

Tutorial Sessions

Title: Sparse and low-rank representation methods in control, estimation and system identification

Organizer: Bo Wahlberg (KTH)

Time and Location: Wednesday, July 17, 2013, 09:50-11:50 (Room F1)

Abstract: This tutorial gives an introduction on how to apply convex optimization methods to select sparse or low-rank representations to problems in control, estimation and system identification. This is an very active area of research with a lot of recent exciting contributions. The basic idea is to use convex relaxation as a heuristic for solving certain combinatorial optimization problems. The main focus of the tutorial will be on extension of using the ℓ_1 -norm as a substitute for the so-called ℓ_0 -norm in order to penalize the number of non-zero elements (sparseness) in a parameter vector. The ℓ_1 -norm regularization concept leads to a vast family of well-known sparse estimation methods in computational statistics, including total variation denoising, basis pursuit and the lasso method. The field of compressed sensing is very much based on the idea of ℓ_1 -norm regularization, and under which conditions this relaxation works. The corresponding convex relaxation for rank-constrained optimization problems is the nuclear norm, that is the sum of the absolute values of the singular values of a matrix.

The application of the ℓ_1 -norm or the nuclear norm penalty in control and estimation of dynamical systems is more recent with a huge range of possible applications. An approach is to extend standard quadratic cost functions, like in LQ and MPC control or Kalman filtering, with penalty terms that stress certain structure, such as sparsity or rank, constraints. For example, the nuclear norm can be used to include rank constraints, for example that the rank of the impulse response Hankel matrix equals the system order, and has very interesting application in system identification.

The tutorial is divided into three parts. The first lecture will give a tutorial on convex optimization algorithms sparse and low-rank representations that can handle very large problems. The second lecture concerns applications of “sparse methods” in control of distributed systems. The third lecture will give a survey of using sparse and low-rank representation methods in system identification.

Session Structure:

09:50-10:30: Convex Optimization Algorithms for Sparse and Low-Rank Representations, Lieven Vandenberghe (UCLA)

10:30-11:10: Sparsity-Promoting Optimal Control of Distributed Systems, Mihailo Jovanovic (University of Minnesota)
11:10-11:50: Sparse and Low Rank Representation Methods in System Identification, Cristian Rojas (KTH), Bo Wahlberg (KTH).

Title: Theory and practice of explicit MPC

Organizers: Colin Jones (EPFL), Michal Kvasnica (Slovak University of Technology in Bratislava), Martin Herceg (ETH)

Time and Location: Wednesday, July 17, 2013, 14:00-16:00 (Room F1)

Abstract: Predictive control is a simple and powerful paradigm for implementing complex control laws and has been proven effective in a wide range of industrial settings. Explicit MPC, or offline pre-computation of the control law, is an approach that allows the implementation of predictive controllers either on extremely limited computational hardware, or at speeds many orders of magnitude beyond what could be achieved in the past, opening up a wide range of new application areas to predictive control. This tutorial session will, through a series of six talks by leading academic and industrial researchers, provide an overview of recent developments within the explicit MPC community. Attendees will receive an introduction to both the theory and the practice of the most influential current methods for implementing explicit MPC controllers in low-cost, embedded hardware. The speakers will also provide an overview of publically, and freely available toolboxes that can implement these methods, leaving the audience not just with an understanding of the strengths and weakness of current approaches, but also with the tools to implement them on their own problems. The session consists of five talks, with the first two providing an overview of current theoretical drives in the area - low-complexity approximation of explicit controllers, the third introducing new computational tools for the design and deployment of explicit MPC and the last two giving insight on the efficacy and desired research directions from the perspective of applications engineers.

