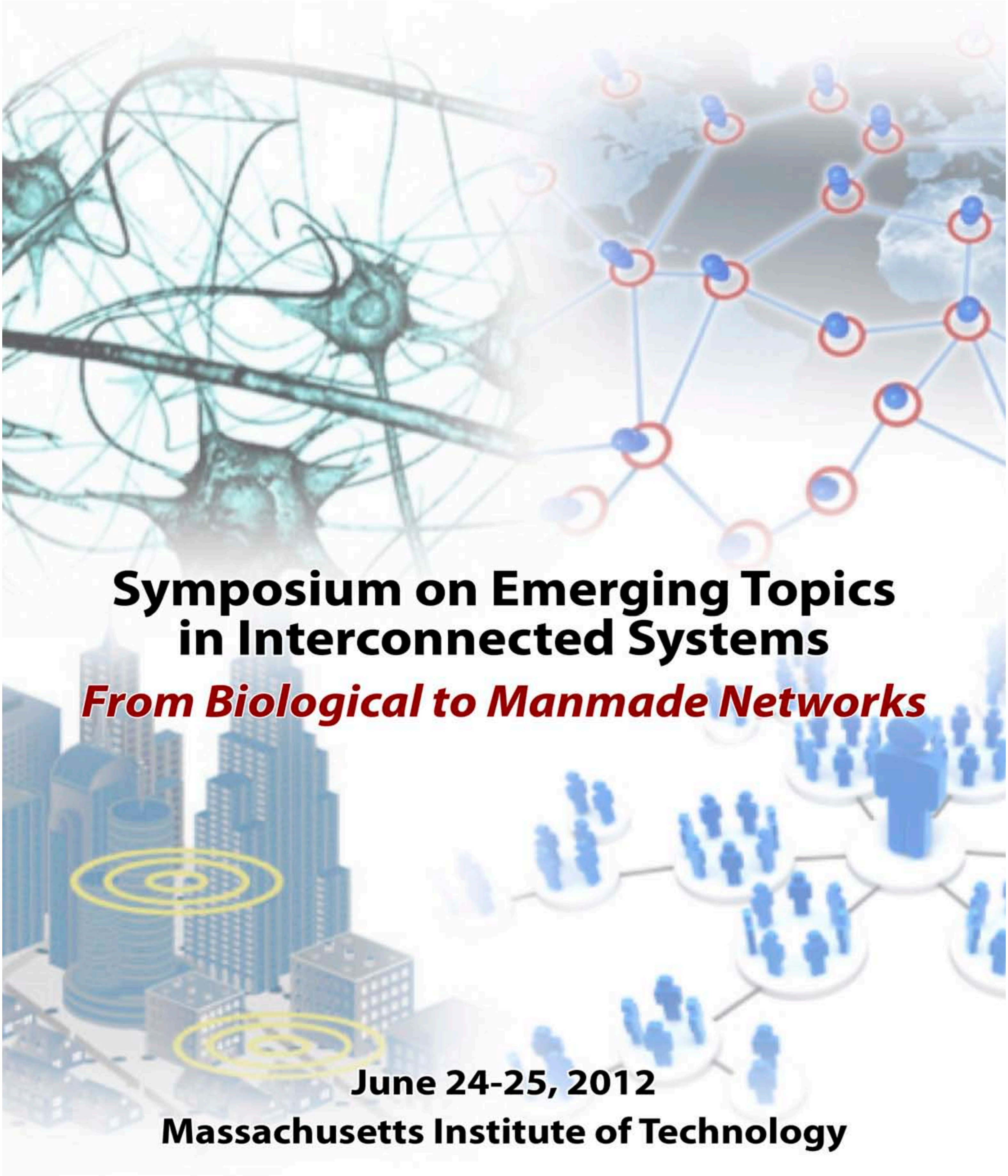

Symposium on Emerging Topics in Interconnected Systems

From Biological to Manmade Networks

June 24-25, 2012

Massachusetts Institute of Technology

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Symposium Description

Technological advancements such as ubiquitous and inexpensive sensing capabilities, high-speed communications enabling the transfer of massive data sets in almost real time, and ever increasing computational power for real-time optimized decisions have contributed to the emergence of large-scale, complex networked systems.

Networked systems are systems that are composed of a large number of smaller subsystems that are dynamically coupled and/or interconnected through a communication medium. Such systems are prevalent in many areas of engineering and sciences, such as communication networks, social networks, transportation networks, biological networks, power networks, and the emerging smart grid.

The science of networked systems is inherently interdisciplinary. In the diverse fields in which networked models arise, network system science must address the associated domain specific modeling issues, as well software and hardware implementations and communications infrastructure. Accordingly, there has been extensive research in many fields dedicated towards deriving guiding principles and theory for the analysis networked systems. Beyond analysis, there also has been significant interest in developing practical methodologies for the design of robust and efficient networked systems.

Of particular interest in networked systems is the phenomenon of systemic risk. While networked systems may perform well under normal operations, they can exhibit fragility in response to certain disruptions resulting in a major system breakdown. In particular, this fragility can arise from seemingly minor and rare disruptions whose collective effect is amplified through a cascade of failures that propagates through the system interconnections. Furthermore, the propagation of failures need not be caused by malicious interventions, but rather stems from the interaction of the interconnected subsystems as they respond to small disruptions. The flash crash of 2010, the recession of 2008, the New England power outage of 2003, or more commonly, the cascaded delays in air travel because of unexpected weather in a hub city like Chicago are just a few of many examples of the systemic risk present in complex interconnected systems.

The growing prevalence of networked systems and the significance of their societal impact have motivated the emergence of a foundational science that allows for measuring, predicting, and containing systemic risk. This symposium is aimed at articulating a picture of the challenges and ideas that will shape the future directions and potential areas of impact of research in the science of networked systems in general and on the emerging field of systemic risk. This meeting will bring together leading researchers who have been influential in shaping the vision of and leading this field. They will present a combination of theoretical analysis and applied experimental research.

Maps and Directions

Sessions & Panels

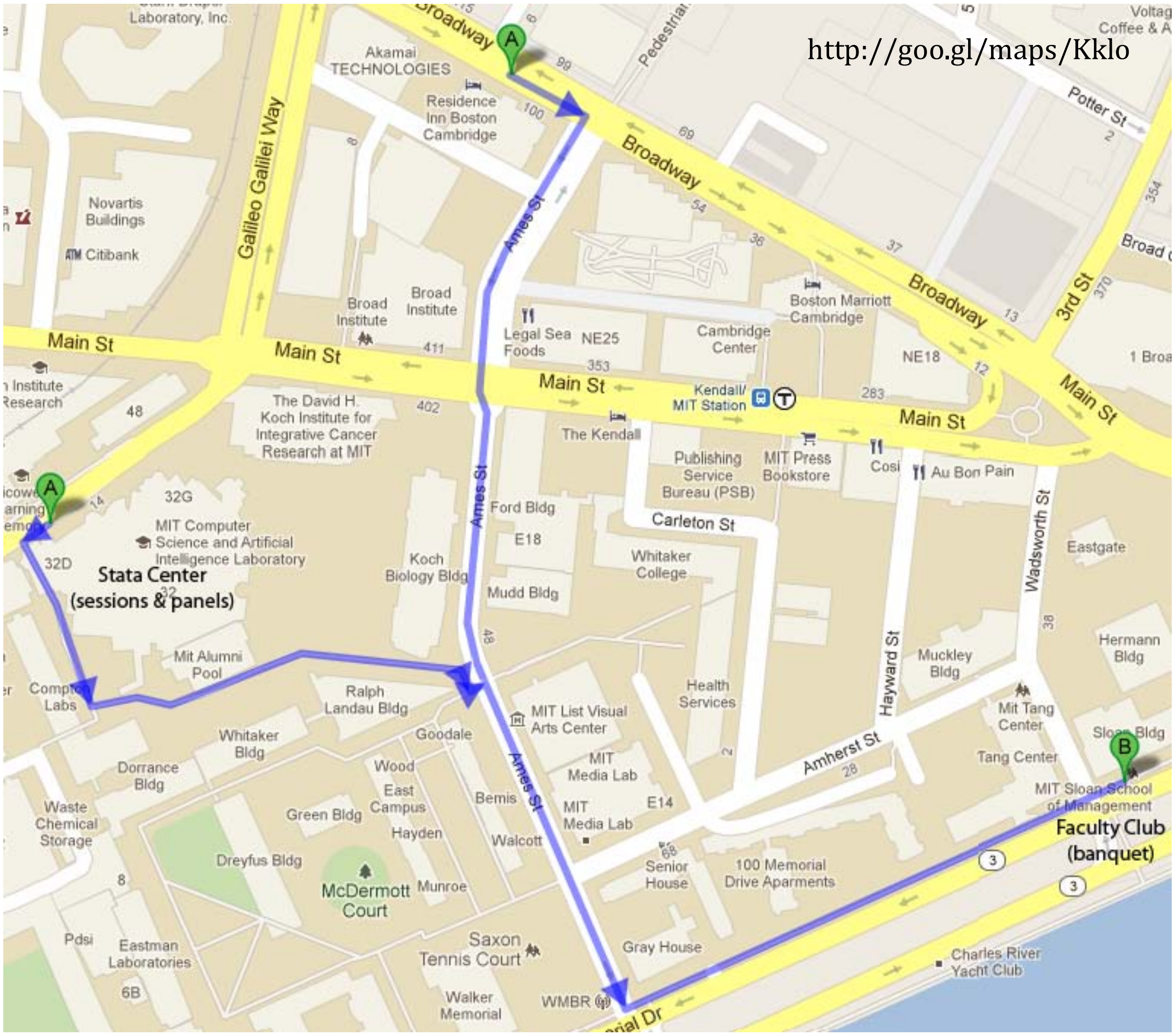
Sessions and panels will be held in room 32-141 of the Ray and Maria Stata Center (Building 32). The building was design by Frank Gehry and is extremely distinctive. The conference, lunches, and breaks will be held on the first floor.

