Resilient Control of Infrastructure Networks

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Book of Abstract

Scientific commitee

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Virtual reinforcement of power grids: a feedback optimization approach

Saverio BOLOGNANI
ETH Zurich

One of the consequences of the integration of renewable energy sources in the generation mix and of electric mobility is the additional stress faced by power distribution grids. Congestion phenomena are expected to become the bottleneck to widespread deployment of these technologies.

As power distribution grids are mostly unmonitored and highly uncertain, responsive feedback solutions are being explored. In this talk we will see show how heuristic decentralized solutions can be inefficient and even detrimental. Instead, we will look into a rigorous feedback design approach based on the tools of autonomous (online) optimization.

Well-posedness, convergence, and robustness guarantees will be discussed, together with the possibility of scalable distributed implementations.

Saverio Bolognani received the Ph.D. degree in information engineering from the University of Padova, Italy. In 2006–2007, he was a visiting graduate student with the University of California at San Diego, USA.

In 2013–2014, he was a Postdoctoral Associate with the Laboratory for Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, MA, USA. He is currently a Senior Researcher with the Automatic Control Laboratory, ETH Zurich, Switzerland.

His research interests include the application of networked control system theory to power systems, distributed control and optimization, and cyber-physical systems.

Multistable Synchronous Power Flows: Geometry, Analysis and Computation

Francesco BULLO
University of California - Santa Barbara

This talk will focus on the phenomena of synchronization and multistability in coupled oscillators networks and power flows. Key questions are how to characterize the transition from synchrony to incoherence and the existence, localization and computation of synchrony power flows.

We will present novel results, including (i) a novel family of sufficient synchronization conditions rigorously identifying the correct functional form of the trade-off between coupling strength and oscillator heterogeneity, and (ii) a rigorous and comprehensive framework for studying the multistability of active power flows in lossless grids.

Francesco Bullo is a Professor with the Mechanical Engineering Department and the Center for Control, Dynamical Systems and Computation at the University of California, Santa Barbara. He was previously associated with the University of Padova (Laurea degree in Electrical Engineering, 1994), the California Institute of Technology (Ph.D. degree in Control and Dynamical Systems, 1999), and the University of Illinois.

His research interests focus on network systems and distributed control with application to robotic coordination, power grids and social networks. He is the coauthor of “Geometric Control of Mechanical Systems” (Springer, 2004) and “Distributed Control of Robotic Networks” (Princeton, 2009); his “Lectures on Network Systems” (CreateSpace, 2018) is available on his website.

He received best paper awards for his work in IEEE Control Systems, Automatica, SIAM Journal on Control and Optimization, IEEE Transactions on Circuits and Systems, and IEEE Transactions on Control of Network Systems. He is a Fellow of IEEE, IFAC, and SIAM. He served on the editorial boards of IEEE, SIAM, and ESAIM journals, and as 2018 IEEE CSS President.

Scales Paradigms in Large-scale networks

Carlos CANUDAS-DE-WIT
CNRS, GIPSA-Lab,

In this talk we presents some results from the ERC Scale-FreeBAck (This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement n. 694209).

The talk deals with the problems of controlling/observing aggregates of large-scale complex systems with a scarce number of actuators and sensors. Aggregates here are "aggregated" variables functions of the systems state-space variables such as mean values. Examples of such a class of systems are traffic networks, Brain neural networks, heating systems, among others. The basic idea is to devise a "virtual" aggregated model of the original large-scale system using the scale-free (SF) metric, which indicate that the degree distributions of the associated graph follows an exponential decaying law. Then, we discuss different partitioning algorithms leading to aggregated graphs with the SF desired distribution. In the talk, I also present the mathematical properties necessary for the average observability/detectability and in particular, the graph's structure needed to such properties to hold. Finally, an example will be given in network epidemiology where a partition algorithm can include the observability conditions and an observed can be designed using boundary measures.

In the second part of the talk, I present a different alternative for reducing system complexity, which consist in representing a large traffic network as a continuum. That is, to approximate a large-scale dynamic graph (where each node represent a variable), by a Partial Differential equation. The objective of this second approach is to use the PDE model for designing boundary estimators and control. This is work in progress.

