IP0

W. T. and Idalia Reid Prize in Mathematics Lecture: Analysis and Control of Coupled PDE Systems Arising in Fluid - Structure and Gas Flow - Structure Interactions

Interactive systems comprising nonlinear dynamics which evolve in two media and are coupled at their interface arise in a variety of applications. These include utter control and suppression in aeroelasticity in both subsonic and supersonic regimes; noise reduction in an acoustic chamber; control of oscillations in fluid-structure interaction, etc. The benchmark models describing the dynamics of these complex systems consist of coupled PDE equations, possibly of different type, say parabolic versus hyperbolic. Coupling takes place at the interface separating the two media. One challenge is then to place a controller localized at such interface for the purpose of achieving a desired performance of the overall coupled system. This leads to interesting mathematical questions such as the analysis of short and long time behavior of the underlying PDE's and their interaction via interface. This lecture will present several new developments in this area and will also underscore open questions.

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IP1

Infinite-dimensional port-Hamilton Systems

Modeling of dynamical systems with a spatial component leads to lumped parameter systems, when the spatial component may be denied, and to distributed parameter systems otherwise. The mathematical model of distributed parameter systems will be a partial differential equation. Examples of dynamical systems with a spatial component are, among others, temperature distribution of metal slabs or plates, and the vibration of aircraft wings. In this talk we will study distributed parameter port-Hamiltonian systems. This class contains the above mentioned examples. The norm of such a system is given by the energy (Hamiltonian) of the system. This fact enables us to show relatively easy the existence and stability of solutions. Further, it is possible to determine which boundary variables are suitable as inputs and outputs, and how the system can be stabilized via the boundary.

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IP2

Coarse-graining the Dynamics of Complex Systems

In current modeling practice for complex systems, including agent-based and network-based simulations, the best available descriptions of a system often come at a fine level (atomistic, stochastic, individual-based) while the questions asked and the tasks required by the modeler (parametric analysis, optimization, control) are at a much coarser, averaged, macroscopic level. Traditional modeling approaches start by deriving macroscopic evolution equations from the microscopic models. I will review a mathematically inspired, systems-based computational enabling technology that allows the modeler to perform macroscopic tasks acting on the microscopic models directly in an input-output mode. This equation-free approach circumvents the step of obtaining accurate macroscopic descriptions. I will discuss applications of this approach and its linking with recent developments in data mining algorithms, exploring large complex data sets to find good "reduction coordinates".

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IP3

Change Changes Things - The Many Facets of Internet Dynamism

The general appeal of abstracting real-world networks to simple static graphs is understandable and has been partly responsible for fueling the new field of "network science." However, as applications to domains like the Internet have demonstrated, such abstractions that ignore much of what engineers consider critical come at a price – even as toy models, they fail miserably when trying to capture, explain, or predict fundamental aspects real-world network behavior. Fortunately, the Internet application also suggests an alternative and more engineering-based approach to the "art" of abstracting real-world networks. This approach emphasizes the critical role of network dynamism and focuses squarely on understanding the cause-effect relationship between network structure (i.e., connectivity) and network function (i.e., usage). I will use specific Internet-related examples to illustrate this approach and discuss its implications on aspects such as measurement, network inference, and network modeling and model validation.

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IP4

Control of Linear Stochastic Systems Revisited

The optimal control of a linear stochastic system driven by a Brownian motion with a quadratic cost functional is well known to have a linear feedback control that is identical to the optimal control for the associated deterministic control problem. In this talk the optimal control of a linear system driven by other Gaussian processes, such as an arbitrary fractional Brownian motion, or by non-Gaussian square integrable processes is described. It is shown in these cases that the optimal control is a sum of the well known linear feedback control and the prediction of the response of a system to the future noise. Some other related control problems are also described.

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IP5

Control and Numerics: Continuous Versus Discrete Approaches

Control Theory and Numerical Analysis are two disciplines that need to be combined when facing most relevant applications. This is particularly the case for problems involving Partial Differential Equation (PDE) modelling. There are two possible approaches. The continuous one, consisting on developing the control theory at the PDE level and, once controls are fully characterized, to implement the numerical approximation procedure. And the discrete one, consisting in doing the reverse, i. e. first discretizing the model and then controlling the resulting discrete system. In this lecture we shall compare these two approaches in two relevant examples: The control of vibrations and the control of flows in the presence of shocks. As we shall see, a number of unexpected phenomena occur and challenging problems arise both from a mathematical and applicational viewpoint.

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IP6

Geometry, Optimization and Control in Robot Coordination

Motion coordination is an extraordinary phenomenon in biological systems and a powerful tool in man-made systems; although individual agents have no global system knowledge, complex behaviors emerge from local interactions. This talks focuses on robotic networks, that is, group of robots that communicate and coordinate their motions to perform useful tasks. I will review some recent adaptive and distributed algorithms based on concepts from queuing and stochastic analysis, geometric optimization, and nonlinear stability theory.

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CP1

Risk-Sensitive Control Under a Markov Modulated Denial-of-Service Attack Model

In this talk, we consider the problem of risk-sensitive stochastic control under a Markov modulated Denial-of-Service (DoS) attack strategy in which the attacker, using a hidden Markov process model, stochastically jams the control packets in the system. For a discrete-time partially observed stochastic system with an exponential running cost, we provide a solution in terms of the finite-dimensional dynamics of the system through a chain of measure transformation techniques which surprisingly satisfies a separation principle, i.e., the recursive optimal control policy together with a suitably defined information state constitutes an equivalent fully observable stochastic control problem. Moreover, on the transformed measure space, the solution to the optimal control problem appears as if it depends on the average path of the DoS attacks in the system.

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CP1

On A Stochastic Reach-Avoid Problem and Set Characterization

We develop a new framework for formulating a class of stochastic reachability problems with state constraints as a stochastic optimal control problem. Previous approaches to solving these problems are either confined to the deterministic setting or address almost-sure stochastic notions. We propose a new methodology to extend the almost-sure notions to a less stringent probabilistic requirement in the stochastic setting. To this end, we first establish a connection between a stochastic reach-avoid problem and a class of different stochastic optimal control problems with discontinuous payoff functions. We then derive a weak version of dynamic programming principle (DPP) for the value function. Moreover, based on our DPP, we give an alternate characterization of the value function as the solution to a partial differential equation in the sense of discontinuous viscosity solutions. Finally we validate the performance of the proposed framework on Zermelo navigation problem in a stochastic setup.

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CP1

Pathwise Convergence Rate for Numerical Solutions of Stochastic Differential Equations and Applications

Devoted to numerical solutions of stochastic differential equations (SDEs), this work constructs a sequence of re-embedded numerical solutions having the same distribution as that of the original SDE in a new probability space. It is shown that the re-embedded numerical solutions converge pathwise strongly to the solution of the SDE. Different from the well-known results in numerical solutions of SDEs, in lieu of the usually employed Brownian motion increments in the algorithm, an easily implementable sequence of independent and identically distributed random variables is used. Applications in stochastic optimal control are also considered

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CP1

A Continuum Mean Field Stochastic Control Approach to the Consensus Problem

In this paper we synthesize consensus behaviour as a stochastic dynamic game problem. In this formulation in a finite population system: (i) each agent has a simple stochastic dynamics with inputs directly controlling its state's rate of change, and (ii) each agent seeks to minimize its individual cost function containing a mean field coupling to the states of all other agents. A continuum approach is taken to this problem via Mean Field (MF) stochastic control theory. Based on this methodology, we synthesize a set of MF decentralized ϵ_N-Nash equilibrium strategies for a system with population size N. These control strategies drive each agent to track the overall population's initial state distribution mean which is reached asymptotically as time goes to infinity. Hence, a finite population system reaches mean-consensus on the overall population's initial state distribution mean.

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CP1

Multi-Resolution Risk-Sensitive Large Population Differential Games with Application to Smart Grid Power Markets

We propose a large population differential game-theoretic approach to analyze the behavior of agents in a smart grid power market. The framework separates the agents into a finite number of groups by resolutions, where interactions among groups are taken to be weak and within each group strong. Further, risk-sensitive nature of the decision making by the agents is taken into account. We characterize, in a homogeneous population, the mean-field Nash equilibrium of the users and the resulting energy storage distribution with a set of coupled PDEs. We study two particular differential games of different levels of resolutions. In both cases, we study the effects of the risk factor and the demand volatility on the smart grid power market. In addition, we show how the weak coupling among the zones affects the power demand of the users and illustrate these effects with numerical examples.

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CP2

Optimal Portfolio and Consumption Subject to Economic Factors

In this talk we examine a portfolio which includes a bond and N stocks which are subjected to M economic factors. We formulate a wealth equation to include instantaneous fraction of wealth invested in the bond and the N stocks and aim to optimize the power utility of the terminal wealth and instantaneous consumption. The results are illustrated by optimizing a portfolio with one bond and one stock which are influenced by one economic factor, namely the gross domestic product.

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CP2

Analyzing and Forecasting Volatility Using Wavelets and Nolinear Time Series Analysis

Use MRA wavelets and denoising techniques, we show ways of analyzing and forecasting stock and commodity volatility. Our analysis show the significant importance of longer term players in understanding volatility vs short term market participants. Using denoising and other nonlienar time series techniques, we show how it is possible to forecast various volatility periods out 3 weeks

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CP2

The Use of MOEAs in Portfolio Construction

Using multiobjective evolutionary algorithms, we show how to construct portfolios of stocks that are mean-variance efficent, exhibit the optimal geometric mean, have a high information ratio and either equal or outperform their benchmarks. Our work was done in the context of a set of constraints that included turnover limits, cardinality (portfolio size), upper and lower limits on stock purchases and limits on market capitalization and style (growth or value). We demonstrate how effective MOEAs can be in dealing with constraints that are non-convex and how those results can be used in a mean-variance framework.

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CP2

Markowitz and Mean-Variance-Skewness-Kurtosis Portfolio Optimization

Since the initial work of Markowitz and subsequent development of portfolio optimization analysis, analytical techniques aimed at addressing complexities associated with higher order moments, particularly, the third and fourth moments of return, i.e., skewness and kurtosis, have been researched extensively. Although efforts to incorporate kurtosis into the portfolio optimization framework have existed for some time theoretically, specific analytical generalizations of the kurtosis calculation have appeared only recently. As a result, since it can be shown that risk averse investors exhibit a preference for higher odd-ordered moments and lower even-ordered moments, we utilize a fourth order Taylor expansion about the mean to identify a utility function, which we subsequently maximize, using first and second order optimality conditions, to identify an optimal portfolio incorporating return, variance, skewness, and kurtosis. This paper provides an empirical investigation into the four-moment optimization framework and affirms the notion that, with non-normal return distributions, higher-order moments can affect optimal portfolio construction.

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CP2

A Direct-Comparison Approach for Portfolio Optimization

We provide an alternative approach to the portfolio optimization problem as opposed to dynamic programming. By the direct comparison of any two policies, we obtain the difference formula for the long-run average growth rate of total wealth. By analyzing the structure of the difference formula, the optimality equation and the policy iteration algorithm for the optimal investment policy can be intuitively derived. The on-line implementation of the policy iteration algorithm is also discussed with numerical examples.

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CP2

Optimal Liquidation of Credit Derivatives in Incomplete Markets

In the incomplete credit derivative market, there may exist more than one equivalent martingale measures that yield different no-arbitrage prices. Under a general reduced-form pricing approach, we consider a defaultable bond holder who maximizes the spread between the prevailing market price and her model price by optimally timing the liquidation of bonds. Analytical characterization and numerical illustration of the liquidation strategy and delayed liquidation premium are provided when the default intensity follows CIR or OU processes.

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CP3

Feedback Control of Dissipative Pde Systems with Incomplete State Information

We address the stabilization of distributed-parameter-systems employing incomplete state measurements and our adaptive proper-orthogonal-decomposition (APOD) methodology. Initially, the incomplete measurements are reconstructed using a gappy-reconstruction procedure and are then utilized to derive and periodically update a reduced-order-model (ROM). The use of APOD methodology allows the development of accurate low-dimensional ROMs for controller synthesis thus resulting in a computationally-efficient alternative to using large-dimensional models with global validity. The methodology is illustrated on a representative distributed process.

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CP3

Some Recent Results on Controllability of Coupled Parabolic Systems: Towards a Kalman Condition

In the last ten years, the study of the controllability properties of coupled parabolic systems has had an increasing interest. It is well known that the controllability of the ordinary differential system $Y' = AY + Bu$ ($n, m \in \mathcal{N}$ with $n, m \geq 1$, $A \in \mathcal{L}(\mathcal{C}^{\setminus})$ and $B \in \mathcal{L}(\mathcal{C}^{\Updownarrow}; \mathcal{C}^{\setminus})$ are given) is equivalent to the Kalman rank condition

$$rank[A \,|\, B] = rank[A^{n-1}B \,|\, A^{n-2}B \,|\, \cdots \,|\, B] = n. \quad (1)$$

In this talk we will present some recent results on controllability of coupled parabolic systems when the control is exerted in a part of the domain (distributed control) or on a part of the boundary of the domain (boundary control). In both cases, we will give a generalization of the algebraic condition (1) which characterizes the controllability properties of a class of parabolic systems. As a consequence of the previous result, we will also see that the distributed and boundary controllability properties of coupled parabolic systems are, in general, not equivalent.

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CP3

Parallel Numerical Solution for Optimal Control of Reaction-Diffusion Equations in Cardiac Electrophysiology

The motivation of this work is on the development and implementation of an efficient numerical techniques to solve an optimal control problem related to a reaction-diffusions system arising in cardiac electrophysiology. A Newton-type method for the monodomain model is developed. We demonstrate the numerical results based on the receding-horizon technique which will be employed to terminate the re-entrant excitations of the transmembrane voltage successfully. Parallelizing such techniques are the primary interest for this presentation.

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CP3

Exact Controllability of a Rayleigh Beam with a Single Boundary Control

Exact controllability is proved for the Rayleigh beam equation $\varphi_{tt} - \alpha\varphi_{ttxx} + A\varphi_{xxxx} = 0$ with a single boundary control active at one end of the beam. We consider all combinations of clamped and hinged boundary conditions with the control applied to either the moment $\varphi_{xx}(l, t)$ or the rotation angle $\varphi_x(l, t)$ at an end of the beam. In each case, exact controllability is obtained on the space of op-

timal regularity for $L^2(0,T)$ controls for $T > 2l\sqrt{\frac{\alpha}{A}}$. Corresponding uniqueness and exact observability results are also obtained for the dual observed system.