Directions to the Stata Center from the Residence Inn/Vassar Street:

1. Turn right out of the building's main entrance and southeast on Broadway
2. Take the first right onto Ames St
3. Take the second right onto Main St
4. Take the first left onto Vassar Street.
5. Enter the second entrance on your left into building 32-D
6. Continue down the hallway until you see 32-141 on your right.

Dinner Banquet

The dinner banquet (on Sunday, May 23rd) will be held at the MIT faculty club at 50 Memorial Drive, Cambridge, MA.



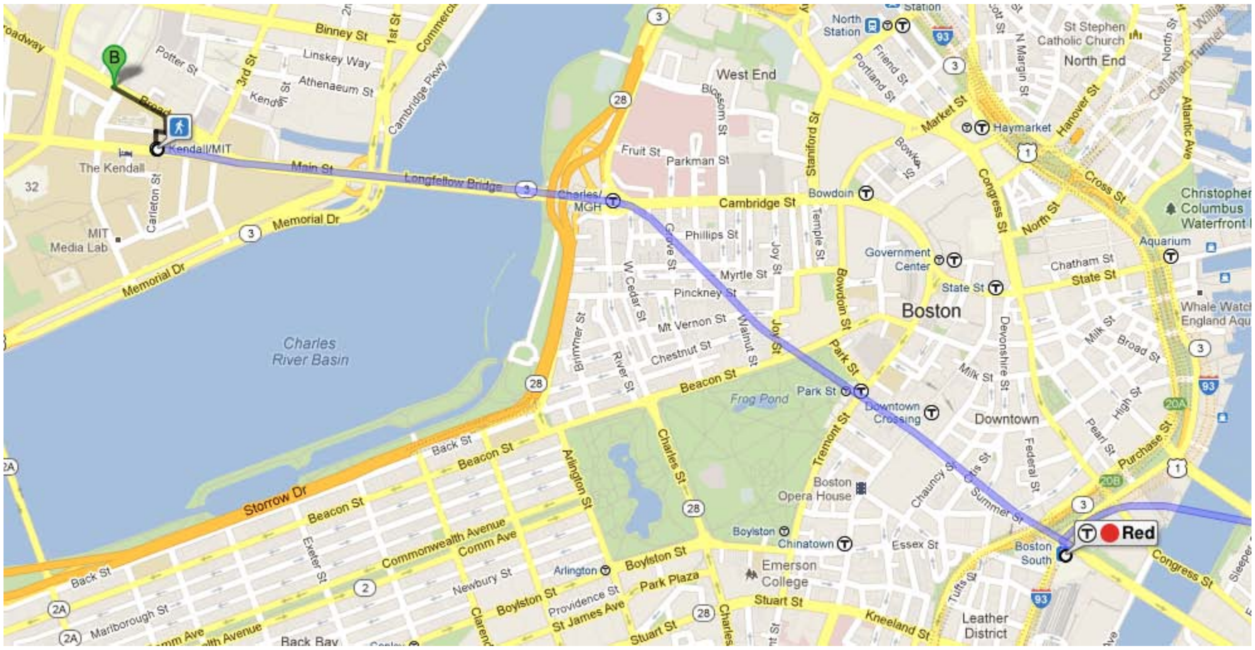
Directions to the Faculty Club from the Residence Inn:

1. Turn right out of the building's main entrance and southeast on Broadway
2. Take the first right onto Ames St
3. Turn left onto the sidewalk by Memorial Drive.
4. Turn left into the MIT Faculty Club/Sloan School of Management building.

Directions to the Faculty Club from the STATA center:

1. Leave the Stata center and head east towards the Kotch Biology Center
2. Turn Right onto Ames Street.
3. Turn left onto the sidewalk by Memorial Drive.
4. Turn left into the MIT Faculty Club/Sloan School of Management building.

By Public Transportation



Directions to the Residence Inn by Public Transportation

1. Take the Silver Line Bus towards South Station.
2. At South Station, transfer to the Red Line (towards Alewife)
3. Get off of the red line at Kendall Square
4. Walk one block west on Main Street, and take a right onto Ames Street
5. Take a left onto Broadway, and take an immediate left into the Residence Inn

Directions to the Stata Center by Public Transportation

1. Follow steps 1-3 above.
2. Walk two blocks west on Main Street, and take a left onto Vassar Street.
3. Take the second left into the Stata Center (Building 32)

Program (Stata Center, room 32-141)

Day 1 - June 24, 2012

Opening 8:00-9:00

8:00-8:45	Registration & Coffee
8:45-9:00	Welcome & Opening Remarks

Session #1: Biological Networks 9:00-11:00

Chair: Jorge Goncalves, University of Cambridge (UK)

9:00-9:30	M. Vidyasagar, UT Dallas
9:30-10:00	Mustafa Khammash, ETHZ
10:00-10:30	Sridevi Sarma, Johns Hopkins University
10:30-11:00	Break

Session #2: Energy & Smart Grid 11:00-12:00

Chair: Sanjay Lall, Stanford University

11:00-11:30	Sean Meyn, University of Florida
11:30-12:00:	Mardavij Roozbehani, MIT

12:15-1:30: **Lunch**

Session #3: Societal Networks 1:30-3:30

Chair: Danielle Tarraf, Johns Hopkins University

1:30-2:00	Devavrat Shah, MIT
2:00-2:30	Ali Jadbabaie, University of Pennsyvlania
2:30-3:00	Ilan Lobel, New York University
3:10-3:30	Break

Session #4: Retrospective Panel 3:30-5:00

3:30-5:00	Moderator:	Jeff Shamma, Georgia Tech
	Panelists:	Sanjoy Mitter, MIT
		Keith Glover, Cambridge University
		Bruce Francis, University of Toronto

Reception & Dinner Banquet- Faculty Club MIT 6:30 – 10:00

Day 2: - June 25, 2012

Session #5: Communication Networks **9:00-10:30**
Chair: Petros Voulgaris, UIUC

9:00-9:30 Venkatesh Saligrama, Boston University
9:30-10:00 Fernando Paganini, Universidad ORT Uruguay
10:00-10:30 Nicola Elia, Iowa State

10:30-10:45 Break

Student Poster Session **10:45-11:30**

11:30-1:00 **Lunch**

Session #6: Control & Estimation over Networks **1:00-3:45**
Chair: Venkatesh Saligrama, Boston University

1:00-1:30 Nuno Martins, University of Maryland
1:30-2:00 Sanjay Lall, Stanford University
2:00-2:30 Emilio Frazzoli, MIT

2:30-2:45 Break

2:45-3:15 Bassam Bamieh, UC Santa Barbara
3:15-3:45 Laura Giarre, University of Palermo

Panel: Systemic Risk **3:45-5:00**
3:45-5:00 Moderator: Pablo Parrilo, MIT
Panelists: John Doyle, Caltech
Munther Dahleh, MIT
Andrew Lo, MIT

Retrospective Panelists

Bruce Francis

Electrical and Computer Engineering
University of Toronto

Looking back on a paper by al. et Dahleh

The 2002 paper by Bamieh, Paganini, and Dahleh entitled "Distributed control of spatially invariant systems" won the 2004 Axelby Award. The paper took earlier work by Melzer and Kuo (1971) and created a general framework for distributed systems and control. The systems are linear and time-invariant, but also spatially invariant. The simplest example is a chain of identical vehicles, a chain infinite in both directions. This talk will review the contribution of the paper and raise a question about the formulation.

