Lecture title	Mathematical Foundations of Neuroscience
Lecturer	dr Filip Piękniewski
Form and amount	30h lecture + 30h lab exercises
Exam requirements	Exam (lecture) + lab assignments

Prerequisites Properties of matrices, eigenvalues, numerical solutions, problems of numerical stability, differential equations (welcomed but not necessary). Elementary Matlab and/or C/C++ skills.

Lecture summary The lecture will deal with mathematical treatment of rather young scientific endeavor of neuroscience. The right mathematical language seems to be supplied by differential dynamical systems, bifurcation analysis and for larger ensembles by statistical mechanics. These tools when properly used allow for fairly biologically correct simulations of neuronal activity (of a pretty large scale), and are believed to shed light on cognitive abilities and emergence of consciousness etc. Students will be presented with the state of the art and directions in which new developments are expected. They will also lean advanced neuromodeling techniques. Lecture in English.

Lecture contents

- Basic information about the brain - its large scale structure, consequences of various damages, methods of brain analysis and imaging. Brain/mind question.
- Neurons and their electrophysiological properties. Hodgkin-Huxley findings and formulation of their equations, action potentials and synapses.
- One dimensional dynamical systems, hysteresis, bistability, phase space analysis, bifurcations and their analysis, integrate and fire models.
- Two dimensional systems, vector fields, equilibria and local linear analysis. Phase portraits and bifurcations.
- Conductance based models and their properties. Reductions to simple models, FitzHugh-Nagumo model, E. Izhikevich simple model.
- Bifurcations of two dimensional dynamical systems and their significance in neuronal excitability.
- Simple neuronal models of various parts of the brain. Bursting, electrophysiology and mathematical interpretation in simplified models.
- Synchronization, modeling synapses, weak coupling, phase resetting curves. Hebbian learning, Spike Timing Dependent Plasticity and spike prop algorithm.
- Numerical simulations of large scale neuronal ensembles, goals and obstacles.

Bibliography

1. E. Izhikevich, Dynamical Systems in Neuroscience, MIT Press 2007
2. Hoppensteadt F.C. and Izhikevich E.M., Weakly Connected Neural Networks, Springer 1997

Extended bibliography

1. P. Dayan, L. F. Abbott, Theoretical Neuroscience and Mathematical Modeling of Neural Systems, MIT Press 2005
2. C. Koch The Quest for Consciousness: A Neurobiological Approach, Roberts & Company Publishers 2004 (available in Polish: Neurobiologia na tropie świadomości, Wydawnictwa Uniwersytetu Warszawskiego 2008)