Multi-Scale Modeling of Electrical Stimulation of the Retina

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Implantable retinal prosthesis has been developed to restore some vision to patients who have been blinded by degenerative diseases, such as Retinitis Pigmentosa or Age-Related Macular Degeneration. These diseases cause degeneration of photoreceptor cells. By electrically stimulating the surviving ganglion and bipolar cells, the damaged photoreceptors may be bypassed and limited vision can be restored. While this has been shown to produce partial vision restoration, the understanding of how the retina cells react to this systematic electrical stimulation is relatively unknown. Better predictive models and a deeper understanding of the neural response to electrical stimulation is necessary for designing a successful prosthesis.

Modeling the retina across multiple spatial scales, from the tissue-level to networks of neurons, would produce a detailed model for simulating these devices. This would allow for the study of how different stimuli, geometry of electrodes, placement of electrodes, etc. effect the pattern of cells firing. In this work, we consider a tissue-level model of a portion of the retina, including an electrode array placed on the surface of the retina. A multi-resolution variant of the Admittance Method (AM) is used to solve for potentials due to one of the electrodes firing on this model. We then construct a small network of ganglion cells, whose connections are based on transmission electron microscopy (TEM) images of a retina. The ganglion cell network is considered to be below the surface of the firing electrode, and the AM results are interpolated to find potentials along the soma and axon of each ganglion cell. NEURON software is then used to simulate activity on the network of ganglion cells, using these potentials as initial conditions.

The results to be presented include the methods used for the simulations, plots of the models at the tissue level and the neuronal network level, and the resulting response at the network of neurons due to a stimulus applied to an electrode at the retina surface.