Plenary Lectures

Models of Real-World Networks: Inhomogeneous Random Graphs and Convergent Graph Sequences

Béla Bollobás
Monday, 5 July, 09.00 – 10.00, Room 1

Béla Bollobás is a Hungarian-born British mathematician who has worked in various areas of mathematics, including functional analysis, combinatorics, graph theory and percolation. As a student, he took part in the first three International Mathematical Olympiads, winning two gold medals. He has been a Fellow of Trinity College, Cambridge since 1970. In 1996 he was appointed to the Jabie Hardin Chair of Excellence at the University of Memphis, and in 2005 he was awarded a Senior Research Fellowship at Trinity College.

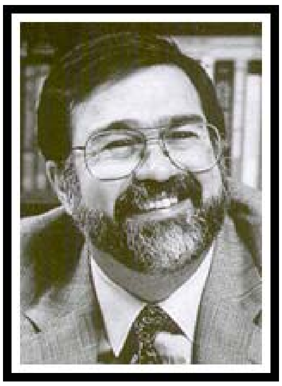
In addition to over 350 research papers on mathematics, he has written several books, including the research monographs "Extremal Graph Theory", "Random Graphs" and "Percolation" (with Oliver Riordan), the introductory books "Modern Graph Theory", "Combinatorics" and "Linear Analysis", and the collection of problems "The Art of Mathematics - Coffee Time in Memphis", with drawings by Gabriella Bollobás. He has also edited a number of books, including "Littlewood's Miscellany".

Béla Bollobás has had a great many research students, including Andrew Thomason, Keith Carne, Timothy Gowers (who was awarded a Fields Medal in 1998) and Imre Leader at the University of Cambridge, Alexander Scott and Oliver Riordan at Oxford, Jonathan Partington and Charles Read at Leeds and Keith Ball and Graham Brightwell in London. He is a Foreign Member of the Hungarian Academy of Sciences; in 2007 he was awarded the Senior Whitehead Prize by the London Mathematical Society.

In memory of Christopher I. Byrnes

Alberto Isidori, Joachim Rosenthal, Anders Lindquist, Giorgio Picci

Tuesday, 6 July, 09.00 – 10.00, Room 1



Chris Byrnes's Work on Feedback Design for Nonlinear Systems

Alberto Isidori

I first met Chris at a Conference organized by Rudy Kalman in 1977. At that time, our research interests were quite apart. I met him again in 1979, at a Conference he had co-organized at Harvard University, and then subsequently at a Conference that I had co-organized in Rome in 1981. This were opportunities for deeper exchanges of ideas on various open issues in system theory and, above all, on a topic that at that time was attracting the interest of many researchers: feedback design for nonlinear systems. We both realized to have a number of viewpoints in common. I eventually invited him for a sabbatical at the University of Rome, that took place in the spring 1983. This visit marked the beginning of a mutually rewarding scientific collaboration, which continued for almost thirty years.

In 1983, one of my major interests was the development of the nonlinear analogue of the notion of zero of a system. I had a fresh experience in developing differential geometric methods of analysis of such systems and I knew that zeros for linear systems can be properly identified by means of geometric methods. Chris, on the other hand, had a fresh experience in studying stabilization of multivariable linear systems via output feedback, and was looking of ways to find a nonlinear analogue of the property that a linear system having all zeros with negative real part can be stabilized by "high gain" output feedback. We found out that the differential geometric setting provided an elegant framework for the extension of the concept of zero to nonlinear systems. We introduced the concept which we called the "zero dynamics" of a system, which are the dynamics characterizing the motions internally arising in a system when input and initial conditions are chosen so as to force the output to remain identically zeros. These dynamics can be explicitly identified by bringing, via suitable changes of coordinates, the state space description of the system into a form where the dynamics in question appear a subsystem. This form eventually become known as "Byrnes-Isidori" normal form. This form was instrumental, in our work and in the work of many others, for proving various versions of the original intuition: systems having a globally asymptotically stable zero dynamics can be stabilized (in a semi-global sense, that is with a guaranteed domain of attraction) by means of output feedback.

One day in 1988, while attending a Conference in southern France, Chris and I started talking of the opportunity of using the newly developed notion of zero dynamics in problems of asymptotically tracking/rejecting exogenous inputs. Aware of the fundaments results developed for linear systems by Davison, Francis and Wonham, we both knew that, in this problem, the notion of zeros plays a fundamental role. In fact, in a linear system the role of the control is precisely that of fixing transmission zeros so as to block exogenous inputs. To make this intuition work, we needed to develop a reasonable setting to investigate how a nonlinear system responds, in steady state, to persistent exogenous inputs. In this respect, Chris observed that a convenient mathematical tool for the analysis of the steady state response of nonlinear systems was the Center Manifold Theorem. This was an intuition full of consequences. In fact, center manifold theory proved instrumental in deriving necessary conditions for the existence of a (local) controller solving a problem of asymptotic tracking. These conditions eventually became known as the "nonlinear regulator equations" and nicknamed "FBI equations", after Francis, Byrnes and Isidori. Again, this conceptual framework became the starting point for numerous contributions, in our work and in the work of others, that eventually brought the theory of output regulation for nonlinear systems to a high degree of sophistication.

