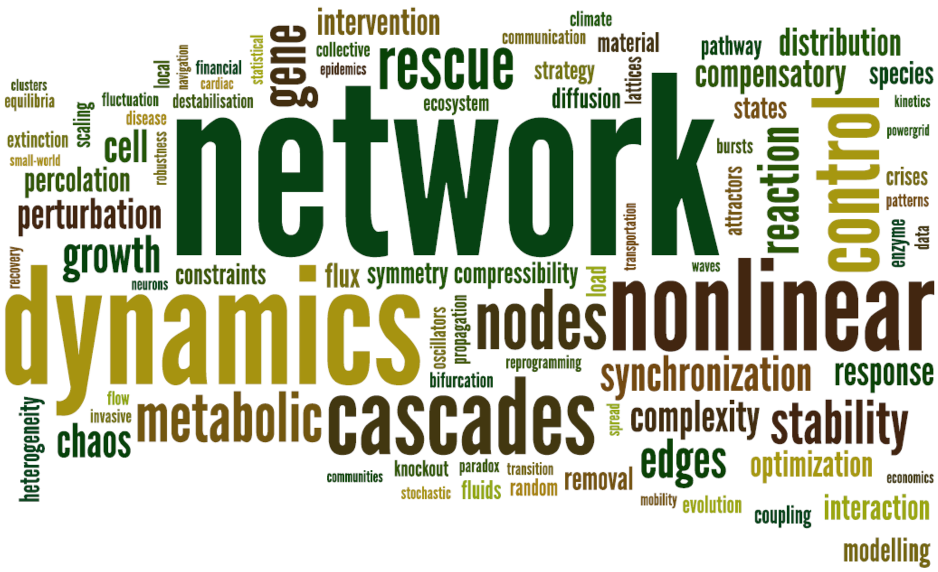
Network Frontier Workshop

Highlighting leading-edge research on complex networks



Program

December 1 – 2, 2011

Northwestern University
Chambers Hall
600 Foster Street
Evanston, IL 60208
USA

Sponsored by
Northwestern Institute on Complex Systems
Weinberg College of Arts and Sciences

Organized by The Motter Group
Scientific organizer: Jie (Rio) Sun
Administrative organizer: Luciana Zanella

Schedule

Thursday, December 1st

8:15 – 8:30	Registration
8:30 – 9:15	Ian Dobson (Iowa State University) *Estimating Propagation and the Statistics of Blackout Extent from Electric Power Grid Cascading Failure Data*
9:15 – 9:40	Raissa D'Souza (University of California, Davis) *Percolation and Cascades in Interdependent Networks*
9:40 – 9:55	Tom Hurd (McMaster University) *Analyzing Contagion in Banking Networks*
9:55 – 10:10	Simone Lenzu (Northwestern University) *Liquidity Shocks in Different Interbank Network Topologies*
10:10 – 10:40	Coffee Break
10:40 – 11:25	Kevin M. Lynch (Northwestern University) *Compiling Global Behaviors into Local Controllers for Mobile Sensor Networks*
11:25 – 11:50	Rachel Leander (The Ohio State University) *Using Optimal Control Theory to Identify Network Structures that Foster Synchrony*
11:50 – 12:05	Artemy Kolchinsky (Indiana University, Bloomington) *Prediction and Modularity in Dynamical Systems*
12:05 – 12:30	Igor Belykh (Georgia State University) *Synchronization in Networks with Mixed Graphs*
12:30 – 2:15	Lunch Break (Allen Center)
2:15 – 3:00	Adilson E. Motter and Sean P. Cornelius (Northwestern University) *Control of Complex Networks with Compensatory Perturbations*
3:00 – 3:25	Zachary G. Nicolaou (California Institute of Technology) *Explicit Negative Compressibility Materials via Network Destabilization*
3:25 – 3:40	Christian Darabos (Dartmouth College) *The Influence of Whole Genome Duplication and Subsequent Diversification on Environmental Robustness and Evolutionary Innovation in Gene Regulatory Networks*
3:40 – 3:55	Maxim N. Artyomov (Broad Institute of MIT and Harvard) *Systematic Identification of Topologically Essential Interactions in Regulatory Networks*
3:55 – 4:25	Coffee Break
4:25 – 5:10	Marty Golubitsky (The Ohio State University) *Patterns of Phase-Shift Synchrony*
5:10 – 5:25	Joel Nishimura (Cornell University) *Robust Convergence of Pulse-Coupled Oscillators on Networks with Delays*
5:25 – 5:40	Per Sebastian Skardal (University of Colorado, Boulder) *Hierarchical Synchrony of Phase Oscillators in Modular Networks*
5:40 – 6:05	Takashi Nishikawa (Clarkson University) *Discovering Network Structure Beyond Communities*

