Doctoral School: **Biology Doctoral School**
Doctoral Program: Neuroscience and Human Biology

Subject code: **BIO/7/16**
Subject title: **Modeling in Neurobiology PR**
Teacher and Neptun code: **Dr. Somogyvári Zoltán (V7T8WL)**
Credits: 4
Class hours: 2 hours/week, practical

Aims of the course

The aim of the course is to give students an insight into the functioning of the nervous system. The role of models is twofold: on the one hand, the nervous system is a complex system, and accurate models are needed to synthesize a wide variety of information. On the other hand, the nervous system models the outside world, and by observing its activity, we can also gather information about these models.
The course is primarily recommended for biologists who are not averse to mathematics or for physicists, engineers, or computer science students interested in how our brains work, but we welcome anyone else. The course consists of 12 lectures, which this year are accompanied by experimental, simple practical tasks (programming in R language).

Contents of the course

Biophysical foundations

- Nerve irritability: introduction, bottom-up and top-down models, comparison of brain and computer
- Conductance based models: membrane, reverse, equilibrium, rest and Nernst potential, action potential, ion channels, gate variables, excitability, Hodgkin-Huxley model, time constant, time scale separation.
- Signal integration and signal propagation in neurons: synapse, synaptic potential, saturation, dendrites, cable equation
- Simple models: analysis of dynamic systems: phase-space, attractor, bifurcation, time scale separation, integrator, resonator, IF and LIF models, rate model, MCP neuron

The neural code

- Efficient coding in sensory systems. Origins of neural variability: input or output, GIF vs. GLM, coding, receptive field, optimal coding: entropy, mutual information
- Decoding: Bayesian rule, decoding, discrimination, sensitivity, choice probability, Fisher information

Networks, Plasticity, adaptation, learning

- Neuron networks: feedforward and feedback network, weight matrix, linearization, rate model, eigenvector, amplification, EI networks, non-normal weight matrix, transient dynamics, origin of variability in networks, balance of stimulation and inhibition
- Biophysics of synaptic plasticity: sensitization, habituation, conditioning in Aplysia, molecular mechanisms of learning. Learning with a teacher: error correction, perceptron, backpropagation.
- Learning without a teacher: Hebb rule and PCA, dimension reduction methods for population activity, using Brain-machine interface dimension reduction; error correction without a teacher.

Navigation and hippocampus

- Memory and hippocampus. Hippocampus and episodic memory, HM, attractor, cell-assembly, Hopfield network.
- Navigation, reinforcement learning and hippocampus. Hippocampal structure, location cells, navigation and design theory and experimental data: reinforcing learning, actor and critique, TD-learning, value-function, prediction error, outlook: relationship between prediction error and dopamine, sequences in the hippocampus: under theta and SPW, prediction and planning

Requirements

Written test
Grade is determined by the test result.

Literature

Lecture slides and most recommended sources are available on the site of the course.

- Somogyvári Zoltán-Zalányi László: Biofizika (jegyzet)
- Újfalussy Balázs: Az idegsejtek biofizikája (Természet világa, 2011)

selected chapters from:

- Pléh Csaba - Kovács Gyula - Gulyás Balázs (szerk): Kognitív idegtudomány. Osiris, Budapest
- Érdi Péter - Lengyel Máté: Matematikai modellek az idegrendszer-kutatásban. p 126-148.
- Fiser József - Nádasdy Zoltán: Neurális kódolás térben és időben. p 171-201
- Nádasdy Zoltán - Fiser József: A tanulás biológiai és mesterséges neurális hálói p 389
- Káli Szabolcs - Acsády László: A hippocampusfüggő memória neurobiológiai alapjai p 359