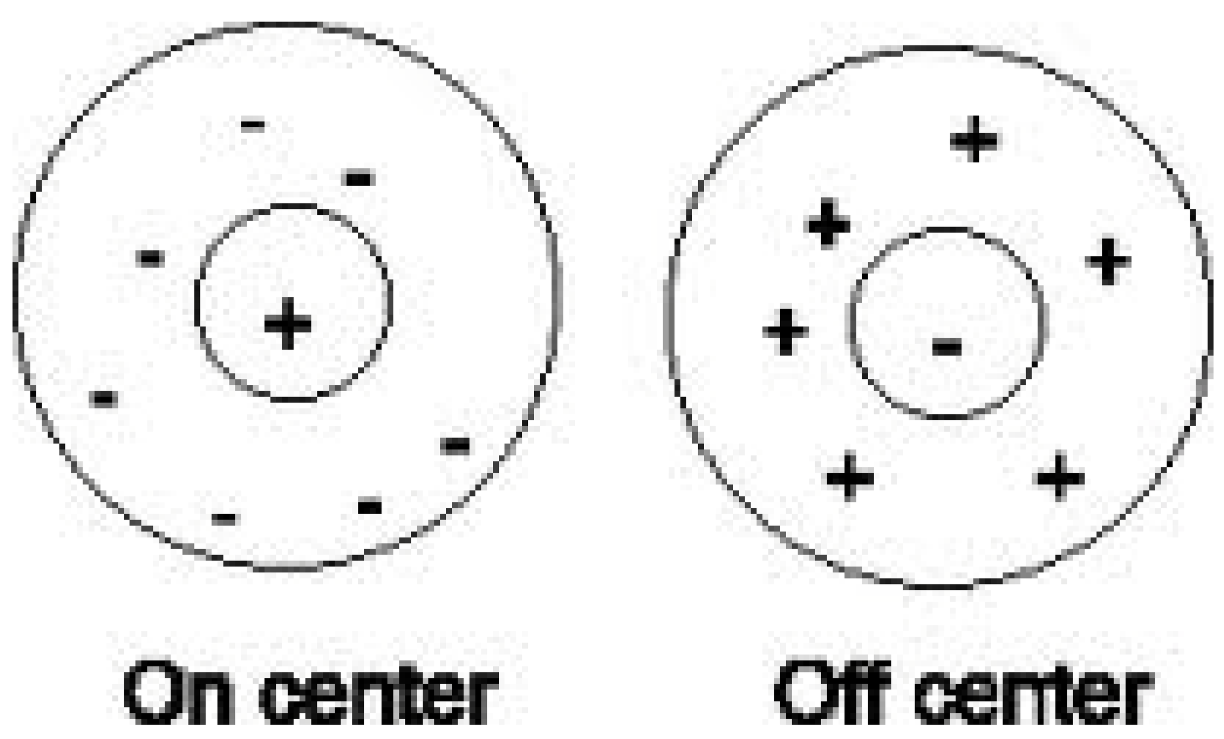


Retina Cell Layers

Three for the direct signal path—photoreceptors, bipolar cells, and ganglion (whose axons are bundled together as the "optic nerve"). And two intermediate layers integrate information laterally—horizontal cells and amacrine cells. The first four layers respond to inputs by passing on analog outputs mediated by the amounts of neurotransmitters released into the synapse. At the ganglia, optic signals are passed on in digital format to the brain.

Contrast Detection Enabled by Center Surround Structure

Connecting neighboring photoreceptors in a bulls eye arrangement 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.