6:05 – 7:30	Wine and Cheese
6:25 – 7:00	Dirk Brockmann (Northwestern University) *"Feel Sick? Follow the Money!" - A Network Perspective on Human Mobility and Global Disease Dynamics*

Friday, December 2nd

8:20 – 9:05	Peter Grassberger (University of Calgary) *Percolations Galore*
9:05 – 9:30	Erik M. Bollt (Clarkson University) *Synchronization as a Process of Sharing and Transferring Information*
9:30 – 9:45	PJ Lamberson (Northwestern University) *Network Games with Local Correlation and Clustering*
9:45 – 10:00	James P. Bagrow (Northwestern University) *Structural and Social Aspects of Human Mobility*
10:00 – 10:30	Coffee Break
10:30 – 11:15	Daniel ben-Avraham (Clarkson University) *Geography and Complex Networks*
11:15 – 11:40	Juan G. Restrepo (University of Colorado, Boulder) *Criticality and Statistics of Avalanches in Network Cascading Processes*
11:40 – 12:05	Lynne Kiesling (Northwestern University) *Economic Regulation, Transactive Technology, and Knowledge in Retail Electricity Markets*
12:05 – 12:30	Jie (Rio) Sun (Northwestern University) *Identification of Interventions to Control Network Crises*
12:30 – 2:15	Lunch Break (Allen Center)
2:15 – 2:30	Yong-Yeol Ahn (Indiana University, Bloomington) *Flavor Network and the Principles of Food Paring*
2:30 – 2:45	Joo Sang Lee (Northwestern University) *Network Model Explains why Cancer Cells Use Inefficient Pathway to Produce Energy*
2:45 – 3:30	Edward Ott (University of Maryland, College Park) *Orbital Stability of Dynamics on Gene Networks*
3:30 – 6:00	Physics & Astronomy Colloquium (Tech L211)
3:30 – 4:00	Refreshments
4:00 – 5:00	Réka Albert (Pennsylvania State University) *Linking the Structure and Dynamics of Biological Regulatory Networks*
5:00 – 6:00	Reception

Session Chairs

December 1, Morning	Jie (Rio) Sun	December 2, Morning	Michael Schnabel
December 1, Afternoon	Thomas Wytock	December 2, Afternoon	Takashi Nishikawa
		December 2, Colloquium	Adilson E. Motter

Abstracts – Keynote Presentations

Réka Albert

Professor
Physics & Biology
Pennsylvania State University

Linking the Structure and Dynamics of Biological Regulatory Networks (Dec 2, 4:00pm)

Interaction between gene products forms the basis of essential biological processes like signal transduction, cell metabolism or embryonic development. Recent experimental advances helped uncover the structure of many molecular-to-cellular level networks, creating a surge of interest in the dynamical description of these processes. Differential equation based modeling frameworks are greatly hampered by the sparsity of known kinetic detail. As an alternative, qualitative models assuming a small set of discrete states for gene products are gaining acceptance. Many results also suggest that the interaction topology plays a determining role in the dynamics of regulatory networks. In this presentation I will explore discrete modeling in several contexts: as the basis of successful predictive models of signal transduction and immune responses, as a tool for inferring regulatory mechanisms, and as a key step in connecting signaling network structure and dynamics.

Daniel ben-Avraham

Professor
Physics
Clarkson University

Geography and Complex Networks (Dec 2, 10:30am)

The actual placing of the nodes of complex networks in space, while optional, or non-applicable in many cases (e.g., citation networks, proteomics and metabolism networks, etc.) is highly relevant and an important part of the system in many other situations (social networks, networks of flight connection, neuron network of the brain, etc.). This problem, known as the "geography" of complex networks, has received surprisingly little attention, and constitutes at present one of the most promising avenues for fruitful research in the area of complex networks. In this talk, I shall discuss some of the basic existing findings about the structure of geographically embedded scale-free networks, and how to navigate geographical networks by decentralized (local) algorithms, and will point at some of the vast areas left wide open to exploration.

Ian Dobson

Sandbulte Professor
Electrical & Computer Engineering
Iowa State University

Estimating Propagation and the Statistics of Blackout Extent from Electric Power Grid Cascading Failure Data (Dec 1, 8:30am)

Large blackouts often involve the cascading failure of transmission lines. We estimate how line outages propagate from observed data, and obtain a branching process probabilistic model of the cascading line outages. Then, given assumed or estimated initial line outages, we can calculate the probability distribution of the extent of the cascading outage. This gives a way to extend risk analysis from the analysis of initial failures to also include the effect of cascading. The bulk statistical approach opens opportunities for monitoring the cascading risk from about one year of standard utility data. We will also make some general remarks about how bulk statistical approaches arise for blackouts and how modeling approaches can fail or be justified.

