Formation Control: Uncertain Distances and Nonrobust Behavior

Brian D O Anderson

The Australian National University and National ICT Australia

Abstract

Suppose a formation shape, in an ambient space dimension of 1,2 or 3, is being controlled through active control of a nominated set of interagent distances. Suppose further that the two agents defining any such distance both try to correct any difference between the actual distance and its desired value. Finally suppose that either there are unequal biases in the measurements of one or more distances by the associated pair of agents, or the two agents have differing views as to what the correct distance should be. It is easy to see that with two agents only, such a situation results in both agents asymptotically moving at the same constant nonzero velocity with, in the second scenario, a spacing between the views held by the two agents as to the correct distance. Much the same happens for a group of agents confined to move on a straight line.

The talk will explain that result, and then go on to consider what happens in the case of formations in an ambient two-dimensional and three-dimensional space.

Biography

Brian Anderson was born in Sydney, Australia, and educated at Sydney University in mathematics and electrical engineering, with a subsequent PhD in electrical engineering from Stanford University. He is a Distinguished Professor at the Australian National University and Distinguished Researcher in National ICT Australia. His awards include the Bode Prize of the IEEE Control System Society in 1992, the IEEE Control Systems Award of 1997, the IFAC Quazza Medal in 1999, the 2001 IEEE James H Mulligan, Jr Education Medal, and, as well as several IEEE and other best paper prizes. He is a Fellow of the Australian Academy of Science, the Australian Academy of Technological Sciences and Engineering, the Royal Society, and a foreign associate of the US National Academy of Engineering. He holds honorary doctorates from a number of universities, including Université Catholique de Louvain, Belgium, and ETH, Zürich. He is a past president of the International Federation of Automatic Control and the Australian Academy of Science. His current research interests are in distributed control, sensor networks and econometric modelling.

Loop shaping from Bode to Glover

K. J. Åström

Lund University

Abstract

The talk gives an historical perspective on loop shaping. The foundation was made by Bode, who discovered the relations between amplitude and phase. Bode also developed a powerful technique for designing controllers that are robust to large variations of process gain. He found a shape of the loop transfer function which gave a constant phase margin for large gain variations which he called the ideal “cut-off characteristic”.

Combined with an experimental method for determining the transfer functions of a system experimentally loop shaping became a standard design method for designing control systems which was used very successfully in the frequency response era. Later Horowitz extended Bodes results to more general process variations leading to the QFT method. Both Bodes and Horowitz methods were graphical and difficult to apply to multi-variable systems. A dramatic improvement were made by Glover and McFarlane and Glover who developed a general technique that was computationally feasible for multi-variable systems.

Biography

Karl Johan Åström was educated at The Royal Institute of Technology (KTH) in Stockholm. After working for IBM Research for five years he was appointed Professor of the Chair of Automatic Control at Lund Institute of Technology/Lund University in 1965 where he established a new department. Åström has broad interests in control and he is listed in ISAHighlyCited. He is a life Fellow of IEEE and he has Erdös number 3. Åström has received many honors among them, the 1987 Quazza Medal from the International Federation of Automtic Control and the 1993 IEEE Medal of Honor. He is a member of the Royal Swedish Academy of Science, the Royal Swedish Academy of Engineering Science and the US National Academy of Engineering.

Closing the GAP Between Models and Data: A Flight Control Application

Gary J. Balas, Andrei Dorobantu, Tryphon Georgiou

University of Minnesota

Abstract

Ensuring the reliability of safety-critical flight control systems is a major challenge for the aerospace industry. The integration of Uninhabited Aerial Systems (UAS) into the airspace adds a new dimension to the challenge: validation and certification of low cost avionics and platforms. Low cost UAS will rely extensively on mathematical models to reduce design costs, speed up the design cycle, validate changes and certify system performance to governmental agencies. Hence efficient and reliable validation of such models based on ground test and flight data is key to the successful and safe integration of UAS into the airspace. The aim of this work is to relate model validation metrics to classical notions of robustness in control theory. The gap metric provides a natural framework to validate aircraft mathematical models in the presence of model error and disturbances. The proposed framework is applied to the University of Minnesota Unmanned Aerial Vehicle Flight test platform.

Biography

Graduate with BS (1982) and MS (1984) from the University of California, Irvine in Civil and Electrical Engineering and PhD (1989) from the California Institute of Technology in Aeronautics and Astronautics. He is started as an assistant professor in the Department of Aerospace Engineering and Mechanics at the University of Minnesota in 1990 and is currently a Distinguished University McKnight Professor and Department Head. His research interests include control of aerospace systems, fault detection and diagnosis, robust and linear, paramter-varying control, control of safety critical systems and transition of control theory to practice. He was elected a Honorary Member of the Hungarian Academy of Engineering in 2012, received the 2010 Prize for the Development of the Hungarian Aeronautical Science from the Hungarian Scientific Association for Transport, American Automatic Control Council O Hugo Schuck Best Paper Award in 2006, and the 2005 IEEE Control System Society Control Systems Technology Award. He is President of MUSYN Inc. and co-developer of the Matlab μ-Analysis and Synthesis and Robust Control Toolboxes. He is a Fellow of the IEEE.

