

## **Towards a Multi-Scale Model for Optimizing Electrode Stimuli in a Retinal Prosthesis**

Kyle Loizos, J. Scott Lauritzen, James R. Anderson, Jefferson Brown,  
Bryan W. Jones, Robert E. Marc, and Gianluca Lazzi  
The University of Utah, Salt Lake City, UT, USA

Retinal prostheses have been developed in order to restore some vision in patients blinded by degenerative diseases, using systematic electrical stimulation to excite cells in the retina that are no longer receiving input from damaged photoreceptors. In attempt to optimize the function of these prostheses, the impact of the stimulation parameters need to be studied to understand how the pulse width, magnitude, and electrode placement affect the retinal tissue being stimulated. To accurately model this electrical stimulation, a multi-scale computational approach is being developed in order to incorporate the electromagnetic field effect on the bulk tissue being stimulated and the resulting underlying neural activity.

A large-scale model of the retina was constructed, including an epi-retinal electrode array placed against the surface of the retina, tissue to be stimulated in the retina, and the surrounding tissue. By using a multi-resolution admittance method, this model was discretized into a three-dimensional circuitual network that incorporates the heterogeneity of all tissues and other materials in the model, based on the dielectric properties for each material. By applying time-varying current source(s), the voltages at each node may be solved for, giving the magnitude of the electric fields due to the given source(s). These voltages may then be applied to a computational model of a retinal neural network as boundary conditions for the extracellular fields the cells are experiencing. NEURON software is called by the time-dependent impedance method, to simulate the neural network response in this model, using a bipolar-ganglion cellular network, including the excitatory synaptic coupling between bipolar cells, and synaptic connections between bipolar, amacrine, and ganglion cells. The model was constructed based on nanoscale connectome data of large-scale retinal networks (augmented by picoscale ultrastructural reimaging), incorporating detailed morphometrics and synaptometrics. Our simulation studies will be further expanded to include more phenomena observed throughout this connectome dataset, and add additional complexity to the mechanisms present in each cell type.

By linking these simulation modalities used to study the bulk tissue response to a driving current source and the cellular network responses to extracellular current stimulation, a system for analyzing the tissues' response to an electrical stimulation is constructed, producing more accurate results than could be obtained by either method independently. Any number of stimulation parameters may then be applied to this model, with the goal of understanding which types of cells are stimulated by which pulse shapes, magnitudes, etc. Through this knowledge, we intend to advance the current technology being used in retinal prosthesis.