NERCCS2022

Keynote Speakers

Keynote speaker 1: 9:45am, Thursday March 31

Peter J. Mucha
Jack Byrne Distinguished Professor
Department of Mathematics
Dartmouth College

Community Detection in Networks: Pruning and Picking Parameters

Networks are all around us, from online social networks to business relationships to family and friends, and the patterns in these connections control the spread of information, ideas, and diseases. Community detection clusters network elements to describe these patterns at the level of connections between the different communities, leading to a wide variety of applications. Numerous software packages are available for community detection, but many of these require parameters to be selected (or assume default values) to control the scale of resolution. Moreover, most of these algorithms are pseudo-random heuristic approximations. As such, one frequently needs to reconcile numerous different partitions of nodes into communities while simultaneously exploring the parameter space. These problems are exacerbated when community detection is extended to multilayer networks, a general construction for describing networks with multiple types of relationships, that change in time, or that connect together different kinds of networks, because of the addition of at least on parameter to specify the coupling between layers. We develop a framework for addressing these challenges that first prunes a set of partitions by a restriction defined by intersecting half-spaces and then picks parameters through stochastic block model inference equivalence with modularity. Our framework works for single networks and multilayer networks, as well as for restricting to a fixed number of communities when desired.

Keynote speaker 2: 9:45am, Friday April 1

Dora Biro
Beverly Petterson Bishop and Charles W. Bishop Professor
Brain and Cognitive Sciences
University of Rochester

Scaling up from individual to collective cognition in bird flocks

The field of collective animal behaviour examines how relatively simple, local interactions among individuals living or travelling together can give rise to complex group-level phenomena. Animal collectives can also be seen as integrated sensory, information-processing, and decision-making units with higher-order computational capabilities. In my research I use a combination of experimental, observational, and theoretical studies to elucidate how individual cognitive capacities and social interactions scale up in the context of ecologically relevant problem-solving by animal groups. I examine, for instance, how members of a group respond to others in ways that give rise to coordinated collective motion, how they jointly share the task of monitoring the environment, how they agree on a route despite conflicts in individual opinion, and how these processes allow groups to solve problems and accumulate knowledge for increasingly better collective performance. In this talk I will give an overview of my lab's work using homing pigeons as a model system: by attaching biologgers (miniature GPSs, accelerometers, and head-mounted sensors) to birds in flocks, we are able to characterise the interaction rules that govern individual birds' movements with respect to their flockmates, the superiority of flocks in finding efficient paths through the environment, the spontaneous emergence and robustness of flight leadership hierarchies, and the cultural transmission of travel route information. I will also discuss the theoretical implications of this work for how knowledge is generated, maintained, and built upon in animal, including human, societies.

Invited Speakers

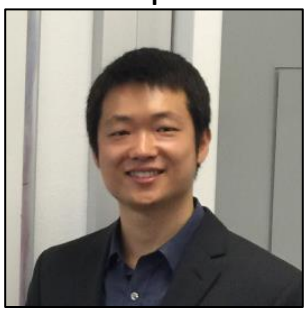
Invited speaker 1: 9:15am, Thursday March 31

Daniel M. Abrams
Associate Professor
Engineering Sciences and Applied Mathematics
Northwestern University

Bactrian states: the emergence of bimodality in oscillator systems and elsewhere

Perhaps because of the elegance of the central limit theorem, it is often assumed that distributions in nature will approach singly-peaked, unimodal shapes reminiscent of the Gaussian normal distribution. However, many systems behave differently, with variables following apparently bimodal or multimodal distributions. In this talk, I will argue that multimodality may emerge naturally as a result of the interplay between local repulsion and distal attraction in a system's dynamics.

Invited speaker 2: 1:30pm, Thursday March 31



Yingji Hu
Assistant Professor
Department of Geography
University at Buffalo, SUNY

GeoAI: Integrating Geospatial Data and AI Models for Social Good

Recent years have witnessed an exponential growth of geospatial data, ranging from remote sensing images and socioeconomic census data to anonymized mobile phone location data and geo-social media data. Meanwhile, the fast advancements of artificial intelligence (AI) and machine learning (ML) provide novel computational tools enabling us to analyze data from new perspectives. By integrating geospatial data with AI models, we can build solutions to help address some of the challenging problems facing our society and make a positive social impact. In this presentation, I will share two studies that leverage geospatial data and AI to help address problems related to natural disasters and public health.

Invited speaker 3: 2:00pm, Thursday March 31

Francesca Bernardi
Assistant Professor
Department of Mathematical Sciences
Worcester Polytechnic Institute

The complex systems of Wikipedia

With over 14 billion views each month, Wikipedia is one of the most visited websites in the world. English language Wikipedia counts almost 6.5 million pages that are constantly being improved by volunteer editors worldwide. While anyone can edit Wikipedia, only about 20% of editors self-identify as female. Who edits Wikipedia matters: articles related to topics traditionally considered of interest to women are less well-covered and only about 18.5% of biographies are about women. In recent years, concerted efforts have begun to close the so-called “Wikipedia gender gap,” but change is slow occurring due to a complex interplay of factors, including technological barriers, time commitment, pages being deleted, and confrontational editing environments. Wikipedia is also a huge source of freely accessible data. In this talk, I will discuss

some of the most recent research focused on understanding the complexities of Wikipedia as it relates to its gender gap amongst editors and content. I will also reflect on some open questions that are of broad interest to Wiki editors.