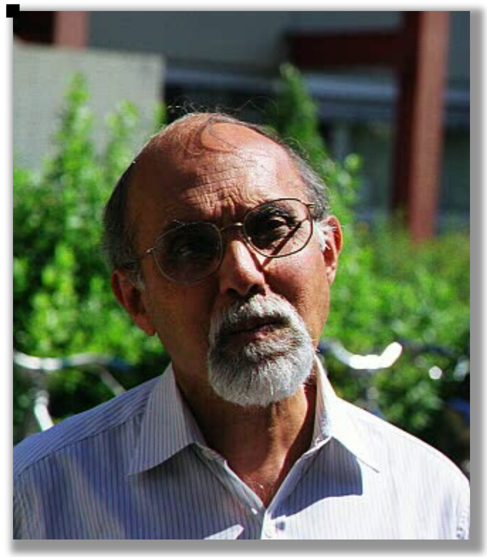
Bruce Francis received his PhD in 1975 at the University of Toronto. He has held research and teaching positions at Berkeley, Cambridge, McGill, Yale, and Waterloo, and is now an emeritus professor at the University of Toronto. A longer biography can be found at https://sites.google.com/site/brucefranciscontact/.

Keith Glover

Department of Engineering
University of Cambridge

Keith Glover received the B.Sc.(Eng) degree from Imperial College, London in 1967, and the S.M., E.E. and Ph.D. degrees from the Massachusetts Institute of Technology in 1971, 1971 and 1973, respectively, all in electrical engineering. In 1976 he joined the faculty of the Department of Engineering at the University of Cambridge where his present position is Professor of Engineering. He was Head of the Department of Engineering from 2002-2009, having previously been Head of the Control Group, Head of the Information Engineering Division, a Deputy Head of Department (Research) and Chairman of the Council of the School of Technology.

Sanjoy Mitter
Laboratory for Information and Decision Systems
Electrical Engineering and Computer Science
Massachusetts Institute of Technology



Sanjoy K. Mitter received his Ph.D. degree from the Imperial College of Science and Technology in 1965. He taught at Case Western Reserve University from 1965 to 1969. He joined MIT in 1969 where he has been a Professor of Electrical Engineering since 1973. He was the Director of the MIT Laboratory for Information and Decision Systems from 1981 to 1999. He has also been a Professor of Mathematics at the Scuola Normale, Pisa, Italy from 1986 to 1996. He has held visiting positions at Imperial College, London; University of Groningen, Holland; INRIA, France; Tata Institute of Fundamental Research, India and ETH, Zürich, Switzerland; and several American universities. Professor Mitter will be the Ulam Scholar at Los Alamos National Laboratories in April 2012 and the John von Neumann Visiting Professor in Mathematics at the Technical University of Munich, Germany from May-June 2012. He was awarded the AACC Richard E. Bellman Control Heritage Award for 2007. He was the McKay Professor at the University of California, Berkeley in March 2000, and held the Russell- Severance-Springer Chair in Fall 2003. He is a Fellow of the IEEE and a Member of the National Academy of Engineering. He is the winner of the 2000 IEEE Control Systems Award. He was elected a Foreign Member of Istituto Veneto di Scienze, Lettere ed Arti in 2003. In 1988, he was elected to the National Academy of Engineering.

His current research interests are Communication and Control in a Networked Environment, the relationship of Statistical and Quantum Physics to Information Theory and Control and Autonomy and Adaptiveness for Integrative Organization.

Systemic Risk Panelists

John Doyle

Control & Dynamical Systems
Electrical Engineering | BioEngineering
California Institute of Technology

John Doyle is the John G Braun Professor of Control and Dynamical Systems, Electrical Engineer, and BioEngineering at Caltech. He has a BS and MS in EE, MIT (1977), and a PhD, Math, UC Berkeley (1984). Current research interests are in theoretical foundations for complex networks in engineering and biology, focusing on architecture, and for multiscale physics. Early work was in the mathematics of robust control, including LQG robustness, (structured) singular value analysis, H-infinity plus recent extensions to nonlinear and networked systems.

Andrew Lo

Charles E. and Susan T. Harris Professor
Professor of Finance
Director, Laboratory for Financial Engineering
Massachusetts Institute of Technology

Andre Lo went to Yale University, BA '80, Economics; Harvard University, AM, PhD '84, Economics. Andrew Lo is a widely recognized expert in financial engineering, computational finance, and neurobiological models of individual risk preferences and financial markets. Lo's research interests include the empirical validation and implementation of financial asset pricing models; the pricing of options and other derivative securities; financial engineering and risk management; trading technology and market microstructure; statistics, econometrics, and stochastic processes; computer algorithms and numerical methods; financial visualization; nonlinear models of stock and bond returns; hedge-fund risk; and return dynamics and risk transparency.

Munther Dahleh

Laboratory for Information and Decision Systems
Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology
(biography at end of document)

Invited Participants

Bassam Bamieh

Professor
Mechanical Engineering
University of California at Santa Barbara

Back to the Future: Stochastic Structured Uncertainty

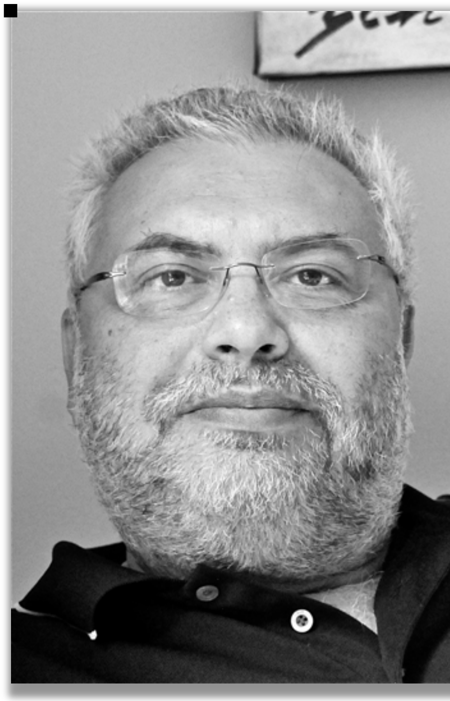
The analysis of dynamical systems with structured uncertainty received much attention in the robust control community starting in the late 80’s. While that literature dealt with mostly deterministic and norm-bounded uncertainties, more recent results have been obtained for the case when uncertainties are stochastic gains. This setting is useful for problems in distributed systems with distributed stochastic elements such as random networks, stochastic hydrodynamic stability and random materials. In this talk, I will give a quick and nostalgic look back at the structured uncertainty literature. I will then describe the newer stochastic structured uncertainty results and discuss some of their implications.

Bassam Bamieh is Professor of Mechanical Engineering at the University of California at Santa Barbara. He received his B.Sc. degree in Electrical Engineering and Physics from Valparaiso University (Valparaiso, IN) in 1983, and his M.Sc. and PhD degrees in Electrical and Computer Engineering from Rice University (Houston, TX) in 1986 and 1992 respectively. Prior to joining UCSB in 1998, he was an Assistant Professor in the Department of Electrical and Computer Engineering and the Coordinated Science Laboratory at the University of Illinois at Urbana-Champaign (1991-98). Professor Bamieh's research interests are in the fundamentals of Control and Dynamical Systems, as well as the applications of systems and feedback techniques in several physical and engineering systems. These areas include Robust and Optimal Control, distributed control and dynamical systems, shear flow transition and turbulence, and the use of feedback in thermoacoustic energy conversion devices.

Professor Bamieh has received several awards and honors for his research, including an IEEE Control Systems Society G. S. Axelby Outstanding Paper Award, an AACC Hugo Schuck Best Paper Award, and a National Science Foundation CAREER award. He was elected a Distinguished Lecturer of the IEEE Control Systems Society (2005), a Fellow of the International Federation of Automatic Control (IFAC) , and a Fellow of the IEEE.