Marty Golubitsky

Distinguished Professor of
Mathematics & Physical Sciences
The Ohio State University

Patterns of Phase-Shift Synchrony (Dec 1, 4:25pm)

This talk discusses a result (joint with David Romano and Yunjiao Wang) that classifies rigid patterns of phase-shift synchrony in time-periodic solutions to general network systems.

Peter Grassberger

Visiting iCORE Research Professor
Physics & Astronomy
University of Calgary

Percolations Galore (Dec 2, 8:20am)

Although percolation theory was considered a mature subject several years ago, recent progress has changed this radically. While "classical" or "ordinary" percolation (OP) is a second order phase transition between long range connectivity and disconnectedness on diluted regular lattices or random graphs, examples have now been found where this transition can range from infinite order to first order. The latter is of particular importance in social sciences, where first order percolation transitions show up as a consequence of synergistic effects, and I will point out analogies with the relationship between percolation and rough interfaces in physics. Another case where first order percolation transitions show up is interdependent networks, although first claims about this have to be substantially modified – in some cases of interdependent networks the transition is second order but in a new universality class. A similar but even more unexpected result holds for so-called "Achlioptas processes" that were originally claimed to show first order transitions, but which actually show second order transitions with a completely new type of finite size scaling. Finally, I will present "agglomerative percolation" (AP), a model originally introduced to understand the claim that network renormalization can demonstrate the fractality of some small world networks. The most exotic feature of AP is that it leads to different scaling behavior on square and triangular 2-d lattices, in flagrant violations of universality.

Kevin M. Lynch

Professor
Mechanical Engineering
Northwestern University

Compiling Global Behaviors into Local Controllers for Mobile Sensor Networks (Dec 1, 10:40am)

Mobile sensor networks can be deployed for tasks such as environmental monitoring. Decentralized control algorithms allow the mobile sensors to adapt to a changing environment and to failure of individual sensors, without the need for a centralized controller.

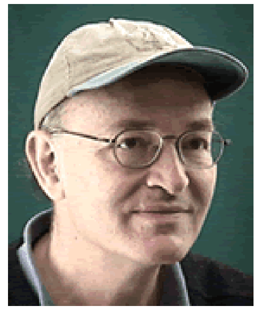
I will describe the control theory and experimental testbed we are developing to support "swarms" of mobile sensors. This work is based on the concept of "information diffusion" in ad hoc communication networks and motion control laws that drive the sensors to optimally acquire information. This work is joint with Prof. Randy Freeman (Northwestern University) and the Naval Research Lab.

Adilson E. Motter

Anderson Professor
Physics & Astronomy
Northwestern University

Control of Complex Networks with Compensatory Perturbations (Dec 1, 2:15pm)

A fundamental property of networks is that the perturbation of one node can affect other nodes, in a process that may cause the entire or a substantial part of the system to change behavior and possibly collapse. Our recent research in metabolic and ecological networks demonstrated that network damage caused by external perturbations can often be mitigated or reversed by the application of compensatory perturbations. Compensatory perturbations are constrained to be physically admissible and amenable to implementation on the network. However, the systematic identification of compensatory perturbations that conform to these constraints has remained an open problem. In this talk, we will present a method to construct compensatory perturbations that can control the fate of general networks under such constraints. Our approach accounts for the full nonlinear behavior of real complex networks and can bring the system to a desired target state even when this state is not directly accessible. Applications to genetic networks show that compensatory perturbations are effective even when limited to a small fraction of all nodes and that they are far more effective when these are the highest-degree nodes in the network. The versatility of our methodology is illustrated through applications to associative-memory, power-grid, and food-web networks. The approach is conceptually simple and computationally efficient, making it suitable for the rescue, control, and reprogramming of large complex networks in various domains.



Edward Ott

Distinguished University Professor
Electrical & Computer Eng., Physics
University of Maryland, College Park

Orbital Stability of Dynamics on Gene Networks
(Dec 2, 2:45pm)

We consider Boolean models of the dynamical evolution of a system of interacting genes, wherein each gene is either on or off (expressing its protein or not expressing its protein), and its state influences the subsequent states of other genes to which it has inputting network connections. Orbital stability is defined for large systems of this type by imagining two system states that are initially close in the sense of Hamming distance and asking whether or not their evolutions lead to subsequent distance convergence or divergence on average. We find a general method of answering this question and investigate the impact on stability of various factors, such as network topology (including assortivity, community structure, small motifs, etc.), nodal dynamics, link delay times, correlation between topological and nodal properties, and finite size effects. We also, introduce and discuss a hypothesis that orbital instability might be a causal contributor to the occurrence of cancer.
Reference: A. Pomerance, E. Ott, M. Girvan, W. Losert, PNAS vol.106, p.8209 (May 19, 2009).

