

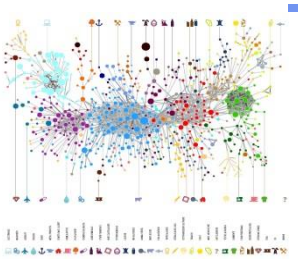


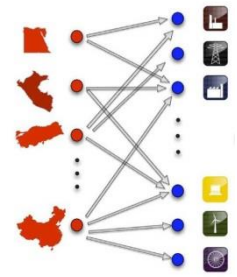


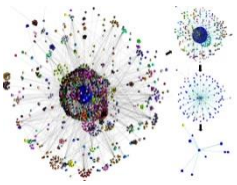
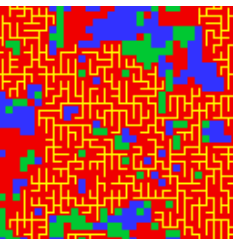

Networks: Theory and Applications

General Description:

Network Theory constitutes a powerful mathematical tool devoted to the study of systems of interacting elements. Its applications cover a large palette of disciplinary fields going from physical systems, like power grids, autonomous systems, disordered materials, etc. or biological applications like the brain network or the gene-protein interactions, ecological systems like plant-pollinator or trophic networks, to the study of social dynamics or even the analysis of complex data structures.

This course is addressed to early stage researchers (ERS), PhD or last year Master students interested in an introduction to this rich and rapid developing field. It is thought to be interdisciplinary; in this respect, a special effort has been made to make it accessible with very low mathematical requirements.

During the lectures we will discuss the practical problems that arise when applying this technique to build models of real systems, along with some strategies to overcome them. Students who need to apply this technique in their own research will have the opportunity to bring their problems to be discussed during the sessions.

The final goal is to provide students both with the necessary background to *understand* the vast literature making use of Network Theory, as well as to present a *toolbox of concepts and methods* allowing them to easily model problems that can be put in terms of a set of interacting agents. It paves the road to a more advanced course on recent advancements and ongoing research hot topics like *spatial networks*, *networks of networks (multiplexes and multilayers), higher order hypergraphs*, *simplicial complexes…*

Pre-requirements: Linear algebra, elementary notions of differential equations, and probability theory.

Teacher: Dr. Laura Hernández,
Associate Professor LPTM, CNRS-CY Cergy Paris University
Laura.Hernandez@cyu.fr, https://www.researchgate.net/profile/Laura_Hernandez13

Practical information:

- Schedule: This course is modular, it consists of 12h of introductory lessons, stating the essential mathematical tools of network theory and 18h devoted to the study of network modeling and applications.
  First part (see chapters 1-3, in blue, below): 3h x 4 weeks. ***This first part, may be of particular interest for the EUTOPIA Artificial Intelligence Learning Community (AI-LC).***
  Second part (models and applications) 3h x 6 weeks, which requires the elements of the first part, is addressed to ESRs interested in applying network theory to model different systems of interacting elements.
  Registration: Students of the EUTOPIA alliance, should send an email to Laura.Hernandez@cyu.fr with subject: Network Theory, Eutopia IA-LC.
- Teaching Language: English.
- Evaluation: if required by different programs of Eutopia IA-LC, the evaluation can be organized as an exam, a memoir, and/or an oral presentation of a personal work.

Program

1. Introduction.

- Motivation: Network Theory as an interdisciplinary tool to study complex systems.
- Definitions, classification and examples of networks' applications in physics, biology, social systems, economy, technology, etc. Properties of the mathematical representation of real world networks.
- Metrics on networks **:**, paths, clustering, degrees…

2. The mathematics of networks

- Diffusion on networks: The graph Laplacian.
- Quantifying the importance of nodes: Centrality measurements, hubs and authorities.
- Quantifying the similarity of the nodes: cosine similarity, Pearson's coefficient
- Community structure: notions and description of different types of algorithms

3. Network models I

- The Uniform Random Graph: The Erdös Renyi graph
- The Small World network: Watts-Stogatz and Newman models
- The Scale Free network: preferential attachment models

4. Network models II: Network generation under general constraints

- The Configuration model
- The Exponential Random Graph

5. Dynamical processes on networks

- Epidemic models in mixed population: SI, SIS, SIR,…
- Epidemic models in networks

6. Recent interdisciplinary applications, for exemple:

- Social systems: Opinion and cultural dynamics, theoretical and data based studies
- Ecology: Mutualistic ecosystems. Trophic networks
- Economy: Product-producer networks. Centralized vs. decentralized markets

Bibliography:

- *Networks*, M.E.J.Newman, Oxford University Press, 2010.
- *Dynamical Processes on Complex Networks*, Barrat, Barthélemy, Vespignani, Cambridge University Press, 2009.
- And several scientific journal articles and reviews that will be indicated during the course.