Nicola Elia

Associate Professor
Iowa State University



Computing over Unreliable Communication Networks

In this talk, we take the unifying view of systems interacting over communication networks as distributed computing systems and propose to study them as networked control systems. Since averaging is central operation to much science and engineering, we first study the problem of distributed averaging over unreliable networks. We point out that a popular and well-behaved algorithm can instead generate a collective global complex behavior when the inter-agent communication happens over unreliable links. To mitigate the effects of the unreliable information exchange we propose a new distributed averaging algorithm robust to noise and intermittent communication. The algorithm and the control perspective are the basis for the development of new distributed optimization systems that we can analyze and design as networked control systems. The approach applies to multi-agent cooperative applications and opens up several directions of research.

Nicola Elia is an Associate Professor of the Dept. of Electrical and Computer Engineering at Iowa State University. He received the Laurea degree in Electrical Engineering from Politecnico di Torino in 1987, and the Ph.D. degree in Electrical Engineering and Computer Science from Massachusetts Institute of Technology in 1996. He worked at the Fiat Research Center from 1987 to 1990. He was Postdoctoral Associate at the Laboratory for Information and Decision Systems at MIT from 1996 to 1999. He has received the NSF CAREER Award in 2001. His research interests include networked control systems, communication systems with access to feedback, complex systems, and computational methods for controller design.

Emilio Frazzoli
Associate Professor
Laboratory for Information and Decision Systems
Department of Electrical Engineering and Computer Science
Massachusetts Institute of Technology

Stability, resilience, and control of transportation systems

In this talk, we will outline some recent results on the analysis of transportation systems, and on the design of robust control policies, e.g., for routing and for traffic signal scheduling. Modeling transportation systems as dynamical flow networks, we first analyze the stability of equilibria under a multi-scale model of driver decisions, combining slow updates on the global state of the network with fast myopic reactions to observed traffic, and present results on the the resilience of such networks under perturbations that reduce link-wise capacity. Subsequently, we introduce a new distributed algorithm for controlling traffic signals, showing that it is maximally stabilizing, and significantly outperforms current state-of-the-art commercial systems on large-scale simulations.

Emilio Frazzoli is an Associate Professor of Aeronautics and Astronautics with the Laboratory for Information and Decision Systems at the Massachusetts Institute of Technology. He received a Laurea degree in Aerospace Engineering from the University of Rome, "Sapienza" , Italy, in 1994, and a Ph. D. degree in Navigation and Control Systems from the Department of Aeronautics and Astronautics of the Massachusetts Institute of Technology, in 2001. Dr. Frazzoli's main research interests lie in the general area of planning and control for mobile cyber-physical systems, with a particular emphasis on autonomous vehicles, mobile robotics, and transportation networks.

Laura Giarrè
Associate Professor (with tenure)
DIEETCAM
Università di Palermo viale delle Scienze
90128 Palermo, Italy

Relations between structure and estimators in networks of dynamical systems

The main focus is on the identification of a graphical model from time series data associated with different interconnected entities. The time series are modeled as realizations of stochastic processes (representing nodes of a graph) linked together via transfer functions (representing the edges of the graph). Both the cases of non-causal and causal links are considered.

By using only the measurements of the node outputs and without assuming any prior knowledge of the network topology, a method is provided to estimate the graph connectivity. It is shown that the method will identify all true links in the network with some spurious links added. It is also shown that the spurious links remain local in the sense that they are added within a hop of a true link. In particular, it is proven that the method determines links to be present only between a node and its “kins'', where kins of a node consist of parents, children and co-parents (other parents of all of its children) in the graph.

With the additional hypothesis of strictly casual links, a similar method is provided that allows one to exactly reconstruct the original graph. Main tools for determining the network topology are based on Wiener, Wiener-Hopf and Granger filtering. Another significant insight provided by the article is that the Wiener filter estimating a stochastic process, represented by a node, based on other processes in a network configuration remains local in the sense that the Wiener filter utilizes only measurements local to the node being estimated. Analogies with the problem of Compressing Sensing are drawn and two greedy algorithms to address the problem of reducing the complexity of the network structure are also suggested.

Laura Giarrè is a poet, a writer, and a Control System Professor at University of Palermo, Italy in the EE Department (DIEETCAM). Her interests are in Identification and Game Theory for Networks. She is in the Scientific Advisory Board of the Andrea Bocelli Foundation.

Jorge Goncalves

University Lecturer
Engineering Control Group
University of Cambridge (UK)

Jorge Goncalves received his Licenciatura (5-year S.B.) degree from the University of Porto, Portugal, and the M.S. and Ph.D. degrees from the Massachusetts Institute of Technology, Cambridge, MA, all in Electrical Engineering and Computer Science, in 1993, 1995, and 2000, respectively. He then held two postdoctoral positions, first at the Massachusetts Institute of Technology for seven months, and from 2001 to 2004 at the California Institute of Technology with the Control and Dynamical Systems Division. Since 2004 he has been a Lecturer at the Information Engineering Division of the Department of Engineering, University of Cambridge. Since 2005 he is also a Fellow of Pembroke College, Cambridge. From June to December 2010 and January to September 2011 he was a visiting researcher at the University of Luxembourg and California Institute of Technology, respectively. His research interests include modelling, analysis and control of complex and hybrid systems. In particular, modelling and analysis in systems and synthetic biology, closely collaborating with biologists in different areas such as circadian rhythms and gene regulatory networks.

Ali Jadbabaie

Professor
Electrical and Systems Engineering
Secondary Appointment: Computer and Information Science, and Operations and Information Management
Co-Director, Market and Social Systems Engineering Program

University of Pennsylvania

Analysis of Customer Subscription Decisions in Networks with Positive Externality

In this talk I will present a game-theoretic model that captures the strategic behavior of customers facing a service subscription purchasing decision. I will focus on a class of products with positive network effects. Customers interact according to a network structure through which the positive externality is conveyed. We use a one-shot simultaneous incomplete information game to model the interaction of customers and provide an equilibrium in which a customer's subscription decision depends on her network centrality. I will apply the results to real network data to illustrate the customers' decisions. I will also discuss the convergence of our equilibrium computing algorithm and explain how the steps of algorithm relate to customers' behavior in reaching the equilibrium in reality. Finally, I will also present some recent results on competitive contagion and product adoption in social networks (Joint work with students Jaelynn Oh and Mike Zargham.)

Ali Jadbabaie received his BS degree in Electrical Engineering from Sharif University of Technology in 1995. He received a Masters degree in Electrical and Computer Engineering from the University of New Mexico, Albuquerque in 1997 and a Ph.D. degree in Control and Dynamical Systems from California Institute of Technology in 2001. From July 2001-July 2002 he was a postdoctoral associate at the department of Electrical Engineering at Yale University. Since July 2002 he has been with the department of Electrical and Systems Engineering and GRASP Laboratory at the University of Pennsylvania, Philadelphia, PA, where he is now an associate professor. He is a recipient of an NSF Career Award, an ONR Young Investigator award, Best student paper award of the American Control Conference 2007, the O Hugo Schuck Best Paper award of the American Automatic Control Council, and the George S. Axelby Outstanding Paper Award of the IEEE Control Systems Society. His research is broadly in network science, specifically, analysis, design and optimization of networked dynamical systems with applications to multi-robot formation control, social aggregation and other collective phenomena.

Mustafa Khammash
Prof. of Control Theory and Systems Biology
Department of Biosystems Science and Engineering
Swiss Federal Institute of Technology-Zurich (ETHZ)
Switzerland

Fiat Lux: Optogenetic Control of Living Cells

One of the key challenges to the analysis and control of genetic networks is that the cellular environment in which these circuits function is abuzz with random noise. Cellular noise results in random fluctuations and is a key source of variability among genetically identical cell populations. In this talk, we describe novel analytical and experimental work that demonstrates how light can be used in combination with single cell measurement technology to achieve precise and robust set point regulation of gene expression in populations of living cells.

Mustafa Khammash received his B.S. degree from Texas A&M University in 1986 and his Ph.D. from Rice University in 1990, both in Electrical Engineering. In 1990, he joined the Electrical Engineering Department at Iowa State University. While at Iowa State University, he created the Dynamics and Control Program and led that control group until 2002, when he became a member of the Mechanical Engineering faculty at the University of California, Santa Barbara. In Santa Barbara, he served as Vice Chair of the Mechanical Engineering Department from 2003 to 2006 and as the Director of the Center for Control, Dynamical Systems and Computation from 2005 to 2011. In 2011 Prof. Khammash moved with his group to Switzerland, joining the Department of Biosystems Science and Engineering at ETH Zurich. Dr. Khammash works in the areas of control theory, systems biology, and synthetic biology.

