Summary

In this course we study mathematical models of neurons and neuronal networks in the context of biology and establish links to models of cognition.

Content

I. Models of single neurons
1. Introduction: brain vs computer and a first simple neuron model
2. Models on the level of ion current (Hodgkin-Huxley model)
3. Two-dimensional models and phase space analysis
II. Neuronal Dynamics of Cognition
5. Associative Memory and Attractor Dynamics (Hopfield Model)
6. Neuronal Populations and networks
7. Continuum models and perception
8. Competition and models of Decision making
III. Noise and the neural code
10. Noise and variability of spike trains (point processes, renewal process, interval distribution)
11. Variance of membrane potentials and Spike Response Models
IV. Plasticity and Learning
12. Synaptic Plasticity and Long-term potentiation and Learning (Hebb rule, mathematical formulation)
13. Summary: Fitting Neural Models to Data

Keywords
neural networks, neuronal dynamics, computational neuroscience, mathematical modeling in biology, applied mathematics, brain, cognition, neurons, memory, learning, plasticity

Learning Prerequisites

Required courses
undergraduate math at the level of electrical engineering or physics majors
undergraduate physics.

Recommended courses
Analysis I-III, linear algebra, probability and statistics
For SSV students: Dynamical Systems Theory for Engineers or "Mathematical and Computational Models in Biology"

Important concepts to start the course
Differential equations, stochastic processes,
Learning Outcomes
By the end of the course, the student must be able to:

• Analyze two-dimensional models in the phase plane
• Solve linear one-dimensional differential equations
• Develop a simplified model by separation of time scales
• Analyze connected networks in the mean-field limit
• Formulate stochastic models of biological phenomena
• Formalize biological facts into mathematical models
• Prove stability and convergence
• Apply model concepts in simulations
• Predict outcome of dynamics
• Describe neuronal phenomena

Transversal skills
• Plan and carry out activities in a way which makes optimal use of available time and other resources.
• Collect data.
• Write a scientific or technical report.

Teaching methods
Classroom teaching, exercises and miniproject

Expected student activities
- participate in ALL in-class exercises.
- do all homework exercises (paper-and-pencil)
- study video lectures if you miss a class
- study suggested textbook sections for in-depth understanding of material
- submit miniprojects

Assessment methods
Written exam (67%) & miniproject (33%)

Supervision
Office hours  No  
Assistants  Yes  
Forum  Yes  
Others  The teacher is available during the breaks of the class. Some exercises are integrated in class in the presence of the teacher and the teaching assistants.

Resources
Bibliography
Gerstner, Kistler, Naud, Pansinski: Neuronal Dynamics, Cambridge Univ. Press 2014

Ressources en bibliothèque
• Neuronal Dynamics / Gerstner

Notes/Handbook
The textbook is online at: http://neuronaldynamics.epfl.ch/

Videos
- http://lcn.epfl.ch/~gerstner/NeuronalDynamics-MOOC1.html
- http://lcn.epfl.ch/~gerstner/NeuronalDynamics-MOOC2.html