Robust stability analysis for feedback interconnections of open-loop unstable systems

Michael Cantoni

University of Melbourne

Abstract
An approach to robust stability analysis for structured feedback interconnections of open-loop unstable systems will be discussed. The approach involves a blend of integral-quadratic-constraint (IQC) and gap metric based analysis. Results that accommodate linear time-varying behaviour will be presented in terms of a recent generalisation of the nu-gap metric.

Biography
Michael Cantoni received the Bachelor of Engineering (Electrical Hons. I) and Bachelor of Science (Applied Mathematics) degrees from the University of Western Australia, Australia, in 1995, and the Doctor of Philosophy (PhD) degree from the University of Cambridge, UK, in 1998. From 1998-2000, he held post-doctoral research positions with the Department of Engineering at the University of Cambridge, UK, and St John's College, Cambridge, UK. Since September 2000, he has been with the Department of Electrical and Electronic Engineering at the University of Melbourne, Australia, where he is an Associate Professor.
He has been an Associate Editor for Systems & Control Letters since 2007 and he previously served on the editorial board of IET Control Theory and Applications. His research interests include robust and optimal control, model approximation, multidimensional signals and systems, and applications such as the automation of large-scale water distribution networks.

IC Engine Control – the Challenge of Downsizing

Dariusz Cieslar

Consultant, dSPACE Ltd

Abstract
Electronic engine management systems have played an essential role in achieving the current standards of passenger vehicles reliability and their low toxic emissions. The associated set of legislated requirements has recently been complemented with an emphasis on reducing CO2 emissions. Addressing this issue has significant technological implications as capturing carbon dioxide from exhaust gases is not a feasible solution. Emissions of CO2 are closely coupled with fuel consumption and belong to the vehicle's, rather than the engine's exclusive, features. Therefore, the range of plausible technologies is broad and the discussion extends also to the energy supply associated with particular concepts. Among the many approaches that have been considered, the most popular include alternative powertrains (e.g. electric, hybrid electric, alternative fuels), engine downsizing, down-speeding and advanced combustion systems.

The concepts of engine downsizing and down-speeding offer reductions in CO2 emissions by reducing engine pumping and friction losses. Conventionally, rated torque and power for downsized units are recovered by means of turbocharging. Delivering a satisfactory transient response of such engines is challenging, because it is affected by the static and dynamic characteristics of the turbo-machinery. The control problem in such a case is dominated by the necessity to observe the physical constraints, which vary in terms of their nature and severity.

Model based control techniques combined with optimisation are a suitable set of tools for investigating such systems. As an illustration, several turbocharger assistance systems with a short-term energy storage are considered here.
A systematic method for evaluating these concepts is discussed. The method is formulated using a controller, which is based on the Model Predictive Control framework and uses a linearised mean value model to optimise the predicted behaviour of the engine. As a result, injecting compressed gas into the exhaust manifold was identified as an effective method, which to date has attracted only a limited attention from the engine research community.

The effectiveness of the exhaust manifold assistance was experimentally verified on a light-duty Diesel engine. This led to the development of the BREES system: a low component count, compressed gas based system for reducing turbo-lag. It was shown that during braking manoeuvres a tank can be charged with compressed gas to the level sufficient for a subsequent boost assistance event.

Biography
Dariusz finished his PhD under Keith's supervision this year, which makes him the latest beneficiary of Keith's long-standing cooperation with Prof Nick Collings in the field of engine control, and, in fact, the last of Keith's PhD students. Dariusz's professional interests include control applications in transportation systems. He has earned his BSc and MSc from Coventry University. Prior to joining the University of Cambridge for his PhD in Control Engineering, he had spent two years at Jaguar Land Rover as a dynamics engineer. Dariusz now works for dSPACE Ltd as an applications consultant

Resilience of Dynamical Transportation Networks

Munther A Dahleh

Massachusetts Institute of Technology

Abstract

In this talk, we present recent results on the stability and robustness properties of transportation networks for various agents' route-choice behaviour. We perform the analysis within a dynamical system framework over a directed acyclic graph between a single origin-destination pair. The dynamical system is composed of ordinary differential equations (ODEs), one for every link of the graph. Every ODE is a mass balance equation for the corresponding link, where the inflow term is a function of the agents' route-choice behaviour and the arrival rate at the base node of that link, and the outflow term is a function of the congestion properties of the link.

We propose a novel decision framework, where the drivers combine their historical knowledge about the global congestion levels with real-time local information to make route choice decisions at every node. We show that, if the rate of update of global information is sufficiently slow and if the drivers make route choice decisions cooperatively, then the Wardrop equilibrium is globally asymptotically stable. We then study the resilience of the flow transferring capability of the whole network under disturbances that reduce the flow carrying capacity of the links. In particular, we characterize various margins of resilience of the network with respect to the topology, 'pre-disturbance' equilibrium, and agents' local route-choice behaviour. We show that the cooperative route choice behaviour is maximally resilient in this setting. We also setup a simple convex optimization problem to find the most resilient 'pre-disturbance' equilibrium for the network and determine link-wise tolls that yield such an equilibrium. Finally, we extend our analysis to link-wise outflow functions that accommodate the possibility of cascaded failures and study the effect of such phenomena on the margins of resilience of the network.