Ilan Lobel
Assistant Professor of Information,
Operations and Management Sciences
New York University

Social Learning and Network Uncertainty

Social learning is the process by which information dispersed in society is aggregated and disseminated. For the last twenty years, researchers have studied how herd behavior can make the social learning process inefficient. In this paper, we argue that herd behavior should actually be considered a second-order effect and that the primary cause of failure of the social learning process is instead network uncertainty. That is, the fact that the topology of the social network is not common knowledge can cause a major failure of the societal process of information aggregation. We catalogue some of the different mechanisms through which network uncertainty disrupts the dynamics of social learning and characterize conditions under which learning succeeds in the presence of network uncertainty. Joint work with Evan Sadler (NYU).

Ilan Lobel is an Assistant Professor of Information, Operations and Management Sciences at New York University's Stern School of Business. Prior to joining NYU Stern in 2010, he was a post-doctoral researcher at the Microsoft Research New England Lab. He received his Ph.D. in Operations Research from the Massachusetts Institute of Technology in 2009 and his B.Sc. in Electrical Engineering from the Pontificia Universidade Catolica of Rio de Janeiro in 2004. Professor Lobel's research focuses on the operations of Internet-based businesses, focusing on issues such as pricing, learning and contract design for dynamic and networked markets.

Nuno Martins

Associate Professor
Electrical and Computer Engineering
Institute for Systems Research
University of Maryland

New Convex Parametrizations for the Design of Sparsity Constrained Controllers

In this talk, I will describe new methods for the design of norm-optimal sparsity-constrained controllers. I will start by presenting a new characterization of the necessary and sufficient conditions for the existence of a stabilizing sparsity-constrained controller, subject to quadratically invariant sparsity constraints (as defined by Rotkowitz and Lall). In addition, I will discuss how this result can be used to construct a convex parametrization of stabilizing controllers that satisfy the sparsity constraint and, in contrast to previous approaches, does not require an initial stabilizing sparsity-constrained controller. This work constitutes an extension of the classical Youla parametrization for the case of norm-optimal controllers subject to quadratically-invariant sparsity constraints . (This is joint work with Dr. Serban Sabau)

Nuno C. Martins received the MS. degree in electrical engineering from I.S.T., Portugal, in 1997, and the Ph.D. degree in Electrical Engineering and Computer Science with a minor in Mathematics from Massachusetts Institute of Technology (MIT), Cambridge, in 2004. He has also concluded a Financial Technology Option program at Sloan School of Management (MIT) in 2004. He is currently Associate Professor at the Department of Electrical and Computer Engineering, University of Maryland, College Park, where he is also affiliated with the Institute for Systems Research and the Center for Applied Electromagnetics. He received a National Science Foundation CAREER award in 2007, the 2006 American Automatic Control Council O. Hugo Schuck Award, the 2010 Outstanding ISR Faculty award and the 2010 IEEE CSS Axelby Award. He is also a member of the editorial board of Systems and Control Letters (Elsevier), Automatica and of the IEEE Control Systems Society Conference Editorial Board.

Sean Meyn

Professor and Robert C. Pittman Eminent Scholar Chair
Electrical and Computer Engineering
University of Florida

Why are you sending prices to my devices?

Real time prices and associated measurement devices have generated fear in recent years. In particular,

- In 2011, massive price swings have generated anger in Texas and New Zealand
- Our own research shows that this is to be expected: in a completive equilibrium real-time prices will reach the choke up price, which has been estimated at upwards of 1/4 million dollars. With transmission constraints, our research concludes that prices can go much higher.
- A recent EIA study shows that consumers are scared of smart meters - they do not trust utility companies to experiment with their meters, or their power bills.

We must then ask, is there any motivation to focus on markets in a real-time setting? The speaker believes there is none. Explanations will be given, and alternative visions will be proposed.

Sean Meyn received the B.A. degree in mathematics from UCLA in 1982, and the Ph.D. degree in electrical engineering from McGill University in 1987 (with Prof. P. Caines). After 22 years as a professor at the University of Illinois, he is now Robert C. Pittman Eminent Scholar Chair in the Dept. of ECE at the University of Florida, and director of the new Laboratory for Cognition & Control. His research interests include stochastic processes, optimization, complex networks, information theory, and power and energy systems.

Fernando Paganini
Electrical & Telecommunications Engineering
Universidad ORT, Uruguay

Content dissemination dynamics in P2P networks through PDEs

Peer-to-peer networks achieve scalability by making each client that downloads a certain content behave as a server uploading to others. These networks and naturally dynamic, and exhibit feedback: population dynamics depends on the available download rates, but these in turn depend on the population contributing to the upload. In this talk we present a partial differential model for such dynamics that keeps track both of population and download progress, and analyze it with control theory techniques. In particular we present a small-gain argument to prove stability of the equilibrium, a frequency domain analysis of variability, and studies of transient dynamics which give very tight predictions of practical systems. We also discuss how these fluid models relate to the classical queueing theory counterparts.

Fernando Paganini received his Ingeniero Electricista and Licenciado en Matemática degrees from Universidad de la República, Montevideo, Uruguay, in 1990, and his M.S. and PhD degrees in Electrical Engineering from the California Institute of Technology, Pasadena, in 1992 and 1996 respectively. From 1996 to 1997 he was a postdoctoral associate at MIT. Between 1997 and 2005 he was on the faculty of the Electrical Engineering Department at UCLA, reaching the rank of Associate Professor. Since 2005 he is Professor of Electrical and Telecommunications Engineering at Universidad ORT, Uruguay.

Mardavij Roozbehani
Principal Research Scientist
Laboratory for Information and Decision Systems
Electrical Engineering and Computer Science
Massachusetts Institute of Technology

Network Effects on Volatility

In this talk, we present new results on analysis of the network effects on volatility of prices in wholesale electricity markets. We present a dynamic model for the evolution of supply, demand, and the Locational Marginal Prices (LMPs). The LMPs are modeled as dual variables corresponding to nodal power balance constraints in a convex power flow optimization over a lossless DC network. We characterize the effects of transmission network constraints on the sensitivity and volatility of the system, and examine the interplay between price volatility, spatial heterogeneity of consumers/producers, and network parameters. In particular, we show that increased heterogeneity amplifies the network effects on volatility.

Mardavij Roozbehani received the B.Sc. degree from Sharif University of Technology, Tehran, Iran, in 2000, the M.Sc. degree in mechanical and aerospace engineering from the University of Virginia, Charlottesville, VA, in 2003, and the Ph.D. degree in aeronautics and astronautics from the Massachusetts Institute of Technology (MIT), Cambridge, MA, in 2008. Since 2012, he has held a Principal Research Scientist position at the Laboratory for Information and Decision Systems (LIDS) at MIT, where he previously held postdoctoral, course instructor, and research scientist positions between 2008 and 2011. His main research interests include distributed and networked control systems, dynamics and economics of power systems with an emphasis on robustness and risk, analysis and design of software control systems, and finite-state systems. Dr. Roozbehani is a recipient of the 2007 AIAA graduate award for safety verification of real-time software systems.

Venkatesh Saligrama
Information Systems and Sciences (ISS) Group
Electrical and Computer Engineering Department
Boston University

Shannon Theory and Sparse Signal Processing

Sparsity naturally manifests in a number of signal processing problems including channel estimation, MIMO radar, group testing, and multi-task learning. Sparsity encodes the fact that in many scenarios the predictions and outcomes are governed by a sparse set of covariates. By considering the sparse subset as a message, we can view sparse signal processing as a version of noisy channel coding theorem due to Shannon. We will adopt this view and present a general result for sample complexity for sparse signal processing problems.

Venkatesh Saligrama is a faculty member at Boston University in the Department of Electrical and Computer Engineering and in the Division of Systems Engineering. His research interests include machine learning, video analytics, and statistical signal processing. He is a recipient of the NSF Career Award, the Presidential Career Award (PECASE) and the ONR Young Investigator Award. He has served as an Associate Editor for IEEE Transactions on Signal Processing and has been on the program committee for several IEEE conferences.

Sridevi Sarma
Assistant Professor
Institute for Computational Medicine
Department of Biomedical Engineering
Johns Hopkins University

Performance Limitations of Thalamic Relay: Insights into Thalamo-Cortical Network Processing, Parkinson's Disease and Deep Brain Stimulation

Thalamic networks in the brain are responsible for strategically filtering sensory information subject to attentional demands. For example, one can gaze at a butterfly and completely be unaware of the flowers and bushes that surround it, even though these surroundings are entirely within the subject's visual field. This occurs because visual thalamic neurons only *relay* the information in the visual field that the subject is paying attention to back to visual cortex for perception. How and when this relay occurs has never been precisely quantified.