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CP3

Experimental Design for Time Dependent Advection-Diffusion-Reaction Problems

Optimal Experimental Design is the task of finding an experiment that behaves best in the sense of reducing uncertainties in the parameters that are to be estimated from it. With Proper Orthogonal Decomposition (POD) one tries to reduce the large dimension of the discretized PDE to get a low dimensional model that can be used in the optimization problem. We want to discuss the limits of the common POD approaches and present improvements by including derivative information into the Reduced Order Model.

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CP3

Estimation and Boundary Control of Finite Dimension for the Navier-Stokes Equations

We study the stabilization, around a stationary solution, of the two-dimensional Navier-Stokes equations in the case of partial observation. First, we construct an approximate solution of the Navier-Stokes equations thanks to this observation. Then, we stabilize locally the Navier-Stokes equations with a boundary feedback control of finite dimension. The approximate solution is used in the feedback law and a coupled system has to be studied.

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CP4

A Predictive Control Approach for Microscopic Processes

The problem of model based control of a microscopic process is investigated. The unavailability of closed-form models and ill-defined process variables are addressed by coupling atomistic realizations with fuzzy system identification. Nonlinear model predictive Controllers are then synthesized to drive the expected behavior of the microscopic process thus achieving an optimal control strategy. The proposed methodology is applied to a Kinetic Monte Carlo (KMC) realization of an industrial thin film deposition process.

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CP4

Strategically Arriving Users into Queueing Systems

Single server queueing systems have been studied extensively under the assumption of renewal inter-arrival and service processes. But in many systems, arriving users choose their time of arrival strategically to minimize delay and other metrics. We consider arrivals into a single-server, single-class queueing system. Under such an assumption, we characterize the equilibrium arrival process in the fluid and diffusion limit. We also characterize the loss in social welfare due to strategically arriving users.

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CP4

Optimal Control in a Dengue Epidemic

The incidence of dengue has grown up in recent decades all over the world. We present an epidemiological model of the host-vector, consisting in a system of ordinary differential equations. Using insecticide and mechanical control, which are currently the available controlling mechanisms to prevent dengue transmission, it is studied the optimal way to apply them, with the aim of reducing simultaneously the number of infected individuals and disease's costs.

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CP4

Approximation of Riccati Operators Based on Diffusive Realization and Its Application to a Filtering

Problem for a Cantilever Array

We present a method dedicated to real-time realization of linear operators solution to Operator Riccati Equations related to large distributed systems. The approximation is based on a combination of a Galerkin-type approximation and the Diffusive Operator Representation. It is applied to an H_∞ filtering problem for an array of cantilevers with interferometry displacement measurement. The computation is implemented on a Field Programmable Gate Array (FPGA).

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CP5
Parameters Estimations of Diffusion Model in An Inhomogeneous Landscape

The mechanism of variation of insect dynamics within an inhomogeneous landscape remains poorly understood. We present an analytical approach: quantifying the insect dispersal model by estimating parameters with Matlab. This paper is concerned with parameter estimations of a diffusion model on two-dimensional domains with rectangular boundaries, which describes the population dynamics of insects traveling within an inhomogeneous landscape. The measurement mean occupancy time is introduced to translate field-collected data on insect movement into quantitative measures.

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CP5
On Many Person Differential Games

A particular type of differential game is introduced, that represents a situation where players change their coalitions. The times of change appear in payoff as parameters. This game is assumed solved. Then a set of similar games is introduced that represents all possible cases of coalition changes. Thus one obtains a set of payoffs. On that set one can introduce any of the known concepts of cooperative game solutions. Simple mathematical examples are presented.

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CP5
Optimal Control of Two-Body Problem: Fixed Final Time Low Thrust Orbital Transfer Around the Earth

Consider a two-body problem Earth-spacecraft. Optimal control is used to compute fixed final time low thrust minimum fuel consumption orbital transfer (minimization of the L^1-norm of the control). The problem is connected to L^2-minimization by differential homotopy. A strategy based on transfers with fixed number of revolutions is given to deal with the many local minima and then compute the optimal solution.

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CP5
Ergodic Semistability Versus Ergodic Agreement

In this research, we develop ergodic semistability theory for both deterministic and probabilistic dynamical systems having a continuum of equilibria. The motivation of this study comes from the development of weaker notion of the stability for deterministic systems and stochastic convergence of random systems. We use ergodic theory and the stochastic analysis tools to present a unified framework for ergodic semistability theory and its Lyapunov analysis approaches to nonlinear dynamical systems. Then we apply the proposed framework to address ergodic agreement problems in multi-agent networks. Finally, we discuss ergodic equipartition for nonlinear dynamical systems which is analogous to the notion of asymptotic equipartition property in Information Theory. This leads to developing the notions of entropy and ectropy for nonlinear dynamical systems borrowed from system thermodynamics.

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CP5
Null Controllability of a Fluid-Structure System

We prove the null controllability of a fluid-structure interaction problem with a distributed control inside the fluid domain. The fluid occupies a bounded domain in dimension 2. A part of the boundary of this domain can move and is modeled by a beam. The system describing this situation is coupled by the force exerted by the fluid on the beam and by the equality of the velocities at the common interface.

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CP5

An Optimization Approach to Bounding the Price Anarchy for Network Games

We present two integer programs (IP's) whose solutions yield graphs with a degree sequence, that is closest to a given degree sequence, in (1) the Manhattan metric and (2) the Earth Mover's metric. Solutions maybe non-unique, providing a way to explore graphs whose degree sequence is close to a (non-)graphical sequence. We relate graphical solutions of this IP to stable collaboration networks via the price of anarchy for which we provide a bound.

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CP6

Adaptive Control System for Smart Homes through Artificial Neural Network

The paper proposes an adaptive smart home system for optimal utilization of power, through Artificial Neural Networks (ANN). The system proposed comprises of Recurrent Neural Network [Jeffrey L. Elman, Finding Structure in Time, Cognitive Science, 1990] to capture Human behavior patterns and Feed Forward Architecture in ANN for security applications in the smart homes. The technique is used to minimize power wastage by learning and adapting to the consumption behavior patterns of the consumers.

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CP6

Multi-Agent Reinforcement Learning-Based Adaptive Traffic Signal Control

This paper presents a novel, distributed multi-agent reinforcement learning-based system that provides adaptive coordinated signal control to minimize the experienced vehicle delay in the transportation network. In the proposed architecture, each intersection (agent) is a player in a stochastic game with each of its adjacent agents. The system is tested on a network in Downtown Toronto using microscopic traffic simulator. The results show about 40% saving in the delay compared to the pre-timed control.

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CP6

Direct Adaptive Control Using Recurrent Artificial Neural Networks

Often times control systems are designed based on simplified linear models of the actual dynamical system. While this is appropriate under most circumstances, designs based on these simplified models tend to lack the robustness that is required if the system's dynamics are not well known. To compensate for these shortcomings, an adaptive control law based on recurrent artificial neural networks is proposed and compared with conventional as well as adaptive radial basis function controller designs.

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CP7

Lti Matrix Systems of Arbitrary Order and the Matrix Impulse Response

LTI systems of arbitrary order are discussed with a matrix basis generated by a fundamental matrix response. We have a variation of constants formula, an extension of the Cayley-Hamilton theorem for several matrices and conditions for controllability and observability of higher-order systems. The eigenanalysis of a controllable system is done through the Krylov method. A stability test is obtained by involving the fundamental matrix response in closed form and the generalized Lucas polynomials.

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CP7

Deterministic Impulse Control Problems: Discrete Approximations of the Quasi-Variational Inequality

In this work, we give some discrete approximations of the quasi-variational inequality related to a general deterministic impulse control problem, in term of the form and the cost of jumps. We show that the approximate function in the discrete quasi-variational inequality converges to a viscosity solution of the quasi-variational inequality associated to the impulse control problem. This result is very important and powerful provided that the value function of the impulse control problem is the unique viscosity solution of the related quasi-variational inequality. We give instances of such result.

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CP7

Discrete Concepts in the Boundary Control of Hyperbolic Systems

Relaxation schemes are well-known and easy to implement discretization schemes for systems of conservation or balance laws. Hereby, the original (nonlinear) system of balance laws is replaced by a linear system of double size,

called the relaxation system. Using asymptotic analysis it can be shown that the relaxation system is well-posed if the new system matrix satisfies the so-called subcharacteristic condition. Under this assumption a solution to the relaxation system is known to converge to a solution of the original system. Furthermore, using IMEX-schemes for the time integration of the numerical scheme, it can be shown that the discretized relaxation system converges to a discretization of the limit equations. To provide consistent schemes for optimal control, we derive conditions such that the discrete adjoint of the relaxation system is a valid discretization of the continuous adjoint relaxation system in the context of smooth solutions. Furthermore, we prove that the discretization of the adjoint relaxation system converges to a discretization of the adjoint limit equation. This discretization then turns out to be the adjoint of the discretized limit equation.

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CP7

The Null Space Property for Sparse Recovery from Multiple Measurement Vectors

This is a joint work with Prof. Ming-Jun Lai. We prove a null space property for the uniqueness of the sparse solution vectors recovered from a minimization in ℓ_p quasi-norm subject to multiple systems of linear equations, where $p \in (0, 1]$. Furthermore, we show that the null space property is equivalent to the null space property for the standard ℓ_p minimization subject to a single linear system. This answers the questions raised in [Foucart and Gribonval'09]. Finally we explain that when the restricted isometry constant $\delta_{2s+1} < 1$, then the ℓ_p minimization will find the s-sparse solution if $p > 0$ is small enough.

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CP7

Numerical Procedure for Optimal Control of Higher Index Daes

The presentation deals with optimal control problems described by higher index DAEs. We introduce a numerical procedure for solving these problems. The procedure, based on the appropriately defined adjoint equations, refers to an implicit Runge-Kutta method for differential-algebraic equations. Assuming that higher index DAEs can be solved numerically the gradients of functionals defining the control problem are evaluated with the help of well-defined adjoint equations. We present numerical examples related to index three DAEs showing the validity of the proposed approach.

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CP7

A Differential-Equation-Free Numerical Algorithm to Stabilize Nonlinear Systems

A numerical method is presented that achieves asymptotic stability without requiring the full knowledge of its underlying deferential equations. In this cascade iterative control design, each step consists of estimating and then desensitizing the input vector field associated with the current iteration. The control is obtained by tracking a desired value along the input vector field at each step. This algorithm provides tuning parameters that can be used to shape the domain of attraction.

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CP8

Dynamics Analysis of a Drillstring Model

We study the qualitative properties of a rotary drilling dynamical system. We build an improved model including axial and torsional wave equations for both the drillstring and the borehole assembly together with realistic boundary conditions. This model is then investigated qualitatively as a nonlinear neutral delay system, using the center manifold theorem and normal forms theory.

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CP8

Modeling, Optimization, Model Validation, and Control of Atomic Force Microscope Arrays

We present theoretical, numerical and experimental results about Atomic Force Microscope arrays: a multi-scale model in elastodynamics, its experimental validation, a tool for parameter optimization, and a robust H_∞ controller for contact mode operation. We show that real-time control can be achieved thanks to an approximation theory based on functional calculus and the Cauchy integral formula implemented by distributed electronic circuits.

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CP8

Optimal Control Applied to a Mathematical Model of HIV/TB Co-infection

We apply optimal control theory to a system of nonlinear ordinary differential equations modeling interactions between HIV and TB at the population level. To reduce the latent and infectious individuals with HIV and/or TB, we use two controls, one for TB treatment, and the other represents the eort of an educational campaign which is oriented to decrease the infection rate of HIV by stimulating susceptible individuals to have a preventive behavior.

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CP9

Hjb Equations for Optimal Control Problems with Delay in the Control

The aim of the talk is to introduce some (possibly stochastic) control problems with delay in the control variable with applications in Economis and Finance and to study the regularity properties of viscosity solutions of the associated HJB equations. More precisely we are interested in the optimal control od systems in the form:

$$dx(t) = [ax(t) + b_0u(t) + \int_{-d}^{0} b_1(\xi)u(t+\xi)d\xi]dt + \sigma dw(t),$$

where x is the state variable and u the control variable. We embed the control problem in a suitable infinite dimensional space and prove a directional regularity result for the value function of problem approaching the HJB equation in a viscosity sense.

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CP9

Feedback Stabilisation of Swirling Flow

We summarize the equations governing the swirling flow of an incompressible inviscid fluid in a pipe of finite length and give an analysis of a feedback control mechanism that leads to stability of the flow. The analysis is "preliminary' in the sense that we develop an approximate system and investigate the stabilization of the approximate system. An interesting feature of the approximate system is that it involves a PDE similar to the KdV equation.

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CP9

Input-to-State Stability Analysis for Time-Varying Systems with Delays

We consider several stability properties in the framework of input-to-state stability for time-varying systems with delays. We follow a natural approach to convert the time-varying system to an auxiliary time-invariant system (of higher dimension) whose output variables are the state variables of the original system. By establishing equivalences between stability properties on the time-varying and the auxiliary time-invariant system, we extend our previous small-gain results for time-invariant systems with delays to the time-varying context.

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CP9

Impulsive Stabilization of Lorenz Systems and Applications

This paper studies impulsive synchronization of two Lorenz systems. Impulsive stabilization results for Lorenz systems are obtained and applied to establish stable impulsive synchronization schemes by employing the Lyapunov-Razumikhin method. Simulation results are also given to illustrate our results.

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CP10

Large Deviations for Two-Time-Scale Markovian Systems and Associated Optimal Control Problems

In this talk we develop large deviations principles for systems driven by continuous-time Markov chains with two-time scales and related optimal control problems. The use of two-time-scale formulation stems from the effort of reducing computational complexity in a wide variety of applications in control, optimization, and systems theory. First, we start with a rapidly fluctuating Markovian system, and then derive large deviations upper and lower bounds for a fixed terminal time under irreducibility conditions. Furthermore, we also establish large deviations principle for time-varying dynamic systems. Finally, we apply the results to the controlled dynamic systems.

