SSM
Scuola Superiore Meridionale

Course title:

Introduction to Complex Systems

Duration [number of hours]**: 24**

PhD Program [MERC/MPS/SPACE]**: MERC**

Name and Contact details of unit organizer(s):

Dr. Davide Salzano
Affiliation(s): Scuola Superiore Meridionale
Website: https://sites.google.com/site/dibernardogroup/group/davide-salzano
Email: d.salzano@ssmeridionale.it

Course Description [max 150 words]**:**

In this course, students will study the fundamentals of modeling, analysis, and control of complex systems, which are characterized by the presence of many nonlinear dynamic agents interacting through a complex network. After examining the foundational concepts related to the analysis and control of nonlinear dynamic systems, students will explore the emergent properties and collective behaviors of such systems.
Additionally, analytical and numerical tools will be introduced to study the convergence, controllability, and observability of these systems. Finally, techniques for controlling complex systems will be examined in depth, along with tools to analyze their performance and robustness.
Throughout the course, examples from applied sciences and engineering will be used to illustrate key concepts and complement theoretical derivations. The example systems and applications will be drawn from various fields, including, for instance, electrical/mechanical networks, sociology, ecology, and robotics.

Syllabus [itemized list of course topics]**:**

- Introduction
- Review of linear/nonlinear systems
- Review of single-agent control
- First practical session (Simulation of dynamic systems)
- Basics of graph theory
- Consensus
- Synchronization
- Pinning control
- Second practical session (Simulation of networked systems)
- Evolving networks
- Risk and complexity
- Third practical session (Control and vulnerability of networks)

Assessment [form of assessment, e.g., final written/oral exam, solutions of problems during the course, final project to be handed-in, etc.]**:**

Discussion of project work to be handed in at the end of the course

Suggested reading and online resources:

1. F. Bullo, Lectures on Network Systems, Kindle Direct Publishing, 2020
2. K.J. Astrom and R.M. Murray, An introduction to for Scientists and Engineering, Princeton University Press, 2008
3. Y. Liu, JJ Slotine, A Barabasi, Controllability of Complex Networks, Nature, vol 473, pp. 167, 2011
4. S. Strogatz, Exploring Complex Networks, Nature, vol. 410, pp. 268, 2001
5. Y. Liu, A. Barabasi, Control Principles of Complex Systems, Reviews of Modern Physics, vol. 88, 2016
6. M. Newman, The Structure and Function of Complex Networks, SIAM Review, 45, 2, 2003