bio/nrod08
theoretical neuroscience

Course Syllabus
Winter 2017

instructor

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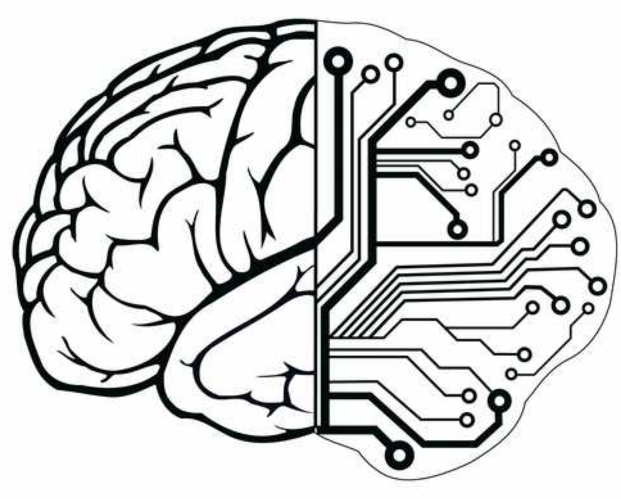
overview and objectives

The brain is a sophisticated information processing device. In fact, despite all our advances in computer science, it is still the most powerful general purpose learning computer on Earth. Indeed, the computations that occur in this incredible, energy efficient computer contained in our skulls underlie our perceptions, thoughts, decisions and memories. Theoretically, if we could crack the operations of this computer, then we could read and write thoughts and memories and create artificial minds, opening the door to brain machine interfaces of the sort only dreamed of in science fiction.

The field of theoretical (or computational) neuroscience is devoted to understanding the brain as a computational device. Using mathematical models of neurons and circuits, theoretical neuroscientists seek a formal understanding of the brain that will allow us to manipulate it in the same ways that we can manipulate other computers. In this class, we will take a multidisciplinary approach to theoretical neuroscience. In addition to learning current mathematical theories of neural computation, we will tie the theories we learn back to biology by studying modern papers that seek a unification of biology and theory. By the end of this course, you should have the beginnings of a formal understanding of how the brain encodes information and learns from experience. This will, hopefully, provide the groundwork for any future work in academia or industry related to neural information processing, brain machine interfaces or artificial intelligence.



prerequisites

(1) NROC34H3 or NROC64H3 or NROC69H3
(2) MATA29H3 or MATA31H3
(3) PSYB07H3 or STAB22H3
Please come and speak to me if you do not have the required prerequisites. This will be a very difficult class without these prerequisites, and you will be removed from the class if you do not have them and you have not made arrangements with me.

lectures

Fridays from 9-11AM in SW316
The first hour of the lectures will be a standard lecture format to learn formal theories (though questions during lecture are welcomed). The second hour will be a discussion-based seminar where we will go over the assigned readings and relate them to the theories we just learned. It is imperative that you do the readings before lecture in order to participate in the discussion (**note**: there is a grade for participation, see below).

tutorials

Mondays from 2-3PM in SW316
The tutorials will be where you will learn about your assignments (see below) and work on them with the TA. **The tutorials are mandatory.** Both assignments will involve writing computer code in Matlab, and the classroom is equipped with laptops with Matlab on them. If you do not know Matlab, do not worry, part of what the tutorials are for is teaching you the basic Matlab you need for the class.

office hours

Fridays from 1:30-3PM in SW525A (back room)
Feel free to come to office hours to discuss class material, get help with the assignments or just to discuss theoretical neuroscience.

course requirements and evaluation

The final grade is based on two assignments (worth 25% each), a final exam (worth 40%), and a mark for participation (worth 10%). **Assignment 1 is due on Tuesday February 7th (week 6), while Assignment 2 is due on Tuesday March 21st (week 11).** The final will be during the standard exam period. The participation mark will be based on all of the post-lecture discussions.

Both assignments will involve creating simulations of neural networks in Matlab. In Assignment 1 you will use information theoretical methods to decode sensory information from spike trains. In Assignment 2 you will create a learning rule that will teach a neural network how to search for hidden rewards. Details of the assignments and initial computer code will be posted on the 3rd and 8th weeks of class before tutorial.

lecture outline

theme	week	date	subject	reading
neural coding and perception	1	Jan. 6	Introduction to neural coding	Jonas & Körding (2016)
	2	Jan. 13	Introduction to information theory and decoding	Quiroga & Panzeri (2009)
	3	Jan. 20	Rate vs. temporal codes	Zuo et al. (2015)
	4	Jan. 27	Predictive coding	Fiser et al. (2016)
	5	Feb. 3	Reading sensory contents	Nishimoto et al. (2011)
	6	Feb. 10	Writing sensory contents	O'Connor et al. (2013)
learning and memory	7	Feb. 17	Introduction to learning and memory via synaptic plasticity	Martin et al. (2000)
	8	Mar. 3	Reinforcement learning	Schultz et al. (1997)
	9	Mar. 10	Auto-associative memories	Wills et al. (2005)
	10	Mar. 17	Unsupervised learning	Zylberberg et al. (2011)
	11	Mar. 24	Deep supervised learning	Lillicrap et al. (2015)
	12	Mar. 31	Creating and erasing memories	Nabavi et al. (2014)

tutorial outline

theme	week	date	subject
assignment 1	2	Jan. 9	Introduction to Matlab
	3	Jan. 16	Linear-nonlinear-Poisson (LNP) models
	4	Jan. 23	Maximum *a posteriori* (MAP) estimation
	5	Jan. 30	Assignment 1 help session 1
	6	Feb. 6	Assignment 1 help session 2
assignment 2	7	Feb. 13	Actor-critic networks
	8	Feb. 27	Temporal difference learning
	9	Mar. 6	Assignment 2 help session 1
	10	Mar. 13	Assignment 2 help session 2
	11	Mar. 20	Assignment 2 help session 3
exam review	12	Mar. 27	Overview and practice questions