In this talk, we utilize a biophysical-based model to quantify relay of a thalamic cell as a function of its input parameters and electrophysiological properties. Specifically, we compute bounds on relay reliability and show how these bounds can explain experimentally observed patterns of neural activity in the basal ganglia in (i) health where reliability is high, (ii) in Parkinson's disease (PD) where reliability is low, and (iii) in PD during therapeutic deep brain stimulation where reliability is restored. Our bounds also predict different rhythms that emerge in the lateral geniculate nucleus in the thalamus during different attentional states.

Sridevi Sarma (M'04) received the B.S. degree in electrical engineering from Cornell University, Ithaca, NY, in 1994, and the M.S. and Ph.D. degrees in electrical engineering and computer science from Massachusetts Institute of Technology, Cambridge MA, in 1997 and 2006, respectively. From 2006 to 2009, she was a Postdoctoral Fellow in the Brain and Cognitive Sciences Department, Massachusetts Institute of Technology. She is currently an Assistant Professor in the Department of Biomedical Engineering, Institute for Computational Medicine, Johns Hopkins University, Baltimore MD. Her research interests include modeling, and estimation and control of neural systems. Dr. Sarma is the recipient of the General Electric Faculty for the future scholarship, a National Science Foundation Graduate Research Fellow, a L'Oreal For Women in Science Fellow, and NSF CAREER award, and the Burroughs Wellcome Fund Careers at the Scientific Interface Award.

Devavrat Shah
Associate Professor
Laboratory for Information and Decision Systems
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Processing Social Data

An important byproduct of the emergence of social networking platforms is an access to abundance of social data in all forms: blogs, clicks, facebook feeds, transactions and tweets. It is of great interest to process this large volume of highly unstructured data to facilitate business decisions, public policy making or better social living. The key challenge lies in the fact that even though data is large in volume, the information content is very limited. Therefore, extracting meaningful answers has become a challenging computational and statistical task. In this talk, I will discuss how to resolve it successfully for important arising in the context of crowd-sourcing, ranking and viral advertising. The key to our success lies in the identification of the appropriate statistical framework for the problems at hand.

Devavrat Shah received his Bachelor of Technology in Computer Science and Engineering from Indian Institute of Technology, Bombay in 1999 with the Presidents of India Gold Medal – awarded to the best graduating student across all engineering disciplines. He received his PhD in Computer Science from Stanford University in 2004. His doctoral thesis titled “Randomization and Heavy Traffic Theory: New Approaches for Switch Scheduling Algorithms” was completed under supervision of Balaji Prabhakar. His thesis was adjudged winnder of George B. Dantzig best dissertation award from INFORMS in 2005. After spending a year between Stanford, Berkeley and MSRI, he started teaching at MIT in Fall 2005. His research focus is on theory of large complex networks which includes network algorithms, stochastic networks, network information theory and large scale statistical inference.

Danielle Tarraf

Assistant Professor
Electrical and Computer Engineering
Johns Hopkins University

Danielle C. Tarraf is an Assistant Professor of Electrical and Computer Engineering at the Johns Hopkins University. She previously held postdoctoral positions in the Division of Control and Dynamical Systems at the California Institute of Technology (2007-2008) and in the Laboratory for Information and Decision Systems at the Massachusetts Institute of Technology (2006-2007). She received her B.E. degree from the American University of Beirut, and her M.S. and Ph.D. degrees from the Massachusetts Institute of Technology.

Her research interests are in the broad area of systems and control theory, particularly as it interfaces with theoretical computer science. Her current focus includes control of hybrid systems; finite memory approximations for control design; problems at the interface of control, algebra, combinatorics, and automata theory; and analysis and robust control of networks.

Prof. Tarraf is the recipient of a 2010 CAREER award from the National Science Foundation, a 2011 Young Investigator Award from the Air Force Office of Scientific Research, and a 2012 Johns Hopkins University Alumni Excellence in Teaching award.

M. Vidyasagar

Professor
Cecil & Ida Green Chair in Systems Biology Science
Erik Jonsson School of Engineering & Computer Science

The University of Texas at Dallas

Reverse-engineering context-specific genome-wide interaction networks and an application to lung cancer

Advances in experimental techniques make it possible to measure simultaneously the expression levels of tens of thousands of genes, and to so for hundreds of tissue samples under a common set of experimental conditions. Constructing interaction networks that are consistent with the data is a major challenge. At present there are two classes of methods for doing so: Information-based methods that produce undirected graphs, and Bayesian networks that produce directed but acyclic graphs. We introduce something called the phi-mixing coefficient between random variables to construct a minimal network that is consistent with the data. This method has been applied effectively to data from lung and ovarian cancer, and has been validated experimentally on lung cancer.

Mathukumalli Vidyasagar received the B.S., M.S. and Ph.D. degrees in electrical engineering from the University of Wisconsin in Madison, in 1965, 1967 and 1969 respectively. Between 1969 and 1989, he was a Professor of Electrical Engineering at various universities in the USA and Canada. His last overseas job was with the University of Waterloo, Waterloo, ON, Canada, where he served between 1980 and 1989. In 1989 he returned to India as the Director of the newly created Centre for Artificial Intelligence and Robotics (CAIR) in Bangalore, under the Ministry of Defense, Government of India. In 2000 he moved to the Indian private sector as an Executive Vice President of India's largest software company, Tata Consultancy Services. In the city of Hyderabad, he created the Advanced Technology Center, an industrial R&D laboratory working in areas such as computational biology, quantitative finance, e-security, identity management, and open source software to support Indian languages. In 2009 he retired from TCS at the age of 62, and joined the Erik Jonsson School of Engineering & Computer Science at the University of Texas at Dallas, and In March 2010 he was named as the Founding Head of the newly created Bioengineering Department. His current research interests are in the application of stochastic processes and stochastic modeling to problems in computational biology, control systems and quantitative finance.

Poster Session Participants

Elie Adam

On Threshold Models over Finite Networks

Advisors: Asuman Ozdaglar and Munther Dahleh

We study a model for cascade effects over finite networks based on a deterministic binary linear threshold model. Our starting point is a networked coordination game where each agent's payoff is the sum of the payoffs coming from pairwise interaction with each of the neighbors. We first establish that the best response dynamics in this networked game is equivalent to the linear threshold dynamics with heterogeneous thresholds over the agents. While the previous literature has studied such linear threshold models under the assumption that each agent may change actions at most once, a study of best response dynamics in such networked games necessitates an analysis that allows for multiple switches in behavior. In this work, we develop such an analysis and construct a combinatorial framework to understand the behavior of the model. To this end, we establish that the agents behavior cycles among different actions in the limit and provide three sets of results.

We first characterize the limiting behavioral properties of the dynamics. We determine the length of the limit cycles and reveal bounds on the time steps required to reach such cycles. We then study the complexity of decision/counting problems that arise within the context. Specifically, we consider the tractability of counting the number of limit cycles and fixed-points, and deciding the reachability of action profiles. We finally propose a measure of network resilience that captures the nature of the involved dynamics. We prove bounds and investigate the resilience of different network structures under this measure.

Amir Ali Ahmadi **(2 posters)**

Convexity and SOS-Convexity

Advisor: Pablo Parrilo

We present several characterizations of sos-convexity---an algebraic, sum of squares based sufficient condition for convexity of polynomials. In contrast to convexity that is NP-hard to check, sos-covexity of a polynomial can be decided efficiently by solving a single semidefinite program. We present some applications in systems and control and then move on to our main result, which is a complete characterization of the dimensions and degrees where convexity and sos-convexity are equivalent. Although for disparate reasons, the remarkable outcome is that convex polynomials are sos-convex exactly in cases where nonnegative polynomials are sums of squares, as characterized by Hilbert in 1888.

Stability of Switched Systems and Path-Complete Graph Lyapunov Functions

Collaborators: Raphaël Jungers and Mardavij Roozbehani

We introduce the framework of path-complete graph Lyapunov functions for analysis of switched and uncertain linear systems (or equivalently for the computation of the joint spectral radius (JSR) of a set of matrices). The technique is based on new connections between ideas from control theory and the theory of finite automata and leads to a large class of semidefinite programming based algorithms for approximation of the JSR with provable guarantees.