Carlos Canudas-de-Wit received his B.Sc. degree in electronics and communications from the Technological Institute of Monterrey, Mexico in 1980. In 1984 he received his M.Sc. in the Department of Automatic Control, Grenoble, France. He was visitor researcher in 1985 at Lund Institute of Technology, Sweden.

In 1987 he received his Ph.D. in automatic control from the Polytechnic of Grenoble (Department of Automatic Control), France. Since then he has been working at the same department as "Director of Research at the CNRS", where He teaches and conducts research in the area of control systems. He is the current leader of the NeCS GIPSA-Lab (CNRS)-INRIA team on Networked Controlled Systems. He has established several industrial collaboration projects with major French companies (FRAMATOME, EDF, CEA, IFREMER, RENAULT, SCHNEIDER, ILL, IFP, ALSTOM).

He has been associate editor of the IEEE-Transaction on Automatic Control, from 1992 to 1997, AUTOMATICA, from 1999 to 2002. He is currently Associated Editor of: the Asian Journal of Control (since 2010), IEEE Transaction on Control System Technology (Since 2013), and the IEEE Transaction on Control of System Networks (since 2013). He holds the presidency of the European Control Association (EUCA) for the period 2013-15, and served at the IEEE Board of Governors of the Control System Society 2011-2014. He holds the ERC Advanced-Grant 2015 Scale-FreeBack for the period 2016-2021. He is IEEE-Fellow of the IEEE Control System Society. He is also IFAC-Fellow. His research publications includes: 200 International conference papers, and 65 published papers in international journals, 5 books, 10 Book chapter, and holds 11 Patents. He has supervised more than 34 Ph. D. students, 11 Post-docs, and more than 35 Ms.

Robust control of traffic flow on networks using chance constrained optimization

Christian CLAUDEL
University of Texas - Austin

Traffic control on networks is a very effective way of addressing traffic congestion. It has been shown in recent years that traffic control problem involving the Lighthill-Whitham-Richards (LWR) model can be formulated as a Linear Programming (LP) problem given that the corresponding initial conditions and the model parameters are fixed. However, these can be uncertain in practical problems. This talk presents a stochastic programming formulation of the boundary control problem involving chance constraints, to capture the uncertainty in the initial conditions. A validation on a simulated road network is conducted, and the optimal control is validated using a Monte Carlo simulation.

Christian Claudel is an Assistant Professor of Civil, Architectural and Environmental Engineering at UT-Austin. He received the PhD degree in Electrical Engineering from UC-Berkeley in 2010, and the MS degree in Plasma Physics from Ecole Normale Superieure de Lyon in 2004. He received the Leon Chua Award from UC-Berkeley in 2010 for his work on the Mobile Millennium traffic monitoring system. His research interests include control and estimation of distributed parameter systems, wireless sensor networks and unmanned aerial vehicles.

AC optimal power flow in the presence of renewable sources and uncertain loads

Fabrizio DABBENE
Centro Nazionale delle Ricerche

The increasing penetration of renewable energy resources, paired with the fact that load can vary significantly, introduce a high degree of uncertainty in the behavior of modern power grids. Given that classical dispatch solutions are “rigid,” their performance in such an uncertain environment is in general far from optimal. For this reason, in this talk, we consider AC optimal power flow (AC-OPF) problems in the presence of uncertain loads and (uncertain) renewable energy generators. The goal of AC-OPF design is to guarantee that controllable generation is dispatched at minimum cost, while satisfying constraints on generation and transmission for almost all realizations of the uncertainty.

We propose an approach based on a randomized technique recently developed, named scenario “with certificates”, which allows us to tackle the problem without the conservative parameterizations on the uncertainty used in currently available approaches.
The proposed solution can exploit the usually available probabilistic description of the uncertainty and variability, and provides solutions with a-priori probabilistic guarantees on the risk of violating the constraints on generation and transmission.

Fabrizio Dabbene is Director of Research at the CNR IEIIT, where he is the coordinator of the Systems Modeling & Control Group. He has held visiting and research positions at The University of Iowa, Penn State University, and the Russian Academy of Sciences Institute of Control Science, Moscow.