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CP10

Thermo-Inspired Semistabilization for Control Systems

Thermodynamics is a physical branch of science that governs the thermal behavior of dynamical systems. The laws of thermodynamics involving conservation of energy and nonconservation of entropy are two of the most useful and general laws in all sciences. In particular, the second law of thermodynamics is intimately connected to the irreversibility of dynamical processes, that is, the status quo cannot be restored everywhere. This gives rise to an interesting quantity known as entropy. Entropy permeates the whole of nature, and unlike energy, which describes the state of a dynamical system, entropy is a measure of change in the status quo of a dynamical system. Motivated by this observation, in this paper we use the entropy function for deterministic systems as a benchmark to design a semistable controller that minimizes the time-averaging of the "heat" of the dynamical system. We present both state feedback control and output feedback control based on the dissipative systems. Furthermore, we convert the control design into an optimization problem with two linear matrix inequalities. An example is used to show the basic design idea and the feature of nonuniqueness of optimal solutions for semistabilization problems.

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CP10

Estimation with Active Sensing

We investigate a sensing system in which a Markov source is observed by a sensor that can communicate noiselessly to a receiver. However, each transmission consumes a fixed amount of power. To conserve energy, at any time instant the sensor may decide not to transmit or to causally encode its observations before transmission. The objective is to choose transmission and estimation policies to minimize a weighted sum of the average transmitted energy and the average distortion. We derive the structure of optimal transmission and estimation policies and use that to derive a dynamic programming decomposition of the system.

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CP10

Statistical Inference of Macroscopic Stochastic Processes from Multiscale Data

The statistical inference of stochastic processes from multiple scale data is a problem that arises often in practice. Yet there exists little understanding of the effects of data collected at different scales than the scale of interest. Using perturbation theory we formalize the problem of multiscale inference for continuous time Markov Processes. We give necessary and sufficient conditions for any consistent estimator to converge to an estimator of a stochastically continuous process. We argue that these conditions are restrictive in practice. We then suggest a way to perform statistical inference on multiscale data that yields consistent estimators that are asymptotically well behaved.

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CP11

Effective Perturbation Distributions for Small Samples in Simultaneous Perturbation Stochastic Approximation

Bernoulli (1,-1) distribution is typically used for perturbation vectors in simultaneous perturbation stochastic approximation and theory has been established to prove the asymptotic optimality of this distribution. However, optimality of the Bernoulli distribution may not retain for small-sample approximations. In this paper, we investigate the performance of segmented uniform distribution for the perturbation vector. For small-sample approximations, we show that the Bernoulli distribution may not be the best for a certain choice of parameters.

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CP11

Modified Bryson-Frazier Smoother Cross-Covariance

Expectation Maximization estimation, when used in conjunction with a Kalman Filter, uses a Rauch-Tung-Striebel Smoother, which requires the extrapolated state error covariance matrix be invertible in order to form the smoother gain to construct both the smoother covariance and smoother single time-step cross-covariance. I derive the modified Bryson-Frazier cross-covariance, which does not require this inversion, and substitute the modified Bryson-Frazier Smoother, allowing dynamics matrices estimation for which the Rauch-Tung-Striebel Smoother cannot be used.

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CP11

Maximum Likelihood Estimation of Linear Gaussian State-Space Models Using Simultaneous Perturbation Stochastic Approximation Method

An iterative method for estimating parameters of a linear Gaussian state-space model using maximum likelihood estimation is developed. The likelihood function at each iteration is evaluated using a Kalman filter. Maximization of

the likelihood function is achieved using the Simultaneous Perturbation Stochastic Approximation method to obtain improved parameter estimates. The most attractive feature of the proposed method is its ease of implementation since it does not require any analytical computations.

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CP11

Stochastic Approximation for Discrete Optimization of Noisy Loss Measurements

We consider the stochastic optimization of a noisy convex loss function defined on p-dimensional grid of points in Euclidean space. By introducing the middle point discrete simultaneous perturbation stochastic approximation (DSPSA) algorithm to this discrete space we show that convergence to the minimum is achieved. Consistent with other stochastic approximation methods, this method formally accommodates noisy measurements of the loss function.

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MS1

Idempotent Expansions for Continuous-time Stochastic Control: Algorithm and Some Error Analysis

Recently it is known that max-plus methods are useful for continuous-time deterministic control problems. One of the advantages is to give state-space-mesh-free numerical methods to Hamilton-Jacobi-Bellman partial differential equations (HJB PDEs) of deterministic controls. In this talk, we provide idempotent numerical methods for HJB PDEs of stochastic control problems by extending min-plus distributive property. To reduce the complexity of the approximated value functions appeared in the algorithm, we propose a projection of the approximated value onto a low-dimensional space. We will discuss what types of error analyses are required in the algorithm.

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MS1

A Convergence Result for a Zero-Sum Sotchastic Differential Game

In this talk we present a convergence result which is useful in the Theory of Stochastic Differential Games in -at least- three cases: the successive approximations method, the vanishing discount technique and the existence of bias and overtaking equilibria. Key in this context is the use the weak*-topology of L^∞ for the space of Markov Controls for this choice of totpology renders such space a compact metric space.

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MS1

Approximation Algorithms in a Class of Minimax Stochastic Systems Under a Randomized Discounted Criterion

We study stochastic control systems under a discounted optimality criterion with random discount rate. The discount process evolves according to a difference equation $\alpha_{t+1} = G(\alpha_t, \eta_t)$, where $\{\eta_t\}$ is a sequence of i.i.d. and nonobservable random variables with unknown distribution θ. The only information owning the controller about such distribution is that θ belongs to a suitable set Θ. Hence, the controller is interested in to select actions directed to minimize the maximum cost on the set of probability measures Θ. Our main objective is to introduce an approximation algorithm for the minimax value function such that it leads up to the construction of minimax policies.

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MS1

Numerical Methods for Continuous-time Controlled Markov Chains: Discounted and Average Criteria

We are concerned with continuous-time controlled Markov chains with denumerable state space and Borel action space. The transition rates of the system, as well as the reward rates, may be unbounded. We are interested in computing (or, at least, approximating) the optimal reward and policies of the discounted and the average reward optimality criteria. Since the dynamic programming equation for the denumerable state problem cannot be explicitly solved, we propose a finite state-and-action truncation technique to approximate the nonfinite control models. For some particular cases, explicit bounds on the approximation errors are given. Our theoretical results are illustrated with numerical approximations to a controlled birth-and-death process with catastrophes.

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MS2

Pontryagin Principles for Infinite-Horizon

Discrete-Time Problems

We consider discrete-time dynamical systems governed by difference equations or difference inequations. We also consider constraints. To establish Pontryagin principles, we proceed by using a reduction to the finite horizon. In finite-horizon problems we can use tools of the static optimization theory. Then we give methods to extend them to the infinite-horizon problems.

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MS2

Cheap Control Problem for Linear Stochastic Systems with State Delays

A finite-horizon quadratic cheap control of linear stochastic systems with state delays is considered. By using the control optimality conditions, the solution of this problem is reduced to solution of the singularly-perturbed boundary-value problem for the set of ordinary and partial differential equations with deviating arguments. An asymptotic solution of this problem is constructed. A suboptimal control in the original problem is designed. A limit behavior of the cost functional optimal value is studied.

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MS2

Explicit Solutions for Singular Calculus of Variational Problems with Infinite Horizon

We consider an optimal infinite horizon calculus of variations problem linear with respect to the velocities. In this framework the Euler-Lagrange equation are known to be algebraic and thus no informative for the general optimal solutions. We prove that the value of the objective along the MRAPs, the curves that connect as quickly as possible the solutions of the Euler-Lagrange equation, is Lipschitz continuous and satisfies an Hamilton-Jacobi equation in some generalised sense. We derive then a sufficient condition for a MRAP to be optimal by using some sign conditions on the function associated to the Euler-Lagrange equation.

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MS2

A Nonintersection Property for Extremals of Variational Problems

We show that if an extremal of an infinite horizon variational problem with vector-valued functions is not periodic, then the corresponding curve in the phase space does not intersect itself. An analog of this result was obtained in our previous work for variational problems with scalar valued functions. The proof of this analog was strongly based on the existence of good periodic functions. In our case the existence of good periodic functions is not guaranteed and the situation becomes more difficult and less understood.

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MS3

Semidiscrete Approximation for LQR Control of Damped Elastic Structures

Abstract not available at time of publication.

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MS3

Exact Boundary Controllability of a Multilayer Rao-Nakra Beam

The three-layer Rao-Nakra beam is a sandwich beam structure consisting of two stiff outer layers and a much more compliant inner core layer. The multilayer version consists of alternating stiff and compliant layers and is described by a Rayleigh type equation for the transverse motion coupled with n wave-type equations that describe the longitudinal motions in the stiff layers. We prove exact boundary controllability using one control for each equation under a variety of boundary conditions.

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MS3

Model Development for Nonlinear Macro Fiber Composite Actuators

Abstract not available at time of publication.

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MS3

Stabilization of a Flow-Structure Interaction-Subsonic Case

Nonlinear oscillations of an elastic structure interacting with a subsonic flow of gas are considered. The interaction takes place on the interface between the two media and it is expressed via boundary conditions involving potential acceleration and structural down-wash. This leads to the model of flow-structure interaction that comprises of a nonlinear plate equation coupled to a three dimensional perturbed wave equation. Existence and uniqueness of finite energy solutions will be presented. This is accomplished by constructing a special inner product space where the flow-structure problem is shown to generate nonlinear semigroup. Subsequently long time behavior of solutions

to the structure subjected to boundary damping will be analyzed. The results presented extend past obtained for more regular models only.

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MS4

Control of Stationary Cross Flow modes Using Patterned Roughness at Mach 3.5

Spanwise-periodic roughness designed to excite selected wave lengths of stationary cross-flow modes was investigated in a 3-D boundary layer at Mach 3.5. The test model was a sharp-tipped 14° right-circular cone. The model and integrated sensor traversing system were placed in the Mach 3.5 Supersonic Low Disturbance Tunnel (SLDT) equipped with a "quiet design" nozzle at NASA Langley RC. The model was oriented at a 4.2° angle of attack to produce a mean cross-flow velocity component in the boundary layer over the cone. Three removable cone tips have been investigated. One has a smooth surface that is used to document the baseline ("natural") conditions. The other two have minute (70μm) "dimples" that are equally spaced around the circumference, at a streamwise location that is just upstream of the linear stability neutral growth branch for cross flow modes. The azimuthal mode numbers of the dimpled tips were selected to either enhance the most amplified wave numbers, or to suppress the growth of the most amplified wave numbers. The results indicate that the stationary cross-flow modes were highly receptive to the patterned roughness. The patterned roughness that was designed to suppress the growth of the most amplified modes had an azimuthal wavelength that was 66% smaller than that of the most amplified stationary cross flow mode. This had the effect to increased the transition Reynolds number by 50%. This research is a precursor to the use of "plasma bumps" as a means of active cross-flow transition control. Its implementation will also be discussed.

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MS4

Aerodynamic Scaling of Active Flow Control: DNS, Windtunnel and Free-Flight Experiments

Abstract not available at time of publication.

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MS4

Nonlinear Filtering of Stochastic Navier Stokes Equation with Ito-Levy Noise

In this Talk, we will discuss the existence and uniqueness of the solution of stochastic Navier-Stokes equation with Ito-Levy noise. Then we will give a brief explanation about the solvability of the measure-valued solutions for the filtering equations (FKK and Zakai equations) associated with stochastic Navier-Stokes equation.

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MS4

Saturation of Estimates for the Maximum Enstrophy Growth in a Hydrodynamic System as an Optimal Control Problem

The global (in time) regularity of solutions of the 3D Navier-Stokes equation remains an open question. This regularity is controlled by the boundedness of the enstrophy $\mathcal{E}$. The best estimate for its rate of growth is $d\mathcal{E}/\lceil\sqcup \leq \mathcal{C}\mathcal{E}^{\ni}$, for $C > 0$, leading to the possibility of a finite–time blow–up when straightforward time–integration is used. We state the problem of saturation of finite–time estimates for the enstrophy growth as an optimal control problem for a PDE, and use the Burgers equation as a "toy model". This problem is solved numerically using an adjoint–based gradient descent method and it is found that the maximum enstrophy growth in finite time is in fact much weaker than predicted by the sharpest analytic estimates available to date.

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MS4

Enhancing Autonomy in Unmanned Systems for National Defense

In this talk we will discuss the theoretical opportunities posed by the requirement of increased autonomy in unmanned systems. Of particular interest are flow control problems, control problems in aero-elasticity, control problems for couple rigid body and viscous flow around the body, multiple moving and rotating bodies etc. The increased emphasis in unmanned systems has intensified the interest in flow control in particular. We will discuss some mathematical trends in this subject as well.

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MS5

Risk-sensitive Control, Ergodic Control and Large Deviation Control Applied to Optimal Investment

Problems of power utility maximization are sometimes studied in terms of risk-sensitive portfolio optimization as a kind of risk-sensitive control. While, risk-sensitive portfolio optimization could be regarded as a robust version of log utility maximization. By regarding in this way way we introduce another expression of the H-J-B equation of risk-sensitive portfolio optimization in which we consider a kind of stochastic differential game. The game is reduced to a stochastic control problem and we shall see its optimal diffusion process play a key role in proving the large deviation estimates for the probability minimizing down-side risk.

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MS5

Arbitrage-free Multifactor Term Structure Models:

A Theory Based on Stochastic Control

Based on the solution of a linear-quadratic stochastic control problem, we present an alternative approach to the pricing of bonds and bond derivatives in a multivariate linear-quadratic model for the term structure. It leads also to an approach that is an alternative to that of computing forward prices by forward measures. It furthermore allows to provide explicit formulas for the computation of bond options in a bivariate factor model. Extensions to the nonlinear case and to the stock market are possible.

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MS5

Long-term Risk-sensitive Portfolio Optimization with State Constraints

Long-term risk-sensitive portfolio optimization is studied with a generalized drawdown constraint and/or floor constraint. Because of the scale-invariant property of the long-term risk-sensitive criterion, very simple characterizations of optimal solutions can be obtained. Linear-Gaussian factor models and Wishart-autoregressive-type factor models are introduced with explicit representations of solutions.