Abstracts – Invited Talks

Dirk Brockmann
Associate Professor
Engineering Sciences & Applied Mathematics
Northwestern University

"Feel Sick? Follow the Money!" - A Network Perspective on Human Mobility and Global Disease Dynamics (Dec 1, 6:25pm)

Human Mobility in our globalised world has reached a complexity and volume of unprecedented degree. More than 60 million people travel billions of kilometres on more than 2 million international flights each week. Hundreds of millions of people commute on a complex web of highways and railroads most of which operate at their maximum capacity. Because the geographical spread of new diseases is driven by mobility processes, the threat of large scale pandemic events has become acute, SARS in 2003 and H1N1 in 2009 are two examples of global epidemic events in recent years. I will report on the discovery of suprisingly simple patterns in human mobility based on the analysis of the geographic circulation of cash in the United States. I will present a complex network perspective on multi-scale human mobility networks, and how these networks offer a way to understand the complexity of global human disease dynamics.

Igor Belykh
Associate Professor
Mathematics & Statistics, Georgia State University

Synchronization in Networks with Mixed Graphs (Dec 1, 12:05pm)

We discuss synchronization in oscillator networks where groups of oscillators are connected into different subnetworks via different individual oscillator's variables. An illustrative example is a network of Lorenz systems where some of the nodes are coupled through the *x*-variable, some through the *y*-variable, and some through both. We extend the connection graph method to prove synchronization in such networks with mixed graphs. We demonstrate that networks with mixed graphs may have drastically different synchronization properties from networks with only one connection graph.

Erik M. Bollt
Harrington Professor
Mathematics, Clarkson University

Synchronization as a Process of Sharing and Transferring Information (Dec 2, 9:05am)

Synchronization of chaotic oscillators has become well characterized by errors which shrink relative to a synchronization manifold. This manifold is the identity function in the case of identical systems, or some other slow manifold in the case of generalized synchronization of non-identical components. On the other hand, since many decades chaotic oscillators have been well understood, in terms of symbolic dynamics, as information producing processes. We study here the synchronization of a pair of chaotic oscillators as a process of their sharing information bearing bits transferred between each other, by measuring the transfer entropy tracked as the global systems transitions to the synchronization state. Further, we discuss the notion of transfer entropy in the measure theoretic setting of transfer operators.

Raissa D'Souza
Associate Professor
Computer Science, Mathematical & Aerospace Eng.
University of California, Davis

Percolation and Cascades in Interdependent Networks (Dec 1, 9:15am)

Random graphs provide a framework for modeling network phenomena, especially phase transitions, such as the sudden emergence of large-scale connectivity. This talk will first present a variant of the classic Erdős-Rényi random graph model of network formation (using the power of two choices), showing that we can alter the location and seeming nature of the phase transition, making for an explosive onset of connectivity. We also develop random graph models of interacting networks, motivated by the fact that individual networks are increasingly interdependent (e.g., the Internet and the power grid, globalization of financial markets). We show that interactions between different types of networks can actually lower critical thresholds and provide stabilizing effects with respect to cascades.

Lynne Kiesling
Distinguished Senior Lecturer
Economics, Northwestern University

Economic Regulation, Transactive Technology, and Knowledge in Retail Electricity Markets (Dec 2, 11:40am)

This talk presents and analyzes the results of a field experiment in which residential electricity customers in Washington State with price-responsive (transactive) digital in-home devices could use those devices to change their electricity consumption autonomously, and could choose a retail contract with real-time prices. This combination of technology and institutional design enabled decentralized coordination rather than requiring imposed central control, and we use complexity science to interpret results that show that the real-time market outcomes were those of a self-organizing and scalable complex adaptive system. These results are a consequence of an important, but overlooked, epistemological aspect of modeling markets as complex adaptive systems – diffuse private knowledge.

Rachel Leander
Postdoctoral Fellow
Mathematical Biosciences Institute
The Ohio State University

Using Optimal Control Theory to Identify Network Structures that Foster Synchrony (Dec 1, 11:25am)

Network structure is known to influence a population's propensity to synchronize. We use optimal control theory to construct networks that allow heterogeneous populations to maintain high levels of synchrony, explore the relationship between population heterogeneity and the structure of the optimal networks, and identify salient optimal network features that may enhance synchrony.

Zachary G. Nicolaou
Graduate Student
Physics, California Institute of Technology

Explicit Negative Compressibility Materials via Network Destabilization (Dec 1, 3:00pm)

Conventional materials deform along the direction of an applied force, with all existing materials expanding when tensioned and contracting when pressured. The opposite behavior – in which the deformation opposes the applied force – is inherently unstable and hence assumed to be unachievable. Exploring network concepts, here I will demonstrate that this can in fact be achieved through destabilizations of stable equilibria of the material's constituents, which gives rise to a stress-induced solid-solid phase transition associated with a twisted hysteresis curve for the stress-strain relationship. I will show how to use this to design materials that can undergo expansion when pressured and/or contraction when tensioned, a phenomenon that we refer to as explicit negative compressibility. Explicit negative compressibility should be contrasted with the commonly found negative incremental stiffness, characterized by a decrease in the resulting restoration force for increasing deformation, which can be regarded as an implicit form of negative compressibility. The strain-driven counterpart of negative compressibility results in a force amplification phenomenon, where a small change in deformation leads to a very large change in force. The proposed materials could be useful for the design of actuators, force amplifiers, micro-mechanical controls, and protective devices, and inspire similar constructions in other types of networks.

