BSCS 2019

Neural Computation

Summary

The purpose of this course is to introduce a mathematical modelling approach to understand brain functionality. We will explore how to build formal theories about the brain with an emphasis on being able to predict measurements. Mathematical tools required to formulate and evaluate hypotheses will be discussed together with interdisciplinary approaches to cognition and cortical computation both on the behavioural and neural levels. We will review state-of-the-art models aiming to predict biophysical quantities in the sensory systems of the brain. We will elaborate on the strong ties that connect cognitive and neuroscience to machine learning and artificial intelligence, focusing on recent advancements in the latter fields.

Mihály Bányai
Wigner Research Centre for Physics of the Hungarian Academy of Sciences
Computational Systems Neuroscience Lab
http://golab.wigner.mta.hu/people/mihaly-banyai/
banyai.mihaly@wigner.mta.hu

DETAILED SCHEDULE

1. Introduction to computational neuroscience

What do we know about the brain? Mathematical modelling of brain functions. Levels of abstraction in neuroscience. Perception as inference. How does vision probably work?

Interplay between cognitive science, computational neuroscience and artificial intelligence. Brief history of the ideas discussed in the course.

Finding the anatomical structures that implement a certain function. Ways to measure neural activity.

2. Knowledge representation and working with uncertainty

How can we store and use knowledge? Formal languages and logic. What is computation? Working with uncertain knowledge. An introduction to probability theory.

Generative probabilistic models. A graphical language to formulate hypotheses. Inference of unobserved quantities. Generating synthetic data from a probability distribution. Learning the regularities of the environment.

3. From behaviour to neurons

Probabilistic models of cognition and behaviour. Mental models of the physical world. How to figure out the mental representation of quantities describing the environment?

Prediction of human behaviour with probabilistic models.

How to tie the variables of a generative model to neural activity? Problems and possibilities of measurement. Hypotheses about neural coding of knowledge and inference. Falsifiable predictions of coding theories.

4. Predicting neural activity

Probabilistic models of the visual cortex. Prediction of receptive field measurements. Prediction of population activity statistics in the primary visual cortex. Hierarchical models of vision.

Decision making based on perception. Learning strategies from experience. Neural correlates of strategy learning. Prediction of neural activity with deep learning models.

What do we really know about the brain?

Prerequisites

The material presented on preceding BSCS courses together with an open attitude towards mathematical notation and abstract thinking will be sufficient to understand the contents of the course. Pointers to resources about technical aspects and recommended readings will be provided to those interested in studying these ideas in more detail.

Examination

Students will be able to choose either essay or group project presentation as a form of examination. Q&A sessions at the end of each day will help the preparation for the exam.