SISSA’s Teaching offer for Ca’ Foscari students

SISSA offers a lively and stimulating learning environment, where students are exposed to a broad range of interdisciplinary subjects. For the students from Ca’ Foscari, SISSA offers an **introductory course in Systems and Computational Neuroscience**. During this course, and more generally during their stay at SISSA, students will have the opportunity to interact with peers from a variety of backgrounds:

- PhD students from the Cognitive Neuroscience (CNS) program at SISSA;
- A selected group of students from the Cognitive Science master program at the University of Trento (CIMeC - one of the elite centers for cognitive science in Italy)
- Students from the International Masters in Physics of Complex Systems, a highly selective program run jointly by Universities Paris-Saclay, Sorbonne Université and Université de Paris, together with Politecnico di Torino, SISSA and the International Centre for Theoretical Physics (ICTP) in Trieste.

The course is composed of 5 modules, each taught by a different faculty member at SISSA. **The course runs from October to January** (and therefore requires presence at SISSA during that time of year), and is worth 12 CFU in total.

Besides the courses, **students are expected to spend at least 6 months doing a research internship in one of the CNS labs**. The thesis work is worth 30 CFU. The scientific activity of all the labs in the program is detailed here: https://phdcns.sissa.it.

Course modules:

Language, Reading and the Brain

Introduction to Systems and Computational Neuroscience: Evolution of Neural Computation

Introduction to Systems and Computational Neuroscience: Tactile Perception

Introduction to Systems and Computational Neuroscience: Visual Perception

Bayesian modeling and information theory for neuroscience and cognitive science

Language, Reading and the Brain

Teacher: Davide Crepaldi

Description:

The course offers an introduction to how the brain deals with language and reading. It does so by focusing on the relationship between sounds/letters and meaning, and the consequent informational landscape that characterises human languages. These questions will bring us outside of the classic territory that is explored in language courses, to touch upon statistical learning, information theory and neural (deep) networks. We will review experimental and computational evidence at the intersection between Linguistics, Cognitive Neuroscience and Experimental Psychology, to discover that language is a peculiar symbolic system, where fundamental randomness is constrained by the learning capability of the brain, and by the dynamics of human social interactions.

A fairly general syllabus is as follows:

1. what's a human language;
2. arbitrariness and information;
3. word frequency distribution and computational models of word meaning;
4. form-to-meaning mapping (morphology and sound symbolism);
5. neural networks and the geometry of language;
6. statistical and implicit learning;
7. localist, non-learning neural networks;
8. language evolution and cognitive constraints.

Introduction to Systems and Computational Neuroscience: Evolution of Neural Computation

Teacher: Alessandro Treves

Description:

The course delineates the evolution of the vertebrate nervous systems, with a particular focus on mammals and among them on the human lineage, contrasting the network organization emerging in different structures, such as the cerebellum, the basal ganglia, the cortex and the hippocampus. Reference is made to abstract styles of neural computation such as reinforcement learning, error-correction and backpropagation of errors, associative memory and self-organizing maps.

Topics:

1. What are we after in the course?

2. Chemical computation – neuromodulators.
3. Elements of information theory. Geometrical computation – early vision in flies, in fish and in mammals
4. Perceptrons and back-propagation. Creative geometry in the basal ganglia and in the cerebellum.
5. Simple models of reinforcement learning,
6. Pyramidal cells, distributed representations, associative plasticity – associative memory for faces with unlabeled data
7. From cortically plausible models to the Hopfield model. Simple associative nets in olfactory cortex, amygdala and orbitofrontal cortex.
8. Competitive nets, extended to the self-organization of cortical maps. Lamination and a realization in sensory cortex.
9. Pure memory in the mammalian hippocampus – David Marr. The statistical physics of flat and curved spatial maps.
10. Random number generators in the Dentate Gyrus, and neurogenesis – analyzing charts and their transitions
11. Memory from statics to dynamics, from semantics to grammar

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Introduction to Systems and Computational Neuroscience: Tactile Perception

Teacher: Mathew Diamond

Description:
The course focuses on the basic principles of organization of the sensory pathways and their target regions of cerebral cortex; mechanisms and properties of sensory transduction; psychophysical methods for quantifying sensory perception; methods for quantifying the relationship between neuronal activity and behavioral performance, with a focus on several lines of inquiry spanning tactile, auditory, and visual perception.

Topics:

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
6. Perceptual memory
7. Neuroscience of perceptual knowledge

Introduction to Systems and Computational Neuroscience: Visual Perception

Teacher: Davide Zoccolan

Description:

The course focuses on the structure and functions of the mammalian visual systems, with a special emphasis on shape processing and object recognition. In addition, the module includes a description of some of the computational approaches that allow modeling and understanding visual functions. In particular, the module introduces the students to: 1) quantitative models of neuronal tuning (e.g., reverse correlation approaches); 2) feedforward neuronal networks for object recognition; and 3) functional models of the visual system using basic machine learning approaches.

More in details, the course is divided into the following sections:

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

Bayesian modeling and information theory for neuroscience and cognitive science

Teacher: Eugenio Piasini

Description:

Ideas at the interface of information theory and Bayesian statistics have long been a source of inspiration and of powerful quantitative methods in neuroscience and cognitive science. This course will focus on some key foundational concepts, and how they are used to formulate and test theories of cognition, perception, and neural processing.

Topics:

1. Introduction to Bayesian inference
2. Perception as Bayesian inference
3. Bayesian inference under sensory noise
4. Cue combination and evidence accumulation
5. Stimulus detection, discrimination and classification
6. Introduction to information theory
7. The efficient coding principle