In 1989 Chris moved to Washington University and two years later he become Dean of Engineering of that University. This inevitably had an impact of the amount of our scientific collaboration, which anyway continued, at an obviously lesser level. In the early 1990's, motivated by the early work of Willems on the notion of passivity of systems, we investigated the problem of when a nonlinear system can be made passive by means of (state) feedback. As in the case of linear systems, it turned out that this is possible if the system has relative degree one and its zero dynamics are stable in the sense of Lyapunov. The result found in this way provided a robust alternative to the popular, but non robust, methods based on feedback linearization. In the early 2000's, it was again Chris' intuition the prime mover behind a joint research in which we proposed to review the concept of "steady state" in a nonlinear system. Reviewing and comparing numerous problems of analysis and design, we came to the conclusion that the most appropriate notion in this respect was the notion of "limit set of a set", which had been developed earlier by Hale and co-authors for autonomous, possibly infinite dimensional, dynamical system. Using this concept in the setting of feedback design, it was possible to lay the foundations for a general, non local, non-equilibrium based, approach to the design of nonlinear regulators.

Chris' enthusiasm, passion and sense of humor were constantly the right catalyst in a series of scientific adventures. He has been part of my personal life for many years, scientifically and socially. In the words of his last student, he was "a great scholar, a gracious host, and a fine man". His untimely death has been a loss not just for his close friends but also for the entire systems and control community.

Codes, Trellis Representations and the Interplay of System Theory and Coding Theory

Heide Glüsing-Lürssen
Wednesday, 7 July, 09.00 – 10.00, Room 1

We will present state realizations (trellises) for convolutional codes and block codes and discuss their system theoretic properties. For convolutional codes we will give an application of such realizations by presenting a MacWilliams Identity which relates the weight distribution of a code to the weight distribution of the dual code. For block codes, state realizations are based on the interpretation of the code (of length n, say) as a set of admissible trajectories (codewords) on the time axis 0, . . . , n − 1. After discussing conventional trellis realizations, we will turn to tail-biting trellises in which the time axis is considered circular and time index arithmetic is performed modulo n. In this case the future and past of trajectories are intertwined. One particular consequence is that minimal tail-biting trellises are not unique. We will show how to obtain all minimal tail-biting trellises for a given code and discuss further properties.

Heide Glüsing-Lürssen received the Ph.D. degree from the University of Bremen (Germany) in 1991 and the habilitation degree from the University of Oldenburg (Germany) in 2000. Both degrees are in Mathematics. After a postdoctoral fellowship at the Mathematics Department of the University of Bremen from 1991 to 1993 she joined the University of Oldenburg where she served as faculty member in the Mathematics Department until 2004. From 2004 until 2006 she was a faculty member in the Department of Mathematics at the University of Groningen (The Netherlands). In 2007 she joined the Department of Mathematics at the University of Kentucky (Ky./USA) as a faculty member. She held visiting positions at the University of Notre Dame (Ind./USA) in 1997-1999, at the University of Magdeburg (Germany) in 2002, and at the University of Kentucky (Ky./USA) in the academic year 2003/2004. Her research interest is focused on the mathematical theory of block and convolutional codes as well as on algebraic systems theory.

Currently she serves as Corresponding Editor for SIAM Journal on Control and Optimization and as Associate Editor for Advances in Mathematics of Communications.

The Mathematical Challenge of Large Networks

László Lovász, Distinguished Lecturer
Wednesday, 7 July, 11.30 – 12.30, Room 1

László Lovász was born on March 9, 1948 in Budapest, Hungary. He obtained his doctoral degree in mathematics from the Eötvös Loránd University, in Budapest, Hungary in 1971. He is a member of the Hungarian Academy of Sciences and several other Academies.

Currently he is Director of the Institute of Mathematics at the Eötvös Loránd University in Budapest. He is recipient of the Wolf Prize, the John von Neumann Theory Prize, the Bolyai Prize, and the Széchenyi Grand Prize. He is President of the International Mathematical Union. His field of research is discrete mathematics, in particular its applications to the theory of algorithms and the theory of computing, and its interactions with classical mathematics.

Robust Control, Multidimensional Systems and Multivariable Function Theory: Commutative and Noncommutative Settings

Joseph A. Ball
Thursday, 8 July, 09.00 – 10.00, Room 1

In the classical 1-D case there is a seamless connection between state-space (time-domain) representations and transfer-function (frequency-domain) representations for linear systems. In particular, the first results on H∞-control were developed in the frequency-domain leading to an active exchange of ideas between mathematicians with backgrounds in function theory and engineers. Eventually elegant computational algorithms for solving the standard H∞-control problem were found in terms of state-space coordinates, first in terms of a pair of coupled Riccati equations, and then completely in terms of Linear Matrix Inequalities. Here we discuss two kinds of extensions of these ideas to the context of multidimensional systems and multivariable function theory, namely: (1) the commutative case, where the transfer-function is a function of several complex variables, and (2) the noncommutative case, where the transfer-function is a function of noncommuting operator (or matrix) variables. Perhaps surprisingly, we shall see that the noncommutative setting provides a much more complete parallel with the classical case than the commutative setting. Many of the ideas of the present report are taken from our survey article [17].

