Interdisciplinarity, networks, data and complex systems: promise and challenges

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Organizer: **Luis M. Rocha**

Understanding complex networked systems is key to solving some of the most vexing problems confronting humankind, from discovering how thoughts and behaviors arise from dynamic brain connections, to detecting and preventing the spread of misinformation, stigma, or unhealthy behaviors across a population. Indeed, modeling network interactions among variables operating at multiple scales is an essential capability for effective interventions in complex systems−for instance, discovering the key variables that affect human well-being which interact at multiple levels from genes to social dynamics.

The field of complex networks & systems (CNS) is interdisciplinary by its very reason of existing: finding general principles of organization in the natural and social sciences. Furthermore, it is closely correlated with computer and data science, since its methods hinge on massive combinatorial searches and inference from big data. This has been particularly true with the recent availability of large amounts of data about human behavior at different scales of organization, ranging from the molecular to the collective behavior of the brain and society. All this data and multilevel interconnectivity, offers an exciting opportunity to root complexity and network science in empirical research, and, conversely, to lead the natural and social sciences to jointly explore uncharted analytical and computational territory to address many of the grand challenges facing humanity.

Traditional disciplines are defined by specific discernable levels of human experience in nature and society, as in Psychology, Sociology, Political Science, Economics, Physics, Chemistry, Biology, etc. In contrast, the disciplines of CNS are orthogonal to such traditional disciplines. Machine Learning is applicable to data from biochemical regulation and consumer behavior alike, for instance, and Dynamical Systems Theory is applicable to chemical reaction systems and equilibrium models in stock market prediction. Certainly the same is true of Network Science. The availability of big data and computers, together with the success of CNS, in effect established a two-dimensional science, whereby traditional disciplines focus on experimental and observational methods to deal with their specific subject matter, and the disciplines of CNS work to establish the generality of their own methods to any type of data, orthogonally to the traditional disciplines. This state of affairs has been important to deepen our knowledge of both the traditional, natural objects of study and the general methodologies enabled by data and computing. However, in practice, neither parallel disciplines nor general-purpose methods are sufficient to achieve interdisciplinarity. Thus, many challenges remain in bringing the methods developed in this field to be useful for science at large:

- ***Training***: it has been difficult to train students from the natural and social sciences on CNS methods. Indeed, graduate training typically occurs in one of the two dimensions: experimental and observational methods in a specific area such as biology and sociology, or in general methodologies such as machine learning and network science. Moreover, shortening of academic training periods in higher education makes it a challenge for students to gain sufficient expertise in the mathematical and computational foundations of CNS, as well as domain-specific laboratory and social analysis methodologies. To produce a new breed of scientists capable of addressing the complex problems of the 21st century, we need to seamlessly integrate the general-purpose, computational expertise of CNS to the deep, domain-specific research methodologies of the natural, behavioral, and social sciences.
- ***Funding***: national agencies (such as the FCT in Portugal) tend to organize opportunities within disciplinary walls and prefer to fund the agendas of lead principal investigators from a discipline. Funding needs to foster diverse teams tackling truly vexing interdisciplinary problems in nature and society, such as identify the potential bio-, neural- and social-network markers in clinical disorders, examine the impact of policy decisions in science, investigate how people form political beliefs and attitudes, or use Twitter and Instagram to predict critical transitions in individual and collective behavior, such as the onset of mental disorder or social unrest.
- ***Collaboration & Team Science***. University departments built within disciplinary walls make it very difficult for a single-PI group to develop competence in CNS as well as the methodology of the natural and social sciences. Rather than only working with general principles of CNS or the deep intricacies of each discipline in science, we need teams to collaborate where the rubber meets the road: when the

general-purpose methods of CNS, enabled by big data, can be used to solve nuanced problems of the natural and social scientist without trivializing them. Teams need to be empowered to escape the silos of disciplinary training and be collectively rewarded, rather than made to follow the single agenda of a lead investigator−no single lab can address the complex challenges of the 21st century. Collaborative teams can respond much more effectively to that need and funding agencies need to foster such collaboration.

In this workshop we will discuss both new exciting opportunities for interdisciplinary research that use CNS methods, as well as discuss how to improve the prospects of training, funding and collaboration necessary for us to solve the most important problems facing humanity.

Presentation and Discussion Schedule

15:30 – 15: 45 – Welcome and Introduction
– Luis M Rocha (Indiana University and Instituto Gulbekian de Ciencia)

15:45 – 16:00 – Luis Bento dos Santos (Banco Santander Totta)

16:00 – 16:15 – Joana Sá (Instituto Gulbenkian)

16:15 – 16:30 – Gonzalo G. de Polavieja (Fundação Champalimaud)

16:30 – 16:45 – José Mendes (Universidade de Aveiro)

16:45 – 17: 00 – Discussion

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