**This work is done in collaboration with Giacomo Como, Ketan Savla, Daron Acemoglu, and Emilio Frazzoli.

Biography

Munther A. Dahleh received his Ph.D. degree from Rice University, Houston, TX, in 1987, in Electrical and Computer Engineering. Since then, he has been with the Department of Electrical Engineering and Computer Science, MIT, Cambridge, MA, where he is now the Associate Department Head. Previously, he was the acting directorof the Laboratory for Information and Decision Systems. He has been a visiting Professor at the Department of Electrical Engineering, California Institute of Technology, Pasadena, CA, for the Spring of 1993. He has consulted for various national research laboratories and companies. Dr. Dahleh is interested in Networked Systems with applications to Social and Economic Networks, Transportation Networks, and the Power Grid. He is the co-author (with Ignacio Diaz-Bobillo) of the book *Control of Uncertain Systems: A Linear Programming Approach*, published by Prentice-Hall, and the co-author (with Nicola Elia) of the book *Computational Methods for Controller Design* published by Springer. Dr. Dahleh is the three times recipient of the George Axelby outstanding paper award for best paper in IEEE Transactions on automatic control. He is also the recipient of the Donald P. Eckman award from the American Control Council in 1993 for the best control engineer under 35. He has given many keynote lectures at major conferences.

Universal laws and architectures in networks: What would Keith do?

John Doyle

California Institute of Technology

Abstract
This talk will focus on progress towards a more unified/integrated theory for control of complex networks motivated by challenges such as sensorimotor control and learning in neuroscience, control and evolution in the bacterial biosphere, and technological architectures such as future smartgrid and Internet. We will argue that forward and reverse engineering of these systems will require a focus on themes pioneered by Keith Glover and the Cambridge Control Group throughout his career, including explicitly designing for robustness, simplicity, and scalability of algorithms and implementations. What is new in these applications is that not only are control laws distributed and automated, but synthesis of control laws must also be as well. This means that design shifts from individual controllers (where traditionally, design cost is amortized over many expensive but identical systems such as commercial jet aircraft) to network architectures of protocols that automatically synthesize and implement layered and distributed control systems. Fortunately, it appears that these systems do and should have universal laws and architectures despite their enormous differences in components and environments. Understanding and exploiting these similarities and differences requires newly subtle interplay between robustness, adaptation, and evolution, estimation and control, model and controller reduction, control and communications and computation, and plant/controller co-design.
A useful starting point is to ask a simple question. What would Keith do?

Biography
John Doyle is the John G Braun Professor of Control and Dynamical Systems, Electrical Engineering, and BioEngineering at Caltech. BS, MS EE, MIT (1977), PhD, Math, UC Berkeley (1984). Current research interests are in theoretical foundations for complex networks in engineering and biology, unifying controls, computing, communications, and physics. Emphasis on architecture, dynamics, feedback, layering, tradeoffs, evolvability. Case studies drawn from throughout technology plus cell biology, physiology, ecology, multiscale physics, neuroscience, and fashion. Early work was in the mathematics of robust control, including extensions to nonlinear and networked systems, with applications in aerospace and process control. Much of this involved visits to Cambridge and typing portions of Keith Glover's papers. His group contributed to the Matlab Robust Control Toolbox, SOSTOOLS (Nonlinear systems analysis), SBML (Systems Biology Markup Language), and FAST (Fast AQM, Scalable TCP) internet protocols. Paper prizes include IEEE Baker (for DGKF), IEEE Automatic Control Transactions (twice), and best conference papers in ACM Sigcomm and AACC American Control Conference. Individual awards include AACC Eckman and IEEE Control Systems Field and Centennial Outstanding Young Engineer Awards. Held national and world records and championships in various sports. Best known for having excellent and forgiving co-authors, students, friends, and colleagues.

Automata-switched Systems: Centralized Control and Team Games

Geir E. Dullerud

University of Illinois

Abstract

Switching is a common feature in control and networked systems, and can occur for instance due to changes in environment, mission objectives, communication infrastructure, or attributes of physical processes. In this talk we will focus on a specific class of switched systems --- automata-switched linear systems. These are linear systems whose model parameters switch non-stochastically according to the dynamics of finite automata. Considered will be feedback control of such systems in (1) a centralized setting where controllers have direct access to the automata states; and (2) a two-player team game where players jointly know the switching modes, but have only partial observations individually. Starting with centralized control, we will define performance and stability for such systems using both worst- and average-case criteria, and show that analysis and feedback synthesis for automata-switched systems can be exactly characterized in terms of a nested chain of semidefinite programs; feasibility of any SDP in the chain provides a performance/synthesis guarantee, and infeasibility provides a lower bound on achievable performance. In part of the work presented we will show how the long-studied receding horizon problem can be posed as a special case of this framework, and provide an exact solution. Secondly decentralized control will be addressed, and we consider a two-player switched team game where player policies can only use local information about current values of switching parameters and feedback measurements, but acquire access to the other player's local information after a one-step delay. In the quadratic cost formulation, we will provide a solution to the optimal team policy in terms of standard linear algebra; this will be achieved via two different approaches, a best-response technique, and a more traditional method from team theory.

