Instructors

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Description

This course will introduce concepts and techniques related to the modeling of neural systems and behavior at an elementary level. The course will span the breadth of neuroscience, from ions to behavior. However, for each of those areas, we will study only one or two equations, calculations, or models in depth. We will also discuss modern applications of theoretical neuroscience. Throughout the course, we will use both math and numerical simulations. Several tutorials will be integrated into the course: on the programming language Python, scientific notation, differential equations, probability, and matrices.

Prerequisites

Introduction to Neural Science – can be waived, email the instructor. Calculus 1 or equivalent – cannot be waived.

Meeting schedule

LectureThursdays 2-4 pmRecitationFridays 2-3 pmBoth lecture and recitation will be held in Room 815 of Meyer Hall.

Tentative syllabus

<u>Week 1 (January 28, 2015)</u>. Logic and logistics of course. History of theoretical neuroscience. Kaleidoscope of theoretical neuroscience questions. What makes a model good or bad? Levels of analysis. *Python tutorial*.

<u>Week 2</u>. Powers of 10 in the brain. Length and time scales in neuroscience, brain sizes and numbers of neurons of animals, scaling laws. Physical quantities sensed by brains. *Tutorial on scientific notation*.

<u>Week 3</u>. The neuron as an electrical circuit. Nernst equation. Resistor-capacitor circuit. Exponential relaxation. *Tutorial on differential equations*.

<u>Week 4</u>. Action potentials. Hodgkin-Huxley model. *Tutorial on coupled differential equations*. Fitzhugh-Nagumo model.

<u>Week 5</u>. Leaky integrate-and-fire model. First passage times. Rate neurons. *Tutorial on probability*.

<u>Week 6</u>. Balance between excitation and inhibition, variability in neural activity, Poisson distribution.

Week 7. Tuning curves. Population codes. Correlations. Tutorial on matrices.

<u>Week 8</u>. Linear-nonlinear-Poisson models, population decoding, maximum-likelihood estimation.

Week 9. Circuits and graphs: connectivity, small worlds.

Week 10. Behavior. Psychometric curve. Signal detection theory. Sources of variability.

Week 11. Bayesian inference.

Week 12. Behavioral models of learning. Prepare projects.

Week 13: Hebbian learning, spike-time-dependent plasticity. Prepare projects.

Week 14 (May 13, 2015). Student project presentations.

Book

Peter Dayan and Larry Abbott, *Theoretical Neuroscience* You need to bring a laptop. If you don't have one, let us know.

Grading

- 20% Attendance and participation in lecture. Students are allowed to miss 3 sessions without explanation; beyond that, a proportional part of the participation grade will be deducted for each missed class. Students are expected to participate in in-class quizzes; failure to do so counts as a missed class.
- 55% Homework and participation in recitation. Best 10 of 12. Collaboration is allowed but every student has to submit their own work.
- 25% Project presentation and project report. The project will be about a problem in or application of theoretical neuroscience.

No midterm or final.

The numerical score will be turned into a letter grade according to the following scale: 90-100 A; 87-89 A-; 84-86 B+; 80-83 B; 77-79 B-; 74-76 C+; 70-73 C; 67-69 C-; 64-66 D+; 60-63 D; 57-59 D-; 0-56 F.