Brain-Inspired Machine Learning

Spring 2016

Instructor:	Emre Neftci	**Time:**	Fri 1:00PM – 3:50PM
Email:	eneftci@uci.edu	**Place:**	SBSG 2200.

Course Overview: Recently, machine learning and artificial intelligence repeatedly broke new grounds in solving complex cognitive tasks (*e.g.* AlphaGo). The relevance of such feats to cognitive sciences is evident, and makes one wonder whether machine learning can also help understand how the building blocks of the brain subserve cognition, or even guide the design of novel brain-inspired learning machines. By studying some recent findings, this course will explore the algorithmic bases of cognitive behavior, and teach how bridges from machine learning to biological processes of learning in the brain can be constructed.

The course will start by introducing the tools necessary for modeling the dynamics of neurons and synapse models and understanding the basics of machine learning. In particular, we will present simplified models of neurons that are amenable for analysis under a machine learning framework. Using this framework, we will construct neural systems for inference and learning tasks relevant for cognition. These models will include pattern recognition with deep learning, sequence learning with reservoir computing and competitive learning, dimensionality reduction, probabilistic inference using neural Monte Carlo sampling. Each class will include a lecture component, and will be followed by hands-on experimentation using software simulations of neurons.

This course is ideal for students interested in doing research in computational neuroscience and machine learning. The course is intended to be accessible to students from a broad range of disciplines, with varying background knowledge in the field. However, quantitative reasoning skills, including basic calculus and computer programming are necessary to understand and implement the core concepts of machine learning and neural dynamics. In case of doubt, interested students are encouraged to e-mail the instructor.

The programs distributed for the hands-on exercises and assignments will be written in Python. If necessary, the instructor will introduce the basic Python programming concepts during the second week. Students that have prior programming skills in Matlab or equivalent should not have any difficulty in following the course. For more information on Python, refer to these resources: `http://www.scipy-lectures.org/intro/index.html` (sections 1.1 through 1.4).

Students will be evaluated on an individual project of their choice and present it orally on week 10 to the class. Ideally, this project should related to the students' research and, if applicable, with data already collected.

The course is based on material from the following books, and may provide useful complementary information.

Key References:

[1] M. A. Nielsen. *Neural Networks and Deep Learning*. 2015.

[2] Wulfram Gerstner, Werner M Kistler, Richard Naud, and Liam Paninski. *Neuronal dynamics: From single neurons to networks and models of cognition*. Cambridge University Press, 2014.

[3] Mark F Bear, Barry W Connors, and Michael A Paradiso. *Neuroscience*. Vol. 2. Lippincott Williams & Wilkins, 2007.

[4] C.M. Bishop. *Pattern recognition and machine learning*. Springer-Verlag New York, Inc. Secaucus, NJ, USA, 2006.

[5] P. Dayan and L.F. Abbott. *Theoretical Neuroscience: Computational and Mathematical Modeling of Neural Systems*. MIT Press, 2001.

Course Pages: `http://nmi-lab.org/teaching`

Teaching Assistant: None

Office Hours:

- **Neftci:** Tu 11:00 - 12:30 or by appointment at SBSG 2308

Tentative Course Schedule:

Introduction to the course ....
Mathematical Models of Biological Neurons ....
Basic Concepts in Machine Learning and Neural Networks ....
Dimensionality Reduction Algorithms ....
Neural models of Associative memory and Spike-based Monte Carlo Sampling ....
Self-Organizing Models, competitive learning and Expectation Maximization ....
Reservoir Computing: Liquid State Machines and the Neural Engineering Framework ....
Spike-Based Neural Networks and Deep Learning ....
Group Projects ....
Final Projects Presentation ....

Grading: Assignments: (50%), Project (50%). Reports and assignments must be submitted before the deadline posted with each assignment sheet. There will be up to 4 individually graded assignments. The overall grade for the assignments will be calculated using the best 3 grades.

Important Dates:

Project Presentation .... Last Friday
Project Report Due .... Friday after end of term