Joseph A. Ball was born in Washington, DC in 1947. He received the B.S. degree in mathematics from Georgetown University, Washington, DC, in 1969, and the M.S. and Ph.D. degrees in mathematics from the University of Virginia, Charlottesville, in 1970 and 1973, respectively.

He joined the faculty at Virginia Tech, Blacksburg, in 1973, where he is currently Professor of Mathematics. Short term visits elsewhere include at the University of California at San Diego, the Weizmann Institute of Science in Israel, the University of Maryland in College Park, the Vrije Universiteit in Amsterdam, the Mathematical Sciences Research Institute in Berkeley, and the Mittag-Leffler Institute in Djursholm, Sweden.

Dr. Ball is currently an Associate Editor for the journals Integral Equations and Operator Theory, Journal of Mathematical Analysis and Applications, and Complex Analysis and Operator Theory, and is a member of the MTNS Steering Committee. His current interests include multivariable function theory and operator theory and their connections with multidimensional systems and robust control theory.

From Qualitative to Quantitative Models of Bacterial Regulatory Networks

Hidde de Jong
Friday, 9 July, 09.00 – 10.00, Room 1

Hidde de Jong obtained MSc degree in Computer Science, Philosophy of Science, and Management Science from the University of Twente (the Netherlands) and completed a PhD thesis in Computer Science at the same university. He joined INRIA in 1998 and is currently a senior research scientist at INRIA Grenoble-Rhône-Alpes and head of the IBIS group. He has been a member of the editorial board of the IEEE/ACM Transactions on Computational Biology and Bioinformatics and the Journal of Mathematical Biology.

Semiplenary Lectures

Modelling High Dimensional Time Series by Generalized Factor Models

Manfred Deistler
Monday, 5 July, 14.00 – 15.00, Room 1

We discuss and analyze generalized linear dynamic factor models. These models have been developed recently and they are used to model high dimensional time series in order to overcome the "curse of dimensionality". The basic idea in factor models is to seperate "comovement" between the variables (caused by a relatively small number of factors) from individual (idiosyncratic) variation. Here factor analysis is considered in a time series context, where concentration of information is performed in the cross-sectional and in the time dimension. The models considered are linear dynamic in nature and stationarity of the processes is assumed. As opposed to the classical case, in the generalized case considered here, a certain form of weak dependence of the noise components is permitted. In the core part of the paper, we are concerned with structure theory, namely with realizing the singular rational spectral density of the latent variables by a linear system. Special emphasis ! is laid on the autoregressive case, which is generic in our setting. These autoregressions may have a singular innovation variance, which may cause multiple solutions for the Yule Walker equations. Finally, identification procedures, using a suitable denoising procedure and estimators suggested by our structure theory, are discussed.

Manfred Deistler is a Professor of Econometrics and System Theory at Vienna University of Technology. He received his Dr. techn. (approximately corresponding to a PhD) from Vienna University of Technology in 1970. Manfred Deistler has served on the editorial board of a number of journals, at present he is an Associate Editor of Journal of Econometrics and of Journal of Time Series Analysis and he is a member of the Advisory Board of Econometric Theory. He is a Fellow of the Econometric Society, a Fellow of IEEE (The Institute of Electrical and Electronic Engineers) and a Fellow of the Journal of Econometrics.

Manfred Deistler's research interests are in econometrics, system identification and time series analysis. As far as theory and methods are concerned the focus of his work is on structure theory and estimation for multivariate ARMAX- and state space systems and for linear dynamic factor- and errors- in- variables models. His current research interests are modelling of high dimensional time series and parameterization of multivariate state space systems. As far as applications are concerned, his current interests are: Forecasting of financial assets, analysis of electroencephalograms and, to a lesser degree, data-driven modelling of combustion engines.

Publications include:

- "The Statistical Theory of Linear Systems". Wiley, New York, 1988 (with E.J.Hannan)
- "Identifiability and Consistent Estimability in Econometric Models". Econometrica 46, 1978, 969-980 (with H.G. Seifert)
- "The Structural Identifiability of Linear Models with Auto-correlated Errors in the Case of Cross-Equation Restrictions". Journal of Econometrics 8, 1978, 23-31
- "Vector Linear Time Series Models: Corrections and Extensions". Adv. in Applied Probability 10, 1978, 360-372 (with W. Dunsmuir und E.J. Hannan)
- "The Properties of the Parametrization of ARMAX Systems and Their Relevance for Structural Estimation and Dynamic Specification". Econometrica 51, 1983,1187-1208
- "The Behaviour of the Likelihood Function for ARMA Models". Adv. in Applied Probability 16, 1984, 843-865 (with B.M. Pötscher)