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MS5

An Optimal Consumption Problem with Partial Information

We consider a finite time optimal consumption problem where an investor wants to maximize the expected HARA utility of consumption and terminal wealth. We treat a stochastic factor model that the means returns of risky assets depend linearly on underlying economic factors formulated as the solutions of linear stochastic differential equations. We consider the partial information case that an investor can not observe the factor process and uses only information of the risky assets. Our problem can be formulated as a stochastic control problem with partial observation. We derive the HJB equation. The equation can be solved to obtain an explicit form of the value function and an optimal strategy. This is different from the complete information case where to explicitly solve the HJB equation for the consumption problem in incomplete market is in general not possible.

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MS6

Drawdown and the Speed of Market Crash

The drawdown of an asset has widely been used as a measure of risk in financial risk management. A closely related measure is the speed of a market crash. This quantity measures the time elapsed between the last reset of the maximum preceding the drawdown and the time of the drawdown. We derive quantities related to the joint distribution of these random variables under diffusion dynamics and use them to price insurance against market crashes.

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MS6

Hope, Fear, and Aspiration

In this paper, we propose a new portfolio choice model in continuous time which features three key human incentives in choice-making: hope, fear and aspiration. By applying recently developed quantile formulation, we solve this model completely. Three quantitative indices: fear index, hope index and lottery-likeness index are proposed to study the impact of hope, fear and aspiration respectively on the investment behavior. We find that the extreme fear would prevent the agent from risking too much and consequently induces a portfolio insurance policy endogenously. On the other side, the hope will drive the agent aggressive, and the more hopeful he is, the more aggressive he will be. Finally, a high aspiration will lead to a lottery-like terminal payoff, indicating that the agent will risk much. The higher the aspiration is, the more risk the agent would or have to take. This is the joint work with Prof. Xunyu Zhou in Oxford and The Chinese University of Hong Kong.

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MS6

Optimal Investment Timing Under Price Discrepancy

We study the timing of derivative purchase and liquidation in incomplete markets. The investor attempts to maximize the spread between his/her model price and the prevailing market price through optimal timing. Both the investor and the market value the options by risk-neutral expectations but under different equivalent martingale measures representing different market views. The structure of the resulting optimal stopping problem depends on the interaction between the respective market prices of risks and the option payoff. A crucial role is played by the delayed purchase premium that is related to the stochastic bracket between the market price and the buyer's risk premia.

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MS6

Optimal Investment and Consumption in a Heston Model with Regime Switching

We consider a consumption and investment problem in a financial market where the stock prices have stochastic volatility and behave following market regimes. An investor decides on the optimal consumption-investment policy that maximizes her total discounted utility of consumption for a power utility function. We provide the verification theorem that solves the problem, and numerical results.

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MS7

Constrained L1 Adaptive Control with Applications to Aerospace Systems

We explore control theory for uncertain nonlinear systems with output constraints. Such systems naturally arise in many applications, such as the control of turbofan engines. We create an adaptive control framework that deals with time-varying nonlinear uncertainties, permits transient analysis, and satisfies output constraints. We use the framework to build an adaptive controller for turbofan engines that ensures safer and faster response while maintaining safety-critical constraints such as temperature, pressure and stall margins.

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MS7

L1 Adaptive Control Theory: Reducing Theory to Practice

We present an overview of L1 adaptive control theory. The main contribution of the theory is the decoupling of adaptation from robustness, which allows for arbitrary increase of the rate of adaptation. This is achieved by formulating the control objective with the understanding that the uncertainties in any feedback loop can be compensated within the bandwidth of the control channel. We conclude with an overview of flight test results on NASA's subscale commercial jet.

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MS7

Adaptive Tracking and Parameter Estimation for Nonlinear Systems with Unknown High Frequency Gains: A Case Study in Strictification

We explore adaptive control problems for nonlinear systems with unknown control gain parameters. We construct controllers that yield uniform global asymptotic tracking and parameter estimation, using a global strict Lyapunov function construction. We illustrate our work using a brushless DC motor turning a mechanical load. We use integral input-to-state stability to quantify the effects of time-varying uncertainties on the motor parameters. This work is joint with Frederic Mazenc and Marcio de Queiroz.

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MS7

Adaptive Feedforward Compensation of Harmonic Disturbances in Nonlinear Systems

We investigate the problem of adaptive feedforward compensation for SISO input-to-state (and locally exponentially) convergent nonlinear systems. Under a set assumptions reminiscent of the LTI literature, the proposed scheme achieves disturbance rejection of a harmonic disturbance at the input of a convergent nonlinear system, with a semi-global domain of convergence. The suitability of the proposed solution is demonstrated by combining results from averaging analysis with techniques for semi-global stabilization.

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MS8

Identifying the Plant and Feedback in Human Postural Control

To address how neural feedback control of human upright stance is related to properties of the plant, we performed joint input-output closed-loop system identification of the plant and feedback. Identified feedback was similar to optimal feedback that minimizes muscle activation under the constraint that upright stance must be stable, but was qualitatively different than feedback that produces additional muscle activation to reduce movements of the body's center of mass or center of pressure.

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MS8

Singular Optimal Controls Reduce Energy Consumption in Human Posture Regulation

Human posture regulation is characterized experimentally by more sway than is consistent with a linear control in the absence of delay and by different responses to perturbations of different magnitude. The solution to an optimal control problem consisting of a linearized multi-segment model of the human and a performance measure that is quartic in the center of pressure and quadratic in the controls replicates these experimental observations. The solution involves optimization with a singular Hessian.

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MS8

Electric Knifefish Feedback Controller Adapts to Stimulus Dynamics in a Locomotor Tracking Behavior

Weakly electric knifefish, *Eigenmannia virescens*, swim forward and backward to track a moving refuge. They track sinusoidal (predictable) and sum-of-sines (pseudo-random) refuge trajectories differently, revealing a nonlinear stimulus-dependent switch in performance. Specifically, they track predictable single-sine trajectories with reduced tracking error and typically less overall movement. This supports the hypothesis that fish generate internal models of stimulus dynamics, hence enabling improved tracking despite reduced motor cost.

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MS8

Head Movement Dynamics Satisfying Donders' Constraint and its Connection with Fick Gimbals

In this talk we study the dynamics of head movement satisfying a constraint originally proposed by Donders in the nineteenth century. Head orientations can be represented by an axis and an angle describing counterclockwise rotation and Donders' law restricts the set of possible orientations that corresponds to a specific pointing direction of the head. The rotation axis of the head is restricted to lie on a Donders' surface and the resulting complex is compared to a mechanical gimbal originally proposed by Fick.

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MS9

A Stochastic Differential Game for the Infinity Laplacian

A two-player zero-sum stochastic differential game, defined in terms of an m-dimensional state process that is driven by a one-dimensional Brownian motion, played until the state exits the domain, is studied.The players controls enter in a diffusion coefficient and in an unbounded drift coefficient of the state process. We show that the game has value, and characterize the value function as the unique viscosity solution of an inhomogeneous infinity Laplace equation.Joint work with R. Atar.

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MS9

Spectral Approximation of An Infinite Dimensional Black-Scholes Equation

We consider the pricing of a European option using a market in which the stock price and the asset in the riskless bank account both have hereditary price structures. Under the smoothness assumption of the payoff function, it is shown that the infinite dimensional Black-Scholes equation possesses a unique classical solution. A spectral approximation scheme is developed using the Fourier series expansion in the space of continuous functions for the Black-Scholes equation. It is also shown that the nth approximant resembles the classical Black-Scholes equation in finite dimensions.

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MS9

Stability for Nonlinear Markov Processes via Relative Entropy

We are concerned with large time and related properties of the distribution of so-called nonlinear Markov processes. Such distributions arise as the limit of the empirical measures of a related system of weakly interacting processes. The stability analysis for nonlinear Markov processes is subtle, and it is difficult to even identify natural forms for candidate Lyapunov functions. We will review progress in an approach to the construction of Lyapunov functions that uses approximations to the prelimit system and limits of relative entropies.

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MS9

Hybrid Switching Stochastic Systems

This talk reports some of our recent work on regime-switching diffusions in which continuous dynamics and discrete events coexist. One of the distinct features is the discrete events depend on the diffusions. We recall the notion of recurrence and regularity. After necessary and sufficient conditions for recurrence are provided, ergodicity will be examined, and stability will be studied. We will also present some of our recent work on numerical solutions of controlled switching diffusions.

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MS10

Fixed Points and Convergence of Discrete Convex Monotone Dynamical Systems

Convex, order preserving maps of R^n are the dynamic programming operators of stochastic control problems with n states, discrete time, and possibly negative discount rate. Following an earlier work generalizing max-plus spectral theory for such maps that are sup-norm non-expansive (discounted case), we show in particular that the set of (tangentially) stable fixed points is isomorphic to a convex inf-semilattice, and characterize the periods of (tangentially) stable periodic points.

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MS10

Generalized, Multi-criteria, Shortest Path Problems on Graphs, Idempotent Semirings, Dualities and the Value of Information

We investigate generalized shortest path problems on graphs with multiple path metrics, that are generalized functions of numerical or logical link weights. We demonstrate that these problems can be formulated as linear optimization or tradeoff problems over partially ordered semirings. We establish conditions for the semirings that guarantee distributed solutions. Considering the information needed for these computations, leads to convexity and duality notions, that help quantify the Value of Information in these distributed optimization problems.

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MS10

Deterministic Optimal Stopping via a Max-plus Affine Power Method

Deterministic optimal stopping describes a class of optimal control problems in which the time horizon is an additional free variable to be selected in maximizing the attendant payoff. A standard solution approach to such problems targets the attendant dynamic programming (differential) equation. Another more recent approach exploits a max-plus affine property of the associated dynamic programming (integral) evolution operator. This work elaborates further details concerning the foundation and implementation of this latter max-plus approach.

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MS10

A Max-plus Approach to the Solution of a Certain Class of Games

We consider numerical methods for solution of discrete-time dynamic games. One may use the min-max and max-plus algebras to develop curse-of-dimensionality-free methods for such problems. The main difficulty is attenuation of a severe complexity growth as one propagates the solution backward via dynamic programming. The complexity is reduced through projection onto a lower-dimensional space. That task motivates development of max-plus convex analysis - specifically the space of max-plus convex functions.

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MS11

A System Identification Approach to Sparse Representations

A topic that lies at the very core of all modeling exercises is that of model structure selection. In some applications of model fitting there exists a natural ordering of the models from low to high complexity. In this case, the search for the best model involves testing each model in sequence. Our interest in the current paper is in a class of problems where there does not exist a natural ordering. We focus in the problem of Multi-band Signal Reconstruction.

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MS11

System Identification Based on Error-In-Variables Estimator

We investigate system identification based on the error-in-variables (EIV) estimator for a class of infinite-dimensional systems. Our proposed algorithm involves singular value decomposition of the input/output measurement data in estimating the approximate graphsubspace of the system, and balanced truncation in obtaining an identified finite-dimensional approximate model to the true system. Identification errors are analyzed and quantified using the apriori knowledge of the unknown system. Our results are validated by numerical simulations of two examples.

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MS11

Stochastic Approximation for Consensus over Dynamic Networks: Analysis via Compatible Nonnegative Matrices

Consensus problems are concerned with coordinating the behavior of distributed agents. In noisy networks, stochastic approximation is useful for reaching consensus. For arbitrarily switching networks, the convergence analysis of stochastic approximation algorithms is difficult due to the poorly structured dynamics in updating the states. To analyze these algorithms, we introduce the notion of compatible nonnegative matrices and develop ergodic theorems for degenerating stochastic matrices defined over randomly varying directed networks. Our approach is potentially useful for cooperative estimation and optimization problems.

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MS11

Persistent Identification of Regime-switching Systems with Structural Uncertainties: Unmodeled Dynamics, Observation Bias, and Nonlinear Model Mismatch

This work is concerned with tracking and system identification for regime-switching parameters. The framework of the identification problems introduced in this paper includes not only the stochastic observation disturbances, but also deterministic unmodeled dynamics, observation bias, and nonlinear model mismatch. Two classes of problems have been investigated. In the fast-switching systems, the switching parameters are stochastic processes modeled by irreducible and aperiodic Markov chains. Instead of tracking real-time parameters, the average of the Markovian parameters are investigated and estimated by the standard least square algorithms. We derived upper and lower bounds on identification errors. It reveals that identification error bounds depend on all of the uncertain terms mentioned above. In the infrequent-switching systems, simulation studies are carried out and demonstrate that system parameters could be tracked with reasonable accuracy by using adaptive-step size algorithms.

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MS12

Asymptotic Analysis for Optimal Investment with Transaction Costs in Finite Time

We consider an agent who invests in a stock and a money market account with the goal of maximizing the utility of his investment at the final time T in the presence of a proportional transaction cost $\lambda > 0$. The utility function is of the form $U(c) = c^p/p$ for $p < 1,\ p \neq 0$. We provide a heuristic and a rigorous derivation of the asymptotic expansion of the value function in powers of $\lambda^{1/3}$. We also obtain a "nearly optimal" strategy, whose utility asymptotically matches the leading terms in the value function.

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MS12

A Non-Zero-Sum Game Approach for Convertible Bonds: Tax Benefits, Bankrupt Cost and Early/Late Call

Convertible bonds are hybrid securities that embody the characteristics of both straight bonds and equities. The conflict of interests between bondholders and shareholders affects the security prices significantly. In this paper, we investigate how to use a non-zero-sum game framework to model the interaction between bondholders and shareholders and to evaluate the bond accordingly. Mathematically, this problem can be reduced to a system of variational inequalities and we explicitly derive the Nash equilibrium to the game. Our model shows that credit risk and tax benefit have considerable impacts on the optimal strategies of both parties. The shareholder may issue a call when the debt is in-the-money or out-of-the-money. This is consistent with the empirical findings of late and early calls (Ingersoll (1977), Mikkelson (1981), Cowan et al. (1993) and Asquith (1995)). In addition, the optimal call policy under our model offers an explanation for certain stylized patterns related to the returns of company assets and stock on calls.