Biography

Geir E. Dullerud received his PhD from Cambridge University in 1994. Currently he is Professor of Mechanical Science and Engineering at the University of Illinois at Urbana-Champaign; there he is also a member of the Coordinated Science Laboratory, where he is Director of the Decision and Control Laboratory. He has held visiting positions at KTH 2013, and Stanford University 2005-2006. Earlier he was on faculty in Applied Mathematics at the University of Waterloo 1996-1998, after being a Research Fellow at the California Institute of Technology from 1994-1995. He has published two books: *A Course in Robust Control Theory*, Texts in Applied Mathematics, Springer, 2000, and *Control of Uncertain Sampled-data Systems*, Birkhauser 1996. His areas of current research interest include convex optimization in control, complex networks, cooperative robotics, stochastic simulation, and hybrid dynamical systems. In 1999 he received the CAREER Award from the National Science Foundation, and in 2005 the Xerox Faculty Research Award at UIUC. He is a SIAM member, and a Fellow of both IEEE and ASME.

When Physics and Control Theory Collide

Bruce Francis

University of Toronto

Abstract
This talk relates in anecdotal form one control theorist's attempt to understand some current physics.

Brief Biography
Bruce Francis was born in Toronto and did all three degrees at the University of Toronto. He spent 1975 - 1984 at a number of universities, including the University of Cambridge. Since 1984 he has been at the University of Toronto. He retired in 2011 and is now an Emeritus Professor.

Robust Control meets Nonsmooth Optimization

Pascal Gahinet

The MathWorks Ltd

Abstract
Robust control theory has taken classical frequency-domain design to the next level and delivered an impressive array of tools and techniques. Yet its adoption in industry has been lagging, often because available tools do not fit existing control structures and workflows. This talk makes a case for freeing robust control from the shackles of Riccati equations and LMIs. By using specialized optimization techniques, we can directly apply the robust control methodology to conventional structures and workflows, which helps bridge the gap between theory and practice. Applications to multi-loop and gain-scheduled control systems illustrate the effectiveness of this approach.

Note: This is joint work with Pierre Apkarian from ONERA, France.

Biography
Pascal Gahinet graduated in 1984 from Ecole Polytechnique in Paris and got a Ph.D. in Electrical Engineering from the University of California, Santa Barbara in 1989. From 1990 to 1996 he was a research fellow at INRIA, France. He has been with MathWorks since 1996 where he has helped shape the Control & Identification product family. His interests include numerical computation, numerical optimization, classical and robust control, and computer-aided control system design.

Closed-loop optimal experiment design: solution via moment extension

Roland Hildebrand and Michel Gevers

University of Louvain

Abstract

We consider optimal experiment design for parametric prediction error system identification of linear time-invariant multiple-input multiple-output (MIMO) systems in closed-loop when the true system is in the model set. The optimization is performed jointly over the controller and the spectrum of the external excitation, which can be reparametrized as a joint spectral density matrix. The optimal solution consists of first computing a finite set of generalized moments of this spectrum as the solution of a semi-definite program. A second step then consists of constructing a spectrum that matches this finite set of optimal moments and satisfies some constraints due to the particular closed-loop nature of the optimization problem. This problem can be seen as a moment extension problem under constraints. We first show that the so-called central extension always satisfies these constraints, leading to a constructive procedure for the optimal controller and excitation spectrum. We then show that, using this central extension, one can construct a broader set of parametrized optimal solutions that also satisfy the constraints; the additional degrees of freedom can then be used to achieve additional objectives.

Biography

Michel Gevers was born in Antwerp in 1945. He obtained an Electrical Engineering degree from the University of Louvain, Belgium, in 1968, and a Ph.D. degree from Stanford University, in 1972, under the supervision of Tom Kailath. He is an IFAC Fellow, a Fellow of the IEEE, a Distinguished Member of the IEEE Control Systems Society. He holds a Honorary Degree (Doctor Honoris Causa) from the University of Brussels and Linköping University, Sweden. He has been President of the European Union Control Association (EUCA) from 1997 to 1999, and Vice President of the IEEE Control Systems Society in 2000 and 2001.

Michel Gevers is Professor Emeritus at the Department of Mathematical Engineering of the University of Louvain, in Louvain la Neuve, Belgium. His present research interests are in optimal experiment design for identification, identifiability and informativity of experiments for classes of polynomial systems, nonparametric identification, and data-based control design. He also spends much time on research evaluation and research management issues.