Dr. Dabbene is a Senior Member of the IEEE. He has served as an Associate Editor for the IEEE Transactions on Automatic Control, Automatica and he is Senior Editor of the IEEE Control Systems Letters. He was Program Chair for the 2010 IEEE Multiconf. on Systems and Control, Chair of the IEEE Technical Committee on CACSD, the IFAC Technical Committee on Robust Control, and will be General Chair of the 2022 IEEE Conf. on Control Theory and Applications. He served as elected member of the IEEE-CSS Board of Governors, as IEEE–CSS Vice-President for Publication Activities for the years 2015–2016, and he is currently Chair of the Italian Chapter of IEEE CSS.

Diagnosability of hybrid dynamical systems

Maria Domenica DI BENEDETTO
Università dell'Aquila

Hybrid systems, i.e., heterogeneous systems that include discrete and continuous-time subsystems, have been used to model control applications, e.g. in automotive control, air traffic management systems, smart grids and intelligent manufacturing. Failure in this kind of applications can cause irreparable damage to the physical controlled systems and to the people who depend on it or may cause large direct and indirect economic losses. Therefore, security for hybrid systems represent a significant concern.
In this respect, observability and diagnosability play an important role since they are essential in characterizing the possibility of identifying the system's hybrid state, and in particular, the occurrence of specific states that may correspond to malfunctioning due to a fault or an adversarial attack.

In this talk, I review and place in context how the continuous and the discrete dynamics, as well as their interactions, intervene in the observability and diagnosability properties of a general class of hybrid systems. I also illustrate under which conditions the hybrid system's state can be correctly estimated even when the system is under attack. An example related to network topology changes due to faults or attacks will illustrate the results.

Maria Domenica Di Benedetto obtained her Master degree (summa cum laude) in Electrical Engineering and Computer Science, University of Roma "La Sapienza", in 1976. In 1981, she obtained the "Docteur-Ingénieur" degree and in 1987 the "Doctorat d'Etat ès Sciences" degree, Université de Paris-Sud (Orsay, France). Since 1994, she has been Professor of Automatic Control at University of l'Aquila. She has been Adjunct Professor and McKay Professor at the Department of EECS, University of California at Berkeley. She has been Visiting Professor at MIT, University of Michigan (Ann Arbor), C.N.R.S. (Poste Rouge, Ecole Centrale, Nantes).

In 2002, she was elected IEEE Fellow. She has been the Director of the Center of Excellence for Research DEWS "Architectures and Design methodologies for Embedded controllers, Wireless interconnect and System-on-Chip" from 2001 to 2019. She is President of the European Embedded Control Institute since 2009. Since 2013, she is President of the Italian Society of researchers in Automatic Control (SIDRA).

Her research interests are in the areas of nonlinear and hybrid systems, networked control systems, and applications to automotive, energy and traffic control.

Formulas for data-driven control: stability, optimality and robustness

Claudio DE PERSIS
Engineering and Technology Institute Groningen

Infrastructures have complex behaviours and their accurate models might be hard to obtain or difficult to work with. On the other hand, for these systems large amount of data are available for measurements and one could try to design controllers complementing the limited knowledge about the systems's model with data that are collected during experiments.

In this talk, I introduce a new technique for directly designing control algorithms starting from input-output data collected in a ”one-shot” experiment performed on the system to control and without requiring any identification step. I show that such design boils down to the solution of data-dependent semi-definite programs, which can be very efficiently solved.

Claudio De Persis received the the Ph.D. degree in System Engineering in 2000 from the University of Rome ”La Sapienza”, Italy.

He is currently a Professor at the Engineering and Technology Institute, Faculty of Sciences and Mathematics, University of Groningen, the Netherlands. He is also affiliated with the Jan Willems Center for Systems and Control. Previously he was with the Department of Mechanical Automation and Mechatronics, University of Twente and with the Department of Computer, Control, and Management Engineering, University of Rome ”La Sapienza”. He was a Research Associate at the Department of Systems Science and Mathematics, Washington University, St. Louis, MO, USA, in 2000-2001, and at the Department of Electrical Engineering, Yale University, New Haven, CT, USA, in 2001-2002.

His main research interest is in control theory, and his recent research focuses on dynamical networks, cyberphysical systems, smart grids and resilient control. He was an Editor of the International Journal of Robust and Nonlinear Control (2006-2013), an Associate Editor of the IEEE Transactions on Control Systems Technology (2010-2015), and of the IEEE Transactions on Automatic Control (2012- 2015). He is currently an Associate Editor of Automatica (2013-present) and of IEEE Control Systems Letters (2017-present).

