AGENDA

AM Session
9:00   Welcome/Opening remarks - Todd Troyer
9:15   Uri Eden, Characterizing Neural Spiking Dynamics Using Point Process Adaptive Filtering
10:15  Break
10:30  Adrienne Fairhall, From Neuronal Dynamics to Adaptive Coding
11:30  Todd Troyer, Stochastic Dynamics of One-Dimensional Model Neurons
12:30  Break for Lunch

PM Session
1:45   Eric Shea-Brown, Cooperative Dynamics in Neural Circuits
2:45   Eugene Izhikevich, Large-Scale Modeling of the Brain
3:45   Break
4:00   Panel discussion

ABSTRACTS

Characterizing Neural Spiking Dynamics Using Point Process Adaptive Filtering

Uri Eden PhD
Assistant Professor of Math & Statistics, Boston University

Although it is well known that brain areas receive, process and transmit information via sequences of stereotyped action potentials, most analyses of neural data ignore the localized nature of spikes. The theory of point processes offers a unified approach to modeling the firing properties of spiking neural systems, and assessing goodness-of-fit between a neural model and observed spiking data. We develop a point process modeling framework and state space estimation algorithms to describe and track the evolution of dynamic representations from individual neurons and neural ensembles. This allows us to derive a toolbox of estimation algorithms and adaptive filters to address questions of static and dynamic encoding and decoding. In particular, we will discuss new work using particle filtering methods to estimate nonlinear dynamical model parameters based on point process observations.

These methods will be illustrated through a number of examples, including an analysis to estimate biophysical parameters of conductance based neural models using only the resulting spike times. In simulation, it is shown that accurate estimation of model parameters and hidden variables is possible for certain classes of dynamical models. Using in vitro spiking data, we apply the methods to identify features of an unknown current responsible for shifting between bursting and tonic firing states. Issues of model identification and misspecification will also be discussed.
From Neuronal Dynamics to Adaptive Coding

Adrienne Fairhall PhD
Associate Professor of Physiology & Biophysics University of Washington

Spiking in the single neuron implements an encoding of the current input which can be characterized as feature detection combined with a nonlinear threshold function. In this talk we will discuss how neuronal dynamics couple with the statistics of the driving input to determine the components of the single neuron code. In general, the components of a coding model change with stimulus statistics; a special case of this is gain scaling, whereby neural systems can encode their inputs relative to their typical scale. We have observed the emergence of this property during development in single cortical neurons. We examine the dynamical basis for this behavior in terms of single neuron biophysics.

Stochastic Dynamics of One-Dimensional Model Neurons

Todd Troyer PhD
Assistant Professor of Biology, University of Texas San Antonio

The simplest class of neural models posit one-dimensional subthreshold dynamics, with action potentials generated when the state variable passes a threshold value. Despite their simplicity, important aspects of the coding properties of such models remain poorly understood. In this talk, we will examine how diffusive noise alters the neural dynamics two canonical one-dimensional models: the leaky integrate and fire (LIF) model and the phase response curve. Adopting a stochastic differential equations perspective, we investigate the LIF model's ability to process signals much more rapidly than expected from its subthreshold dynamics, and explain the relationship between the mean and variance of the phase response curve. At the end of the talk, I will speculate about a possible generalized framework that combines aspects of both models by defining a new state variable that yields a uniform density function at equilibrium.

Cooperative Dynamics in Neural Circuits

Eric Shea-Brown, PhD
Assistant Professor of Applied Math, University of Washington

The brain's networks contain numerous mechanisms that can lead to synchronized (or correlated) dynamics among cells. Moreover, different patterns of correlations can have a wide range of impacts on the fidelity with which a network encodes incoming signals -- degrading this coding, enhancing it, or doing very little at all. Faced with these diverse possibilities, we seek organizing principles along two lines. First, using simplified circuit models, we develop explicit links between the (normal form) dynamics of single cells and the "two-point" correlations produced among pairs of cells. Next, we address a remarkable fact from recent empirical studies. The activity of many circuits — especially in the retina — is often captured by statistical models based on these pairwise correlations alone. We describe circuit mechanisms that guarantee such a pairwise-based description — and mechanisms that lead it to fail, opening the door to a high level of complexity in the resulting dynamics.
Large-Scale Modeling of the Brain

*Eugene Izhikevich, PhD*

*Co-Founder, Chairman & CEO, Brain Corporation, Editor-in-Chief, Scholarpedia*

The understanding of the structural and dynamic complexity of mammalian brains is greatly facilitated by computer simulations. We present here a detailed large-scale thalamocortical model based on experimental measures in several mammalian species. The model spans three anatomical scales. (i) It is based on global (white-matter) thalamocortical anatomy obtained by means of diffusion tensor imaging (DTI) of a human brain. (ii) It includes multiple thalamic nuclei and six-layered cortical microcircuitry based on in vitro labeling and three-dimensional reconstruction of single neurons of cat visual cortex. (iii) It has 22 basic types of neurons with appropriate laminar distribution of their branching dendritic trees. The model simulates one million multicompartmental spiking neurons calibrated to reproduce known types of responses recorded in vitro in rats. It has almost half a billion synapses with appropriate receptor kinetics, short-term plasticity, and long-term dendritic spike-timing-dependent synaptic plasticity (dendritic STDP). The model exhibits behavioral regimes of normal brain activity that were not explicitly built-in but emerged spontaneously as the result of interactions among anatomical and dynamic processes. We describe spontaneous activity, sensitivity to changes in individual neurons, emergence of waves and rhythms, and functional connectivity on different scales. This talk is based on the PNAS paper