Invited speaker 4: 2:30pm, Thursday March 31

Abigail Jacobs
Assistant Professor
Department of Informatics and Complex Systems
University of Michigan

Complex & responsible social/technical infrastructures

The structure and dynamics of complex, critical infrastructures---from algorithmic hiring systems to the Internet---reflect social and technical processes. I draw on a range of empirical strategies to understand how system structure impacts outcomes; how social inequalities can be embedded and reproduced in technical systems; and how the social dynamics surrounding technical systems can reveal sources of risks and harms. Drawing from examples in systems safety, organizational networks, and responsible AI, I show how a systems perspective reveals new insights and open questions.

Invited speaker 5: 9:15am, Friday April 1

Eleni Katifori
Assistant Professor
Department of Physics and Astronomy
University of Pennsylvania

My Dynamics and learning in complex vascular networks

Complex life larger than a humble nematode would not be possible without a circulatory system. Plants, fungi, and animals have developed vascular systems of striking complexity to solve problems of long-distance nutrient delivery, waste removal, and information exchange. The dynamics of flow within these vascular systems is dependent upon the dynamics of their power source. Responding fast to a change of these dynamics is critical for the fitness of living flow networks, e.g. the animal vasculature, which are subject to frequent and sudden shifts when the pump (the heart) transitions between different steady states.

In this talk we explore the role of dynamics in determining the form and shaping the function of complex vascular networks. We will discuss how mechanical information in the form of pressure pulses is propagated and dissipated in the network, and eventually discuss how the network development and eventual structure is affected by the dynamics of the power source, and the operational cost of having a pulse.

Invited speaker 6: 1:30pm, Friday April 1

Jean-Gabriel Young
Assistant Professor
Department of Mathematics and Statistics
University of Vermont

Uncertain network science: estimation techniques and applications

A large body of recent work in network science deals with errors in network data. In this talk, I will briefly review a Bayesian framework for handling such errors that can be applied to empirical data in any format, even when the data

contain substantial measurement error and when the nature and magnitude of that error is unknown. The output of this framework is an estimate of the structure of a network from imperfect data. I will then survey several applications where uncertainty makes a big difference, from network epidemiology to network ecology, and discuss model extensions and future research directions.

Invited speaker 7: 2:00pm, Friday April 1

Caitlin Hult
Assistant Professor
Department of Mathematics
Gettysburg College

Neutrophil dynamics affect Mycobacterium tuberculosis granuloma outcomes and dissemination

Mathematical models, data analytics, statistical analysis, and visualization techniques are valuable tools in the effort to determine the mechanisms that drive the spatiotemporal dynamics and organization of complex biological systems. In this talk, I will discuss how mathematical modeling enhances understanding of the immune response to human infection with the bacteria Mycobacterium tuberculosis (Mtb), which results in the formation of unique, emergent lung structures called granulomas. Due to the duration and dynamic nature of this immune response (years to decades), as well as the involvement of processes that occur over tissue, cellular, and molecular scales, we take a multiscale and mechanistic computational modeling approach. We build a hybrid agent-based model through which we generate simulated granulomas whose range of spatial configurations reflects the heterogeneity observed experimentally, and we investigate how the behavior of neutrophils, a newly added model cell type, contributes to Mtb pathology. Through the use of uncertainty and sensitivity analyses, we predict which neutrophil processes drive granuloma severity and structure and we suggest that neutrophils influence CFU burden during both innate and adaptive immune responses. We also show that neutrophils can facilitate local dissemination of granulomas and thereby enable the spread of infection. Through our work, we hope to advance understanding of the nuanced role of neutrophils in determining granuloma outcome beyond current experimental capabilities.

Invited speaker 8: 2:30pm, Friday April 1

Scott Rich
Krembil Brain Institute
University Health Network
University of Toronto

Multistability and bifurcations in epileptogenic neural circuits

Epilepsy is a neurological disorder characterized by the recurrence of seizure, a sudden and drastic shift of neural circuits into hyper-active and hyper-synchronous neuronal firing that spreads throughout the brain. How neural circuits affected by epilepsy (epileptogenic circuits) transition between these antithetical dynamics is a paramount question in epilepsy research. Computational and mathematical investigations are uniquely poised to probe this question, considering that these transitions exhibit qualitative and quantitative similarities to bifurcations in dynamical systems. In this talk, I will review recent interdisciplinary research in the Neuron to Brian Lab that applies the dynamical systems concepts of multistability and bifurcations to propose new hypotheses explaining the vulnerability of epileptogenic neural circuits to seizure-like behavior. These mechanisms, having theoretical, computational, and experimental support, highlight pathways to the seizure state that are the potential target for next-generation clinical interventions, such as the use of neurostimulation.