Takashi Nishikawa
Assistant Professor
Mathematics, Clarkson University

Discovering Network Structure Beyond Communities (Dec 1, 5:40pm)

To understand the formation, evolution, and function of complex systems, it is crucial to understand the internal organization of their interaction networks. Partly due to the impossibility of visualizing large complex networks, resolving network structure remains a challenging problem. In this talk, I will describe an approach that overcomes this difficulty by combining the visual pattern recognition ability of humans with the high processing speed of computers to develop an exploratory method for discovering groups of nodes characterized by common network properties, including but not limited to communities of densely connected nodes. Without any prior information about the nature of the groups, the method simultaneously identifies the number of groups, the group assignment, and the properties that define these groups. The results of applying our method to real networks suggest the possibility that most group structures lurk undiscovered in the fast-growing inventory of social, biological, and technological networks of scientific interest.

Juan G. Restrepo
Assistant Professor
Applied Mathematics, University of Colorado, Boulder

Criticality and Statistics of Avalanches in Network Cascading Processes (Dec 2, 11:15am)

I will discuss recent work on the effect of network topology on cascading processes. The motivation for our work is a series of recent experiments on cascades of excitation observed in rat cortical tissue cultures. First, I will describe how the critical point at which self-sustained activity emerges in the absence of a sustained stimulus depends on the network topology. Second, I will present an analysis of the statistics of the duration and size of excitation cascades (quantities with experimental relevance) in terms of the topology of the network. Our work is applicable to individual networks described by an adjacency matrix and is complementary to previous approaches based on network ensembles.

Abstracts – Contributed Talks

Yong-Yeol Ahn
Assistant Professor
Informatics & Computing
Indiana University, Bloomington

Flavor Network and the Principles of Food Pairing (Dec 2, 2:15pm)

Animals, especially omnivores, feed selectively to fulfill energy needs and nutrient requirements, guided by chemical cues perceived as flavors. Among animals, humans exhibit the most diverse array of culinary practice. The diversity raises the question whether there are any general patterns of ingredient combination that transcend individual tastes and cuisines. We introduce a flavor network that captures the chemical similarity between culinary ingredients. Together with recipe datasets of various cuisines, the flavor network shows that Western cuisines have a tendency to use ingredient pairs that share many flavor compounds, supporting the food pairing hypothesis used in molecular gastronomy. By contrast, East Asian cuisines tend to avoid compound sharing ingredients.

Maxim N. Artyomov
Postdoctoral Associate
Broad Institute of MIT and Harvard

Systematic Identification of Topologically Essential Interactions in Regulatory Networks (Dec 1, 3:40pm)

Screens monitoring the effect of deletion, knock-down, or over expression of regulatory genes on their target gene expression are critical for deciphering the organization of complex regulatory networks. However, since perturbation assays cannot distinguish direct from indirect effects, derived networks are significantly more complex than the true underlying one. Previous approaches to identify a minimal network topology consistent with the results of a perturbation screen only presented approximate methods with major limitations and are often applicable only to simple network topologies. Here, we present an approach to systematically find a family of core networks for an input network of any topology with an arbitrary number of activating and inhibiting interactions. Using a novel matrix representation of the network topology we reduce the problem of identifying the core underlying networks to counting self-avoiding random walks on the original network. This systematic approach allows us to globally analyze the network's topology to determine the functional effect of modifications such as edge removal. Exigo outperforms previous approaches on simulated data, and successfully uncovers the core network structure when applied to real networks derived from perturbation studies in yeast and mammals, providing a valuable tool for accurate global analysis of gene regulatory networks.

James P. Bagrow
Research Assistant Professor
Engineering Sciences & Applied Mathematics
Northwestern University

Structural and Social Aspects of Human Mobility (Dec 2, 9:45am)

Research on human mobility and social dynamics has been revolutionized by the appearance of pervasive mobile electronics such as cellular phones, capturing activity patterns across extensive populations. Using country-wide data from mobile phone users, we find that human mobility is dominated by a small group of frequently visited and dynamically close locations, forming a primary "habitat", along with a number of subsidiary habitats representing additional travel. These habitats are both well separated and spatially compact. We find that motion within these habitats exhibits distinct temporal scaling and that the time delay to enter subsidiary habitats is a primary factor in the spatial growth of human travel. A majority of users possess habitats that occupy single temporal and social contexts and exhibit high temporal and social predictability when occupying infrequently visited habitats, implying deep connections between activity and mobility dynamics.