- "General Structure and Parametrization of ARMA and State Space Systems and its Relation to Statistical Problems". In: E.J. Hannan, P.R. Krishnaiah, M.M. Rao (eds.): Handbook of Statistics 5, North Holland, Amsterdam, 1985, 257-277
- "The Common Structure of Parametrizations for Linear Systems". Linear Algebra and its Applications 122/123/124, 1989, 921-941(with L. Wang)
- "Consistency and Relative Efficiency of Subspace Methods". Automatica, 31, No. 12, 1995, 1865-1875 (with K. Peternell and W. Scherrer)
- "Nonnegative Realization of a Linear System with Nonnegative Impulse Response". IEEE Tr. CAS (Transactions on Circuits and Systems) 43, No 2, 1996, 1-8 (with B.D.O. Anderson, L. Farina and L. Benvenuti)
- "A Structure Theory for Linear Dynamic Errors in Variables Models". SIAM Journal on Control and Optimization, Vol. 36, No. 6, 1998, 2148-2175 (with W. Scherrer)
- "Consistency and Asymptotic Normality of some Subspace Algorithms for Systems without Observed Inputs". Automatica, 35, 1999, 1243-1254 (with D. Bauer und W. Scherrer)
- "An Analysis of the Parametrization by Data Driven Local Coordinates for Multivariable Linear Systems". Automatica,Vol. 40, No. 5, 2004, 789-803 (with T. Ribarits und T. McKelvey)
- "An Analysis of Separable Least Squares Data Driven Local Coordinates for Maximum Likelihood Estimation of Linear Systems". Automatica, Special Issue on Data-Based Modelling and System Identification, Vol 41, No 3, 2005, 531-544 (with T. Ribarits und B. Hanzon)
- "Identification of Factor Models for Forecasting Returns". Journal of Financial Econometrics, Vol.3, No 2, 2005, 256-281 (with E. Hamann)
- "Properties of Zero-free Transfer Function Matrices". SICE Journal of Control, Measurement, and System Integration (Invited Paper), Vol.1, No.4, 284-292, 2008 (with BDO Anderson)
- "Properties of Zero-free Spectral Matrices". IEEE Tr. AC (Transactions on Automatic Control), 2009, 2365-2375, (with BDO Anderson)
- “Generalized Linear Dynamic Factor Models - An Approach via Singular Autoregressions”. to appear in European Journal of Control (Invited Paper) 2010 (with BDO Anderson, W. Chen, A. Filler and Chr. Zinner)

Smith-Predictor Type Structure for a Class of Infinite-Dimensional Systems: Optimal Control and Performance Limitation Formula

Kenji Kashima
Monday, 5 July, 14.00 – 15.00, Room 14

In this talk we investigate control problems for infinite-dimensional systems whose transfer matrices are expressible in terms of a rational transfer matrix and a scalar (possibly irrational) inner function. This class of systems is capable of describing many practical control problems, when weighting functions are rational and plants have at most a finite number of unstable modes or zeros. In the first half of this talk the concept of Smith-predictors, that was originally used for I/O delay systems, is extended to the aforementioned class of systems. This allows us to reduce the optimal control problems to easily checkable criteria that do not require the solution of operator-valued equations. Furthermore, the obtained (stabilizing or suboptimal) controllers are shown to have the structure of Smith-predictors, or their dual. In the second half of the talk we derive a new expression for the H^2 performance limit, based on state-space representation. The resulting formula, given as a functional of the inner function, helps us to understand how achievable H^2 performance deteriorates due to the plant’s nonminimum phase properties or unstable modes. The example of a linear quantum control system suffering from feedback delay is given to illustrate the result.

Kenji Kashima was born in 1977 in Oita, Japan. He received his Bachelor's degree in engineering and his Master's and Doctoral degrees in informatics from Kyoto University, Japan, in 2000, 2002 and 2005, respectively. He is currently an Assistant Professor of the Graduate School of Information Science and Engineering, Tokyo Institute of Technology. His research interests include general theory for infinite-dimensional systems and stochastic systems, and their applications focusing on emerging areas.

Some Problems with Connecting Renewable Energy Sources to the Grid

George Weiss
Monday, 5 July, 14.00 – 15.00, Room 15

In this paper, we review some challenges resulting from the grid connection of powerful renewable energy generators that produce randomly fluctuating power and have no mechanical inertia. We propose and develop the idea of operating an inverter to mimic a synchronous generator. We call the inverters that are operated in this way synchronverters. Using synchronverters, the well-established theory/algorithms used to control synchronous generators can still be used in power systems where a significant proportion of the generating capacity is inverter-based. We describe the dynamics, implementation and operation of synchronverters. The real and reactive power delivered by synchronverters connected in parallel and operated as generators can be automatically shared using the well-known frequency and voltage drooping mechanisms. Synchronverters can be easily operated also in island mode and hence they provide an ideal solution for microgrids or smart grids.

