UNIVERSITY OF TORONTO
FACULTY OF ARTS & SCIENCE | Department of Mathematics

Departmental PhD Thesis Exam

Wednesday, June 26th, 2024 at 2:00 p.m. (sharp)
via Zoom / BA6183

PhD Candidate : Belal Abuelnasr

Supervisor : Adam R. Stinchcombe

Thesis title : Modelling and Simulating Retinal Dynamics and Physiology

Abstract

We present a detailed physiological model of the (human) retina that includes the biochemistry and electrophysiology of phototransduction, neuronal electrical coupling, and the spherical geometry of the eye. The model is a parabolic-elliptic system of partial differential equations based on the mathematical framework of the bi-domain equations, which we have generalized to account for multiple cell-types. We discretize in space with non-uniform finite differences and step through time with a custom adaptive time-stepper that employs a backward differentiation formula and an inexact Newton method. A refinement study confirms the accuracy and efficiency of our numerical method. We generalize our time-stepping scheme to higher order and derive estimates for the corresponding local truncation errors. Numerical simulations using the model compare favourably with experimental findings, such as desensitization to light stimuli and calcium buffering in photoreceptors. Other numerical simulations suggest an interplay between photoreceptor gap junctions and inner segment, but not outer segment, calcium concentration. Applications of this model and simulation include analysis of retinal calcium imaging experiments, the design of electroretinograms, the design of visual prosthetics, and studies of ephaptic coupling within the retina.

http://blog.math.toronto.edu/GraduateBlog/yourthesislink.pdf