NX-465

Computational neurosciences: neuronal dynamics

Gerstner Wulfram

Cursus	Sem.	Type
Auditeurs en ligne	E	Opt.
Biomedical technologies minor	E	Opt.
Computational and Quantitative Biology		Opt.
Computational biology minor	E	Opt.
Computational science and Engineering	MA2, MA4	Opt.
Computational science and engineering minor	E	Opt.
Computer science	MA2, MA4	Opt.
Cybersecurity	MA2, MA4	Opt.
Data Science	MA2, MA4	Opt.
Electrical Engineering		Opt.
Electrical and Electronical Engineering	MA2, MA4	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Neuro-X minor	E	Opt.
Neuro-X	MA2, MA4	Opt.
Neuroscience		Opt.
SC master EPFL	MA2, MA4	Opt.

Language of teaching	English
Credits	5
Session	Summer
Semester	Spring
Exam	Written
Workload	150h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

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. The focus is on brain dynamics approximated by deterministic or stochastic differential equations.

Content

I. Models of single neurons
1. Introduction: brain, computers, and a first simple neuron model
2. Models on the level of ion current (Hodgkin-Huxley model)
3./4. Two-dimensional models and phase space analysis
II. Neuronal Dynamics of Cognition
5. Associative Memory and Attractor Dynamics (Hopfield Model)
6. Neuronal Populations and mean-field methods
7. Continuum models and perception
8. Competition and models of Decision making
III. Noise and the neural code
9. Noise and variability of spike trains (point processes, renewal process, interval distribution)
10: Variance of membrane potentials and Spike Response Models
11. Population dynamics: Fokker-Planck equation
12. Fitting Neural Models to Data
13. Neural Manifolds and low-dimensional dynamics
14. Summary

Keywords

neural networks, neuronal dynamics, computational neuroscience, mathematical modeling in biology, applied mathematics, brain, cognition, neurons, memory, decision making

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, Linear equations,

Learning Outcomes

By the end of the course, the student must be able to:

- Analyze stochastic models
- Predict effects of stochasticity in biology
- Describe neuronal phenomena
- Analyze two-dimensional models in the phase plane
- Solve linear one-dimensional equations
- Develop a simple model by separation of time scales
- Analyze connected networks in the mean-field limit
- Predict outcome of neural dynamics
- Prove stability

Transversal skills

- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Collect data.
- Continue to work through difficulties or initial failure to find optimal solutions.
- Write a scientific or technical report.

Teaching methods

- Video lectures, combined with inverted classroom discussions, exercises and miniproject.
- Short mooc-style videos are available for all lectures
- Textbook available as support
- Only the first lecture is 'live' and also used to discuss organizational issues
- Weekly motivation emails

Expected student activities

-participate in exercise and inverted classroom sessions
- do all exercises (paper-and-pencil)
- study all video lectures
- study suggested textbook sections for in-depth understanding of material
- submit miniprojects

Assessment methods

Written exam and miniproject.

Resources

Bibliography

Gerstner, Kistler, Naud, Paniniski: Neuronal Dynamics, Cambridge Univ. Press

Ressources en bibliothèque

- Retrouver les références à la Bibliothèque

Websites

- https://neuronaldynamics.epfl.ch/
- https://lcnwww.epfl.ch/gerstner/NeuronalDynamics-MOOCall.html

Moodle Link

- https://go.epfl.ch/NX-465

Videos

- https://lcnwww.epfl.ch/gerstner/NeuronalDynamics-MOOCall.html