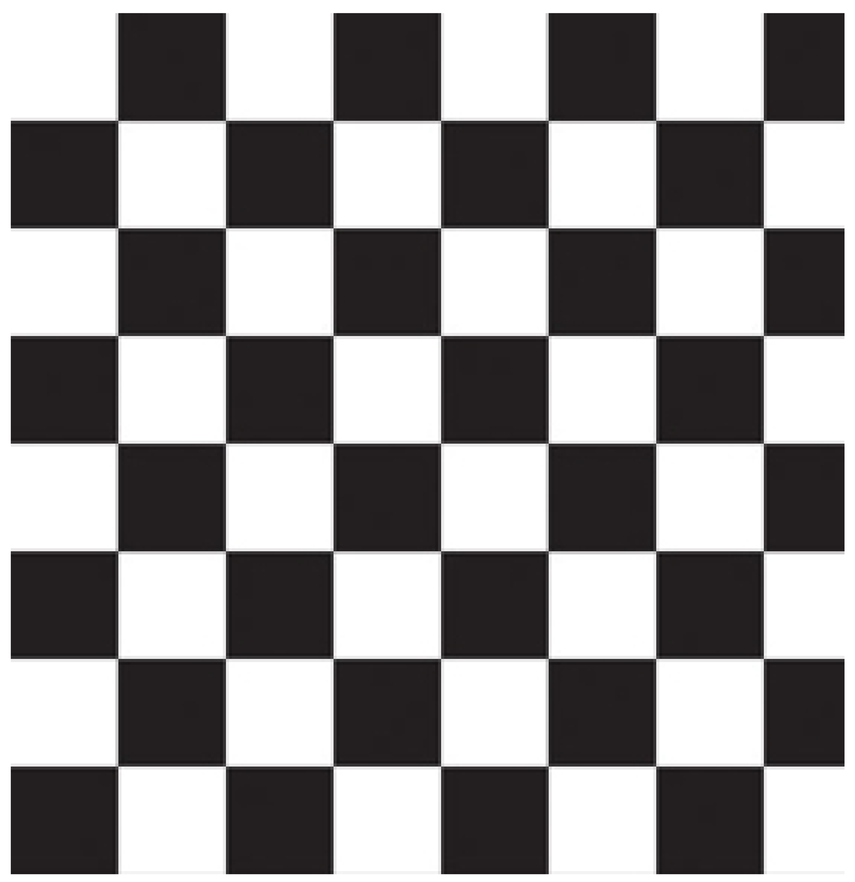
Building the Eye

Photoreceptors are distributed in a anatomically accurate, spatially dependent manner with a high concentration of cones at the fovea and a greater concentration of rods at the periphery. A blind spot is included as well. Horizontal and bipolar cell arrays are input manually. The eye is then "wired" together based on the selected center-surround dimensions.

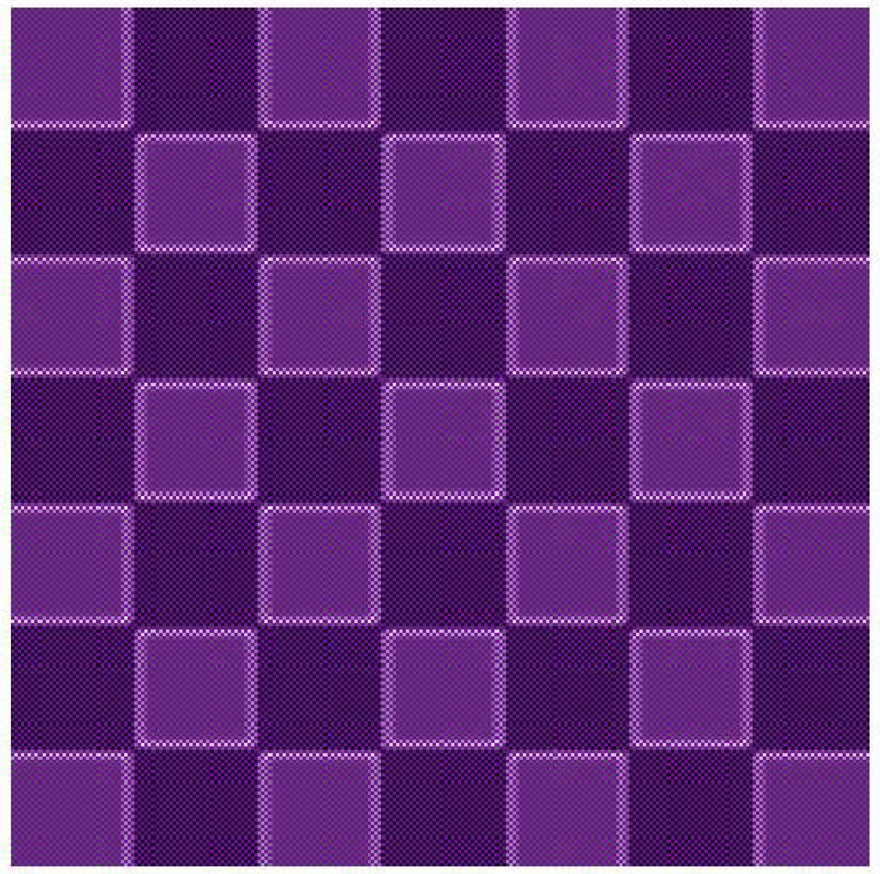
Image Processing

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.