Data-enabled predictive control in autonomous energy systems

Florian DÖRFLER
ETH Zürich

We consider the problem of optimal and constrained control for unknown systems. A novel data-enabled predictive control (DeePC) algorithm is presented that computes optimal and safe control policies using real-time feedback driving the unknown system along a desired trajectory while satisfying system constraints. Using a finite number of data samples from the unknown system, our proposed algorithm uses a behavioral systems theory approach to learn a non-parametric system model used to predict future trajectories. We show that, in the case of deterministic linear time-invariant systems, the DeePC algorithm is equivalent to the widely adopted Model Predictive Control (MPC), but it generally outperforms subsequent system identification and model-based control. To cope with nonlinear and stochastic systems, we propose salient regularizations to the DeePC algorithm. Using techniques from distributionally robust stochastic optimization, we prove that these regularization indeed robustify DeePC against corrupted data. We illustrate our results with nonlinear and noisy simulation case studies from autonomous energy systems as well as aerial robotics.

Florian Dörfler is an Associate Professor at the Automatic Control Laboratory at ETH Zürich.

He received his Ph.D. degree in Mechanical Engineering from the University of California at Santa Barbara in 2013, and a Diplom degree in Engineering Cybernetics from the University of Stuttgart in 2008. From 2013 to 2014 he was an Assistant Professor at the University of California Los Angeles.

His students were winners or finalists for Best Student Paper awards at the 2019/2013 European Control Conference, the 2016 American Control Conference, and the 2017 PES PowerTech Conference. His articles received the 2010 ACC Student Best Paper Award, the 2011 O. Hugo Schuck Best Paper Award, the 2012-2014 Automatica Best Paper Award, and the 2016 IEEE Circuits and Systems Guillemin-Cauer Best Paper Award.

He is a recipient of the 2009 Regents Special International Fellowship, the 2011 Peter J. Frenkel Foundation Fellowship, and the 2015 UCSB ME Best PhD award.

Macroscopic traffic flow models on road networks

Paola GOATIN
Inria Sophia Antipolis - Méditerranée

The talk will review the main macroscopic models of vehicular traffic flow on networks, focusing on the description of dynamics at junctions.

I will then show some optimal control application, as well as some recent developments accounting for the impact of modern navigation systems.

Dr. Paola Goatin is currently Research Director at Inria Sophia Antipolis - Méditerranée and leader of the project-team ACUMES (Analysis and Control of Unsteady Models for Engineering Sciences). Before joining Inria in 2010, she held an Associate Professor position at Toulon University.

She got her PhD in Applied Mathematics from SISSA-ISAS (Italy) and her Habilitation in Mathematics from Toulon University.
Paola Goatin is an expert of analysis and numerical simulation of hyperbolic systems of conservation laws, with special focus on traffic flow applications.

From 2010 to 2016 she held an ERC Starting Grant on “Traffic Management by Macroscopic models”. In 2014, she was awarded the Inria - Académie des Sciences prize for young researchers. She is author of about 60 articles published on international journals and 20 conference proceedings.

Resilient control of automated transport vehicles and their influence on traffic

Karl H. JOHANSSON
KTH Royal Institute of Technology

Automated and connected road vehicles enable large-scale control and optimisation of the transport system with the potential to radically improve fuel efficiency, decrease the environmental footprint, and enhance safety.

In this talk we will focus on automated heavy-duty vehicle platooning, which is currently being implemented and evaluated by several truck manufacturers world-wide. We will discuss how to deploy feedback control of individual platoons utilising the cellular communication infrastructure and how such controlled platoons can be used improve overall traffic conditions. It will be argued that the average total variation of traffic density can be reduced and thereby creating incentives for platooning beyond fuel savings and driver support. Extensive experiments done on European highways will illustrate system performance and safety requirements. The presentation will be based on joint work with collaborators at KTH and at the truck manufacturers Scania and Volvo.

Karl H. Johansson is Professor at the School of Electrical Engineering and Computer Science, KTH Royal Institute of Technology.