George Weiss received the Control Engineer degree from the Polytechnic Institute of Bucharest, Romania, in 1981 and the Ph.D. degree in Applied Mathematics from the Weizmann Institute, Rehovot, Israel, in 1989.

He has been working at Brown University (Providence), Virginia Tech (Blacksburg), the Weizmann Institute (Rehovot), Ben-Gurion University (Beer Sheva), the University of Exeter, Imperial College London, and currently he is with Tel Aviv University. His research interests are distributed parameter systems, operator semigroups, control applied in power electronics, repetitive control and periodic linear systems. He is also doing work as a consultant in power electronics. He is a co-author (with Marius Tucsnak) of the book Observation and Control for Operator Semigroups (Birkhauser, 2009).

Variable Robustness Control: Principles and Algorithms

Marco C. Campi
Tuesday, 6 July, 14.00 - 15.00, Room 1

Robust control is grounded on the idea that a design should be guaranteed against all possible occurrences of the uncertain elements in the problem. When this philosophy is applied to securing a desired performance, it often leads to conservative, low performing, designs because emphasis is all placed on the worst-case situation. On the other hand, in many applications a 100%-guarantee is not necessary, and it may be convenient to opt for a small compromise in the guarantee level, say 99%, in favor of a (possibly significant) improvement in the performance. While the above reasoning sets a sensible principle, to date the real stumbling-block to its practical use is the lack of computationally-tractable algorithmic methods to trade guarantees for performance. This paper aims to open new directions to address this problem, and we show that this result can be achieved through randomization.

Marco Claudio Campi is Professor of Automatic Control at the University of Brescia, Italy.

In 1988, he received the doctor degree in electronic engineering from the Politecnico di Milano, Milano, Italy. From 1988 to 1989, he was a Research Assistant at the Department of Electrical Engineering of the Politecnico di Milano. From 1989 to 1992, he worked as a Researcher at the Centro di Teoria dei Sistemi of the National Research Council (CNR) in Milano and, in 1992, he joined the University of Brescia, Brescia, Italy. He has held visiting and teaching positions at many universities and institutions including the Australian National University, Canberra, Australia; the University of Illinois at Urbana-Champaign, USA; the Centre for Artificial Intelligence and Robotics, Bangalore, India; the University of Melbourne, Australia; the Kyoto University, Japan.

Prof. Campi is an Associate Editor of Systems and Control Letters, and a past Associate Editor of Automatica and the European Journal of Control. From 2002 to 2008, he served as Chair of the Technical Committee IFAC on Stochastic Systems (SS) and he is currently vice-chair for the Technical Committee IFAC on Modeling, Identification and Signal Processing (MISP). Moreover, he has been a distinguished lecturer of the Control Systems Society. Marco Campi's doctoral thesis was awarded the "Giorgio Quazza" prize as the best original thesis for year 1988. In 2008, he received the IEEE CSS George S. Axelby outstanding paper award for the article The Scenario Approach to Robust Control Design, co-authored with G. Calafiore.

The research interests of Marco Campi include: randomized methods, robust convex optimization, system identification, adaptive and data-based control, robust control and estimation, and learning theory.

Synthesis of Electrical and Mechanical Networks

Malcolm C. Smith
Tuesday, 6 July, 14.00 - 15.00, Room 14

The synthesis of electrical networks whose driving-point immittance is some prescribed positive-real function has given rise to a rich classical theory including the celebrated results of Brune, Darlington, Bott and Duffin etc. After the 1970s, there was a decline in interest due to the increasing prevalence of active circuits. Despite the relative maturity of the field, some basic questions remained unanswered, e.g. on the most efficient realisations for transformerless synthesis. The latter question becomes important again in the context of mechanical networks with the introduction of the inerter as an ideal two-terminal analogue of the capacitor (in contrast to the mass element which is analogous only to the grounded capacitor). This talk will discuss the motivation for passive mechanical network synthesis, survey some classical results of electric circuit synthesis, and discuss recent progress on the concept of regular positive-real functions and its application to transformerless synthesis.

Malcolm C. Smith received the B.A. (M.A.) degree in mathematics, the M.Phil. degree in control engineering and operational research, and the Ph.D. degree in control engineering, from Cambridge University, England in 1978, 1979, and 1982, respectively. He was subsequently a Research Fellow at the German Aerospace Centre, Oberpfaffenhofen, German, a Visiting Assistant Professor and Research Fellow with the Department of Electrical Engineering at McGill University, Montreal, Canada, and an Assistant Professor with the Department of Electrical Engineering, Ohio State University, Columbus. In 1990, he joined the Engineering Department, University of Cambridge, where he is currently a Professor. He is a Fellow of Gonville and Caius College and a Fellow of the IEEE. His research interests are in the areas of robust control, nonlinear systems, electrical and mechanical networks, and automotive applications. He received the 1992 and 1999 George Axelby Best Paper Awards in the IEEE Transactions on Automatic Control for papers coathored with Tryphon T. Georgiou. He is a winner of the Sir Harold Hartley medal of the Institute of Measurement and Control.