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MS12

Commodity Storage Valuation

We present a general valuation framework for commodity storage facilities, for non-perishable commodities. We consider the case of a storage facility small enough so that injections and withdrawals do not influence the price of the underlying commodity. We allow for mean-reversion and seasonality in the price of the commodity, and allow for injection and withdrawal costs. To find the optimal actions for the storage owner we present an iterative numerical algorithm and prove its convergence. We illustrate our framework with numerical examples for the case of storage facilities for oil, natural gas, and water.

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MS12

Valuation of Stock Loans with Jump Risk

This paper investigates pricing problems of both infinite- and finite-maturity stock loans under the hyper-exponential jump diffusion model. In the infinite-maturity case, we obtain a closed form pricing formula by deriving the moment generating function of the first passage time of the underlying process and solving the related optimal stopping problem explicitly. In the finite-maturity case, we provide an accurate analytical approximation to the stock loan price.

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MS13

LQR Control of von Karman Vortices

In this talk, we discuss stabilization of von Karman vortex shedding by cylinder rotation. To address this classical problem, we seek solutions to Riccati equations that result from discretization of the Navier-Stokes equations. The computational challenges are addressed by using model reduction methods for solving Chandrasekhar and Lyapunov equations. Closed-loop simulations will be presented that demonstrate the feasibility of this approach for low Reynolds number flows.

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MS13

Adaptive Guidance and Control for Hypersonic Vehicles

We present an account of nonlinear adaptive control techniques that have been developed, in collaboration with the US Air Force Research Laboratories, towards the design of flight control systems for air-breathing hypersonic vehicles. In particular, we present several steps leading to the design of a flight control system architecture comprised of a robust adaptive inner-loop controller, an anti-windup module and a self-optimizing guidance system. Finally, we briefly discuss open problems and current research directions.

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MS13

Load Estimation from Structural Measurements

Our sense of touch allows us to feel the forces in our limbs when we walk, swim, or hold our arms out the window of a moving car. We anticipate this sense is key in the locomotion of natural flyers. Inspired by the sense of touch, our overall goal is to develop techniques for the online real-time estimation of aerodynamic loads for flight control applications (involving, e.g., micro air vehicles). In a step toward this goal, we propose a general algorithm for the direct estimation of distributed steady loads over bodies from embedded noisy deformation-based measurements. We consider a linear elastic membrane as an example, and then present the derivation of the algorithm in a more general framework. Our method differs from other recent approaches to this problem in that the algorithm does not require an ad-hoc a priori parameterization of the unknown load. We show that the algorithm produces load estimates that converge to a "natural" distributed load estimate as the computational mesh is refined.

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MS14

Recent Developments in Nonlinear Markov Control Processes

The talk will be devoted to the recent advances in the analysis of nonlinear Markov control problems and its connections with controlled interacting particles systems, mean field games, Nash Certainty Equivalence principle and related developments. Nonlinear Markov semigroups can be considered as nonlinear deterministic dynamic system on the set of measures. However, probabilistic interpretation makes the difference. Nonlinear Markov processes describe the families of processes (parametrized by initial distributions) s.t. to each trajectory there corresponds a 'tangent' (time non-homogeneous) Markov process. For these processes future depends on the past via its present position and distribution. On the other hand, these processes can be obtained as dynamic LLN (laws of large numbers) of Markov models of interacting particles.

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MS14

Mean Field for Markov Decision Processes: from Discrete to Continuous Optimization

We study the convergence of Markov Decision Processes made of a large number of objects to optimization problems on ordinary differential equations (ODE). We show that the optimal reward of such a Markov Decision Process, satisfying a Bellman equation, converges to the solution of a continuous Hamilton-Jacobi-Bellman (HJB) equation based on the mean field approximation of the Markov Decision Process. We give bounds on the difference of the rewards, and a constructive algorithm for deriving an approximating solution to the Markov Decision Process from a solution of the HJB equations. We illustrate the method on three examples pertaining respectively to investment strategies, population dynamics control and scheduling in queues. They are used to illustrate and justify the construction of the controlled ODE and to show the gain obtained by solving a continuous HJB equation rather than a large discrete Bellman equation.

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MS14

Stochastic Models for the Environmental Transnational Pollution Control Problem

With a few exceptions, dynamic games in the literature on the environmental transnational pollution control problem have been developed in a deterministic framework. In this contribution, we provide a stochastic dynamic game formulation of this problem when environmental damage arises from accumulation in the atmosphere of stock pollutants, such as CO2. We propose stochastic dynamic models where the inherent uncertainty of the cumulated stock pollutants evolution due to environmental and meteorological factors is considered. We calculate the optimal path of abatement as the solution of the stochastic game for both cooperative and non-cooperative behavior of the countries. The optimality criteria considered in our setting are both, the classical expected total discounted cost, and a stochastic performance criteria such that a particular country does not exceed a target total discounted cost. To illustrate our model, we present some numerical results based on real scenarios for six different regions.

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MS15

Fast Marching Characteristics-Based Schemes for Hamilton-Jacobi Equations

We present some recent advances in the approximation of Hamilton-Jacobi equations with applications to nonlinear optimal control problems and differential games. We will focus on numerical methods which improves the computational efficiency of semi-Lagrangian schemes. The idea is to improve and generalize Fast Marching methods originally introduced by Sethian in 1996 for the eikonal equation, possibly preserving the local nature of the algorithm. The goal is to obtain fast converging methods with a low computational cost and a simple implementation.

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MS15

Solution Stability in Parametric Control with Bang-bang and Singular Arcs

We consider optimal control problems where the control enters the state equation linearly with focus on their parameter dependency. In case of pure bang-bang (vector-valued) optimal controls, directional differentiability of the switching times is obtained. If the control includes so-called singular arcs, we present a first stability result for scalar controls under suitable controllability and optimality conditions. Examples illustrate stable and unstable situations.

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MS15

On the Method of Characteristics in Optimal Control Theory

The method of characteristics, a classical construction of solutions of first order partial differential equations, can be adapted for the construction of solutions to the Hamilton-Jacobi-Bellman equation. Essentially, given a parameterized field $\mathcal{F}$ of extremals (consisting of controlled trajectories and an adjoint variable so that the conditions of the Maximum Principle are satisfied,) the running cost along these controlled trajectories becomes a solution to the Hamilton-Jacobi-Bellman equation. The corresponding controls provide relative extrema when compared to other admissible controlled trajectories with the property that the corresponding trajectories lie in the region covered by the field $\mathcal{F}$. In this talk we apply this technique to discuss the behavior of the value function near singularities by relating these with singularities in the parametrization. If time permits, we also show the applicability of these constructions to prove optimality of syntheses involving chattering controls (e.g., for the classical Fuller problem) without a need to successively integrate the cost along the infinitely many chattering control segments.

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MS15

Trajectories in a Closed Region of the State Space

Estimates on the distance of a nominal state trajectory from the set of state trajectories that are confined to a closed set have an important role in optimal control. They have been used to establish regularity properties of the value function, to characterize the value function in terms of the HJB equation and for other purposes. We discuss the validity of various presumed estimates and some open questions, for state constraint sets with non-smooth boundaries.

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MS16

Sampled-Data Control of Parabolic PDEs with Measurement Delays

We present a model-based controller design method for processes modeled by parabolic PDEs with discretely-sampled and delayed measurements. The controller includes a finite-dimensional inter-sample model predictor that compensates for measurement intermittency, and a propagation unit that compensates for the delays. Discrete-event system and singular perturbation techniques are used to characterize the stability properties of the infinite-dimensional closed-loop system in terms of model accuracy, the sampling rate, the delay size, and the choice of actuator/sensor locations.

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MS16

Amplification of Stochastic Disturbances in Weakly Inertial Channel Flows of Viscoelastic Fluids

We demonstrate that large velocity variances can be sustained even in weakly inertial stochastically-forced channel flows of viscoelastic fluids. The underlying physical mechanism involves polymer stretching that introduces a lift-up of flow fluctuations similar to vortex-tilting in inertia-dominated flows of Newtonian fluids. The phenomenon examined here provides a possible route for the early stages of a transition to elastic turbulence and might be exploited to enhance mixing in microfluidic devices.

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MS16

Two Nonlinear Control Techniques Employed on a Flexible Aircraft-Inspired Model

A multiple component structure consisting of two Euler-Bernoulli beams connected to a rigid mass is used to model the heave dynamics of an aeroelastic wing micro aerial vehicle, which is acted upon by a nonlinear aerodynamic lift force. This talk includes theoretical analysis of the linearized model and two approaches for computing nonlinear controllers - linear quadratic tracking and feedback linearization inner loop with sliding mode outer loop - to achieve a morphing trajectory over time.

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MS16

Balanced POD Algorithms for Model Reduction of PDE Systems

Balanced POD is an algorithm introduced by Rowley for model reduction of linear ordinary differential equation systems. The algorithm uses solution snapshots of certain linear time dependent differential equations to approximate the balanced truncated reduced order model. Many researchers have used balanced POD for model reduction of linearized fluid flows and other parabolic PDE systems. We discuss potential issues with balanced POD for non-parabolic PDE systems, and propose modifications of the algorithm that overcome these difficulties.

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MS17

Controlling the Onset of Turbulence by Streamwise Traveling Waves

We examine the efficacy of streamwise traveling waves for controlling the onset of turbulence in a channel flow. We show that, relative to the uncontrolled flow, the downstream traveling waves with properly designed speed and frequency can significantly reduce sensitivity which makes them well-suited for controlling the onset of turbulence. In contrast, the velocity fluctuations around the upstream traveling waves exhibit larger sensitivity to disturbances. Our theoretical predictions are verified using simulations of the nonlinear flow dynamics.

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MS17

Viscous Flow Past Moving and Rotating Bodies: Stochastic Analysis and Control

In this talk, we discuss the model of a viscous fluid filling an infinite space exterior to an obstacle in the presence of noise. The obstacle moves in curved path with rotation. We first prove the existence and uniqueness of solutions for the stochastic Navier-Stokes equations which depends continuously on the prescribed speed of the obstacle by transforming the equation defined on a time dependent domain into an equation on a fixed domain. Then in the second main result we establish an optimal way to accelerate the obstacle from rest to a given speed. This work is motivated

by control of unmanned autonomous system.

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MS17
Optimal Control of Shock Wave Attenuation in Two-Phase Flow with Application to Ignition Overpressure in Launch Vehicles

Blast wave attenuation via liquid droplet addition is a technique used by NASA on Ignition Overpressure waves. In an effort to optimize the technique, and possibly for other applications, a novel algorithmic method of solution is presented for a newly formulated optimal control problem. The objective functional penalizes the overpressure above some threshold at the final time as well as the initial amount of water used. A new adjoint-based solution procedure will be presented.

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MS17
A New Approach for Fluid Flows Control

Fluid flow control is of great economical interests in many fields of applications. Controlling a flow consists in changing its state or to maintain it in its current state. In this presentation, we show that existing flow control methods suffer from limited observations, from measurements noise, and from the initialization process involved in the observer required to reconstruct the flow state. To deal with these issues, we present a very promising approach: the vision-based approach.

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MS17
Reduced-Order Modeling for Fully-Coupled Fluid and Structural Dynamics of Flexible Flapping Wings

As a fully-coupled fluid-solid system, numerical simulation of flexible flapping wings faces many challenges by itself. On the other hand, even the best simulation results can hardly provide direct guidance for flow control. Here, we first use a global approach to solve both fluid and solid in a combined Eulerian formulation. Then, based on the same philosophy, we can obtain reduced-order models by applying POD/Galerkin projection on the simulation data of a uniform Eulerian description of fluid, structure, and their interaction.

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MS18
Model Reduction of Parametrized Systems

We present a novel approach to model order reduction of parametrized systems. For two-variable rational functions $H(s,t)$ we construct models of low complexity in both variables s (frequency) and t (parameter). From given measurements $H(s_i,t_j)$ at points (s_i,t_j), we construct a 'tall' Loewner matrix. We then solve a least squares problem to obtain the reduced order model, given in a novel state-space canonical form. We also provide an efficient formula for computing the approximation error.

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MS18
Model Reduction of Nonlinear Control Systems in Reproducing Kernel Hilbert Space

We introduce a novel data-driven order reduction method for nonlinear control systems, drawing on recent progress in machine learning and statistical dimensionality reduction. The method rests on the assumption that the nonlinear system behaves linearly when lifted into a high (or infinite) dimensional feature space where balanced truncation may be carried out implicitly. This leads to a nonlinear reduction map which can be combined with a representation of the system belonging to a reproducing kernel Hilbert space to give a closed, reduced order dynamical system which captures the essential input-output characteristics of the original model. Empirical simulations illustrating the approach are also provided.

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MS18
Towards a Systematic Approach to Reduce Complex Bioprocess Models for control design - Application to the Anaerobic Digestion Model No.1 (ADM1)

A mathematical reduction method named Homotopy is applied to the Anaerobic Digestion Model No. 1 or ADM1, cf. (Batstone et al., 2002). The proposed method neglects the slow dynamics keeping only the fastest ones in using the technique of eigenvalue-state association. This transformation is described by the Homotopy matrix H. Simulations show that both the initial and the reduced models exhibit similar steady states while the outputs are also reasonably well approximated.

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MS18
Model Reduction for Transition Delay in Boundary Layer Flows

The dynamics and control of disturbances in boundary layer flows are investigated from an input-output viewpoint. Localized sensors and actuators with compact spatial support are distributed near the wall in arrays spanning the homogeneous span-wise direction. The aim is delay the laminar-turbulent transition. From the linearized Navier-Stokes equations with the inputs and outputs balanced modes are extracted using the snapshot method. Balanced reduced-order models (ROM) are constructed and the performance analysed. It is shown that the low-dimensional models ($r = 60$) are able to capture the dynamics between the actuators and sensors. These models are finally used to design a feedback controller to suppress the growth of perturbations inside the boundary layer; to account for the different temporal and spatial behaviour of the two main instabilities of boundary layer flows, we design two controllers. We demonstrate that the two controllers reduce the energy growth the disturbances substantially and efficiently. When initial perturbation with realistic amplitudes of the initial perturbation are considered, the perturbation energy reduction results in a delay of the transition. Effect of the actuation on the disturbances and the effort of the controller are characterized in the nonlinear regime.