He received MSc and PhD degrees from Lund University. He has held visiting positions at UC Berkeley, Caltech, NTU, HKUST Institute of Advanced Studies, and NTNU. His research interests are in networked control systems, cyber-physical systems, and applications in transportation, energy, and automation networks. He has served on the IEEE Control Systems Society Board of Governors, the IFAC Executive Board, and the European Control Association Council.

He has received several best paper awards and other distinctions from IEEE, IFAC and ACM. He has been awarded Distinguished Professor with the Swedish Research Council and Wallenberg Scholar with the Knut and Alice Wallenberg Foundation. He has received the Future Research Leader Award from the Swedish Foundation for Strategic Research and the triennial Young Author Prize from IFAC. He is Fellow of the IEEE and the Royal Swedish Academy of Engineering Sciences, and he is IEEE Distinguished Lecturer.

Tracking performance of time-varying nonconvex optimization with application to OPF

Steven LOW
California Institute of Technology

Optimal power flow (OPF) problems are fundamental for power system operations. They are nonconvex and, in future applications, time-varying.

We present a first-order proximal primal-dual algorithm and a second-order algorithm for general time-varying nonconvex optimization and bound their tracking performance. We incorporate real-time feedback in our algorithms for applications to time-varying OPF problems, and illustrate their tracking performance numerically.
Joint work with Yujie Tang, Caltech, *Emiliano Dall'Anese*, U of Colorado, *Andrey Berstein, NREL*.

Steven Low is the Gilloon Professor of the Department of Computing & Mathematical Sciences and the Department of Electrical Engineering at Caltech. Before that, he was with AT&T Bell Laboratories, Murray Hill, NJ, and the University of Melbourne, Australia where is currently an honorary Professor. He was a co-recipient of IEEE best paper awards and is an IEEE Fellow.

His research on communication networks is accelerating more than 1TB of Internet traffic every second. He was a member of the Networking and Information Technology Technical Advisory Group for the US President's Council of Advisors on Science and Technology (PCAST) in 2006.

He received his B.S. from Cornell and PhD from Berkeley, both in EE.

Towards a Scalable Theory of Control

Anders RANTZER
Lund University

Classical control theory does not scale well for large systems like traffic networks, power networks and chemical reaction networks. To change this situation, new approaches need to be developed, not only for analysis and synthesis of controllers, but also for modelling and verification.

In this lecture we will present some general classes of networked control problems for which scalable distributed controllers can be proved to achieve the same performance as the best centralized ones. We will also show how network realizable controllers can be synthesized using convex optimisation and implemented using a network structured version of Internal Model Control. Applications in water, energy and traffic networks will be discussed.

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 and 2015/16 he was Taylor Family Distinguished Visiting Professor at University of Minnesota. During 2008-18 he coordinated the Linnaeus center LCCC at Lund University and he currently serves as head of department.

He is a Fellow of IEEE, a member of the Royal Swedish Academy of Engineering Sciences and past chairman of the Swedish Scientific Council for Natural and Engineering Sciences.

His research interests are in modeling, analysis and synthesis of control systems, with particular attention to uncertainty, optimization, scalability and adaptation.

Physical Flow over Networks: Analysis, Control and Computation

Ketan SAVLA
University of Southern California

Network flow provides a compelling framework to model several civil infrastructure systems, including transportation and power. Traditionally, network flow methodologies have focused predominantly on fast computation of performance metrics in static settings, under only flow conservation. Extensions to additional canonical physical constraints and dynamics underlying civil infrastructure systems, and to robustness analysis and control synthesis have been challenging. This is, in part, due to non-convexity, switched dynamics and hybrid state space.

We discuss limitations of classical system theoretic tools in addressing these challenges, and present recent results that overcome these by exploiting structure through the lens of monotonicity, equivalent relaxation, incremental network reduction, and principled abstraction synthesis. Case studies and examples to illustrate the proposed methodologies will also be presented.

Ketan Savla is an associate professor and the John and Dorothy Shea Early Career Chair in Civil Engineering at USC, with joint appointment in the Departments of Civil and Environmental Engineering, Electrical Engineering-Systems, and Industrial and Systems Engineering. Before joining USC, he was a research scientist in the Laboratory for Information and Decision Systems at MIT.

