

Introduction to complex systems science

A course for PhD students, *Alma Mater Studiorum* Università di Bologna

February/March 2018 - DISI, Via Sacchi 3, Cesena

Instructor: Andrea Roli (DISI-Cesena, Università di Bologna)

About the course

The attendees will be introduced to the corpus of theories and methods that scientists and engineers currently use to understand complex systems. Examples of complex systems are the brain, ant colonies, cities, cells, robot swarms, just to mention some. Despite the individual peculiarities characterising these systems, common properties can be identified among complex systems. Hence, complex systems science aims at providing a unifying view to deal with complexity. In the course, the main principles and methods for modelling, analysing and simulating complex systems will be illustrated. The subjects will be taught by providing both the theoretical foundations and prominent examples in the natural sciences, engineering and technological fields.

Syllabus

- Introductory concepts in complex systems science: complex vs. complicated, dynamics, evolution, adaptation, learning, feedback-loops, trees and tangled hierarchies, emergence.
- Principles of systems modelling.
- Dynamical systems: notions of phase and state space, trajectory, attractor, stability, bifurcations.
- Discrete dynamical systems. Case study: logistic map.
- Chaos and fractals.
- Phase transitions and criticality. Case studies: Ising model and Boolean networks.
- Emergence and self-organisation.
- Principles of information theory for complex systems.
- Complex networks.

Learning and assessment modalities

The course will be organised in four slots of five hours each, divided into class lectures and practical activities (exercises, software experiments and data analysis). It will be taught either in Italian or English at the preference of the attendees. The final assessment requires the students to prepare a short paper on a complex systems topic, agreed with the instructor, and possibly revised according to the instructor's remarks; the final acceptance of the paper means that the exam is passed.

Teaching materials

Lecture notes and slides will be provided by the instructor, along with papers and a list of bibliographical references and additional material. All the course material is in English.

Lecture Schedule

Lectures will be held on 23/2, 2/3, 9/3 and 23/3, from 14:00 to 19:00, at the meeting room (1st floor).