Quantify the Unstable

Li Qiu
Tuesday, 6 July, 14.00 - 15.00, Room 15

The Mahler measure, a notion often appearing in the number theory and dynamic system literature, provides a way to quantify the instability in a linear discrete-time system.

Li Qiu received his Ph.D. degree in electrical engineering from the University of Toronto, Toronto, Ont., Canada, in 1990. He joined the Hong Kong University of Science and Technology, Hong Kong SAR, China, in 1993, where he is now a professor of Electronic and Computer Engineering.

Prof. Qiu's research interests include system, control, information theory, and mathematics for information technology. He served as an associate editor of the IEEE Transactions on Automatic Control and an associate editor of Automatica. He is now a Distinguished Lecturer of IEEE Control Systems Society and has served as the general chair of the 7th Asian Control Conference, which was held in Hong Kong in 2009. He is a fellow of IEEE.

Learning Algorithms for Risk-Sensitive Control

Vivek S. Borkar
Wednesday, 7 July, 10.30 – 11.30, Room 1

This is a survey of some reinforcement learning algorithms for risk-sensitive control on infinite horizon. Basics of the risk-sensitive control problem are recalled, notably the corresponding dynamic programming equation and the value and policy iteration methods for its solution. Basics of stochastic approximation algorithms are also sketched, in particular the ‘o.d.e.’ approach for its stability and convergence, and implications of asynchrony. The learning schemes give stochastic approximation versions of the traditional iterative schemes for solving dynamic programs. Two learning schemes, Q-learning and the actor-critic method, are described along with their convergence analysis. As these ‘ideal’ schemes suffer from ‘curse of dimensionality’, one needs to use function approximation as a means to beat down the dimension to manageable levels. A function approximation based scheme is described for the simpler problem of policy evaluation. Some future research directions are pointed out.

Prof. Vivek S. Borkar got his B.Tech. in Electrical Engg. from Indian Institute of Technology, Mumbai, in 1976, M.S. in Systems and Control Engg. from Case Western Reserve Uni. in 1977, and Ph.D. in Electrical Engg. and Computer Science from Uni. of California, Berkeley, in 1980.

He was with the Centre for Applicable Mathematics of the Tata Institute of Fundamental Research in Bangalore during 1982-1989, Indian Institute of Science, Bangalore during 1989-1999, and at Tata Institute of Fundamental Research, Mumbai, since April 1999, where he is a Senior Professor with the School of Technology and Computer Science. He has also held visiting positions in several institutions such as Uni. of Twente, MIT, Uni. of Maryland, Uni. of California, Berkeley, Uni. of Illinois at Urbana-Champaign. He has won several national honors and is a Fellow of IEEE. His research interests are in stochastic optimization and control - theory, algorithms, and applications.

Challenges of Tracking Single Molecules in Live Cells

Raimund Ober
Wednesday, 7 July, 10.30 – 11.30, Room 14

For centuries microscopy has played an important role in biological investigations. Despite this long history, quite recently microscopy investigations of cells have undergone revolutionary developments. This is due to two independent but equally important developments. Modern molecular biology, and in particular the use of the green fluorescent protein, allow from the highly specific labeling of proteins in live cells. On the engineering side it is the development of highly sensitive imaging detectors, combined with computer control that allows images to be recorded with unprecedented sensitivity. This had as a result that, over the last decade, the imaging of single molecules in a live cell has become possible.

This new discipline of single molecule microscopy poses a significant number of exciting problems for engineers and mathematicians. For example, the classical notions of resolution limits for microscopes need to be re-evaluated. Current experiments in our lab and others show that distances at least one order below those predicted by Rayleigh's criterion can be determined. Estimation algorithms for locations of single molecules are the core of the analysis of most single molecule imaging approaches. The question therefore arises how well these locations can be determined. We will present an information theoretic approach to this and other problems in single molecule microscopy.

Raimund J. Ober received the Ph.D. degree in engineering from Cambridge University, Cambridge, U.K., in 1987.

From 1987 to 1990, he was a Research Fellow at Girton College and the Engineering Department, Cambridge University. In 1990, he joined the University of Texas at Dallas, Richardson, where he is currently a Professor with the Department of Electrical Engineering. He is also Adjunct Professor at the University of Texas Southwestern Medical Center, Dallas. He is an Associate Editor of Multidimensional Systems and Signal Processing and Mathematics of Control, Signals, and Systems, and a past Associate Editor of IEEE Transactions on Circuits and Systems and Systems and Control Letters. His research interests include the development of microscopy techniques for cellular investigations, in particular at the single molecule level, the study of cellular trafficking pathways using microscopy investigations, and signal/image processing of bioengineering data.