Ali Faghih

Towards Efficient Integration of Renewables Using Energy Storage: Optimal Sizing and Management

Advisor: Munther A. Dahleh
Mentor: Mardavij Roozbehani

The primary concerns of this work are twofold: to understand the economic value of storage in the presence of ramp constraints and exogenous electricity prices, and to understand the implications of the associated optimal storage management policy on qualitative and quantitative characteristics of storage response to real-time prices. We present an analytic characterization of the optimal policy, along with the associated finite-horizon time-averaged value of storage. We also derive an analytical upperbound on the infinite-horizon time-averaged value of storage. This bound is valid for any achievable realization of prices when the support of the distribution is fixed, and highlights the dependence of the value of storage on ramp constraints and storage capacity. While the value of storage is a non-decreasing function of price volatility, due to the finite ramp rate, the value of storage saturates quickly as the capacity increases, regardless of volatility. We then present a computational framework for understanding the behavior of storage as a function of price and the amount of stored energy, and for characterization of the buy/sell phase transition region in the price-state plane. Finally, we study the impact of marketbased operation of storage on the required reserves, and show that the reserves may need to be expanded to accommodate market-based storage.

Rose T. Faghih

Broad Range of Neural Dynamics from a Time-Varying FitzHugh-Nagumo Model and Its Spiking Threshold Estimation

Advisors: Munther A. Dahleh, Emery N. Brown
Mentor: Ketan Savla

We study the use of the FitzHugh-Nagumo (FHN) model for capturing neural spiking. The FHN model is a widely used approximation of the Hodgkin-Huxley model that has significant limitations. In particular, it cannot produce the key spiking behavior of bursting. We illustrate that by allowing time-varying parameters for the FHN model, these limitations can be overcome while retaining its low-order complexity. This extension has applications in modeling neural spiking behaviors in the thalamus and the respiratory center. We demonstrate the use of the FHN model from an estimation perspective by presenting a novel parameter estimation method that exploits its multiple time-scale properties, and compare the performance of this method with the Extended Kalman Filter in several illustrative examples. We demonstrate that the dynamics of the spiking threshold can be recovered even in the absence of complete specifications for the system.

Andras Gyorgy

Modularity in Complex Gene Transcription Networks

Advisor: Domitilla Del Vecchio

A promising approach to decipher the complexity of biomolecular networks is to predict their behavior from that of the composing modules. Unfortunately, the behavior of a module changes once connected in the network [1] due to retroactivity effects. Retroactivity arises whenever two molecules bind describing the effect that these molecules become unavailable for other reactions. Recent experimental evidence demonstrates that the effects of retroactivity can be severe in signaling pathways [2], changing both the dose-response curve of a module and its dynamic response to input stimuli. Despite playing an important role in system phenotype, retroactivity is not yet characterized in complex gene transcription networks.

Here, we mathematically characterize retroactivity. We first introduce the retroactivity to the input of a gene, similar to the impedance of an electrical component, as a function of measurable biochemical parameters. Second, we define the internal retroactivity of module M accounting for loading effects presented by the genes in M on its own dynamics. Then, we introduce the input retroactivity of module M to module N describing the load module M presents to N. Both retroactivities can be calculated by combining the retroactivity to the input of genes in M, just as we determine the equivalent impedance of an electrical circuit at any two terminals by combining the impedances of the individual components. Based on these retroactivities, we describe how interconnected modules affect each other's behavior. We therefore recover the advantage of a modular approach to understand the dynamics of complex systems by augmenting the description of a module with internal and input retroactivites.

We illustrate the implications first by demonstrating that neglecting retroactivity can lead to the conclusion that negative feedback speeds up the system response to input perturbations, while in fact, it can slow down the response. Second, we focus on an activator-repressor clock and investigate coupling effects and noise propagation due to combinatorial regulation.

Sertac Karaman's

Random Graphs and Percolation in Robot Motion and Control: Practical Algorithms and Fundamental Limits

Advisor: Emilio Frazzoli

Robot motion planning, i.e., the problem of planning a collision-free path from an initial configuration to a final configuration, is embedded and essential in almost all robotics applications. Moreover, it has found a many applications in a number of diverse domains ranging from drug discovery to computational geometry. In this work, using the theory of random graphs and percolation theory, we study randomized sampling-based motion planning algorithms as well as the fundamental limits of motion planning problems in stochastic environments. On one hand, our algorithmic study leads to the first asymptotically-optimal and computationally-effective sampling-based motion planning algorithms. Moreover, this work extends the domain of sampling-based algorithms in a number of novel directions, including planning with temporal logic specifications, stochastic optimal control, and differential games. On the other hand, our work on the fundamental limits of high-speed motion reveals a phase transition phenomenon in the existence of infinite collision-free trajectories through stochastic environments.

Mihalis Markakis

Dynamic Scheduling in Queueing Networks with Heavy-Tailed Traffic

Advisors: Eytan Modiano and John Tsitsiklis

We consider the problem of scheduling in a switched queueing network with a mix of heavy-tailed and light-tailed traffic, and analyze the impact of heavy-tailed traffic on the performance of Max-Weight policies. As performance metric we use delay stability: a queue is delay stable if its expected steady-state delay is finite, and delay unstable otherwise. First, we show that a queue receiving heavy-tailed traffic is delay unstable under any scheduling policy. Then, we focus on the celebrated Max-Weight scheduling policy, and show that a light-tailed queue that conflicts with a heavy-tailed one is also delay unstable. Surprisingly, we show that a light-tailed queue can be delay unstable, even when it does not conflict with heavy-tailed traffic. Delay stability in this case depends on the arrival rates to the different queues. In order to generalize this result, we establish a connection between delay instability of queues in the stochastic network, and the evolution of the corresponding fluid model from certain initial conditions. This connection provides a *systematic and practical methodology for identifying delay unstable queues* in any given switched network. Finally, we turn our attention to the parameterized class of Max-Weight-α scheduling policies. We show that if the α- parameters are chosen suitably, then the sum of the α-moments of steady-state queue lengths is finite. We provide an explicit upper bound to the latter quantity, from which we derive results regarding the delay stability of queues, and the optimal scaling of higher order queue length moments with traffic intensity.

Mitra Osqui

Frequency Selective Analog to Digital Converter Design: Optimality, Fundamental Limitations, and Performance Bounds.

Advisor: Alexandre Megretski

Analysis and design of Analog to Digital Converters (ADCs) is studied within an optimal feedback control framework. A general ADC is modeled as a causal, discrete-time dynamical system with outputs taking values in a finite set. The performance measure is defined as the worst-case average intensity of the filtered input-matching error, i.e., the frequency weighted difference between the input and output of the ADC. Optimal ADC design is characterized in terms of the solution of a Bellman-type inequality, and a computational framework is presented for designing general ADCs; providing a certified upper bound on the performance of the designed ADC; and a certified lower bound on the performance, which reveals a limitation of design that cannot be overcome by any ADC. Finally, we prove optimality under certain conditions of a class of ADCs, which can be viewed as generalized Delta-Sigma Modulators (DSMs), with respect to the selected performance measure. An analytic expression for the performance is given. Furthermore, our result proves separation of quantization and control for this class of ADCs subject to some technical conditions.

Sabatino Santaniello **(2 posters)**

Modeling Reinforcement Mechanisms elicited by Deep Brain Stimulation in Neuronal Networks

Advisor: Sridevi V. Sarma

High frequency (HF, i.e., >100Hz) regular Deep Brain Stimulation (DBS) of the basal ganglia is a clinically recognized treatment for movement disorders (e.g., Parkinson's disease, essential tremor, and dystonia). Despite an extensive assessment of the clinical effects of HF DBS, the neuronal mechanisms of DBS still remain unknown. It has been proposed that the therapeutic merit of HF DBS stems from the regularization of the discharge patterns in the basal ganglia, which masks existing pathological oscillations along the motor loop. Although this hypothesis is consistent with experiments in humans and animal models of Parkinsonism, it is still unknown how these effects would stem from the application of DBS in the basal ganglia, perhaps because (i) the resultant changes in the discharge patterns along the motor loop are non-stationary and (ii) the mechanisms of DBS exploit both direct antidromic and indirect orthodromic projections, whose effects overlap (reinforcement) and cannot be easily isolated with current computational tools (e.g., PSTH, correlograms, etc.). We developed a computational framework based on point-process models that capture non-stationary temporal dependencies among several neurons simultaneously recorded; that isolate direct vs. indirect effects of the DBS input in a closed-loop neuronal network; and, that quantify the effects of the DBS frequency on the neuronal response in a target nucleus. The framework is assessed in simulation on a computational model of neuronal network and then used to characterize the discharge patterns of neurons collected in the motor striatum of two non-human primates (macaca mulatta) during DBS of the subthalamic nucleus (STN) at several frequencies (25 up to 130Hz). Results indicate that HF STN DBS suppresses non-stationary recurrent patterns and inter-neuronal dependencies in the striatal spike trains (period ranging between 3 and 50ms), while the latency between post-stimulus response and DBS pulse decreased with the DBS frequency. Both observations are proved to be an effect of the reinforcement mechanism.