Session Structure:

14:00-14:20: Explicit Model Predictive Control: Basics, Fast Implementations, Advantages and Limitations, Alberto Bemporad (IMT Institute for Advanced Studies Lucca)

14:20-14:40: General Purpose Computational Tool for Explicit MPC: MPT3.0, Martin Herceg (ETH)

14:40-15:00: Complexity Reduction in Explicit MPC: From Theory to Implementation, Michal Kvasnica (Slovak University of Technology in Bratislava)

15:00-15:20: Approximate nonlinear explicit MPC based on reachability analysis, Davide Raimondo (University of Pavia), Martin Mönningmann (Ruhr-Universität Bochum)

15:20-15:40: High-speed high-performance model predictive control of power electronics systems, Sébastien Mariéthoz (ETH)

15:40-16:00: Explicit MPC Applications in the Mechatronics Industry: Technology Transfer Potential and Current Limitations, Stefano Di Cairano (Mitsubishi Electric Research Laboratories)

Title: Distributionally robust optimization

Organizers: Daniel Kuhn (Imperial College London), Karthik Natarajan (Singapore University of Technology and Design)

Time and Location: Wednesday, July 17, 2013, 16:20-18:20 (Room F1)

Abstract: The mainstream approach to modeling uncertainty that is adopted in almost all of the existing literature on stochastic (dynamic) programming is to assume that all uncertain problem parameters are governed by a known probability distribution. This stochastic approach has several shortcomings. Firstly, probability distributions must be estimated from observed data and are therefore affected by estimation errors. Hence, they are themselves uncertain. Even worse, estimation errors in input parameters of optimization problems are amplified and lead to biased (overly optimistic) optimization results. Moreover, the evaluation of expected values, quantiles and other probability functionals that often appear in stochastic optimization problems generally require a discretization of the underlying distribution. Commonly used discretization schemes suffer from slow convergence rates and easily render optimization problems intractable if many discretization points are included. In this tutorial we employ a new modeling paradigm that has emerged in modern robust optimization and that describes the uncertain parameters through uncertainty sets (ranges of possible values) or families of probability distributions with prescribed properties (e.g. generalized moments). This robust approach enables modelers to incorporate information about estimation errors into optimization problems and therefore results in a more realistic account of uncertainty. By optimizing in view of the worst-case realization within the given uncertainty set (or the worst-case distribution within the given family), one can mitigate the undesirable bias in the optimization results characteristic for stochastic uncertainty models. Maybe surprisingly, the resulting (distributionally) robust optimization problems can often be solved exactly and in polynomial time, in marked contrast to the intractable approximate models obtained via discretization of stochastic models. The tutorial is divided into two parts. The first part of the tutorial deals with distributionally robust models in convex optimization and the second part deals with discrete optimization.

Session Structure:

16:20-17:20: Distributionally Robust Convex Optimization, Daniel Kuhn (Imperial College London)

17:20-18:20: Distributionally Robust Discrete Optimization, Karthik Natarajan (Singapore University of Technology and Design)

Title: Control of electrical energy systems

Organizer: Ian Hiskens (University of Michigan)

Time and Location: Thursday, July 18, 2013, 09:20-11:20 (Room F1)

Abstract: The tutorial will provide an introduction to control applications within electrical energy systems. An overview of existing power system control strategies will initially be provided. This will consider both frequency and voltage regulation. The impact of new technologies, including renewable generation, non-disruptive load control and storage, will be discussed. Also, a shift from preventative to corrective control will be considered. The second section of the tutorial will consider energy supply systems that exhibit tight coupling between multiple energy carriers such as electricity, natural gas and heat. Energy hub concepts will be introduced as a framework for systematically describing interconnections between energy carriers. Applications of energy hub networks will be explored, including optimal scheduling of multiple energy resources, and the development of control strategies that prevent failures from cascading across infrastructure boundaries. The third section of the tutorial will provide an overview of load control strategies. Load control enhances the responsiveness of power systems, enabling applications that range from load shifting to tracking the variable output of renewable generation. Coordinated control of large numbers of highly dispersed and diverse loads will be discussed. Technical challenges will be considered, and a variety of applications considered.

