Public Abstract

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Graduation Term:SP 2017

Department:Electrical Engineering

Degree:PhD

Title:Neural Systems Modeling: Three Case Studies

Computational neuroscience attempts to reverse engineer brain circuits at the cellular and system levels to better understand the function and behavior of neurons and networks in the brain and body. Mathematical models represent neurons as equivalent circuits to study their electrical properties. These neuron models can be combined into larger networks to study network behavior of biological structures. Computational models allow neuroscientists to test hypotheses much faster than physical experiments on biological cells, and can be used to make predictions to assist neuroscientists. While single cell neuron models attempt to replicate the membrane potential and ionic current behavior of individual neurons, network models connect many individual cell models with synaptic connections to study the interaction and communication between cells in a biological system. This dissertation involves three studies of computational models at both the individual neuronal level and the network level.

1. Generation and preservation of the slow underlying membrane potential in a model bursting neuron. A model of a class of slow-wave bursting cells was developed to investigate and generalize correlations among maximal current conductances that might generate and preserve its underlying oscillation. The underlying oscillation of the membrane potential was divided into three phases: generation, maintenance, and termination. The contributions of this study include suggestions that different current modules can co-regulate to preserve the characteristics of each phase

2. Cellular and synaptic correlates of pattern formulation in a hippocampal model. We adapted a computational network model of the hippocampus to include biologically realistic conductance-based cells in CA3 and dentate gyrus (DG) regions. The contributions of this study include findings that inhibition was the dominant factor influencing the recruitment of a CA3 cell into a pattern, and differential connectivity and inhibitory dynamics between BCs and OLM cells enabled the former to control the recruitment of specific pyramidal cells into the CA3 pattern, and the latter to regulate pattern size.

3. Genesis of Hippocampal Theta Rhythm in a Computational Model. The mechanisms involved in the generation of hippocampal theta remain poorly understood. We have outlined the procedure to study the genesis of theta by adapting a computational network model of the rodent hippocampus.