Optimal Control-based Bayesian Detection of Clinical and Behavioral State Transitions

Accurately detecting hidden clinical or behavioral states from sequential measurements is an emerging topic in neuroscience and medicine, which may dramatically impact neural prosthetics, brain-computer interface and drug delivery. For example, early detection of an epileptic seizure from sequential EEG measurements would allow timely administration of anticonvulsant drugs or neurostimulation, thus reducing physical impairment and risks of overtreatment.

We develop a Bayesian paradigm for state transition detection that combines optimal control and Markov processes. We assume that neural activity is a stochastic process generated by a Hidden Markov Model and develop a detection policy that minimizes a cost function of both probability of false positives and accuracy (lag between estimated and actual transition time). Our strategy automatically adapts to each newly acquired measurement based on the state evolution model and the relative loss for false positives and accuracy, thus resulting in a time varying threshold policy. This is a quickest detection paradigm adapted to measuring neural processes and was used in two applications: (i) detection of movement onset (behavioral state) from subthalamic single unit recordings in 7 Parkinson’s disease patients performing a motor task; (ii) early detection of an approaching seizure (clinical state) from multichannel intracranial EEG recordings in four patients with drug-resistant epilepsy (168 hours of continuous recordings, 26–44 electrodes, 33 seizures). Our paradigm performs significantly better than chance and improves over widely used detection algorithms.

Yunjian Xu

Pricing of Fluctuations in Electricity Markets

Advisor: John N. Tsitsiklis

For dynamic markets with supply friction (e.g., for an electricity market), where demand fluctuations may lead to significant ancillary cost to suppliers, the real-time marginal cost pricing mechanism, where a time-varying price that equals the suppliers' instantaneous marginal cost is charged on the demand, may not achieve social optimality. We propose a dynamic pricing mechanism that explicitly discourages demand fluctuations by taking into account the externality conferred by consumer actions on future ancillary cost. Through a dynamic game-theoretic formulation, we show that the proposed pricing mechanism achieves social optimality asymptotically, as the number of consumers increases to infinity. Numerical results demonstrate that compared with marginal cost pricing, the proposed mechanism creates a stronger incentive for consumers to shift their peak load, and therefore has the potential to reduce the need for long-term investments in peaking plants.

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Acknowledgements:

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Munther A. Dahleh

Munther Dahleh's research career has produced significant contributions to the science of networked systems, with several fundamental and path-breaking advances in theory, methodology, and practice.

Dahleh's research has addressed three essential elements of networked systems: i) robust operations, ii) distributed decisions, and iii) constrained communication. The following discussion provides selective highlights of Dahleh's multiple contributions to these topics.

Robust operations: The topic of robust control concerns the analysis and design of decision and control systems that recognize and explicitly account for modeling errors. Dahleh's early work pioneered the framework of optimal robust control in the presence of persistent bounded disturbances. The paper "L1 optimal feedback controllers for MIMO discrete-time systems" (1987) derived the first solution to an optimal control design problem in this framework and was recognized by a George S. Axelby Outstanding Paper Award for the IEEE Transactions on Automatic Control. Dahleh went on to make multiple research contributions to the broader topic of robust control, including methods for robust system identification, adaptive robust control, achievable performance under nonlinear controllers, robust control methods for automata and discrete-state models, and computational tools for general robust control optimization.

Distributed decisions: Networked systems realize a collective behavior through the distributed decisions of the interconnected components. Not surprisingly, the emergent behavior under distributed computations can differ significantly from a centralized computation architecture. One line of Dahleh's research has addressed the implication of distributed computations in engineered control designs. The paper "Distributed control of spatially invariant systems" (2002) characterized the spatial interconnection structure of distributed optimal controllers and led to a second Axelby Outstanding Paper Award. More recently, Dahleh has investigated the impact of distributed computation in societal models. For example, the paper "Bayesian learning in social networks" (2008) investigates the problem of information cascades and the phenomenon of herding, where individual decisions are based on detailed private information and coarse observations of the decisions of others. Dahleh's ongoing work on societal network models includes the impact of distributed decisions on energy pricing volatility and the convergence of distributed routing decisions (such as commuter traffic) under real time disruptions.

Constrained communication: An essential limitation in networked systems is constrained communication between subsystems. In the absence of such limitations, the networked system effectively can replicate a centralized architecture and thereby lose its networked characteristics. Dahleh's research has investigated the implications on achievable performance in the presence of communication constraints. The paper "Feedback control in the presence of noisy channels: Bode-like fundamental limitations of performance" (2008) examines the impact of a limited capacity channel for feedback control and derives an analog of the celebrated Bode sensitivity integral that exactly characterizes the loss of achievable performance. Impressively, this paper led to a **third** *Axelby Outstanding Paper Award*. Dahleh's other contributions to constrained communications include the impact of communication channels on collective computations (averaged consensus being one example) and optimal allocation of limited sensing and communication resources.

True to the interdisciplinary nature of networked systems, Dahleh's research in these and other areas has included collaborations with economists, neurobiologists, and collaborators across multiple engineering departments.

Munzer Dahleh: driving his life through waves and storms…

Although I attended few of Munzer's talks when I was a Ph.D student in Florence ('89) and then as assistant professor in Torino ('92), our friendship began in 1994 at the CDC in Orlando. At the CDC, we really got to know each other. We talked, walked, laughed, and discussed life over several cups of coffee. Our friendship has since survived hurricanes, losses, births and deaths, new jobs and places, new friends and students, and was nurtured by a few cigars and many, many cups of coffees (double espresso with no sugar and an extra shot of water for him and double espresso with sugar for me).

When I was asked to write about Munzer, the question I posed is: "who is Munzer?" Is he the youngest spoiled child of the English Teacher Wisam and the Engineer Abdullah from the West Bank of Palestine, or the diligent scholar of the Islamic Scientific college, eager to solve mathematical problems or do his aunt's homework? Or is he the young boy who was spending his Sundays at the pool with his beloved older brother, Mohammed? Is he the student who loved to play basketball at Rice University or the brilliant young man who got his Ph.D at age 24? Is he the husband of Jinane, the father of Deema, Hilal and Yazeed, or the House Master at McGregor? Is he the devoted advisor to countless MIT graduates or the visionary associate department head of EECS?

Perhaps he is all of the above and more. I still learn new things about Munzer. Last December, late at night at a Beverly Hills hotel (after attending an exciting fund raiser as guests of Andrea Bocelli), Munzer confessed to me how much he hated the city of Los Angeles since the first time he visited Pasadena and Caltech. This is despite the fact that he spent his sabbatical there in 1992, and that this was city where his beloved brother spent most of his last couple of years and where he passed away in 2000. He came to MIT at the age of 25 as assistant professor and spent half of his life in Cambridge, the city he loves and truly belongs to. Passing by the Infinite Corridor, you may have seen a picture of a young curly haired (much more hair back then!) version of him, standing by a blackboard and talking with a chalk in his hand and the other hand dancing in the air, as usual, explaining the concept he was talking about. The picture is not there anymore, but it is so vivid in my memory that I can see him, the 25 year old young assistant professor, teaching in his lucid and very impressive way. Once, when I was visiting him at MIT, I attended one of his lectures and as I suspected, I realized that clarity was his trademark and the sign of a brilliant and deep mind, the sign of a Bravo Professor.

Speaking of Munzer, I can't help but to mention numbers; the same numbers that he loved as a young scholar: among the twenty eight Ph.D. Students he supervised, half are successful professors in academia, five are academic fellows at excellent institutions, and the rest have had great careers in a diverse walks of life. Eight out of his ten postdoctoral fellows are successful professors and leaders in the field. He is three times winner of the prestigious George Axelby award (matched only by the late George Zames and his good friend Tryphon Georgiou). He got the Donald P. Eckman award when he was 30 years old. He is now associate head of a department of more than 120 professors and has been a professor for 25 years.

You may wonder what his answer to the posed question is. Once, while sharing a cup of our usual coffee, he looked into my eyes, moved his hands in the air and told me: "Laura, no one knows what I really think deep inside and who I really am. But, Isn't this true for everyone else?"

I once wrote a poem about life and my friendship with Munzer: 'Together we have suffered, together we have joked, together we have traveled, smoked cigars, and drunk coffee. Picking here and there moments of pure essential simplicity, we have just walked on the sand, breezing the wind and looking at the waves on the shore."