Stimulus



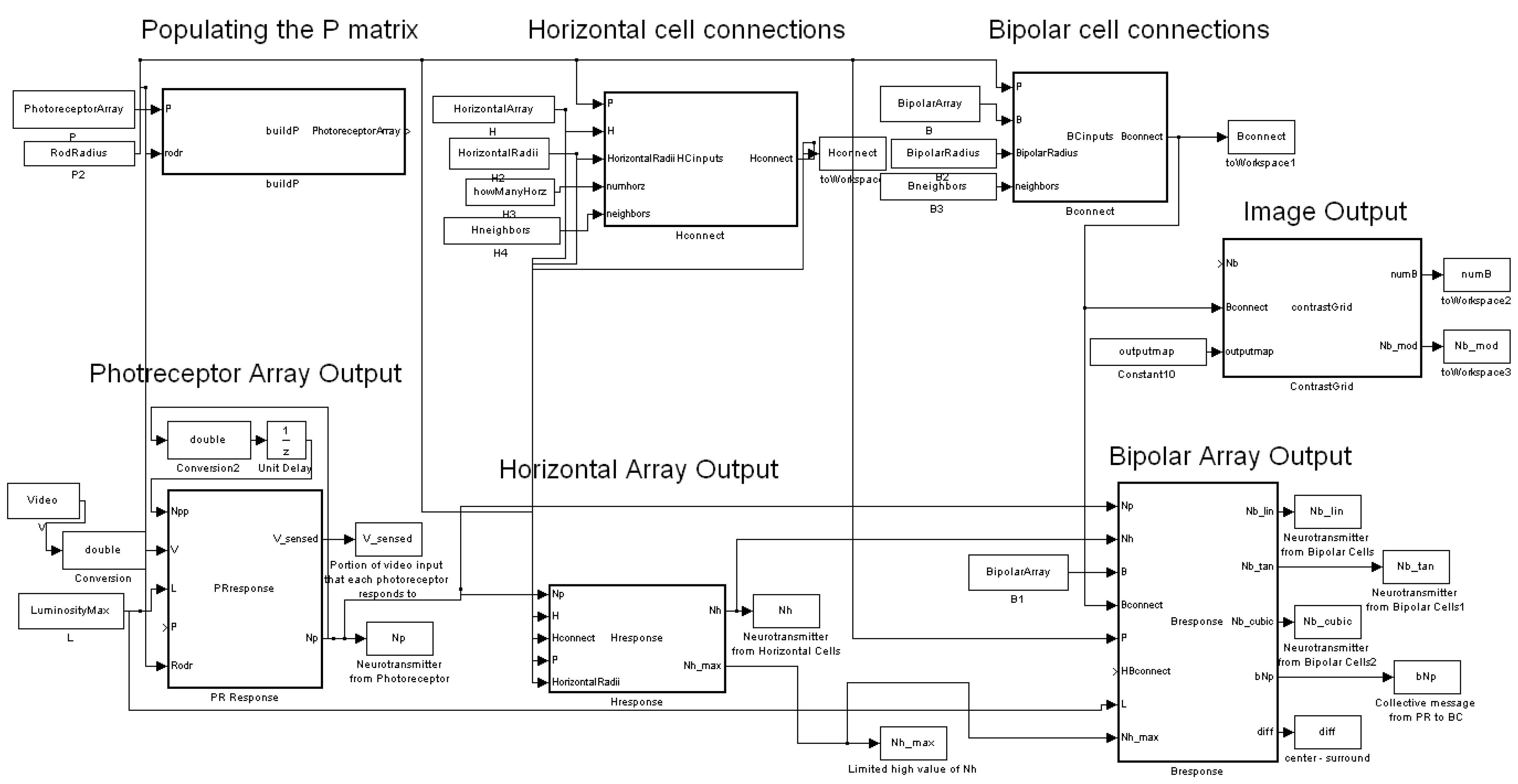
Model Output



Results

Currently, the system detects only contrast and light levels. Grey 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.

Simulink Model



This material is based upon work supported by the National Science Foundation under an RET Site Project with Grant #: EEC-0807286