Michel Gevers has published more than 260 papers and conference papers, and two books: *Adaptive Optimal Control - The Thinking Man's GPC*, by R.R. Bitmead, M. Gevers and V. Wertz (Prentice Hall, 1990), and *Parametrizations in Control, Estimation and Filtering Problems: Accuracy Aspects*, by M. Gevers and G. Li (Springer-Verlag, 1993).

The VAAC Harrier and H-infinity Loop Shaping - What Did We Learn?

Rick Hyde

The MathWorks Ltd

Abstract

The presentation will start with a review the work that led to the first flight test of a gain-scheduled H-infinity control law. The flight was a success, but more importantly many insights were gained along the way related to control law design such as the importance of feedback architecture and careful management of actuator constraints. Using these insights, plus subsequent experience gained from working on missile autopilots, I will present my top ten lessons learnt pertaining to successful multivariable control deployment.

Biography

Rick gained a BA in Engineering followed by PhD in robust control at Cambridge University. His work on robust control focused on applying H-infinity loop shaping control methods to the DERA VAAC Harrier, and this culminated in a successful flight test in 1992 when he was a postdoctoral RA. He then went on to work with BAE Dynamics on missile guidance & control systems, continuing work in this area and contributing to the Aerospace Blockset when he later joined MathWorks Ltd (formerly Cambridge Control Ltd). Following a brief period at Bristol University where Rick taught mechatronics, he is now a software developer at MathWorks working on Simscape™-based modelling libraries with primary focus on SimElectronics®.

Control motifs in the hypoxic response of cells

Pablo A. Iglesias

The Johns Hopkins University

Abstract
Homeostasis, the ability of a cell or organism to maintain a steady state by adapting to changing conditions, is a recurring theme in biology. Cells achieve homeostasis using complex regulatory systems that employ a variety of control mechanisms, including feedback loops and feed forward elements. In this talk I will discuss the regulatory pathway in the fission yeast Schizosaccharomyces pombe, which allows the yeast to adapt to hypoxia (low oxygen) by increasing transcription of genes needed for the yeast to survive under hypoxic conditions. I will demonstrate how a computational model allows us to show that two distinct regulatory functions of Ofd1, a protein involved in the hypoxic response, are necessary for the system to achieve the level of performance observed experimentally, a finding that would be very difficult to obtain by in vivo experimentation. In addition to elucidating general principles of biological regulation, this model quantifies our understanding of an oxygen-sensing pathway whose parts are conserved among several species of fungi as well as in human cells. This is joint work with Peter Espenshade and Joshua Porter.

Biography
Pablo A. Iglesias was born in Caracas, Venezuela. He received the B.A.Sc. degree in Engineering Science from the University of Toronto in 1987, and the Ph.D. Degree in Control Engineering from Cambridge University in 1991. Since then he has been on the faculty of The Johns Hopkins University, where he is currently the Edward J.Schaefer Professor of Electrical Engineering. He also holds appointments in the Departments of Biomedical Engineering, and Applied Mathematics & Statistics. He has had visiting appointments at Lund University, The Weizmann Institute of Science, the California Institute of Technology and the Max Planck Institute for the Physics of Complex Systems. His current research interests focus on the use of control and dynamical system theory to study biological signal transduction pathways, particularly those involved in regulating directed cell motion and cell division.

Stochastic control of multi-player systems

Sanjay Lall

Stanford University

Abstract
For centralized control systems, one of the major simplifying ideas is the separation principle, which states that one can make optimal choices of control actions based only on estimates of the system state. We discuss how this changes for multiplayer control systems, and give new simple separation principles which work in this setting.

Biography
Sanjay Lall is Associate Professor of Electrical Engineering and Associate Professor of Aeronautics and Astronautics at Stanford University. Previously he was a Research Fellow at the California Institute of Technology in the Department of Control and Dynamical Systems, and prior to that he was NATO Research Fellow at Massachusetts Institute of Technology, in the Laboratory for Information and Decision Systems. He received the Ph.D. in Engineering and B.A. in Mathematics from the University of Cambridge. Professor Lall's research focuses on the development of advanced engineering methodologies for the design of control systems which occur in a wide variety of aerospace, mechanical, electrical and chemical systems. Professor Lall received the George S. Axelby Outstanding Paper Award by the IEEE Control Systems Society in 2007, the NSF Career award in 2007, Presidential Early Career Award for Scientists and Engineers (PECASE) in 2007, and the Graduate Service Recognition Award from Stanford University in 2005.

Will Machine Learning Change the System Identification Paradigm?

Lennart Ljung

Linköping University

Abstract
State-of-the-Art System Identification works with well defined model structures and Maximum-likelihood type parameter estimation algorithms. This paradigm is well founded and supported by theory, algorithms, software and industrial applications. Machine Learning tackles essentially the same family of problems, and has been very successful in attracting wide interest, with a (seemingly) different box of tools. The question is what impact this will have on the system identification community. This presentation looks at a few aspects of this question, primarily at the roles of regularization, kernel methods, and Gaussian process regression.