Session Structure:

09:20-10:00: Overview of Power System Controls, Ian Hiskens (University of Michigan)

10:00-10:40: Energy Hub Concepts and Controls, Goran Andersson (ETH)

10:40-11:20: Demand Response Strategies for Enhanced Control of Power Systems, Duncan Callaway (UC Berkeley)

Title: Partial control of agents on networks and applications to rerouting a subset of drivers on freeways

Organizers: Alexandre Bayen (UC Berkeley) and Jack Reilly (UC Berkeley)

Time and Location: Thursday, July 18, 2013, 13:40-15:40 (Room F1)

Abstract: As roadways in the world become increasingly congested and space to expand the network continues to diminish, efficient utilization of existing infrastructure becomes increasingly important. Intelligent coordination of drivers and the road network is a vital aspect of the effort. In this tutorial, we discuss how centralized control of both drivers and infrastructure leads to improvements in congestion levels and travel times for all drivers. We discuss the inherent inefficiencies of selfish drivers and how route coordination of a subset of drivers via direct driver communication can alleviate the inefficiencies. The problem is presented in the game-theoretic framework of Stackelberg games on a network with static flow models inspired by freeway networks. The tutorial also covers the topic of coordinated metering of onramp traffic lights to improve freeway travel times. We discuss how prediction of future travel patterns can be utilized in a finite-horizon optimal control scheme and present a novel ramp metering algorithm, which employs the adjoint method to efficiently compute gradients for descent-based optimization algorithms. We conclude with a presentation of a model for the partial rerouting problem for realistic freeway networks that also makes use of the adjoint method.

Session Structure:

13:40-14:40: Nash equilibria and Stackelberg games on horizontal queueing networks, Jack Reilly (UC Berkeley)

14:40-15:40: Adjoint-based optimization of PDE systems on networks with applications to ramp metering and partial rerouting, Alexandre M. Bayen (UC Berkeley).

Title: Cyber-secure control

Organizers: Henrik Sandberg (KTH) and Bruno Sinopoli (Carnegie Mellon University)

Time and Location: Thursday, July 18, 2013, 16:00-18:00 (Room F1)

Abstract: The objective of this tutorial session is to give an overview of the current state of art in the increasingly important area of cyber security in networked control systems. The first half of the session is devoted to give an introduction to available theoretical tools in secure control. The second half is devoted to introduce various applications in power network control systems, but also to give an industrial perspective

on the area from one of the leading computer and network security companies.

Session Structure:

16:00-16:40: Theory for Secure Control Systems, Bruno Sinopoli, (Carnegie Mellon University)

16:40-17:00: Game Theory for Secure Control, Cedric Langbort (UIUC)

17:00-17:40: Secure Control and Applications in Power Systems, Henrik Sandberg (KTH)

17:40-18:00: Air-gap to always-connected: an industry perspective on security for control systems, Robert Griffin (RSA Security).

Title: Systems and synthetic biology: case studies and computational challenges

Organizer: Heinz Koepl (ETH)

Time and Location: Friday, July 19, 2013, 09:20-11:20 (Room F1)

Abstract: Tutorial abstract: With recent advances of measurement technology in molecular biology more and more quantitative and multivariate data about cellular processes become available. This invites the computational modeling of such processes in order to rationalize the measured data and to predict new behavior. On the other hand, novel molecular methods to manipulate a given cell were further developed and the design of new functionality through the integration of novel genetic constructs into a host cell becomes routine. Synthetic biology emphasizes the rational forward engineering of novel functionality through the composition of small well-characterized genetic parts. This approach resembles the design process of man-made complex systems, for which a rich computational toolset have been developed over the years. Corresponding methods in synthetic biology are still in their infancy. The aim of this tutorial is to provide to control engineers an introduction to systems and synthetic biology and to point out the current computational challenges in the modeling and forward design of bio-molecular circuits.

Session Structure:

09:20-10:00: Tutorial on Synthetic Biology, Yaakov Benenson (ETH)

10:00-10:40: Applied Modeling and Theory for Stochastic Descriptions of Biochemical Networks, Mustafa Khammash (ETH)

10:40-11:20: Differential Equation Models in Systems and Synthetic Biology, Gheorghe Craciun (University of Wisconsin-Madison)