BSCS
Cognitive Informatics II | IDSY305, PSYC305

lecture: **Plasticity and learning**
date: Nov. 4-8.
lecturer: Balázs B Ujfalussy, PhD
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office hours: Wednesday, 15:00 - 17:00

Suggested reading:
- papers TBA
- Squire et al., Fundamental Neuroscience, chapters 49-50.
- Peter Dayan and L.F. Abbott : Theoretical Neuroscience, chapters 8-10.
- Paul W Glimcher: Decisions, Uncertainty, and the Brain, The Science of Neuroeconomics
- David MacKay: Information Theory, Inference, and Learning Algorithms, chapters 38-42.

Synopsis:
We can easily recognise complex visual patterns such as the face of an old friend, memorise unique events like a football scene, learn new skills like skating or a foreign language. All these abilities rely on the concerted interaction of millions of neurons composing the brain and especially on the remarkable plasticity of their biophysical properties responsible for the flexible and adaptive behavior.

The aim of this course is to introduce, understand and appreciate the various forms of learning and plasticity that is constantly happening in our brain during the everyday life. Each day of the course will be built around a recent systems neuroscience paper studying plasticity and learning from a different viewpoint. We will start each day by replicating (a human-version of) the behavioral experiment used in the paper and discuss the experimental design. The two main lectures of the day will introduce the theoretical and the neurobiological background of the paper. The students will have the opportunity to program and run simple models to simulate the tasks to be solved by the brain and to get hands on experience with the problem of learning by interactions with the data. We will close the day by returning to the paper to discuss its specific contribution to the field and propose possible extensions.

Day 1. Hopfield model of memory. Memory systems in the brain, difference between learning and memory, the neuronal basis of learning: synaptic plasticity, potentiation, depression, homeostasis, stability, hippocampus, recurrent networks; memories: associative, distributed, fault tolerant; learning rule, perceptron, Hebb’s rule and non-Hebbian plasticity, supervised, unsupervised, reinforcement learning, Hopfield network, dynamical systems, fix-point attractor, convergence.

Day 2. Reinforcement learning. Pavlovian (or classical) and instrumental conditioning, dopamin, basal ganglia, ventral tegmental area, prediction errors, multi-factor learning rules, neuroeconomics, eligibility trace, model-based versus model free control, state space, value function, action, policy, exploration/exploitation dilemma, temporal difference learning, lessons from modern reinforcement learning - AlphaGo and others.

Day 3. Unsupervised learning. Developmental programs, activity dependent or stimulus induced plasticity; learning representations, tuning curves, the hierarcy of the sensory systems, spontaneous activity, self-supervision, generative models, recognition models, mixture models, clustering, Gaussian mixtures, inference, uncertainty, autoencoders, deep learning - lessons and open questions.

Day 4. Learning predictive models. Hippocampal place cells, theta oscillations and sharp wave-ripples, phase precession, theta sequences, behavioral evidence for the role of hippocampus in model based planning, replay: forward - backward, awake and sleep; dynamical generative models, inference, filtering, smoothing and predictions.

Day 5. Consultation, written exam