Biography
Lennart Ljung was born in 1946 in Malmö, Sweden. and received his Ph.D. in 1974 in Automatic Control from Lund Institute of Technology. He has been Professor of the chair of Automatic Control in Linköping since 1976. Professor Ljung has held visiting positions at Stanford and MIT and has written several books on System Identification and Estimation. He is an IEEE Fellow, an IFAC Fellow and an IFAC Advisor as well as a member of the Royal Swedish Academy of Sciences (KVA), a member of the Royal Swedish Academy of Engineering Sciences (IVA), an Honorary Member of the Hungarian Academy of Engineering and a Foreign Associate of the US National Academy of Engineering (NAE). Professor Ljung has received honorary doctorates from the Baltic State Technical University in St Petersburg, from Uppsala University, Sweden, from the Technical University of Troyes, France, from the Catholic University of Leuven, Belgium and from Helsinki University of Technology, Finland. In 2002 he received the Quazza Medal from IFAC, and in 2003 he received the Hendrik W. Bode Lecture Prize from the IEEE Control Systems Society, and he was the recipient of the IEEE Control Systems Award for 2007.

Stochastic Dissipative Systems

Sanjoy K. Mitter

Massachusetts Institute of Technology

Abstract
In this talk, I discuss a generalization of Willems' ideas on dissipative systems to stochastic systems. A definition of a storage function in the stochastic setting is proposed and its connections to the value function of a Bellman equation is discussed. (Joint work with Vivek Borkar and Ari Arapostathis.)

Biography
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.

Fast Model Predictive Control

Manfred Morari

ETH Zurich

Abstract
In the 1980s Model Predictive Control (MPC) became the algorithm of choice in the process industries for demanding multi-variable applications involving constraints. Today's vastly more powerful computational resources and a series of new algorithms have made these tools suitable for problems of essentially any size and time scale. I will describe the road taken and illustrate the effectiveness with industrial examples from the automotive and power electronics domains and the industrial energy sector.

Biography
Manfred Morari was head of the Department of Information Technology and Electrical Engineering at ETH Zurich from 2009 to 2012. He was head of the Automatic Control Laboratory from 1994 to 2008. Before that he was the McCollum-Corcoran Professor of Chemical Engineering and Executive Officer for Control and Dynamical Systems at the California Institute of Technology. He obtained the diploma from ETH Zurich and the Ph.D. from the University of Minnesota, both in chemical engineering. His interests are in hybrid systems and the control of biomedical systems. In recognition of his research contributions he received numerous awards, among them the Donald P. Eckman Award, the John R. Ragazzini Award and the Richard E. Bellman Control Heritage Award of the American Automatic Control Council, the Allan P. Colburn Award and the Professional Progress Award of the AIChE, the Curtis W. McGraw Research Award of the ASEE, Doctor Honoris Causa from Babes-Bolyai University, Fellow of IEEE, IFAC and AIChE, the IEEE Control Systems Technical Field Award, and was elected to the National Academy of Engineering (U.S.). Manfred Morari has held appointments with Exxon and ICI plc and serves on the technical advisory boards of several major corporations.

Feedback and Control in Biological Circuit Design

Richard M. Murray

California Institute of Technology

Abstract
Biological systems make use of feedback in an extraordinary number of ways, on scales ranging from molecules to cells to organisms to ecosystems. In this talk I will discuss the use of concepts from control and dynamical systems in the analysis and design of biological feedback circuits at the molecular level. After a brief survey of relevant concepts from synthetic biology, I will present some recent results that combine modeling, identification, design and experimental implementation of biological feedback circuits. These results include the use of intrinsic noise for system identification in transcriptional regulatory networks, analysis of the role of multiple feedback loops in providing robust behavior (ultrasensitivity and biomodality), development of in vitro circuits for rate regulation and even detection, and the use of time delay as a means of designing biomolecular feedback dynamics. Using these results as examples, I will discuss some of the open problems and research challenges in the area feedback control using biological circuits.

Biography
Richard M. Murray received the B.S. degree in Electrical Engineering from California Institute of Technology in 1985 and the M.S. and Ph.D. degrees in Electrical Engineering and Computer Sciences from the University of California, Berkeley, in 1988 and 1991, respectively. He is currently the Thomas E. and Doris Everhart Professor of Control & Dynamical Systems and Bioengineering at Caltech. Murray's research is in the application of feedback and control to networked systems, with applications in biology and autonomy. Current projects include specification, design and synthesis of control protocols for networked control systems and analysis and design of biomolecular feedback systems for synthetic biology.

Scalable Robustness Analysis Using Integral Quadratic Constraints

Anders Rantzer

Lund University

Abstract

The concept of Integral Quadratic Constraint (IQC) has long been known as a versatile tool for robustness analysis of dynamical systems. Numerous common model imperfections can be efficiently described this way, for example parametric uncertainty, disturbances with bounded frequency content and nonlinear effects such as friction and hysteresis. Based on this idea, rigorous bounds on performance deviations can be computed using semi-definite programming. Computer tools for robustness analysis using IQCs were developed already in the 1990s. However, computational complexity has remained an obstacle for more wide-spread use in applications.