Coping with Time Delays in Networked Control Systems

Hitay Özbay
Wednesday, 7 July, 10.30 – 11.30, Room 15

In networked control systems, where controller and plant exchange information over a communication network, performance of the feedback system depends on certain properties of the communication channels. For example, packet loss, network delay and delay jitter have negative effect on networked system performance. Depending on the communication infrastructure, different mechanisms are implemented to reduce the packet loss rate and network induced delay in communication networks. In this paper, one of these mechanisms, namely, buffer/queue management is studied. It will be shown that techniques from robust control of uncertain time delay systems can be used effectively. Simpler low order controllers (PI and PID) are also considered. The effect of controller parameters on various performance metrics are illustrated.

Hitay Ozbay is a Professor of Electrical and Electronics Engineering at Bilkent University, Ankara, Turkey. Currently he is on sabbatical leave at INRIA Paris-Rocquencourt, France (September 2009 to July 2010). Hitay received the B.S. degree in Electrical Engineering from Middle East Technical University (Ankara, Turkey) in 1985, the M.Eng degree in Electrical Engineering from McGill University (Montreal, Canada) in 1987, and the Ph.D. degree in Control Sciences and Dynamical Systems from the University of Minnesota, (Minneapolis, USA) in 1989. He was with the University of Rhode Island (1989-1990) and then with The Ohio State University, Department of Electrical and Computer Engineering, (1991-2006). He served as an Associate Editor for the IEEE Transactions on Automatic Control (1997-1999), for Automatica (2001-2007), and was a member of the Board of Governors of the IEEE Control Systems Society (1999). He is a vice-chair of the Technical Committee Networked Control Systems of IFAC (since 2005). His area of interest is robust control of infinite dimensional systems, and engineering applications of this theory.

Dynamic "Magic" Graphs in Cooperative Networked Systems

John S. Baras
Thursday, 8 July, 14.00 – 15.00, Room 1

John S. Baras, Lockheed Martin Chair in Systems Engineering

B.S. in Electrical Eng. from the Nat. Techn. Univ. of Athens, Greece, 1970; M.S. and Ph.D. in Applied Math. from Harvard Univ. 1971, 1973. Since 1973 with the Electrical and Computer Engineering Department, and the Applied Mathematics Faculty, at the University of Maryland College Park. Since 2000 faculty member in the Fischell Department of Bioengineering. Founding Director of the Institute for Systems Research (ISR) from 1985 to 1991. Since 1991, has been the Director of the Maryland Center for Hybrid Networks (HYNET). Fellow of the IEEE and a Foreign Member of the Royal Swedish Academy of Engineering Sciences. Received the 1980 George Axelby Prize from the IEEE Control Systems Society and the 2006 Leonard Abraham Prize from the IEEE Communications Society. Professor Baras' research interests include control, communication and computing systems.

Orthogonal Rational Functions and Non-Stationary Stochastic Processes: A Szegö Theory

Laurent Baratchart
(based on joint work with L. Golinskii, S. Kupin, M. Olivi and V. Lunot)
Thursday, 8 July, 14.00 – 15.00, Room 14

We present a generalization of Szegö theory of orthogonal polynomials on the unit circle to orthogonal rational functions. Unlike previous results, the poles of the rational functions may tend to the unit circle under smoothness assumptions on the density of the measure. Just like the Kolmogorov-Krein- Szegö theorem may be interpreted as an asymptotic estimate of the prediction error for stationary stochastic processes, the present theory yields an asymptotic estimate of the prediction error for certain, possibly nonstationary, stochastic processes. The latter admit a spectral calculus where the time-shift corresponds to multiplication by elementary Blaschke products of degree 1 (that reduce to multiplication by the independent variable in the stationary case). When the poles of the best predictor tend to a point on the unit circle where the spectral density is nonzero, the prediction error goes to zero, i.e. the process is asymptotically deterministic.

Laurent C. Baratchart was born in Cotonou, Dahomey in 1955. He graduated from the Ecole Nationale Supérieure des Mines de Saint-Etienne, France in 1978, and received the docteur-ingénieur degree from the Ecole des Mines de Paris (Prof. P. Bernhard, advisor) and the thèse d'Etat degree from the university of Nice (Prof. A. Galligo, advisor), respectively in 1982 and 1987.

He joined the French National Institute for Research in Computer Science and Control (INRIA), in 1982, where he is currently head of the project "Analysis and Problems of Inverse type in Control and Signal processing (APICS)" at INRIA Sophia-Antipolis Mediterranée. Short term visits elsewhere include at the Vanderbilt University (Fall 2009) in Nashville, the Mittag-Leffler Institute in Djursholm (2003), Sweden and University of Florida in Gainesville (1988).

Dr. Baratchart is currently a member of the Editorial Boards of "Computational Methods and Function Theory" and "Complex Analysis and Operator Theory". He is a member of the PICOF 2010 and MTNS 2010 Program Committee. He is the scientific and administrative supervisor of the ANR AHPI grant (2008-2011). His current research interests include approximation theory, function theory, potential theory, harmonic analysis, inverse problems and controlled dynamical systems.

