Network science – from structure to dynamics

Overview

The ultimate goal of network science is to understand, predict and control the actual behavior of complex networked systems. For instance, to mitigate the spread of a disease through a social network, foresee the effect of a genetic perturbation on the activity of a sub-cellular network or quantify the functional resilience of an infrastructure network. Towards this end, the recent years have seen spectacular advances in our ability to accurately map complex social, biological and technological networks. Yet to fully conquer these pertinent goals – understanding, predicting and controlling – we must progress network science to its next stage: developing tools to systematically translate our rich topological findings into dynamic predictions. How do signals propagate along network links? What are the conditions for efficient propagation, e.g., a global epidemic or for a rapidly decaying propagation, i.e., a perturbation that remains localized. In this course we will learn about the state-of-the-art of this emerging field, beginning with the most updated findings on the structural characteristics of real networks and culminating in the recently developed formalisms on how to translate these characteristics into predictions on the network's observed dynamic behavior. We will introduce a variety of mathematical tools based from graph theory, linear algebra and nonlinear dynamics that lay the basis for the analysis of large scale complex interconnected systems.

Our main goal is to teach and engage the students with the state-of-the-art of network science, from the fundamental discoveries on the structure of real-world networks to the most recent developments in predicting their dynamics. At the end of the course the students will acquire the basic tools that will allow them to embark on an academic level research project in the area of network dynamics. Specifically, participants will learn and apply:

1. The foundations of complex systems and their relation to network science.
2. The practical tools to analyze and visualize complex networks – e.g., degree distribution, correlation analysis etc..
3. Hands on application of the most common models for network construction.
4. Constructing and analyzing nonlinear network dynamics for biological, social and technological systems.

The course will include frontal lectures on the theoretical material, complemented by several hours dedicated to personal tutoring - face-to-face or in small groups. Students will also receive practical hands-on exercises, and perform a numerical project in groups, based on existing datasets that will be prepared by the teaching faculty. The groups for the student projects will be encouraged to include students from different disciplines, to foster interdisciplinary collaboration. The goal is to make the course an intensive learning experience, designed to bring the students to an ideal starting position of their anticipated research in network science.

We plan a five day course, comprising thirteen hours of lectures, two hours of hands-on tutorials and two hours devoted to presentations by the students.

Modules	**A: Complex systems and networks** **B: Characteristics of real world networks** **C: Network models and evolution** **D: Network dynamics – nonlinear models on networks**
You Should Attend If…	▪ You are a graduate students at the Masters, Ph.D. or Postdoc level, or an exceptional undergraduate student. ▪ You are an open minded faculty from academia, government research institutions, private organizations or industry who wishes to enter into network science. ▪ You come from a background of Mathematics, Physics, Computer science, Computational biology, Engineering, Brain research, Computational sociology, Data science or similar area.
Fees	The participation fees for taking the course is as follows: **Industry/ Research Organizations: Rs 10,000** **Academic Institutions (students): Rs 2,500*** **Academic Institutions (faculty): Rs 4,000*** The above fee include all instructional materials, computer use for tutorials and assignments, laboratory equipment usage charges, 24 hr free internet facility. The participants will be provided with accommodation on payment basis. * **Fee concession will be considered for individual having limited financial support**

The Faculty

Dr. Baruch Barzel completed his Ph.D. in Physics from the Hebrew University of Jerusalem, Israel in 2010, and continued to pursue his postdoctoral research at the Network Science Institute of Northeastern University and at the Channing Division of Network Medicine, Harvard Medical School. From 2014, Dr. Barzel is the head of the Complex Network Dynamics Lab at the Mathematics Department of Bar-Ilan University, Israel (www.barzellab.com), leading a diverse group of students and postdocs on the pursuit of a theory of network dynamics. An expert on network dynamics, Dr. Barzel has published several high impact papers on the subject and established theoretical tools to bridge between network topology and its observed dynamic behavior.

Dr. Sarika Jalan is a Professor of Physics and adjunct faculty in the Discipline for Biosciences and Biomedical Engineering at Indian Institute of Technology (IIT) Indore, India. The Complex Systems Lab at IIT Indore lead by her revolves around Network Science. Using network theory, nonlinear dynamics and computational techniques, the lab, on one hand, works on fundamental aspects of complex systems and network science research and on other hand applies techniques developed in the lab to real-world systems coming from Biology and Social science. Her recent interests are multilayer networks, synchronization, and optimization and graph spectra.

Course Coordinator

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