In this presentation, we will discuss a method to drastically improve the computational scalability of IQC analysis, using sparse decomposition of positive definite matrices. This makes it possible to verify stability and performance of large-scale systems with certificates that can be verified individually for each component. Connections to model reduction and robust control will also be addressed.

Biography

Anders Rantzer received a PhD in 1991 from KTH, Stockholm, Sweden. After postdoctoral positions at KTH and at IMA, University of Minnesota, he joined Lund University in 1993 and was appointed professor of Automatic Control in 1999. The academic year of 2004/05 he was visiting associate faculty member at Caltech. Since 2008 he coordinates the Linnaeus center LCCC at Lund University. For the period 2013-15 he also serves as chairman of the Swedish Scientific Council for Natural and Engineering Sciences. Rantzer has been associate editor of IEEE Transactions on Automatic Control and several other journals. He is a winner of the SIAM Student Paper Competition, the IFAC Congress Young Author Price and the IET Premium Award for the best article in IEE Proceedings - Control Theory & Applications during 2006. He is a Fellow of IEEE and a member of the Royal Swedish Academy of Engineering Sciences. His research interests are in modeling, analysis and synthesis of control systems, with particular attention to uncertainty, optimization and distributed control.

Managing Transaction Costs in a Dynamic Trading Strategy

James Sefton & Sylvain Champonnois

Imperial College London

Abstract

Transaction cost risk is the risk that an investor cannot exploit a good investment opportunity because it involves too high a transaction cost. Hedging transaction cost risk generate an intertemporal hedging motive that complements the well-known intertemporal hedging demands of Merton (1973).

The paper sets up the dynamic portfolio problem in the presence of time-varying risk premiums and transactions costs. We are able to derive an explicit solution in terms of a risk-sensitive Riccati equation and show the connections to the stochastic discount factor that prices the assets. Further we show the optimal portfolio has a clear structure in terms of a weighted average of solutions to an instantaneous mean-variance problem. We use the approach to design a dynamic value strategy.

Biography

James Sefton has worked both in academia and industry; he is currently a Professor of Economics at Imperial College Business School, but was previously a Senior Quantitative Analyst at UBS Investment Bank. As an academic, he participates in the current UK pension debate, as a financial analyst he specialises in understanding asset pricing anomalies and equity investment strategies.

His career has been equally eclectic. James qualified first as an Information Engineer, before completing his PhD at Cambridge University under the supervision of Keith Glover in 1991. His career as an economist began at the Department of Applied Economics, Cambridge University, and then at the National Institute for Economic and Social Research. He led a variety of projects including one to compile the first set of UK Generational Accounts (which now forms the basis of H.M. Treasury's annual Long term Fiscal Sustainability Report), one funded by D.W.P. investigating the impact of the means-testing of pension benefits on early retirement, and another to build an equilibrium asset allocation model for the Inland Revenue.

He has published widely in areas as varied as computable general equilibrium modelling, national accounting, portfolio management and econometrics. In 2001 he was appointed to a Chair of Economics at Imperial College and became an Executive Director at UBS.

Loop shading, localised behaviours, and multi-resolution feedback systems

Rodolphe Sepulchre

University of Cambridge

Abstract
The foundation of computational neuroscience is a nonlinear RC circuit modelling the electrical activity of the neural membrane. This conductance-based modelling principle was proposed by Hodgkin and Huxley in 1952 and mostly unchallenged to date. In an effort to extract the signalling principles of such circuits, we introduce a particular class of nonlinear behaviours characterized by a localization constraint in range, time, and space. We propose an elementary feedback motif that robustly achieves this localization and that is repeatedly found in conductance-based models. The proposed feedback motif is a natural atom for multi resolution feedback systems. We argue that this principle could have some generality in multiscale spatiotemporal signalling.

Biography
Rodolphe Sepulchre is Professor of Engineering at Cambridge University and a fellow of Sidney Sussex College. He received the engineering degree (1990) and the PhD degree (1994), both in mathematical engineering, from the Université catholique de Louvain, Belgium. He was a BAEF fellow in 1994 and held a postdoctoral position at the University of California, Santa Barbara from 1994 to 1996. He was a research associate of the FNRS at the Université catholique de Louvain from 1995 to 1997. Since 1997, he has been professor at the Université de Liège and still maintains a part-time appointment in the department of Electrical Engineering and Computer Science. He was department chair from 2009 to 2011. He held visiting positions at Princeton University (2002-2003) and the Ecole des Mines de Paris (2009-2010) and part-time positions at the University of Louvain (2000-2011) and at INRIA Lille Europe (2012-2013).

