NERCCS 2019

- Pre-Conference School on Complex Systems -

- Wednesday April 3, 2019 -

Schedule

9:00-9:20am - Overview of Complex Systems and Pre-Conference School

Dane Taylor, University at Buffalo, SUNY

9:20-10:10am - Self-Organization from Basic Physical Principles

Georgi Y. Georgiev - Worcester Polytechnic Institute, Assumption College, & Tufts University

Explaining self-organization in matter starts with non-equilibrium thermodynamics. It is impossible to have any structure of a system if it is in its most improbable random state. Energy structures it in such a way as to create flow channels, and to minimize the product of energy and time for the matter to cross the system. This means that the constraints to motion are reduced, and from an insulator for energy, the system turns into a conductor for it. In other words, it obeys the principle of least action, as everything else in the universe. Structure is the configuration of the system ensuring the least action for the matter to cross the system at the given conditions. It can be computed or engineered to follow this rule. The principle of least action can become a basic engineering and computational tool if we are to be able to design the best possible systems, in the shortest possible time. This will give an advantage to economic entities that use it. We will start with the basics of self-organization, what is known, what are the open questions, and what are some of the future directions at the forefront of research. One of the pressing tasks in complexity is to extend the principle of least action to interacting, dissipative complex systems and to derive their best structure based on it. Another is to study the time evolution of self-organization from the big bang until now, termed cosmic evolution, by Eric Chaisson, and what other characteristics of the complex systems does it depend on and how.

10:10-11:00am - Exploration of Dynamic Complex Systems from the Perspective of Nonlinear and Nonstationary Time Series

Changqing Cheng - SUNY Binghamton

The recent leap forward in sensing, computing, and communication technologies, and the consequent availability of abundant data sources, has transformed the way real-world complex systems are monitored and controlled. Remarkably, forecasting the evolution of complex systems is noted as one of the ten grand challenges of modern science. The vast amount of time series sensing data from complex systems capture the dynamic behaviors and causalities of the underlying processes and provide a tractable means to predict and monitor system state evolution. However, the nonlinear and nonstationary dynamics of the underlying processes pose a major challenge for accurate modeling and forecasting. For most real-world systems, the vector field of state dynamics is a nonlinear function of the state variables, i.e., the relationship connecting intrinsic state variables with their autoregressive terms and exogenous variables is nonlinear. Time series emerging from such complex systems exhibit aperiodic (chaotic) patterns even under steady state. Also, since real-world systems often evolve under transient conditions, the signals obtained therefrom tend to exhibit myriad forms of nonstationarity. Nonetheless, methods reported in the literature focus mostly on forecasting linear and stationary processes. This lecture presents a summary of recent advances in nonlinear and nonstationary time series modeling, in time domain, frequency domain, dynamic state space and network construction. Applications in forecasting and change detection will also be discussed.

11:00-11:20am - Short Break

11:20am-12:10pm - Network Models for Complex Systems

Sarah Muldoon - University at Buffalo, SUNY

Network theory – the science of mapping physical systems to mathematical graphs – provides an attractive methodology to describe and quantify real-world systems. In this course, we will first introduce the modeling framework used to model complex networks and explore the mathematical foundations of network theory. We will then briefly discuss some commonly used network statistics for quantifying network structure and evolution. The course will especially emphasize connections to real-world data and the importance of interpreting network statistics in the context of the system being studied. Students will be provided with extensive references to current literature, computational libraries and toolboxes, and visualization software in order to promote further learning beyond this introductory course.

12:10-1:00pm - Data Analytics of Complex Systems

Alfredo Morales - New England Complex Systems Institute & MIT Media Lab

This data analytics lessons will cover skills needed to transform raw data into visualizations and insight. The course will cover fundamental construction and analysis of models including identifying what is to be modeled, constructing a mathematical representation, analysis tools and implementing and simulating the model in a computer program. Analytic methods to be covered include: distribution fitting, data mining, machine learning (regression, classification and clustering), network analysis and time series analysis. Particular attention will be paid to choosing the right level of detail for the model, testing its robustness, and discussing which questions a given model can or cannot answer.