Pre-Conference Workshops

All pre-conference workshops will take place on Sunday, December 11, 2011, the day prior to the start of the CDC, from 8:30 am – 5:00 pm. Workshop registration will open at 7:00 am on December 11.

L_1 Adaptive Control and Its Transition to Practice
Organizers: Naira Hovakimyan (University of Illinois at Urbana-Champaign) and Chengyu Cao (University of Connecticut)
Additional Participants: Enric Xargay (University of Illinois at Urbana-Champaign)

Abstract: This workshop will cover the foundations of robust control, Lyapunov stability theory and will present the recent developments on L1 adaptive control theory with flight test results of a subscale commercial jet from a recent NASA program on Aviation Safety. The architectures of L1 adaptive control theory decouple the estimation loop from the control loop and with that allow for arbitrary fast rates of adaptation without sacrificing robustness. The fast estimation loop in these architectures approximates the system inverse arbitrarily closely within the bandwidth of the control channel. The workshop will present the principles of the theory for state feedback and output feedback, using simple examples for illustrations. Matched and unmatched uncertainties, SPR and non-SPR systems will be discussed in details. Upon discussing some UAV applications, flight tests of a generic transport aircraft model of NASA's AirSTAR facility will conclude the presentation.

The Work of Peter Crouch
Organizers: Anthony M. Bloch (University of Michigan), Fátima Silva Leite (University of Coimbra)

Abstract: Peter Crouch, a Fellow of the IEEE, a key figure in the development of nonlinear control theory, and a longtime Dean of the Arizona State University and University of Hawaii Colleges of Engineering, will turn 60 this year. We propose to celebrate this occasion with a one-day workshop dealing with the state-of-the-art in areas to which Crouch has made key contributions. We feel this joint CDC-ECC meeting is particularly appropriate since Peter has so many connections on both sides of the Atlantic. Topics of the workshop include: Splines and Optimal Control, Discrete Control Systems and Numerical Analysis, Nonholonomic Control Systems, Geometry of Optimal Control.

Applied Robust Control: From Theory to Automotive Industrial Applications
Organizers: Francis Assadian (Cranfield University), Sajjad Fekri (Cranfield University), Ilya Kolmanovsky (University of Michigan)

Abstract: During the last two decades, there have been great advances in the theory of robust uncertainty-tolerant multivariable feedback control system design, which can accommodate a wide range of operating conditions, process changes, and unmeasured disturbances etc, in order to achieve a desired degree of robustness for MIMO control systems. While robust control systems have been successfully applied in many practical applications, Automotive Industry has not derived much benefit from these advanced control techniques. One of the main reasons for this, perhaps, is the fact that the increasing rate of new technology introduction in the automotive industry far exceeds that of other industries. On the other hand, there is limited resource in legacy automotive control systems to aid development for these novel and complex systems; as a result, there is a continuous increase in the gap between the control theory and the practical control strategies applied to the existing production vehicles. This gap results in significant missed opportunities in addressing several fundamental functionalities of the vehicle including fuel economy, emissions, driveability, unification of control architecture, and integration of the Automotive Mechatronics units on-board vehicle, to name a few. Therefore, it is vital to design advanced control systems, in a timely fashion and with the associated cost and risk, to be developed and implemented within the challenging automotive domain. In this workshop, we present and discuss how to bridge this gap, which is a challenge for the automotive control discipline, by employing the robust MIMO feedback control designs with emphasis on a number of practical automotive control applications. We shall address that Automotive Mechatronics (and its relevant applications) are currently more affordable to be developed, tested and implemented in production vehicles by employing the recent advancements of semiconductor and microcontroller technologies and that of their ever-increasing computational power. It is also highlighted that the key competitive differentiators of tomorrow's vehicles will be entirely dependent on the advanced control algorithms and Mechatronics systems and that they could open up new research opportunities for both academia and industry in the future.

Control Systems Security: Challenges and Directions

Organizers: Bruno Sinopoli (Carnegie Mellon University), Shreyas Sundaram (University of Waterloo), Tamer Basar (University of Illinois Urbana Champaign), Francesco Bullo (UC Santa Barbara), Karl H. Johansson (Royal Institute of Technology, Sweden), William H. Sanders (University of Illinois at Urbana-Champaign)

Abstract: Control systems play a central role in a multitude of life-critical applications, from nuclear plants, power grids and manufacturing to aerospace systems and transportation. Disruptions in such applications (either by intent or by accident) could have dire consequences, and thus a concerted effort must be made to ensure that the underlying control systems are resilient to components that behave in malicious or unpredictable ways. Traditional control system security measures based on air-gaps and safety-through-obscurity are no longer sufficient, as control networks become increasingly connected to corporate backbones and utilize off-the-shelf components. The recent sophisticated intrusion of micro-controllers in nuclear plants by the Stuxnet worm is a prime example of the vulnerability of control systems to attacks.