Mathematical Finance with Heavy-Tailed Distributions

Mathukumalli Vidyasagar
Thursday, 8 July, 14.00 – 15.00, Room 15

Nonlinear Filtering and Systems Theory

Ramon van Handel
Friday, 9 July, 14.00 – 15.00, Room 1

The fundamental connection between the stability of linear filtering and linear systems theory was already remarked in Kalman's seminal 1960 paper. Unfortunately, the linear theory relies heavily on the investigation of the explicit Kalman filtering equations, and sheds little light on the behavior of nonlinear filters. Nonetheless, it is possible to establish surprisingly general connections between the stability of nonlinear filters and nonlinear counterparts of basic concepts in linear systems theory: stability, observability, detectability. The proofs of these results are probabilistic in nature and provide significant insight into the mechanisms that give rise to filter stability. The aim of this paper is to review these recent results and to discuss some of their applications.

Ramon van Handel was an undergraduate student at the Vrije Universiteit in Amsterdam, The Netherlands, and received the Ph.D. degree from the California Institute of Technology in 2007. After spending a year at the Department of Operations Research and Financial Engineering at Princeton University as a postdoctoral researcher, he joined this department as a faculty member in 2009. His broad research interests are in the fields of probability theory, stochastic analysis, and their applications.

Controllability of Networked Systems

Magnus Egerstedt
Friday, 9 July, 14.00 – 15.00, Room 14

In this paper we investigate the controllability properties associated with networked control systems whose information exchange takes place over a static communication network. The control signal is assumed to be injected into the network at a given input node and its influence is propagated through the network through a nearest-neighbor interaction rule employed to ensure network cohesion. In particular, the problem of driving a collection of mobile robots to a given target destination is studied, and conditions are given for this to be possible, based on tools from algebraic graph theory. The main result is a necessary and sufficient condition for an interaction topology to be controllable, given in terms of the network's external, equitable partitions.

Magnus B. Egerstedt was born in Stockholm, Sweden, and is a Professor in the School of Electrical and Computer Engineering at the Georgia Institute of Technology, where he has been on the faculty since 2001. He received the M.S. degree in Engineering Physics and the Ph.D. degree in Applied Mathematics from the Royal Institute of Technology in 1996 and 2000 respectively and he spent 2000-2001 as a Postdoctoral Fellow at the Division of Engineering and Applied Science at Harvard University. Dr. Egerstedt's research interests include hybrid and networked control, with applications in motion planning, control, and coordination of mobile robots, and he serves as Editor for Electronic Publications for the IEEE Control Systems Society and Associate Editor for the IEEE Transactions on Automatic Control. Magnus Egerstedt is the director of the Georgia Robotics and Intelligent Systems Laboratory (GRITS Lab), is a Senior Member of the IEEE, received the ECE/GT Outstanding Junior Faculty Member Award in 2005, and the CAREER award from the U.S. National Science Foundation in 2003.

Quantum Linear Systems Theory

Ian R. Petersen
Friday, 9 July, 14.00 – 15.00, Room 15

This paper surveys some recent results on the theory of quantum linear systems and presents them within a unified framework. Quantum linear systems are a class of systems whose dynamics, which are described by the laws of quantum mechanics, take the specific form of a set of linear quantum stochastic differential equations (QSDEs). Such systems commonly arise in the area of quantum optics and related disciplines. Systems whose dynamics can be described or approximated by linear QSDEs include interconnections of optical cavities, beam-spitters, phase-shifters, optical parametric amplifiers, optical squeezers, and cavity quantum electrodynamic systems. With advances in quantum technology, the feedback control of such quantum systems is generating new challenges in the field of control theory. Potential applications of such quantum feedback control systems include quantum computing, quantum error correction, quantum communications, gravity wave detection, metrology, atom lasers, and superconducting quantum circuits.

A recently emerging approach to the feedback control of quantum linear systems involves the use of a controller which itself is a quantum linear system. This approach to quantum feedback control, referred to as coherent quantum feedback control, has the advantage that it does not destroy quantum information, is fast, and has the potential for efficient implementation. This paper discusses recent results concerning the synthesis of H-infinity optimal controllers for linear quantum systems in the coherent control case. An important issue which arises both in the modelling of linear quantum systems and in the synthesis of linear coherent quantum controllers is the issue of physical realizability. This issue relates to the property of whether a given set of QSDEs corresponds to a physical quantum system satisfying the laws of quantum mechanics. The paper will cover recent results relating the question of physical realizability to notions occuring in linear systems theory such as lossless bounded real systems and dual J-J unitary systems.

Ian R. Petersen was born in Victoria, Australia. He received a Ph.D in Electrical Engineering in 1984 from the University of Rochester. From 1983 to 1985 he was a Postdoctoral Fellow at the Australian National University. In 1985 he joined the University of New South Wales at the Australian Defence Force Academy where he is currently Scientia Professor and an Australian Research Council Federation Fellow in the School of Engineering and Information Technology. He has served as an Associate Editor for the IEEE Transactions on Automatic Control, Systems and Control Letters, Automatica, and SIAM Journal on Control and Optimization. Currently he is an Editor for Automatica. He is a fellow of the IEEE. His main research interests are in robust control theory, quantum control theory and stochastic control theory.