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MS19
On the Reachability of Tropical Eigenspaces

One of the tasks in the theory of multi-processor interactive systems is the question of achievement of a steady regime. A convenient way of describing a steady regime is using a tropical (max-plus) eigenvalue-eigenvector system. The question of achievement of a steady regime is then equivalent to the reachability of an eigenspace by a matrix orbit with a given starting vector. If an eigenvector is reached by any orbit then the matrix of the system is called strongly stable. If none of the eigenspaces is reached by orbits starting from outside the eigenspaces then the matrix is called weakly stable. We give a full and efficient characterisation of both strongly and weakly stable matrices.

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MS19
The Legendre Transform and Max-plus Finite Elements

In this paper we discuss the use of the Legendre transform to construct a max-plus finite element approximation method. Max-plus arithmetic is becoming an important approach in nonlinear control, as the dynamic programming equation is max-plus linear for deterministic nonlinear control problems.

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MS19
Separation Results in Max-plus Algebra

A hemispace is a convex set that has convex complementary. We will discuss the structure of max-plus hemispaces. Hemispaces are relevant due to StoneKakutani theorem on separation of two disjoint convex sets by hemispaces.

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MS19
Tropical Linear Programming and Parametric Mean-payoff Games

We develop tropical linear programming, motivated by applications in static analysis of computer programs. The tropical linear programming is solved by constructing an associated parametric mean payoff game problem. Developing a kind of Newton iteration scheme, we reduce the problem to a sequence of one-player mean payoff games. Unboundedness and optimality of a given point can be certified by a winning strategy of one of the players.

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MS20
Distributed Ocean Monitoring via Integrated Data Analysis of Coordinated Buoyancy Drogues

An unanswered need in oceanography is to sample the ocean at higher-resolution spatial and temporal scales than presently possible. In this talk, we describe progress at developing a mobile observatory system based on swarms of buoyancy-controlled drogues capable of scientific data analysis and coordinated motion control within the shear layers of the ocean circulation. In particular, we describe cooperative strategies to reconstruct simple unknown flow fields and detect basic ocean phenomena such as internal waves.

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MS20

Efficient Deployment of Drifters in Flow Environments

Motivated by sensor network problems in river and channel flow environments, we present a study of efficient drifter trajectories under quadratic and constant flow velocity profiles. The optimal control problems define a metric in the channel that can be used to assign exploration regions to different sensors and so define coverage algorithms for drifters. While for time-optimal trajectories, partitions in constant flows determine Zermelo regions, energy-optimal trajectories produce a version of the additively-weighted Voronoi partition.

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MS20

Multi-vehicle Control and Optimization for Spatiotemporal Sampling

We describe a layered feedback approach to multi-vehicle control and optimization for coordinated sampling of spatiotemporal processes. We apply estimation theory to evaluate candidate sampling trajectories and select the ideal trajectories by optimizing over the trajectory parameter space. We synthesize distributed algorithms for feedback stabilization of coordinated sampling trajectories in a flowfield by applying tools from nonlinear control and dynamics. The theoretical results are illustrated by application to environmental sampling in the ocean and atmosphere.

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MS20

A Theoretical Lower Bound for Controlled Lagrangian Particle Tracking Error

Autonomous underwater vehicles are flexible sensor platform for ocean sampling and surveillance missions. However, navigation of these vehicles in unstructured ocean environments poses a challenging problem. Ocean models may be used to improve navigation performance; in turn, the observed positions of the vehicles may be used to increase accuracy of ocean model flow prediction. We present a theoretical lower bound on the steady-state error in position prediction for underwater vehicles using ocean model flow data.

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MS21

Linear Switched Dynamical System with Periodically Switched Stability

In this talk, we will discuss the stability of a linear switched system that is periodically switched stable, using ergodic theory. We will show that periodically switched stability implies almost sure stability in the Markov probability sense.

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MS21

Quantifying the Stability and Stabilizability of Switched Systems

The notion of generating functions is introduced as a framework to study quantitatively the stability and stabilizability of switched systems, including randomly switching systems. Several important quantities, such as the joint spectral radius, Lyapunov exponent, L2-induced gain, stabilizability index, can be characterized uniformly in such a framework. Efficient numerical algorithms will be proposed for the estimations of these quantities.

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MS21

Complexity for Switched Linear Systems

It is well-known that switched systems can generate chaotic behaviors. But the existed examples which can generate chaos are those of switched affine systems (not a real switched "linear" systems). Furthermore, the switching signals of generating chaos must be chosen to be dependent on the state variables. So such kind of switched systems is actually a truely nonlinear systems. In this paper, we will discuss the complexity of a "true" switched linear systems. In particular, we will give examples of switched linear systems that can have dense orbits (hypercyclic) by state-independent switching control signal.

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MS21

Joint Spectral Radius of Finite Rank-One Matrix Family

An explicit computable formula is proposed for calculating the joint spectral radius of a fiite rank-one matrix family, where the problem of finding maximum spectral radius over arbitrary matrix products is formulated as a linear programming problem, the optimal objective of which could be inferred without much computational costs. In particular, we have proved that the finiteness conjecture is always true for finite rank-one matrix family. Several numerical examples are also given to verify our formula. Finally, our result is applied to investigate some general cases considered in previous literatures.

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MS22

Stochastic-Volatility, Jump-Diffusion Optimal Portfolio Problem with Jumps in Returns and Volatility

The risk-averse, Merton-type optimal portfolio problem is treated with consumption in continuous time for stochastic-jump-volatility, jump-diffusion (SJVJD) models. New developments are the use of SJVJD models with double-uniform jump-amplitude in returns and single-uniform jump-amplitude in volatility. The control variables are the stock fraction and the consumption rate. Computational results are presented for optimal portfolio values, stock fraction and consumption policies.

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MS22

Dynamic Advertising and Pricing with Constant Demand Elasticities

We analyze stochastic dynamic generalizations of the classical Dorfman-Steiner problem and derive optimal pricing, advertising, sales promotion, etc. policies for a monopolist who is selling a fixed number of products over a finite time horizon. The inventory is supposed to evolve according to a pure death process where the jump intensity depends on the control rates, e.g. price posted and advertisement rate set. We assume the intensity to have a product form and let the elasticities, e.g. the price as well as the advertizing elasticity, to be constant. We derive explicit formulae for the value function and the optimal policies. Moreover, we show structural properties of these functions and extend these results to discrete time models with more general transition mechanisms.

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MS22

Utility Maximization of an Indivisible Market: Optimal Switching with Constraints and Utility Maximization of an Indivisible Market

In this talk, we treat utility maximization problems when the market is indivisible and the transaction costs are included, in which there is a so-called solvency region given by the minimum margin requirement. The underlying problem is formulated as an optimal switching problem with constraints, degenerate diffusion, and unbounded domain. We provide sufficient conditions leading to the continuity of the value function. By virtue of the continuity, the value function is shown to satisfy the dynamic programming principle, and is characterized as the unique viscosity solution of a certain quasi-variational inequality.

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MS22

Econometric Analysis via Filtering for Ultra-High Frequency Data

We propose a general nonlinear filtering framework with marked point process observations incorporating other observable economic variables for ultra-high frequency data. We derive filtering equations to characterize the evolution of the likelihoods, posteriors, Bayes factors and posterior model probabilities. We prove a powerful convergence theorem so as to construct consistent, easily-parallelizable, recursive algorithms for implementing Bayesian inference in real-time for streaming UHF data. The general theory is illustrated by a specific model built for U.S. Treasury Notes transactions data from GovPX.

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MS23

Zero-Sum Stochastic Dynamic Games with Intermittent Noisy Measurements

The talk will discuss the existence, uniqueness, and characterization of saddle-point solutions to a class of two-player zero-sum stochastic dynamic games (ZSSDGs) where the state information is acquired by the players through a noisy channel which however intermittently fails, with the failure governed by a time-independent Bernoulli process. When the failure rate is zero, we have the standard ZSSDG with identical noisy measurements for the players (in which case derivation of the "complete" saddle-point solution is still quite subtle), and for the other extreme case when the failure rate is one, we have the open-loop ZSSDG. For the intermediate case when the failure rate is in between zero and one, we will show that the saddle-point solution involves, under some conditions, a Kalman filter (or extended Kalman filter) with intermittent (or missing) measurements; in this case a restricted certainty equivalence holds. We will also discuss the more challenging problem where the failure of the transmission of the common noisy measurement of the state to the players is governed by two independent Bernoulli processes with possibly different rates. We will consider two scenarios in this case: (i) the players are not aware of the failure of links corresponding to each other, and (ii) this information is available (that is players share explicitly or implicitly the failure information) but with one step delay. Extensions to nonzero-sum stochastic games constitute yet another class of challenging problems, which will be addressed briefly.

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MS23

Modeling and Analysis of Deception in Adversarial Games

Deception modeling is quite challenging because concepts such as beliefs, conscious and subconscious bias, and emotion are difficult to quantify. In this presentation, we discuss our new results in the modeling and analysis of deception within the setting of adversarial games. Using tools from system and control theory such as state estimation and stochastic control, we show how our results quantitatively capture ideas within the psychology and deception community.

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MS23

On Risk Stopping Games under Partial Information

The classical models in risk theory consider a single type of claim. Based on these models with extensions various problems are investigated as the ruin problem, the optimal control of dividends and optimal stopping problems. The classical process is modified to take into account the changes in an environment and various practical and theoretical aspects like the model of premium and interest rate (see Ferenstein & Pasternak–Winiarski [3]). When there are several business lines with separate arrival processes then the underlying counting process can be a multivariate renewal process (see e.g. Bäuerle and Grübel [1] for the investigation of these aspects). The decision makers rarely can observe all claim arrivals. The problem of optimal stopping of the multivariate risk process under partial observation is formulated. Based on a representation of stopping times for point processes (see Brémaud [2] and its extension Szajowski [4]) the precise structure of optimal stopping strategies are obtained. The considered model is motivated by the reinsurance contracts. Some aspects of multilateral models related to such contracts are presented.

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MS23

Turnpike Theorems for Stochastic Games

Turnpike theorems for rather general class of stochastic games will be presented including turnpikes in the set of stratetgies as well as turnpikes in the state space. Thus we show that if a game of this class is played long enough, then, independently of initial states and final goals, the optimal strategies are near the stationary ones and the corresponding distribution on the state space is also near the stationary one, apart from some short periods in the initial and final stages of the game.

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MS24

Optimal Control of the Sweeping Process

We consider some optimal control problems for the so-called sweeping (or Moreau) process governed by the normal cone mapping to moving controlled sets. To the best of our knowledge, such problems have never been studied in the literature. The main results include existence theorems and necessary optimality conditions obtained via the method of discrete approximations by using advanced tools of variational analysis and generalized differentiation.

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MS24

Fractional Variational Calculus with Classical and Combined Caputo Derivatives

We give a proper fractional extension of the classical calculus of variations by considering variational functionals with a Lagrangian depending on a combined Caputo fractional derivative and the classical derivative. Euler-Lagrange equations to the basic and isoperimetric problems are proved, as well as transversality conditions.

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MS24

Inner Approximations in the Proof of the Maximum Principle

In this talk we describe a method of inner approximations in problems of constrained optimal control. Inner approximations are approximations where admissible trajectories satisfy the constraints of the original problem exactly, rather than approximately. We demonstrate how this method can be used to obtain maximum-principle type results for various nonsmooth problems.

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MS24

The Fractional Calculus of Variations

Fractional calculus has its origin in the following question: can the meaning of derivatives of integer order n be extended to when n is any number (irrational, fractional or complex)? Recent developments in the fields of science, engineering, economics, bioengineering, and applied mathematics, have demonstrated that many phenomena in nature are modeled more accurately using fractional derivatives and integrals. In the last few years, several works have been dedicated to create a new Fractional Variational Calculus. The new theory has been used to develop Fractional Mechanics, and to model the dynamics of many physical systems. In this talk we present a personal view to the subject and recent results.

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MS25

Computing Moments of the Exit Time for Piecewise Deterministic Markov Processes

We present a numerical method to compute the moments of the exit time for piecewise-deterministic Markov processes (PDMP). Our approach is based on the quantization of an underlying discrete-time Markov chain related to the PDMP. The approximation we propose is easily computable and is flexible with respect to the value of the parameters defining the problem. We prove the convergence of the algorithm and obtain bounds for the rate of convergence. Examples are presented.

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MS25

Ergodic Property of the Elasto-Plastic Oscillator Excited by a Filtered Noise

A stochastic variational inequality is proposed to model an elasto-plastic oscillator excited by a filtered noise. We prove the ergodic properties of the process. This extends Bensoussan-Turi's method with a significant additional difficulty of increasing the dimension. Two points boundary value problem in dimension 1 are replaced by elliptic equations in dimension 2. In our context, Hasminskii's method leads to study degenerate Dirichlet problems with partial differential equation as non local boundary conditions.

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MS25

Uniform Exponential Ergodicity of Continuous-time Controlled Markov Chains

We are concerned with a continuous-time controlled Markov chain with denumerable state space, Borel action sets, and unbounded transition rates. We are interested in exponential ergodicity of the control model, uniformly in the class of stationary policies. This property is specially useful when dealing with controlled Markov chains under the average reward and related optimality criteria (such as, for instance, bias or sensitive discount optimality). In this presentation we introduce sufficient conditions yielding uniform exponential ergodicity and we compare them with other sufficient conditions proposed in the literature. We also study some applications of practical interest.

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MS25

Analysis of Production Decisions under Budget Limitations

The talk focuses on when to intervene in the evolution of a production system by changing the production level when each change incurs a cost. The goal is to maximize the expected return subject to these intervention costs over at most a finite number of intervention cycles. An explicit formula for the value function and a set of optimal times at which to change production are determined with the aid of a nonlinear function.

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MS26

Numerical Computation of Transient and Gain Bounds for Systems with Finite Nonlinear Lp-gain

Nonlinear Lp-gain is a generalization of the standard Lp-gain property that finds application in stability theory. While transient and gain bounds underpin the statement of both properties, the generalized property uses nonlinear (rather than linear) gain bounds, thereby inducing a function-valued system norm. Consequently, bisection-based computational methods derived from dissipative systems theory cannot readily be applied. This work presents an alternative approach to this computation, based on a variational characterization of the nonlinear Lp-gain.