Christian Darabos
Postdoctoral Research Fellow
Computational Genetics Laboratory, Dartmouth College

The Influence of Whole Genome Duplication and Subsequent Diversification on Environmental Robustness and Evolutionary Innovation in Gene Regulatory Networks (Dec 1, 3:25pm)

Within biological systems, global genetic perturbations, in particular whole genome duplications, are extremely rare as they are highly unfavorable to the organism. Nevertheless, these constitute powerful mechanisms in the discovery of new phenotypes, and their protection against environmental perturbation. Here, we use Random Boolean Networks to simulate such events in a numerical model. Applying Evolutionary Algorithms, we investigate the influence of these genetic mechanisms on the relationship between evolutionary innovation and environmental robustness in gene regulatory networks and the resulting phenotypes. In living organisms, whole genome duplication is highly detrimental in ancestral environments; however it provides fitness advantages in novel environments. This comes at the cost of reduced environmental robustness. Our models mimic these behaviors and help us explain this phenomenon. We can then replicate the rapid diversification that follows the duplication observed in nature as seen through our duplicated Boolean networks. Simply by removing non-functioning regulatory interactions, our systems can partly negotiate this trade-off between improving evolutionary innovation and sustaining environmental robustness. We conclude by discussing the implications, limitations, and future directions of our research.

Tom Hurd
Professor
Mathematics, McMaster University

Analyzing Contagion in Banking Networks
(Dec 1, 9:40am)

A probabilistic framework is introduced that represents stylized banking networks and aims to predict the size of contagion events. In contrast to previous work on random financial networks, which assumes independent connections between banks, the possibility of disassortative edge probabilities (an above average tendency for small banks to link to large banks) is explicitly incorporated. We give a probabilistic analysis of the default cascade triggered by shocking the network. We find that the cascade can be understood as an explicit iterated mapping on a set of edge probabilities that converges to a fixed point. A cascade condition is derived that characterizes whether or not an infinitesimal shock to the network can grow to a finite size cascade, in analogy to the basic reproduction number R_0 in epidemic modeling. It provides an easily computed measure of the systemic risk inherent in a given banking network topology. An analytic formula is given for the frequency of global cascades, derived from percolation theory on the random network. Two simple examples are used to demonstrate that edge-assortativity can have a strong effect on the level of systemic risk as measured by the cascade condition. Although the analytical methods are derived for infinite networks, large-scale Monte Carlo simulations demonstrate the applicability of the results to finite-sized networks. Finally, we propose a simple graph theoretic quantity, which we call "graph-assortativity", that seems to best capture systemic risk.

Artemy Kolchinsky
Graduate Student
Center for Complex Networks & Systems
Indiana University, Bloomington

Prediction and Modularity in Dynamical Systems
(Dec 1, 11:50am)

Identifying and understanding modular organizations is centrally important in the study of complex systems. Several approaches to this problem have been advanced, many framed in information-theoretic terms. Our treatment starts from the complementary point of view of statistical modeling and prediction of dynamical systems. It is known that for finite amounts of training data, simpler models can have greater predictive power than more complex ones. We use the trade-off between model simplicity and predictive accuracy to generate optimal multiscale decompositions of dynamical networks into weakly-coupled, simple modules. State dependent and causal versions of our method are also proposed.

PJ Lamberson
Senior Lecturer, Kellogg School of Management
Senior Research Associate, NICO
Northwestern University

Network Games with Local Correlation and Clustering (Dec 2, 9:30am)

This paper develops a model of games played in a network that allows for local correlation in players' strategies. For example, two colleagues are likely to use a common software package because it facilitates collaboration, giving rise to local positive correlation in software choice. The model is applied to two specific classes of games, games of strategic complements and substitutes, which correspond to technology adoption and public goods provisions problems, respectively. Games of strategic complements are shown to have two winner-take-all equilibria separated by a tipping point, analogous to the epidemic threshold in models of disease spread. The model predicts a unique equilibrium independent of initial strategies in games of strategic substitutes. Using this framework I also examine the dependence of equilibrium outcomes on network clustering – the probability that two individuals with a mutual friend are friends of each other. I find that clustering increases the provision of public goods and makes it easier for a beneficial new technology to break into a market dominated by a less preferred standard. This may in part explain the success of Facebook's much discussed strategy of initially focusing on college campuses in defeating the once dominant social network, MySpace.