The need for a rigorous theory of security in control systems has recently started to gain attention as a fertile and important area of research. For critical infrastructure projects, security must now be designed into control systems as a non-negotiable feature, rather than tacked on at the end. A key challenge for the controls community is thus to understand how to leverage system dynamics to analyze and design secure control mechanisms. The goal of this workshop is to present the challenges in this area, together with tools and approaches that have been recently developed to address this problem. Future directions for research will be proposed and highlighted. The target audience is students, researchers and practitioners from academia and industry who are interested in learning about (and contributing to) the emerging field of control systems security. The workshop will feature tutorial-style talks, giving the

audience a control systems view of security, and how to best combine different perspectives to develop reliable and resilient systems.

For more information, visit https://ece.uwaterloo.ca/~ssundara/cdc_secure_workshop.html

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Traffic Modeling and Estimation at the Age of Smartphones: Leveraging Statistical Modeling and Optimal Control

Organizers: Alex Bayen (University of California at Berkeley, USA), Christian Claudel (KAUST University, Saudi Arabia), Daniel Work (University of Illinois at Urbana Champaign, USA), Sebastien Blandin (University of California at Berkeley, USA), Aude Hofleitner (University of California at Berkeley, USA)

Abstract: Classical highways macroscopic traffic modeling theory dates back to the 1950's, with the development of scalar first order hyperbolic traffic models inspired from hydrodynamics (the Lighthill Whitman Richards model). Later, Hamilton Jacobi equations were used to model vehicles labels as the state variable instead of density. So-called second order flow models consider a second state variable and offer additional modeling capabilities which include the possibility to model different driving behaviors. On arterial networks and urban streets, because of the presence of traffic signals with (in general) unknown signal timing and due to the importance of exogenous events, traffic modeling requires the use of statistical models based on hydrodynamic theory. We will present these different modeling approaches and their respective discretization required for numerical computations.

Data assimilation consists in optimally combining field measurements with the mathematical model of a system, in order to estimate its current state or forecast its future state. In this workshop, we present data assimilation algorithms for the case of different mathematical models described above. Filtering based estimation algorithms derived from Kalman filter extensions, and appropriate for nonlinear dynamical systems (specifically the ensemble Kalman filter) are presented. Applications of optimal control to estimation with integral first order models and fault sensor diagnosis will be introduced. Machine learning based inference algorithms capable of leveraging massive historical datasets and sparse real-time probe vehicle measurements will be presented.

In this workshop, we leverage our years of experience in traffic modeling, estimation and data fusion gathered from the design and development of the *Mobile Millennium* system (http://traffic.berkeley.edu), which provides real-time traffic estimates on the road network of Northern California. This workshop targets industry, research and government organizations, and various groups facing similar challenges in the development of cyber-physical systems. In particular, this workshop leverages partnerships with mobile internet companies such as Nokia, Navteq or Telenav who are developing traffic monitoring technology. Modeling and estimation techniques presented in this workshop are not limited to traffic and may be of interest to research groups working on applications of control and machine learning as well as research groups in distributed parameter systems and control of PDEs (water networks, meteorology, air quality, etc.).

Robust Hybrid Control Systems

Organizers: Rafal Goebel (Loyola University), Ricardo G. Sanfelice (University of Arizona), Andrew R. Teel (UC, Santa Barbara)

Abstract: Hybrid dynamical systems, when broadly understood, encompass dynamical systems where states or dynamics can change continuously as well as instantaneously. Hybrid control systems arise when hybrid control algorithms --- algorithms which involve logic, timers, clocks, and other digital devices --- are applied to classical dynamical systems or systems that are themselves hybrid. Hybrid control may be used to improved performance and robustness properties compared to classical control, and hybrid dynamics may be unavoidable due to the interplay between digital and analog components of a system.

The workshop has three main parts. The first part presents various modeling approaches to hybrid dynamics, focuses on a particular framework which combines differential equations with difference equations, and illustrates the framework through several examples. The second part shows how classical stability analysis tools, for example Lyapunov necessary and sufficient conditions and invariance principles, carry over to the hybrid dynamics. The third part applies the stability analysis tools to present various hybrid control examples and analyze their stability and robustness properties.

The workshop is based in part on the 2009 IEEE Control Systems Magazine paper by the workshop organizers, titled ``Hybrid Dynamical Systems", which received the 2010 IEEE Control Systems Magazine Outstanding Paper Award.