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MS26

Improve Sensor Placement by Using Empirical Covariance Matrices

The problem of optimal sensor placement is studied based on a concept of quantitatively defined observability. The goal is to maximize the observability of a system by placing sensors at the right locations. To verify the applicability to large scale systems, data assimilation based on 4D-VAR is used to compare the error of estimation for an example of Burgers equation. It is shown that improved observability results in reduced error of estimation in data assimilation.

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MS26

Mathematics and Flight Implementation of Pseudospectral Optimal Control

Over the last decade, pseudospectral (PS) optimal control theory has paved the way for solving a large class of optimal control problems whose applications range from quantum control to climate control. In aerospace applications, there are significant challenges in flight implementation of optimal control. Many of these challenges can be overcome by exploiting the spectral convergence property of PS methods. In this talk, we discuss the mathematics of PS methods and its recent flight implementation onboard a NASA space telescope called TRACE. The flight test results demonstrate that it is possible to design and implement, in orbit, a variety of minimum-time maneuvers that enhance the spacecraft's agility. The flight experiment is the first ever implementation of time-optimal maneuvers. A surprising outcome of this implementation is the reduction in peak power consumption with faster maneuvering capability.

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MS26

Efficient Numerical Approaches via Min-Plus Methods for Quantum Control and Computing Applications

It is anticipated that the application of quantum technology would have a strong impact on several advanced engineering systems. One of the major obstacles in this direction of research is that the optimal control of quantum systems is subject to the well known issue of a curse of dimensionality. This is made worse owing to a drastic growth in the dimension of the system with the number of components (qbits) used. This work will discuss the development and application of recently developed min-plus reduced dimensionality techniques to solve problems that are intractable by conventional grid based methods.

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MS27

Stochastic Optimal Control of Discrete Time Systems Subject to Ambiguity

The aim of this paper is to address optimality of control strategies for stochastic control systems subject to uncertainty and ambiguity. Uncertainty is often used to describe the situation when the true dynamics and the nominal dynamics for which optimal controls are sought, are different but they are defined on the same state space. Ambiguity is used to differentiate situations in which the true dynamics belong to a higher dimensional state space than the nominal dynamics and the pay-off is defined on a higher dimensional state space. The paper will start with a brief summary of existing methods dealing with optimality of stochastic systems subject to uncertainty and discuss their shortcoming when stochastic systems are ambiguous. The issues which will be discussed are the following. 1) Modeling methods for ambiguous stochastic systems, 2) formulation of optimal stochastic control systems subject to ambiguity, 3) optimality criteria for ambiguous stochastic discrete time control systems including principle of optimality and dynamic programming. A particular class of ambiguous stochastic systems is optimal control strategies based on nominal dynamics which are not absolutely continuous with respect to the true dynamics.

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MS27

Controlled Diffusion Processes with Cost Constraints

Our problem is to maximize a given long-run average reward subject to a constraint on a similar cost. A standard result for this problem is, under suitable assumptions, the existence of stationary deterministic (as opposed to randomized) optimal control policies. Here we obtain the latter result by means of a certain parametric family of unconstrained HJB equations having appropriate regularity properties.

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MS27

There and Back Again: Minimizing the Time for a Diffusion to Shuttle Between Two Points

Motivated by an application in MCMC, we investigate the problem of minimising the time, τ, for a reflecting diffusion to shuttle from 0 to 1 and back to 0. We may choose any drift for the diffusion. We solve the problem in the cases where we seek to minimise $E[\tau]$ and where we seek to maximise $E[e^{-s\tau}]$. The "adapted" optimal control turns out to be somewhat singular in a quite natural way.

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MS27

Sequential Decisions Under Partial Information

Suppose one must make at each time a decision u_k, incurring a loss $l(u_k, X_k)$. However, the stochastic process X_k is not observable: decisions are based on an auxiliary observed process Y_k. Is it possible to choose a strategy that minimizes the pathwise time-average loss? In the fully observed case the pathwise optimal strategy always coincides with the Bayesian decision strategy, but surprising phenomena appear in the case of partial observations due to the conditional ergodic theory of partially observed systems. From the control perspective, this is a prototype for the question: does a separation theorem hold for pathwise time-average cost criteria?

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MS28

Stabilization and Control of Acoustic -structure Interactions Arising in Acoustic Environment with Porous Walls

Structural acoustic interactions arising in modeling of acoustic environments with porous walls is considered. The model consists of a semilinear wave equation coupled to a parabolic -like equation . The nonlinear coupling takes place on the interface and involves boundary traces of the wave solutions. The first goal is to construct a semigroup describing the flow that is invariant on a suitably selected state space. The well-posedness results existing in the past literature display discrepancy between the topology of initial conditions and topology of the resulting trajectory. It will be shown that this problem can be resolved with a suitable definition of the state space. In the second part of the talk both strong and uniform stabilizability of the semigroup will be analyzed. Strong stabilizability is shown by appeal to suitable Tauberian type of theorems. Uniform stability is proved by using weighted energy methods along with geometric arguments. Several optimal control strategies will be discussed within the context of stabilized structures.

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MS28

Multi-input Optimal Control Problems Arising in Mathematical Models for Combination Therapies of Cancer

In this talk we shall analyze mathematical models for combination therapies for cancer as optimal control problems. We shall consider combinations of novel treatment approaches like tumor anti-angiogenesis, an indirect cancer treatment approach that targets the vasculature of the tumor, or immunotherapy which gives a boost to the immune system with traditional treatments that aim at killing cancer cells like chemotherapy or radiotherapy. Formulating the mathematical models for these therapies leads to multi-input control problems with each control modeling a separate drug action. There exist various approaches for choosing the objective. Depending on the model we minimize the size of the tumor at the end of treatment and maximize the immunocompetent cell-densities (if included in the model) while keeping side effects low. This leads to optimal control problems with many challenging features due to their multi-input system structure. Analytical and numerical results about the structures of optimal controls will be presented providing insights into dosage and sequencing of the drugs in these treatments.

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MS28

Constrained Optimization for a Rod with Self-contact

Minimizing the integrated pointwise potential of a stationary elastic rod dates back to Euler. In this case the minimization is complicated by the requirement that the rod is treated as a solid tube without permitting self-penetration. This is a nonconvex inequality constraint and construction of the basic normal cone at a minimizer views this as the imposition of an infinitude of scalar constraints, requiring an infinite "sum rule'.

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MS28

Optimal Control on Stratified Domains

Bressan and Hong recently introduced a class of dynamical systems with discontinuous, but structured, vector fields. These are called stratified domains, and we shall present new results for the Mayer and Minimal time problem defined on these domains.

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MS29

Relaxed Controls, 2-player Differential Games, Preisach Hysteresis, and Mixing Distributions in Statistical Inverse Problems

In numerous applications in the biological and engineering sciences, one encounters inverse problems where the uncertainty and/or variability in parameters and mechanisms to be modeled are a fundamental part of the problem formulation. This is in addition to the data-driven uncertainty that arises naturally in most inverse problems. We discuss a Prohorov metric based theoretical framework and an associated computational methodology for such problems. In statistical inverse problem formulations these problems are usually discussed in the context of "mixing distributions", but the mathematical foundations can be found in much earlier work on relaxed controls (sliding regimes, chattering controls) of Young, Filippov, Warga, et al. Recent efforts employ these tools in the treatment of two player non-cooperative differential games governed by partial differential equations, and in the treatment of Preisach hysteresis in smart materials. In this expository lecture we outline these connections and present results from our recent efforts using these ideas in several applications.

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MS29

Consensus Adaptive Parameter Estimation for Positive Real Infinite Dimensional Systems

The agreement between state and parameter estimates for a class of infinite dimensional systems that utilize distributed filters is investigated. The unknown parameters take the form of a structured perturbation with an unknown constant parameter, and the nominal system satisfies the positive real lemma. The adaptive observers generated by m agents follow the established structure of adaptive identifiers with the added feature of a penalty term in both the state and parameter estimates. Unlike earlier efforts, the proposed adaptive laws include a penalty term of the mismatch between the parameter estimates by the other agents.

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MS29

Zero Dynamics Inverse Design and the Regulator Equations for Boundary Control Systems

In this talk, we describe a systematic methodology for the design of control laws for solving problems of regulation for wide classes of linear distributed parameter systems using boundary control and sensing. In this work we have significantly extended our earlier work on design methods based on geometric constructs involving the regulator equations for a broad class of Boundary Control Systems. In particular we have discovered important insight into the practical solution of regulation problems for boundary control systems using our recently developed zero dynamics inverse design methodology. We have applied this methodology to numerous prototypical examples of linear boundary control systems acting in bounded domains in several spatial dimensions. Moreover, we are now able to show that the zero dynamics design method is intimately related to the geometric design method. Indeed, for certain problems of output regulation the regulator given by the zero dynamics inverse is precisely the regulator equations whose solution provides the desired control law.

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MS29

Numerical Calculation of H-infinity Optimal Actuator Locations for Infinite-dimensional Systems

In most control systems governed by partial differential equations, the location of actuators can be chosen. The actuator locations should be selected in order to optimize the performance criterion of interest. In this talk, optimal actuator location using H_∞control is considered. That is, both the controller and the actuator locations are chosen to minimize the effect of disturbances on the output. A framework forcalculating H_∞ optimal actuator location will be presented and illustrated with numerical examples.

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MS30

Model-based Feedback Control of Flow Instabilities Using Reduced-order Models

The talk will focus on model-based feedback control of the cylinder wake at low Reynolds numbers. A reduced-order model of the cylinder is found by applying the Eigensystem Realization Algorithm – a method developed in the structural dynamics community for modal parameter identification and model reduction – to data from direct numerical simulations. Using this model, controllers are designed using $\mathcal{H}_\infty$ loop-shaping techniques, and good results are obtained. Encouragingly, the reduced-order model is also able to explain results from previous feedback control studies.

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MS30

Development of New Tools for Urban Fluid Mechanics Travel Report from an Ongoing Journey

In this presentation we chronicle our exploits in the endeavor to develop modern, low-dimensional tools that are suitable for the description as well as prediction of very-high Reynolds number turbulent flows in domains of high geometric complexity. Our prime tool is proper orthogonal decomposition, but we found that this needs to be complemented by additional techniques. Finally, we have some intriguing evidence that a certain correlation matrix may well hold the key to new discoveries.

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MS30

A Stochastic Lagrangian Particle Model and Nonlinear Filtering for Three Dimensional Euler Flow with Jumps

In this paper we will introduce a stochastic Lagrangian particle model with jumps for the three dimensional Euler flow and study the associated nonlinear filtering problem. We apply results from backward integro-differential equation problem to prove uniqueness of solution to the Zakai equations.

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MS31

Coherence, Mutual Information, and Approximate Entropy in Intracranial EEG Evaluation of a Resting State Network

The study of brain networks in epilepsy is based on pairwise measurements of relationships. Such pairwise relationships can be estimated from brain electrical activity measured from scalp EEG, from intracranial electrodes during monitoring for epilepsy surgery, or with fMRI measurements. Three notable measures to study relationships: coherence, mutual information, and approximate entropy will be used to study activity in different parts of the brain using human intracranial EEG data.

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MS31

Control in Infinite versus Finite Dimensional Stochastic Systems with Fractional Brownian Motion

The solutions of stochastic linear-quadratic control problems for systems driven by a fractional Brownian motion having the Hurst parameter in the interval (1/2, 1) are given. The systems are described in either a Euclidean space or a Hilbert space. These systems and their optimal control solutions are contrasted. Some examples are provided for the latter case where the control and the noise may be restricted to the boundary of the domain.

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MS31

A Finite Element Approach to Solution of Singular Stochastic Control Problems

This paper establishes a finite element approach to the solution of singular stochastic control problems. Such problems are first reformulated as infinite-dimensional linear programs over a space of occupation measures. The objective is to find an optimal choice of measures. An (approximate) optimal solution is obtained using finite elements whereby densities are determined by solving an approximating finite-dimensional linear program. Convergence is established. Numerical examples show this approach is

more accurate than standard solution techniques.

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MS31

Identification and Adaptive Control of Branching Processes

In this paper a controlled branching process is modeled in continuous time with a Brownian motion. An estimation problem is solved for an unknown parameter in the stochastic equation that describes the branching process and an adaptive control is given that is self-optimizing. Similar results are obtained for a branching process with immigration.

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MS32

Stochastic Portfolio Optimization with Bounded Memory

We consider a portfolio management problem of Mertons type in which the risky asset return is related to the return history. The problem is modeled by a stochastic system with delay. The investors goal is to choose the investment control as well as the consumption control to maximize his total expected, discounted utility. Under certain situations, we derive the explicit solutions in a finite dimensional space and the verification results are obtained. Moreover, we will consider stochastic models with delays in more general form. This is a joint work with Mou-Hsiung Chang and Yipeng Yang.

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MS32

Optimal Algorithms for Trading Large Positions

In this paper, we are concerned with the problem of efficiently trading a large position on the market place. If the execution of a large order is not dealt with appropriately this will certainly break the price equilibrium and result in large losses. Thus, we consider a trading strategy that breaks the order into small pieces and execute them over a predetermined period of time so as to minimize the overall execution shortfall while matching or exceeding major execution benchmarks such as the volume-weighted average price (VWAP). The underlying problem is formulated as a discrete-time stochastic optimal control problem with resource constraints. The value function and optimal trading strategies are derived in closed-form. Numerical simulations with market data are reported to illustrate the pertinence of these results.

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MS32

Time-inconsistent LQ Problems

Classical optimal control problems are time-consistency: an optimal control for a given initial pair will be automatically optimal of the system starting from a later time moment with a corresponding initial state. However, such a time-consistency will not be available in various situations. In this talk, we will present some results concerning time-consistent solutions to time-inconsistent LQ problems.

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MS33

Learning and Resilience to Information Deception in Adversarial Networked Systems: The Necessity and Structure of a Trusted Core

We investigate distributed inference and learning problems in networked systems with adversaries. We analyze the effects of adversarial attacks on the solutions and characterize the solution robustness and resiliency as functions of network topology and adversary distribution. We demonstrate that existence of a small subnetwork of trusted nodes (trusted core) provides substantial improvements to solution robustness and resilience. We characterize these improvements as functions of the degree of trust, connectivities and location of trusted nodes.

