BioE332A: Large-Scale Neural Modeling

Catalog Description: Emphasis is on modeling neural systems at the circuit level, ranging from feature maps in neocortex to episodic memory in hippocampus. Simulation exercises to explore the roles of cellular properties, synaptic plasticity, spike synchrony, rhythmic activity, recurrent connectivity, and noise and heterogeneity; quantitative techniques to analyze and predict network behavior; modeling projects to study neural systems of interest (second half of two-quarter sequence). Work in teams of two; run models in real-time on neuromorphic hardware developed for this purpose.

Course sequence: BioE332A, the first in this two-course sequence, is based on weekly ***three-hour labs*** (simulation exercises) performed in groups of two. Accompanying lectures provide the background needed to understand and perform these labs. BioE332B, the second course in the sequence, builds on these lessons through a quarter-long ***modeling project***. Accompanying guest lectures introduce relevant background, ranging from data analysis to experimental techniques.

Prerequisites: Biology students should have a differential equations course (e.g., Math 42); no background in engineering is required. Engineering students should have a neurobiology course (e.g., Bio 20); otherwise the instructor's permission is required. Undergraduates need the instructor's permission.

Goals: Link structure to function by developing circuit-level computational models of the nervous system. These models are studied in weekly lab exercises.

Target Audience: This course is intended to draw students from multiple disciplines with an interest in interdisciplinary approaches. Students are encouraged to pool their expertise in different areas by working in groups of two.

Instructor: Kwabena Boahen, Bioengineering Dept (boahen@stanford.edu).
Assistant: Chris Sauer, EE Dept (csauer@stanford.edu).
Website: brainsinsilicon.stanford.edu/courses

Textbooks: None required. For background reading, **Eugene M. Izhikevich's** monograph, ***Dynamical Systems in Neuroscience***, provides a good introduction to neural modeling.

Grading: Your grade will be based on the best 9 of 10 ***lab write-ups***; you get to drop one. You will also have to give a ***data blitz***, where your team presents their results from one (or two) of the labs to the class.

Late policy: Lab write-ups are due at the beginning of the following week's lab session. It is a ***third of a grade off the first day*** an assignment is late, and ***another third of a grade off the second day***. Assignments more than ***two days late will not be accepted***. ***Prelabs*** are also due at the beginning of your lab section; it is a ***full grade off*** that lab if they are not completed by then.

Topics:

Overview

- Computational Neuroscience

Synapse and Neuron Models

- Synaptic Cleft and Receptor
- Integrate-and-Fire Neuron
- Spike generation

Neuron Behaviors

- Frequency Adaptation
- Bursting

Neuron Interactions

- Phase Response Curve
- Two-Neuron Example

Synchrony

- Inhibitory Networks
- Role of Delay

Attention

- Excitatory-Inhibitory Networks
- Neuromodulation

Synaptic Plasticity

- Spike-Timing Dependent Plasticity
- Feedforward Synapses

Plasticity & Synchrony

- Recurrent Synapses
- Combating Variability

Associative Memory

- Storing Patterns
- Recalling Patterns

Revised 1/5/09