More information available at http://www.u.arizona.edu/~sricardo/index.php?n=Main.Workshops

Universal Laws, Architectures, and Behaviors of Robust, Evolvable Networks

Organizers: John C. Doyle (California Institute of Technology), John G Braun (California Institute of Technology)

Abstract: This workshop will review recent progress on developing a “unified” theory for complex networks involving several elements: hard limits on achievable robust performance (misnamed “laws”), the organizing principles that succeed or fail in achieving them (architectures and protocols), the resulting high variability data and “robust yet fragile” behavior observed in real systems and case studies (behavior, data), and the processes by which systems evolve (variation, selection, design).

Insights into what the potential universal laws, architecture, and organizational principles are can be drawn from three converging research themes. First, detailed description of components and a growing attention to systems in biology and neuroscience, the organizational principles of organisms and evolution are becoming increasingly apparent. Biologists are articulating richly detailed explanations of biological complexity, robustness, and evolvability that point to universal principles and architectures. Second, while the components differ and the system processes are far less integrated, advanced technology’s complexity is now approaching biology’s and there are striking convergences at the level of organization and architecture, and the role of layering, protocols, and feedback control in structuring complex multiscale modularity. Third, new mathematical frameworks for the study of complex networks

suggests that this apparent network-level evolutionary convergence within/between biology/technology is not accidental, but follows necessarily from their universal system requirements to be fast, efficient, adaptive, evolvable, and most importantly, robust to perturbations in their environment and component parts. We have the beginnings of the underlying mathematical framework and also a series of case studies in classical problems in complexity from statistical mechanics, turbulence, cell biology, human physiology and medicine, neuroscience, wildfire ecology, earthquakes, economics, the Internet, and smartgrid. This will be the heart of the workshop, and will build on theory that has grown out of the controls community.

Not surprisingly, we will emphasize robustness and optimization as central unifying themes. Below are recent papers that could serve as background reading for this workshop, and we plan to have a more extensive guide available to attendees before CDC. In the workshop, we will attempt to summarize the last decade or so of research that has branched out substantially from mainstream control into other areas of engineering, but also science and medicine, but still maintains strong thematic contact with controls.

Recent Advances in Model Reference Adaptive Control: Theory and Applications

Organizers: Anthony J. Calise (Georgia Institute of Technology), Eric N. Johnson (Georgia Institute of Technology), Tansel Yucelen (Georgia Institute of Technology), Girish Chowdhary (Georgia Institute of Technology)

Abstract: Research in adaptive control theory is motivated by the presence of uncertainties. Uncertainties in real-world systems are inevitable and may be a result of modeling inaccuracies, external disturbances, actuator failures, or airframe damage. Adaptive control is also motived by the desire to reduce control system development time and cost for systems that undergo frequent evolutionary design changes, or that have multiple configurations or environments in which they are operated. This workshop is intended for those who want to receive an introduction to adaptive control as well as those who wish to find out more about some of the latest developments in adaptive control. The workshop will leverage the research experience of the presenters in both theory and practice of adaptive control and provide participants with software examples and other learning resources. Beginning with a brief review of nonlinear stability theory, this workshop will present a review of a number of well-established methods in Model Reference Adaptive Control (MRAC), a leading methodology in adaptive control. Both linear and nonlinear MRAC formulations will be discussed along with a discussion of robustness of MRAC approaches. Classical MRAC modifications, including sigma-mod, e-mod, and projection based modifications will be discussed. The concept of persistency of excitation will be explored through the study of online parameter identification problems. Participants will have the opportunity to use provided software to simulate MRAC design and analysis.

The workshop will then continue on to discuss the successes and lessons learned of successful implementations of MRAC to real-world systems, including unmanned aerial systems. Methods for adaptation in presence of actuator saturation and sensor noise will be discussed. The workshop will also introduce recent developments in adaptive loop recovery approach that allows the approximate retention of reference model loop properties such as relative stability margins and allows the adaptive

controller to mitigate effects of time-delays. It will be shown how the notion of Kalman filtering can be used to update adaptation gains to meet a given performance criteria without excessive tuning.

Several recent advances in MRAC will also be discussed. These include the novel concurrent learning adaptive control and derivative-free adaptive control approaches. Concurrent learning is a memory-enabled adaptive control method that uses online selected and recorded data concurrently with instantaneous measurements for adaptation. Concurrent learning guarantees exponential tracking error as well as parameter error convergence for a class of adaptive control problems if the system states are exciting over a finite interval, persistency of excitation is not required. Derivative-free adaptive control is particularly well suited for systems with sudden (and possibly discontinuous) change in uncertain dynamics, such as those induced through reconfiguration, payload deployment, docking, or structural damage. It provides superior adaptation and disturbance rejection properties, and computable transient and steady-state performance bounds. Finally the connections between machine learning and adaptive control will be explored in the framework of neuro-adaptive control.

