NBIO 729 – Neural Information Processing.

Fall, 2014

Instructor: Paul B. Manis, Ph.D.

Contact: pmanis@med.unc.edu

Schedule: M, 3:00-4:30 pm, Mondays. G101 POB except 9/15/2014 in G111.

Text: There is no single text for this course. However, we will work from individual chapters in the following texts, as well as primary literature:

1. Izhikevich, E.M., "Dynamical Systems in Neuroscience" (MIT Press, 2007). The entire book is available as a PDF online at : http://www.izhikevich.org/publications/dsn.pdf
2. Carnevale, N.T., and Hines, M.L. "The Neuron Book", Cambridge Press 2005. PDFs of the individual chapters can be accessed at: http://ebooks.cambridge.org/ebook.jsf?bid=CBO9780511541612
3. Grun, S, Rotter, B. "Analysis of parallel sike traints" Springer Series in Computational Neuroscience, Volume 7, 2010, available at: http://download.springer.com/static/pdf/804/bok%3A978-1-4419-5675-0.pdf?auth66=1410363256_1f2628a5ee4372900f7ed426aa2a2933&ext=.pdf (specifically, Chapter 13 by Johnson et al.)

Course Description

This discussion/reading seminar covers the fundamentals of nervous system information processing and integration, with examples from sensory systems. Information processing is examined from the level of single cells through networks. Topics include spiking models of neurons, dynamical systems at the single cell level, theoretical analyses of synaptic plasticity, analysis of spike trains, concepts of information theory, neural networks, and emergent properties of neural networks. Readings will be from the primary literature. Prerequisites include at least 1 year of calculus, familiarity with MATLAB or Python (or permission of the instructor), and NBIO 722/723 (or an equivalent general neuroscience course).

The course will consist of 2 parts. In the first part we will discuss processing in single cells, including approaches to both creating models and to the analysis of spiking patterns and their relationship to the input of the cell, and analysis of processing at the single cell level. In the second part, we will discuss neural networks, including pattern generation, oscillations, emergent properties of networks, and computational approaches to networks. In all parts, we will also read seminal papers in the field (i.e., there will be an historical context).

Final project:

Due December 8 2014.

The final project can be in one of 2 forms:

1. Develop a simple single cell model and to evaluate it's computational performance using some aspect of information theory across a particular set of inputs; or develop a simple

network model using integrate-and-fire neurons or biophysically realistic neurons do demonstrate a simple network processing task. This may be done in Matlab, Python, NEURON, or BRIAN. The model should be written up as a 4-5 page paper (excluding figures, references and code) that describes the hypothesis that was tested, the rationale for the model, the results, and discusses those results. Appended to the paper should be key figures of results, full citations, and the final source code.

2. Write a paper that compares and contrasts two existing schemes of information processing in a single neural structure from papers in the literature. This paper should include at least one independent computation related to the papers. The paper should be 10-12 pages, exclusive of figures and references.

The final paper in either project form should include:
1. A title page (title, author, PID, date).
2. Numbered pages.
3. Double spaced, 12 point font, 1" margins. References in APA standard style (see http://www.library.cornell.edu/resrch/citmanage/apa or http://www.apastyle.apa.org).
4. Reference list, alphabetized, full citations (Authors (year) Title. Journal: startpage-endpage, DOI if available).
5. Figures – please put figures at the end of the manuscript, one per page, with legend.
6. If you use figures from another paper, please make proper attribution in the Figure legend, and include the paper in the reference list.

Grading:
Grading will be based on two components. 25% of the grade will depend on class participation and discussion. 25% will depend on problem sets. 50% will depend on the final project.

Sequence:
Part 1: The single cell
- Topic 1: Representation of "information" in the brain. What is "information" ? Information theory (Shannon). Mutual information. Problem sets on "information"
- Topic 2: The neuron action potential: ion channel regulation of firing. Measurements of timing. Hodgkin and Huxley equations. How to make measurements to create HH models.
- Topic 3: Solving the HH model: coupled ODEs. NEURON. Issues, computations, constraints. NEURON/matlab problem sets. The roles of other ion channels, state models.
- Topic 4: Non-linear dynamics 1. Ion channels as computational elements. Action potential threshold, bursting. Dendritic channels and contribution to dynamics. Phase plane analysis. Reading: Rinzel/Izhekivich.
- Topic 5: Linear analysis: A window into information processing. Revcor, STRF, STA: methods and interpretation. Voltera Kernels and other non-linear analyses. Reading: Fairhall/Slee/Spain
- Topic 6: Multiple currents, multiple models, convergence of excitability and networks (Marder)

Part 2: Networks

- Topic 1: Early concepts of neural networks – the evolution of Perceptrons. McCullogh-Pitts, Rosenblatt, Minsky and Papert. "Learned" perception. Ubiquity of plasticity mechanisms in network construction.
- Topic 2: Themes, topologies and simple computations of "real" neural networks. Marr-Albus cerebellum.
- Topic 3: "Liquid state machines" (Maas).
- Topic 4 Network states. Up/Down, gating, thalamic states. Propagation of activity through layers of networks.