Joo Sang Lee
Graduate Student
Physics & Astronomy, Northwestern University

Network Model Explains why Cancer Cells use Inefficient Pathway to Produce Energy (Dec 2, 2:30pm)

The Warburg effect – the use of the (energetically inefficient) fermentative pathway as opposed to (energetically efficient) respiration even in the presence of oxygen – is a common property of cancer metabolism. Here, we propose that the Warburg effect is in fact a consequence of a trade-off between the benefit of rapid growth and the cost of protein synthesis. Using genome-scale metabolic networks, we have modeled the cost of cellular resources for protein synthesis as a growth defect that increases with the concentration of enzymatic proteins. Based on our model, it can be concluded that the cost of protein production during rapid growth drives the cell to rely on fermentation to produce ATP. We also identify an intimate link between extensive fermentation and rapid biosynthesis. Our findings emphasize the importance of protein synthesis as a limiting factor on cell proliferation and provide a novel mathematical framework to analyze cancer metabolism.

Simone Lenzu
Visiting Pre-Doctoral Fellow
Kellogg School of Management, Northwestern University

Liquidity Shocks in Different Interbank Network Topologies (Dec 1, 9:55am)

In this paper we develop an interbank market with heterogeneous financial institutions that enter into lending agreements on different network structures. Credit relationships (links) evolve endogenously via a fitness mechanism based on agents' performance. By changing the agent's trust on its neighbor's performance, interbank linkages self-organize themselves into very different network architectures, ranging from random to scale-free topologies. We study which network architecture can make the financial system more resilient to random attacks and how systemic risk spreads over the network. To perturb the system, we generate a random attack via a liquidity shock. The hit bank is not automatically eliminated, but its failure is endogenously driven by its incapacity to raise liquidity in the interbank network. Our analysis highlights the role of information in shaping different interbank topologies. Moreover, allowing agents to endogenously react to random attacks, our analysis shows that a random financial network can be more resilient than a scale-free one in case of agents' heterogeneity ad market segmentation.

Joel Nishimura
Graduate Student
Applied Mathematics, Cornell University

Robust Convergence of Pulse-Coupled Oscillators on Networks with Delays (Dec 1, 5:10pm)

The ability of pulse-coupled oscillators to achieve a synchronous solution can be complicated by complex network structure and time delay across edges. While many systems have their performance impaired by the addition of either of these, we describe a class of oscillators which mix excitation and inhibition so as to be robust to both delays and network structure. Furthermore, we can produce explicit bounds on the convergence time and show a region of guaranteed convergence [1]. We also present new work that leverages graph topology to probabilistically expand this basin in either asymptotic or finite sized systems. These results provide new and more robust methods for synchronization of sensor nets and also have biological implications.

[1] J. Nishimura and E. J. Friedman, PRL (2011).

Per Sebastian Skardal
Graduate Student
Applied Mathematics, University of Colorado, Boulder

Hierarchical Synchrony of Phase Oscillators in Modular Networks (Dec 1, 5:25pm)

We study synchronization of sinusoidally coupled phase oscillators on networks with modular structure and a large number of oscillators in each community. Of particular interest is the hierarchy of local and global synchrony, i.e., synchrony within and between communities, respectively. Using the recent ansatz of Ott and Antonsen, we find that the degree of local synchrony can be determined from a set of coupled low-dimensional equations. If the number of communities in the network is large, a low-dimensional description of global synchrony can be also found. Using these results, we study bifurcations between different types of synchrony. We find that, depending on the relative strength of local and global coupling, the transition to synchrony in the network can be mediated by local or global effects.