His current research interests are in control and coordination problems on nonlinear spaces, optimization on manifolds, analysis and synthesis of rhythmic networks, aiming at a better understanding of the role of oscillations in the brain. He co-authored the monographs "Constructive Nonlinear Control" (Springer-Verlag, 1997) and "Optimization on Matrix Manifolds" (Princeton University Press, 2008). He is currently Editor-in-Chief of Systems and Control Letters and has been an Associate Editor for SIAM Journal of Control and Optimization, the Journal of Nonlinear Science, and Mathematics for Control, Signals, and Systems. In 2008, he was awarded the IEEE Control Systems Society Antonio Ruberti Young Researcher Prize. He is an IEEE fellow and an IEEE CSS distinguished lecturer since 2010.

Near Ideal Behaviour of a Modified Elastic Net Algorithm in Compressed Sensing

Mathukumalli Vidyasagar

University of Texas

Abstract

In recent years the subject of compressed sensing has found wide applicability. The main results in this area state that it is possible to recover a sparse signal exactly by making a small number of error-free measurements, or approximately via a small number of noisy measurements, by minimizing the ell_1 norm of the residual vector. This approach is closely related to the so-called LASSO algorithm for regression. In the world of regression, LASSO is often replaced by the so-called Elastic Net (EN) algorithm, but it is not known whether the solution of the EN has the same desirable properties as the solution of the LASSO. In this talk, it is shown that by modifying the EN algorithm, it is possible to achieve all of the same properties. In particular, there is nothing special about the ell_1 norm. There are infinitely many norms that permit the exact/approximate recovery of sparse signals with error-free/noisy measurements.

Biography

M. Vidyasagar was born in Guntur, India on 29 September 1947. After completing his Ph.D. at the University of Wisconsin in 1969, he spent the next 20 years in Canada and USA as a professor of Electrical Engineering. In 1989 he returned to India, first as Director of the Centre for Artificial Intelligence and Robotics under the Government of India, and then as an Executive Vice President of Tata Consultancy Services, India's largest software company. In 2009 he retired from TCS and joined the University of Texas at Dallas as Cecil & Ida Green Chair in Systems Biology Science. He is the author of 10 books and nearly 140 journal articles. He has received many awards and honours, the most notable of which are: Fellowship in The Royal Society, the IEEE Control Systems (Field) Award, and the Rufus Oldenburger Medal of ASME.

Information processing and control in biological systems; some fundamental limits

Glenn Vinnicombe

University of Cambridge

Abstract

Many biological processes, from insect vision to gene regulation, are constrained by the effects of delays and small numbers. There are many different ways of attempting to quantify this. In order to rigorously capture the limitations, to keep us honest, we choose to look at their impact on the system's ability to solve causal estimation and control problems. Models of biological systems are, at best, sparsely characterised; with large margins of error even then. Our general approach is to assume that some observable aspects of the sensing or regulatory network are known and to then abstract away the rest of the network by optimising over it. What is the best that nature could be doing, given the constraints it is acting under? For the regulation of copy numbers of molecules in the cell we will show that the limitations imposed by delays in response or by small numbers of signalling molecules are severe, particularly when they occur in combination. For insect vision, an understanding of the fundamental limitations in early visual processing leads to a better understanding of more complex problems. We propose this approach as a new way of studying biological dynamics; where lack of knowledge need not prevent us from saying some things with confidence.

Biography

Glenn Vinnicombe graduated with a BA in Engineering from Cambridge in 1984. From 1984 to 1987 he was with British Aerospace, working primarily on the design and flight test of control systems on the Airbus A320. He returned to Cambridge in 1987 as a College Lecturer at Churchill College, obtaining the PhD degree in 1993. He has held faculty positions at the Department of Mechanical Engineering, University of Minnesota, and in the Department of Aeronautical Engineering, Imperial College, London and is currently a Reader in Control Engineering at the University of Cambridge, Department of Engineering. His current research is primarily concerned with design principles for feedback regulation in networks (particularly communication and power distribution) and biological systems.

A System Approach to Investing in Uncertain Markets

Kemin Zhou

Louisiana State University

Abstract
In this talk, we try to understand a stock market from a system point of view. It is said that the only certainty in any stock market is the uncertainty. Hence robust control theory may play a critical part in achieving superb performance in the stock market. We propose a new technical analysis technique to give us a timely indicator for going in and out of the market so that excellent return can be achieved. We have back-tested our approach with historical data with various market indexes and ETF funds. The results are extremely encouraging.

Biography
Kemin Zhou received the B.S. degree from Beijing University of Aeronautics and Astronautics in 1982 and the M.S.E.E. and Ph.D. degrees from the University of Minnesota in 1986 and 1988, respectively. Since 1990, he has been with Louisiana State University where he is the Roy Paul Daniels Distinguished Professor and Mark and Carolyn C. Guidry Professor in Electrical and Computer Engineering. He is a co-author of three books in control engineering: Robust and Optimal Control (Prentice Hall, 1995), Essentials of Robust Control (Prentice Hall, 1997), and Introduction to Feedback Control (Pearson Prentice Hall, 2009). He is or was an associate editor of Automatica, IEEE Transactions on Automatic Control, SIAM Journal on Control and Optimization, Systems and Control Letters, Journal of System Sciences and Complexity, and Journal of Control Theory and Applications. He is a Fellow of IEEE and the American Association for the Advancement of Science.