Matlab Modeling of Retina Anatomy and Function

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Background

- Explosion in research at intersection of engineering and medicine
- Neuro-Robotics is an emerging field
  - Brain-controlled smart prostheses
  - Retinal implants
  - National Geographic: Biorobotics
- Personal interest in neuroscience, brain function, and sensor systems
Purpose: Retina Model

- To capture function by modeling form
- To develop a research tool to provide insight into the structure of the retina
- To develop simplified image processing algorithms
- Future development of jOcular Implant
Motion/Edge Detection & Tracking

Display current state (light & Dark) of each sensor
Edge detection/Contrast detection
Motion detection
Tracking
Algorithms

- Rc-Time scaled 0-10, then displayed using debug command.

- Takes the difference of adjacent readings and asks IF they are greater than 2, if so THEN display a line.

- Debug command displays the diffx value in ASCII code which will display a vertical line or an empty space.
Circuit Anatomy

- The RC-Time is used to display the light levels in the specified area.
Model Overview

- **Build the eye**
  - Constructing each layer of the retina (Photoreceptors, Bipolar, and Horizontal cells)
  - Connections between the layers
  - Using matrices to display each cell and their locations

- **Image processing**
  - Contrast

- **Difficulties**
  - Switching from manually to automatically inputting the video

- **Data/ Results**
  - Displaying image

- **Future Directions**
Retina Cell Layers
Building the eye

- Constructed different layers of the retina
- Photoreceptors occupy the entire retina
  - Cones are about 10 times larger than rods
- There are fewer horizontal cells than photoreceptors
- Bipolar cells occupy the same locations as the horizontal cells
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(label: Photoreceptor Array)

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(label: Horizontal/Bipolar Array)
Building the eye

Distribution of Rods and Cones in the Retina
Building the eye

- Creating connections between the cell layers
- Photoreceptors must be able to communicate with the horizontal and bipolar cells in order to send messages to the brain
- Neurotransmitters send signals between layers
Center-Surround Structures
SIMULINK Model

Populating the P matrix

Horizontal cell connections

Bipolar cell connections

Photoreceptor Array Output

Horizontal Array Output

Bipolar Array Output

Image Output
Image Processing

- The eye must be able to detect contrast

Input

Output
A few difficulties

- Scaling
- Output graphics
- Embedded matlab function use a limited function library
  - Ex: nnz
Future

- Color
- Scaling
- Validating model using clinical data
- Modeling amacrine and ganglion cell connections