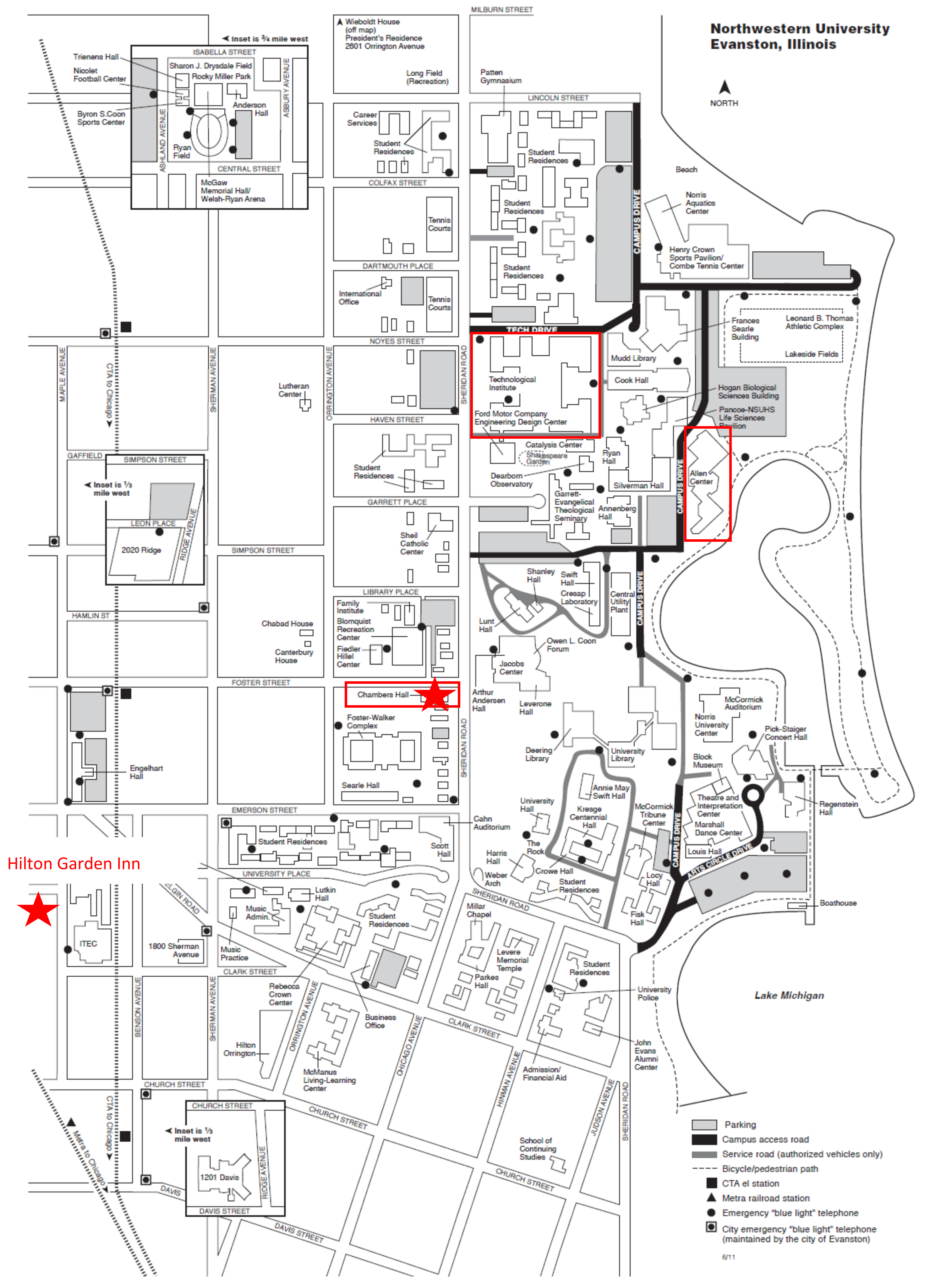
Jie (Rio) Sun
Postdoctoral Research Associate
Physics & Astronomy, Northwestern University

Identification of Interventions to Control Network Crises (Dec 2, 12:05pm)

Large-scale crises in financial, social, infrastructure, genetic and ecological networks often result from the spread of disturbances that in isolation would only cause limited damage. Here I will present a method to identify and schedule interventions that can mitigate cascading failures in general complex networks. When applied to competition networks, our method shows that the system can often be rescued from global failures through actions that satisfy restrictive constraints typical of real-world conditions. However, under such constraints, interventions that can rescue the system from subsequent failures exist over specific periods of time that do not always include the early postperturbation period, suggesting that scheduling is critical in the control of network cascades.

Other Participants

Daniel Abrams, Northwestern University
Timothy Caldwell, Northwestern University
Kristine Callan, Duke University
Julia Poncela Casasnovas, Northwestern University
Sean Cornelius, Northwestern University
Matthew Elwin, Northwestern University
Jacob Foster, University of Chicago
Daniel Grady, Northwestern University
David Guarrera, DARPA/Booz Allen Hamilton
Sascha Herrmann, Northwestern University
Brian Keegan, Northwestern University
Daniel Larremore, University of Colorado, Boulder
Mark Panaggio, Northwestern University
Jerry Rhee, Northwestern University
Damien Rontani, Duke University
Epaminondas Rosa, Illinois State University
David Rosin, Duke University
Serguei Saavedra, Northwestern University
Narimon Safavi, WBEZ Chicago Public Media
Michael Schnabel, Northwestern University
Siavash Sohrab, Northwestern University
Samuel Stanton, US Army Research Office
Nick Switanek, Northwestern University
Dane Taylor, University of Colorado, Boulder
Brian Uzzi, Northwestern University
Alex Waagen, University of California, Davis
Daniel Wells, Northwestern University
Olivia Wooley, Northwestern University
Thomas Wytock, Northwestern University
Haley Yaple, Northwestern University
Yang (Angela) Yang, Northwestern University


Northwestern University
Evanston, Illinois
NORTH
Hilton Garden Inn
Chambers Hall
Technological Institute
Ford Motor Company Engineering Design Center
Allen Center
Lake Michigan
Parking
Campus access road
Service road (authorized vehicles only)
Bicycle/pedestrian path
CTA el station
Metra railroad station
Emergency "blue light" telephone
City emergency "blue light" telephone (maintained by the city of Evanston)
6/11