Optimal Adaptive Control: Online Solutions for Optimal Feedback Control and Differential Games Using Reinforcement Learning

Organizers: Frank L. Lewis (University of Texas Arlington), Draguna Vrabie (United Technologies Research Center), R. Babuska (Delft University of Technology) and L. Busoniu (INRIA, Lille, France)

Abstract: Optimal feedback control design is performed offline by solving equations such as the algebraic Riccati equation (ARE) or the Hamilton-Jacobi-Bellman (HJB) equation. Full system dynamics must be known. In machine learning and artificial intelligence, reinforcement learning is a class of algorithms that provide online solutions to optimal control problems in real-time while circumventing explicit system modeling and identification. These methods provide adaptive techniques to learn optimal control policies in real-time based on data measured along the system trajectories. For the LQR, for instance, they provide adaptive methods that converge to the solution to the algebraic Riccati equation (ARE) in real-time without knowing the system A matrix.
This workshop will present and discuss reinforcement learning algorithms developed for optimal control purposes. Adaptive algorithms will be presented that learn the solutions to optimal control problems and games online in real-time. The goal is to outline the connection between reinforcement learning methods and optimal control problems. Applications on actual engineered systems will be discussed, highlighting several issues that arise in real-life control.

The workshop will include discussion of:
Basics of Reinforcement Learning: Markov Decision Processes, model-based and model-free learning, offline and online RL methods.
Approximate Reinforcement Learning: Extensions of RL methods with function approximation, enabling the application to continuous-valued problems.
Reinforcement Learning (RL) in Multi-Agent Systems: Includes multi-agent stochastic games and multi-agent RL algorithms.
Online Learning of Optimal Control Solutions – Online adaptive algorithms for learning continuous-time optimal control solutions in real-time for linear and nonlinear systems. These algorithms converge to the solution of the ARE, or to approximate local, smooth solutions to the HJB equation.

Online solution for H-Infinity Control and Zero-Sum games – Online adaptive algorithms that converge in real-time to approximate local, smooth solutions to the Hamilton-Jacobi-Isaacs equation. Adaptive tuning methods are given that learn the optimal saddle point solution in real time and also maintain system stability while learning.
Cooperative/Non-Cooperative Multi-Player Games – Adaptive control algorithms for solving in real-time the coupled AREs or HJ equations for multi-player games.

Foundations and Future Perspectives to Cooperate in Control and Monitoring with India
Organizers: Mathukumalli Vidyasagar (University of Texas at Dallas), Françoise Lamnabhi-Lagarrigue (CNRS/EECI), H.S. Jamadagni (IISC Bangalore)

Speakers and moderators (in alphabetical order):

Ravi Banavar (IIT Bombay, India), Hiri Jamadagni (IISC Bangalore, India), Pramod P. Khargonekar (University of Florida, US), Svetlana Klessova (inno, France), P. R. Kumar (University of Illinois, US), Francoise Lamnabhi-Lagarrigue (CNRS-EECI, France), Romeo Ortega (CNRS, France), Jorge Pereira (European Commission, DG Information Society and Media), Tariq Samad (Honeywell, US), Neeraj Suri (University of Dortmund, Germany), Mathukumalli Vidyasagar (University of Texas at Dallas, US).

Abstract: India has a proud heritage in mathematics, leading to systems engineering and monitoring technologies. The root of contemporary linear system theory may be traced to Aryabatta, unquestionably the father of the Diophantine equation, as it is known in the west. More recent examples include a systematic approach to randomized algorithms for solving NP-hard design problems. This workshop aims to review foundations and Indian contributions to monitoring and control systems research during the past five decades, to highlight latest trends, and to inform the audience about cooperation opportunities. The realm of contributions of the invited speakers is extremely wide. It covers fundamental methodological research like input-output theory, large scale systems, H_infinity theory, and adaptive and stochastic control. It includes also seminal contributions in classical applied fields like power systems, power electronics and robotics, as well as cutting edge areas like wireless communication system and bio-medical applications. All the speakers have kept very close contact with India and have played a major role in fostering collaborations with the EU and the USA. Their complementary expertise will help to inspire the audience on new challenges in the topic. Although the workshop has a specific focus on India, it will be relevant and useful to all those who are interested in new insights on challenges and opportunities in control systems and monitoring, including graduate students and post-doctoral researchers. This workshop is presented under the auspices of the European Commission's FP7 project Euclid on EU-India collaboration in monitoring and control http://www.euclid-india.eu. Workshop agenda and speakers bios are available at the workshop web page: http://www.euclid-india.eu/cdc-ecc.