He received his PhD in Electrical and Computer Engineering from the University of California at Santa Barbara. His current research interest is in distributed robust and optimal control, dynamical networks, state-dependent queueing systems, and incentive design, with applications in civil infrastructure and autonomous systems.

His recognitions include NSF CAREER, an IEEE CSS George S. Axelby Outstanding Paper Award, and AACC Donald P. Eckman Award. He serve(d) as an associate editor for the Conference Editorial Board of IEEE CSS, the IEEE Transactions on Intelligent Transportations Systems, the IEEE Control Systems Letters, and the IEEE Transactions on Control of Network Systems.

Matching and Mechanisms as Potential Approaches for Control of Infrastructure

Jeff S. SHAMMA
King Abdullah University of Science and Technology

The nature of infrastructure networks naturally lends itself to distributed decision architectures, where individual but interconnected components take decisions based on local information and interactions. First, while there may be an overall system planner, the scale of such systems effectively prohibits centralized approaches in which a single actor has full information and full authority. Second, the individual components may be driven by self-interest, and accordingly must be incentivized to induce behaviors that are desirable from the system planner's perspective.

This talk gives an overview of two game theoretic approaches to address such settings. The first is distributed matching, in which self-interested agents self-organize into mutually satisfactory partnerships. The second is dynamic mechanism design, where allocation of incentives occurs in an evolving manner. The talk presents selected recent results as well as future research questions motivated by the potential application to control of infrastructure.

Jeff S. Shamma is a Professor of Electrical Engineering at the King Abdullah University of Science and Technology (KAUST) and the Director of the Center of Excellence for NEOM Research at KAUST.

Shamma received a Ph.D. in systems science and engineering from MIT in 1988. Prior to joining KAUST, he was the Julian T. Hightower Chair in Systems & Control in the School of Electrical and Computer Engineering at Georgia Tech.

Shamma is a Fellow of the IEEE and the IFAC (International Federation of Automatic Control), and a recipient of the NSF Young Investigator Award, American Automatic Control Council Donald P. Eckman Award, and Mohammed Dahleh Award. He is currently the deputy editor-in-chief for the IEEE Transactions on Control of Network Systems and a Distinguished Lecturer of the IEEE Control Systems Society.

Non-normal dynamics and the efficient information propagation in linear networks

Sandro ZAMPIERI
Università di Padova

While there exists a consistent number of contributions in computational neuroscience that support the hypothesis that non-normality makes the information transmission more efficient in neuronal networks, no quantitative analysis has been proposed, analysis that would allow the comparison of different network topologies.

In this contribution we propose a model that puts in a precise frame the arguments proposed in those papers. Based on this model, we propose a metric that, through the Shannon capacity of a suitable channel build from a linear dynamical network, enables to quantify the information transmission efficiency. This allows to confirm that non-normality enhance the channel capacity, but only in the high noise regime. Finally we specify which non-normality degree plays a role in this enhancement.

Sandro Zampieri received the Laurea degree in Electrical Engineering and the Ph.D. degree in System Engineering from the University of Padova, Italy, in 1988 and 1993, respectively. Since 2002 he is Full Professor in Automatic Control at the Department of Information Engineering of the University of Padova. He has been the head of the Department of Information Engineering from 2014 until 2018. In 1991-92, 1993 and 1996 he was Visiting Scholar at Laboratory for Information and Decision Systems, MIT, Cambridge. He has held visiting positions also at the Department of Mathematics of the University of Groningen and at the Department of Mechanical Engineering of the University of California at Santa Barbara.

Prof. Zampieri has published more than 100 journal and conference papers. He has delivered several invited seminars and he was member of the Technical Program Committee for several international conferences. He was general chair of the 1st IFAC Workshop on Estimation and Control of Networked Systems 2009, program chair of the 3rd IFAC Workshop on Estimation and Control of Networked Systems 2012 and publication chair of the IFAC World Congress 2011. He served as an Associate Editor of the Siam Journal on Control and Optimization on 2002-2004 and as the chair of the IFAC technical committee ”Networked systems” on 2005-2008. Since 2012 he is serving as an Associate Editor of IEEE Transactions of Automatic Control.

His research interests include automatic control and dynamical systems theory, and in particular distributed control and estimation and networked control and control under communication constraints.