Complex Networks:
Structure and Nonlinear Dynamics

Overview

The discovery of the laws governing the structure and dynamics of complex systems is one of the greatest challenges of modern science. These systems are characterized by the presence of different levels of self-organization, each of them determining the behavior of the next. The most important property of complex systems is the impossibility to predict their overall behavior from the knowledge of their individual properties or as if they were isolated system's components. Understanding and predicting the behavior of these systems is of great importance in many branches of Science since the global functioning of complex systems of different nature and scales, from cells to the brain and societies, is the result of the complex interaction between their very many fundamental components.

One way to address the problem of complexity in such systems is by studying their structure and function. During the last decade, important discoveries show that there is a common pattern of self-organization that emerges over and over again in different complex systems. Somehow, the interactions between elements (species, individuals, genes, proteins, routers) that occur in real systems (physical, biological, social and communication) give rise to networks that share a large number of common features, being the most important one the heterogeneity of the number of contacts per unit, usually referred as the scale-free effect. The common structural patterns shared by real complex systems motivated the birth of Complex Network theory [see for instance Physics Reports 424, 175 (2006)] whose fundamental idea is to discover the structure of interactions between the components of a system and relate it to the emergent behavior displayed by it.

Based on its wide applicability and the availability of data about the interactions of real complex systems, the last several years have witnessed a spectacular advance in the field of Complex Networks. The discoveries of this growing and interdisciplinary field of research has helped to understand how the structure of the interconnections between units drives the emergence of many collective behaviors such as epidemics, social consensus, synchronization, cooperativity and jamming, among others, thus forcing to revisit the nonlinear models (that up to date were studied under mean field assumptions) to incorporate the heterogeneity of the interactions in its mathematical formulation.

The goal of this course is to review the main achievements and ideas developed in the recent years, and that have opened a new way to understand and interpret the functioning of complex networks. Starting from the basic properties of real networked systems and the construction of synthetic networks, a review and explanation will be given on the dynamical properties that emerge as a consequence of the heterogeneity of the interactions between the units composing them. With this aim, focus will be given to diffusion processes and the onset of jammed states, epidemic models, the emergence of synchronization phenomena, and social dynamics under the framework of evolutionary games.

At the same time, the aim has been fixed to provide exposure to the students to a comprehensive set of practical problems and exercises to be made on different data sets corresponding to real networks. These exercises are planned to be performed in groups of 3-4 students so to foster the collaborative work and the interplay of the different expertise they might have. The participation of the students attending to the course will be encouraged. With this aim, it is planned to have oral presentations by students where they will have the opportunity of explaining the work performed during the days of the course.

The Course is planned to have a duration of 5 days comprising 11 hours of lectures, 3 hours of solving questions to the students and 2 hours devoted to presentations by the students. Also case studies and assignments will be shared to stimulate research motivation of participants.

Modules	The course will cover: Introduction to Network Science, Network Metrics and Measures in Real Networks, Network models, Simple Diffusion Processes and Random Walks in Networks and Multiplex Networks, Epidemic Spreading in Networks, Epidemic Spreading in Metapopulations, Synchronization in Complex and Multiplex Networks and some case studies and assignments. **Number of participants for the course will be limited to thirty.**
You Should Attend If…	▪ you are a researchers from government/private organizations/industry including R&D sector ▪ you are a faculty from from reputed academic institutions and technical institutions ▪ you are a student (B. Tech. / M. Sc./ M. Tech. / Ph D)
Fees	The participation fees for taking the course is as follows: **Participants from abroad : US $400** **<u>Indian Participants</u>** **Industry Organization : INR 10,000** **Research Scientists/ Faculty : INR 5,000** **Students : INR 2,500** The above fee include all instructional materials, computer use for tutorials & and assignments, 24 hr free internet facility, accommodation and meals.
Time frame of the course & Venue	**September 12-16, 2016** Department of Physics, National Institute of Technology Durgapur Mahatma Gandhi Avenue, Durgapur, West Bengal, India htpp://www.nitdgp.ac.in

The Faculty

Dr. Jesús Gómez-Gardeñes is an Associate Professor of the Department of Condensed Matter Physics & Institute for Biocomputation and Physics of Complex Systems (BIFI) – Facultad de Ciencias, Universidad de Zaragoza, Zaragoza, Spain. His research interests include statistical physics, nonlinear dynamics and the theory of complex networks, emergence of collective phenomena out of nonlinearity and the structure of interactions in complex systems, energy localization, synchronization, random walks, traffic congestion, disease propagation and evolutionary dynamics.

Dr. Hirok Chaudhuri is an Assistant Professor of the Deaprtment of Physics of National Institute of Technology Durgapur, West Bengal, India. His research interest is the nonlinear analysis of geochemical and geophysical data pertaining to earthquakes.

Course Co-ordinator

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