Fall 2010

Psyc 403C/503C

Introduction to Computational Neuroscience

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Class website: http://emotion.nsma.arizona.edu/CompNeuro/
Wednesdays: 1:00pm-4:00pm, Life Sciences North #352

Course Goals

Current neurophysiological techniques allow for the collection of very large amount of data. This data collection is however limited to only a few neurons at a time, or a few trials per neurons, and require labor-intensive experimental paradigms that are focused on very specific hypotheses. Computational neuroscience offers new tools to quickly formulate and test hypotheses on the neural mechanisms underlying behavior. This course will cover the basic simulation techniques available to biophysical modeling. The first part of the class will be devoted to single and multiple compartmental models, intrinsic neuron properties and dendritic integration. The second part of the class will focus on synaptic transmission and networks of biophysical neurons. Modeling papers will be discussed and evaluated for their explanatory and predictive potentials. Knowledge of a programming language (such as Matlab) and basic introductory Neuroscience is required. See Website for self-assessment of computational abilities. The class is hands on and a laptop computer is required.

Texts: Papers distributed in class.
Suggested support textbooks (not mandatory):

- Theoretical Neuroscience (Dayan and Abbott)
- SNM: Spiking Neuron Models (Gerstner and Kistler)
- MNM: Methods in Neuronal Modeling (Koch and Segev)
- Biophysics of Computation (Koch)
- FCN: Foundations of Cellular Neurophysiology (Johnson and Wu)
- Neuroscience, 3rd edition (Purves et al.)
- Numerical Recipes in C (Press, Teukolsky,Vetterling, Flannery)

Grading Policy:

There will be 1 midterm exam, 1 final and homeworks. Homeworks (indicated by **HW** below) will be given bi-weekly on average. Few quizzes will be for extra credits and will be given randomly during the semester. The final is comprehensive. Midterm and final exams cover assigned readings and lecture material. The final grade will be assigned as follows:

Undergraduate grading scale:

- Final	**30 %**
- Midterm	**20 %**
- Homeworks + class participation	**50%**

Graduate grading scale:

- Final	**30 %**
- Midterm	**20 %**
- Homeworks + class participation	**20%**

- Final project 30%

<u>Syllabus Outline (subject to 'fine tuning')</u>

Week1 Introduction to modeling: The different kinds of models.

Week2 Basic recording techniques: Single and multi unit data.

Part I: Simulations of single neurons

Week3 Introduction to the NEURON simulator.
Readings: (Hines and Carnevale, 1997)

Week4 Models of individual currents: activation, inactivation. **HW1.**
Readings: (Hodgkin and Huxley, 1952)

Week5 The currents flora and their functional significance.
Readings: MNM (Chapt 5)

Week6 Multiple channels and calcium dynamics. **HW2.**
Readings: MNM (Chapt 4)

Week7 Morphology and dendritic integration.
Readings: (Pyapali et al., 1998; Stuart and Spruston, 1998; Cook and Johnston, 1999)

Week8 **Midterm** and intrinsic properties: bursts, frequency preference, excitability.

Part II: Simulations of neural networks

Week9 Kinetics models of synaptic transmission. The receptor flora. **HW3.**
Readings: (Destexhe et al., 1994)

Week10 Stochastic synapses, short-term synaptic dynamics and synaptic noise.
Readings: (Dobrunz and Stevens, 1997; Varela et al., 1997; Matveev and Wang, 2000; Destexhe et al., 2001)

Week11 Small networks: central pattern generators. **HW4.**
Readings: (Marder and Selverston, 1992)

Week12 Large networks: information transfer and neural coding.
Readings: (Knight, 1972; Bialek and Rieke, 1992; Samsonovich and McNaughton, 1997)

Week13 Simplified models of neurons and networks. **HW5.**
Readings: SNM (Chapt 4)

Week14 Projects Presentations and **Final.**

References

Bialek W, Rieke F (1992) Reliability and information transmission in spiking neurons. Trends Neurosci 15:428-434.

Cook EP, Johnston D (1999) Voltage-dependent properties of dendrites that eliminate location-dependent variability of synaptic input. J Neurophysiol 81:535-543.

Destexhe A, Mainen ZF, Sejnowski TJ (1994) Synthesis of models for excitable membranes, synaptic transmission and neuromodulation using a common kinetic formalism. J Comput Neurosci 1:195-230.

Destexhe A, Rudolph M, Fellous JM, Sejnowski TJ (2001) Fluctuating synaptic conductances recreate in vivo-like activity in neocortical neurons. Neuroscience 107:13-24.

Dobrunz LE, Stevens CF (1997) Heterogeneity of release probability, facilitation, and depletion at central synapses. Neuron 18:995-1008.

Hines ML, Carnevale NT (1997) The NEURON simulation environment. Neural Comput 9:1179-1209.

Hodgkin AL, Huxley AF (1952) A quantitative description of membrane current and its application to conduction and excitation in nerve. Journal of Physiology 117:500-544.

Knight BW (1972) Dynamics of encoding in a population of neurons. J Gen Physiol 59:734-766.

Marder E, Selverston AI (1992) Modeling the stomatogastric nervous system. In: Dynamic Biological Networks: The stomatogastric nervous system (Harris-Warrick RM, Marder E, Selverston AI, Moulins M, eds). Cambridge, Massachusetts

London, England: The MIT Press.

Matveev V, Wang XJ (2000) Differential short-term synaptic plasticity and transmission of complex spike trains: to depress or to facilitate? Cereb Cortex 10:1143-1153.

Pyapali GK, Sik A, Penttonen M, Buzsaki G, Turner DA (1998) Dendritic properties of hippocampal CA1 pyramidal neurons in the rat: intracellular staining in vivo and in vitro. J Comp Neurol 391:335-352.

Samsonovich A, McNaughton BL (1997) Path integration and cognitive mapping in a continuous attractor neural network model. J Neurosci 17:5900-5920.

Stuart G, Spruston N (1998) Determinants of voltage attenuation in neocortical pyramidal neuron dendrites. J Neurosci 18:3501-3510.

Varela JA, Sen K, Gibson J, Fost J, Abbott LF, Nelson SB (1997) A quantitative description of short-term plasticity at excitatory synapses in layer 2/3 of rat primary visual cortex. J Neurosci 17:7926-7940.