Master Programme in Physics of Complex Systems

INTRODUCTION TO SYSTEMS AND COMPUTATIONAL NEUROSCIENCE (4 ECTS)

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COURSE DESCRIPTION:
This course covers a range of fundamental ideas in systems and computational neuroscience, with a particular focus on sensory perception.

EXPECTED LEARNING OUTCOMES:
Students will be familiar with the core ideas in the neuroscience of vision and touch, and in the Bayesian theory of perception. They will be able to navigate and interpret the modern research literature on vision, touch, and Bayesian models of perception.

PRE-REQUIREMENTS
No special requirements. The course is self-contained, and all relevant prerequisites in mathematics, probability, and biology are introduced during the lectures.

COURSE TOPICS

Part 1. Physiology and functions of the mammalian visual system (an introduction to systems/computational neuroscience)

Introduction to anatomy and physiology of the visual system
A systems/computational approach to the study of the visual system; Anatomy of the visual system
Classic findings about physiology of lower-level visual areas
Data analysis approaches in Systems Neuroscience
Classic findings about physiology of higher-level visual areas
Descriptive models of visual neurons
How to build models of visual neuronal responses (i.e., stimulus/response maps)
Mechanistic models of the visual system
Inferring the mechanisms underlying the response properties of visual neurons
Functional models of the visual system
Understanding neuronal population codes

Part 2. Sensory Systems: Tactile Perception

1. Introduction to the study of the cerebral cortex
2. Sensory maps in the cerebral cortex
3. Transduction
4. Somatosensory system and pain
5. Methods for computational neuroscience of perception

6. Encoding and decoding
7. Perceptual memory
8. Neuroscience of perceptual knowledge

Part 3: Bayesian modeling of perception
Perception as Bayesian inference
Bayesian inference under sensory noise
Cue combination and evidence accumulation
Discrimination, detection and classification

COURSE STRUCTURE: mainly frontal lectures, except 3 hours of computational demonstrations in the Bayesian modeling module

READING MATERIALS:

No additional reading material is necessary beyond what is provided during lessons. However some of the teachers' material comes from these sources and students are invited to seek additional background there:

- Dayan, P. & Abbott, L. F. Theoretical Neuroscience. (MIT Press, 2001).
- Martin, A. R., Brown, D. A., Diamond, M. E., Cattaneo, A. & De-Miguel, F. F. From Neuron to Brain, Sixth Edition. (Oxford University Press, 2021).
- Rieke, F., Warland, D. & Bialek, W. Spikes: exploring the neural code. (The MIT Press, 1999).
- Wichmann, F. A. & Hill, N. J. The psychometric function: I. Fitting, sampling, and goodness of fit. Perception & Psychophysics 63, 1293-1313, doi:10.3758/BF03194544 (2001).
- Ma, Koerding and Goldreich (2022). Bayesian Models of Perception and Action (https://www.cns.nyu.edu/malab/bayesianbook.html)
- Richard McElreath (2nd ed 2020). Statistical Rethinking. (https://xcelab.net/rm/)

STUDY MATERIALS*:*
Bayesian modeling: some computational notebooks will be shared. For the rest, students will be able to follow with their notes and using the references shared each week in class.

ASSESSMENT AND GRADING CRITERIA: Written exam.