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MS33

Decision Making Among Networked Mobile Agents for Secure Information Flow in an Adversarial Environment

In the last two decades, the topic of cooperative deployment and control of autonomous agents has attracted a wide interest among researchers in control, game theory and artificial intelligence. This talk will introduce a new class of problems that arises in multi-vehicle coordination due to the presence of a mobile adversary in the communication network. The intrusion is modeled as a pursuit-evasion game and leads to new results and challenges in the area of security in cyber-physical systems. The talk will specifically focus on the connectivity maintenance problem in vehicular networks in the presence of a jammer. Some scenarios that differ in the number of players and their dynamics will be presented. The talk will conclude with some recent results on power allocation among mobile agents in team jamming problems.

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MS33

Stochastic Network Games with Recourse

The problem of attacking an intelligent network has received much attention in recent years, using game theoretic techniques. One particular aspect that complicates this problem is when the effects of the attack are uncertain. In this work, we consider when the attacker observes and adapts to the success of the attack. We develop algorithms for computing adaptive attack strategies based on performace bounds, and illustrate the effect of these strategies in simple games.

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MS33

Reasoning about the Adversary in Hypergames

We consider scenarios where players have different perceptions about the game they are involved in and observe perfectly the actions of other players. We are interested in asymmetric engagements, where some players enjoy an informational advantage. Our goal is to develop learning schemes that gain information from the opponent's actions. By studying the evolution of the so-called H-digraph, we characterize the vulnerabilities in the belief of the players and discuss algorithmic methods for exploiting them.

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MS34

Stability of Discrete-time Switched Homogeneous Systems and its Applications

Switched homogeneous systems (SHSs) form an important class of hybrid, switched systems, including switched linear systems. In this talk, we address stability of SHSs under different switching polices, such as arbitrary switching and optimal switching, from several perspectives, e.g. generalized joint spectral radius and the recently introduced generating function approach. The connection between these perspectives will be discussed. And extensions to the conewise homogeneous inclusions and an application to distributed sensor networks under switching topology will be presented.

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MS34

Issues Arising in Discretising Switched Linear Systems

In this lecture we discuss discretisation of switched systems. The matter is straightforward for LTI systems, but much less so for switched systems. Our results indicate that quadratic stability is robust with respect to certain discretisations. This provides additional motivation for the study of quadratic stability.

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MS34

Guaranteed Stability of Continuous-time Switched Linear Systems

For switched linear systems, guaranteed stability means stability under an arbitrary switching. We discuss the equivalence between the stabilities and the existence of common (weak) Lyapunov functions. Furthermore, the well-known stability notions, such as attractivity, asymptotic stability, and exponential stability, are shown to be equivalent to each other. For a continuous-time switched system, we prove that asymptotic stability is equivalent to the negativity of the least measure of the (subsystem) matrix set, which could be seen as a generalization of the largest real part of a single matrix. We also discuss the possibility of converting a switched system into a quasi-normal form by means of a common and possibly non-square coordinate transformation.

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MS34

A Characterization of the Generalized Spectral Radius with Kronecker Powers

Based on Turans power sum theory, we extend a recent result obtained by Blondel and Nesterov (SIAM J. Matrix Anal. Appl., Vol.27, No.1, pp.256-272, 2005) by deriving a new characterization of the generalized spectral radius in terms of Kronecker powers.

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MS35

On Normal Forms for Nonlinear Hamiltonian Control Systems

We introduce a new method for deriving normal forms for nonlinear control systems. This method allows to deduce the normal forms for Hamiltonian systems in a simple way.

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MS35

Subriemannian Smoothing and Data Assimilation

in Collective Behavior

Recent work in analysis of biological flight data has exploited geometric methods from control theory. In this talk we extend these to the investigation of data on dynamics of collectives. We discuss associated variational principles (subriemannian smoothing problems) and their extremals. We also discuss cross-validation analysis for underlying parameters.

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MS35

Balancing for Nonlinear Systems with Application to Model Reduction and Sensitivity Analysis

We review the method of short time local balancing along a nominal ?ow for smooth nonlinear control systems. We characterize the corresponding reachability and observability Gramians as solutions to nonlinear extended Lyapunov equations, and present a rationale for obtaining a global reduced model as a multi-mode multi-dimensional dynamical system with a cellular complex as state space. The method can be adopted to perform a dynamic parameter sensitivity analysis.

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MS36

Numerical Approximation of Nash Equilibria for a Class of Differential Games

In this talk we deal with the numerical approximation of Nash equilibria for a special class of m-player noncooperative games. We consider the infinite horizon control problem via the associated system of m Hamilton-Jacobi equations derived from the Dynamic Programming Principle and propose a fully-discrete scheme. The numerical solution is obtained via a fixed point formulation which also allows for an analysis of some properties of the approximation scheme. Well-posed and ill-posed problems for two players in several dimensions will be presented.

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MS36

Partially Observed H^∞-control with Maximum Running Cost

H^∞-control problems can be formulated as zero-sum games between controllers and deterministic disturbances. In this talk, we consider a partially observed H^∞-control with a maximum of a running cost over time. We first reformulate the problem in terms of an information state which is a sufficient statistic for describing the system. Then the problem can be a completely observable differential game of the information state in an infinite-dimensional space. We show that the value function of the game is a viscosity solution of a quasi-variational inequality in the infinite-dimensional space.

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MS36

Issues Concerning the Role of Information in Dynamic Games

Games are an ideal vehicle for showcasing the crucial role information plays in decision systems. The role of information is further amplified in dynamic games. One then refers to the information pattern of the game. In our paper conceptual issues related to the dynamic game's information pattern, tractability and/or intractability, and computational complexity, are discussed. A hierarchy of discrete-time deterministic and stochastic games with information patterns which increase in complexity is analyzed, and insights into the dynamics of information systems are obtained. Results which quantify the cost of uncertainty are derived. Special attention will be given to nonzero-sum dynamic games and the role the information pattern plays in nonzero-sum dynamic games.

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MS36

An Inter-group Conflict Model Integrating Perceived Threat, Vested Interests and Alternative Strategies for Cooperation

This paper is an extension of our previous inter-group simulation conflict model designed to integrate rational choice concepts with psychological dynamics. The previous approach modeled conflict as multiple dynamic compound Poisson stochastic processes where a rate of aggressive behavior was specified for group leaders and depended on three dimensions: perceived external threat, perceived success of a conflict strategy, and vested interest in a conflict strategy. The extended model incorporates information on alternative strategies for cooperation.

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MS37

Valuation of Swing-options with Implict and Ex-

plicit Risk Constraints

We consider the problem of computing the value of swing options when implicit or explicit risk constraints are imposed on the pay-offs. The price process of the underlying commodity is assumed to be a continuous-time Ornstein-Uhlenbeck process. We present models and algorithms for such problems which are based on discrete-time dynamic programming approximations. The techniques and some theoretical results as well as numerical results are illustrated by analyzing different examples.

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MS37

Joint Regular Properties of a Class of Hamilton-Jacobi-Bellman Equations with Recursive Functional

Herein, we investigate the regular properties of a class of Hamilton-Jacobi-Bellman (HJB) Equations which raises from some stochastic recursive control problem. We first obtain some joint Lipschitz continuity for a general class of HJB equations whose cost functional is characterized by some BSDE or reflected BSDE (RBSDE). We also establish some joint semi-concavity for these HJB equations.

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MS37

On Optimal Harvesting Problems in Random Environments

An optimal harvesting strategy is determined for a single species living in random environments. Harvesting acts as a singular stochastic control on the size of the population. Strategies are evaluated using the expected total discounted income from harvesting up to the time of extinction; the income rate is allowed to be state- and environment-dependent. A new sufficient condition is established for continuity of the value function for the regime-switching model.

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MS37

Mean-Variance Portfolio Selection for Partially-Observed Point Processes

In a ultra-high frequency trading environment, we study the classical mean–variance portfolio selection problem in an incomplete market with one bond and multiple stocks. Each stock price is modeled as a collection of counting processes, the noisy observation of the intrinsic value process. With incomplete information, we obtain a separation principle and derive the efficient strategies, which involves filtering. Moreover, we develop a numerical scheme for the efficient strategies via particle representation.

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MS38

Some Singular Control Problems for Stochastic Networks in Heavy Traffic

Singular diffusion control problems with state constraints arising from heavy traffic analysis of controlled stochastic processing networks will be considered. Wellposedness of the associated HJB equation will be established. Convergence of value function of the stochastic network control problem, in the heavy traffic limit, to that of the diffusion control problem will be shown. Based on joint works with Atar, Ghosh, Ross and Williams.

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MS38

Heavy Traffic Approximations for Waiting Times of a Queueing System with General Abandonment

For a G/GI/1+G type single server queueing system with impatient customers, we establish the heavy traffic approximation for the scaled offered waiting time. Limiting process is a diffusion, whose non-linear drift depends on the patience-time distribution of the customers. We also obtain the convergence of the expected value of an infinite horizon cost functional associated with the queueing system to that corresponding to the limiting diffusion process.

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MS38

On the Continuity of Stochastic Exit Time Control

Problems

We determine a weaker sufficient condition than that of Theorem 5.2.1 in Fleming and Soner (2006) for the continuity of the value functions of stochastic exit time control problems.

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MS38
Optimal Stopping for Non-Linear Expectations

We develop a theory for solving continuous time optimal stopping problems for non-linear expectations. Our motivation is to consider problems in which the stopper uses risk measures to evaluate future rewards.

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MS39
Power Series Solutions to the Dynamic Programming Equation for Time-varying Discrete Nonlinear Systems

In this work we propose a method for computing approximate solutions to the dynamic programming equation (DPE) arising from a discrete time-varying nonlinear control problem. Given an optimal trajectory x^* and optimal control u^*, we formulate an optimization problem for the transverse dynamics $z = x - x^*$ and $v = u - u^*$, resulting in a time-varying DPE. In the spirit of Al'brekht, we compute a time-varying power series solution to the DPE in a neighborhood of x^*.

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MS39
A Patchy Dynamic Programming Method for the Numerical Solution of Hamilton-Jacobi Equations

We present an approximation method for the solution of Hamilton-Jacobi equations which combines a patchy decomposition of the domain and a dynamic programming scheme. The patchy vector fields leading to the decomposition are inspired by a class of piecewise smooth vector fields introduced by Ancona and Bressan to study feedback stabilization problems. Since the subdomains are invariant with respect to the patchy vector fields, we can split the computation of the solution in each sub-domain and use a parallel method.

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MS39
A Higher Order Method for Solving the Infinite Horizon Hamilton-Bellman-Jacobo Equation

We present a modified version of the Patchy algorithm of Krener and Navasca for solving the infinite horizon Hamilton-Jacobi-Bellman equation. We show that the algorithm has higher order accuracy in a region of the state space where the problem data and optimal cost are smooth, and the optimal cost is a Lyapunov function.

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MS39
Numerical Methods for Hybrid Optimal Control with Autonomous Switching

We compare several numerical techniques for solving hybrid optimal control problems. We find estimation of the optimal switching times and construct optimal control and cost which minimize a cost associated with the dynamics. The methods include gradient descent, patchy method as well as efficient Krylov-based approach. The hybrid optimal control problem comes from the study of the stabilization of a second order differential equation with control occurring through a play operator. The play operator describes certain types of hysteric behavior such a mechanical play between gears.

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PP1
Unmanned Aerial Reconnaissance and Rescue Vehicle Systems (UARRVS)

The paper proposes a swarm of aerial vehicles, which provides low-cost, low-maintenance rescue service solution in addition to being a comprehensive terrain mapping and surveillance system. The system proposed does real-time vision-based target detection and generates contours for

terrains. Through this paper, the principle of swarm robotics has been extended to the realm of surveillance and rescue operations [Gerardo Beni, From Swarm Intelligence to Swarm Robotics, Swarm Robotics LNCS 3342, Berlin, 2005], ensuring efficient control.

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PP1

Feedback-Based Monte Carlo Computation of Fim for Multivariate Normal Distribution

The Fisher information matrix (FIM) summarizes the amount of information in the data and has wide applications in modeling, system analysis and estimation. However, there are many situations where an analytical form of FIM is not available. Conventionally, a resampling-based method is used to compute FIM. Here, we numerically illustrate a new method to estimate FIM – Feedback-based Monte Carlo approach. We show that this is an improved method over the resampling-based approach.

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PP1

Prediction of Limit Cycles in a Control System with Nested Feedback Loops

A technique and algorithms were produced to predict the occurrence of a limit cycles in a control system with nested feedback loops. The algorithms were developed through the use of different methods of describing functions including random and sinusoidal. The algorithm was applied to simulations in software (P-Spice and Matlab) and then extrapolated to work in our hardware. The results from the software simulation and the hardware (or actual occurrence) were compared.

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PP1

Robust Path Recognition Based on Time Varying Kalman Filter

This presentation introduces a robust recognition for mobile robot by using Kalman filter. A novel disturbance rejection method by using Kalman filter with robust color system is introduced. The covariant matrix of proposed Kalman gain varies to environment. The covariant matrix of Kalman gain have to change depending on the conditions of disturbance or brightness variation. Because these signals are usually unknown, this covariant values is assumed constant, however. Therefore, enough accuracy of rejection is not obtained by this method. We propose a time-varying Kalman gain based on template and show the validity of our method for path recognition of mobile robot under changes in illumination.

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PP1

Sensorless Tracking of Control for Wind Power Generating System via Fuzzy Model-Based CMAC

This paper proposes a maximum wind power tracking control using a Takagi-Sugeno fuzzy type cerebellar model articulation controller (T-S CMAC). The controller is designed based on cerebellar model articulation controller (CMAC) is used to estimate maximum wind power through CMAC which has auto-learning property. According to the state from wind energy conversion system (WECS), the controller would track the maximum power by learning more than hundred of thousand times. Using this controller we can find out that computation is less than original controller with self-learning skill, and the tracking time would be less than traditional controller.The effectiveness of proposed controller is performed and shown satisfactory numerical resuls.

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PP1

Variable Structure Control for Nonlinear Systems with Multiple Time Delays

This paper proposes variable structure control using a fuzzy neural network (FNN) and linear matrix inequality (LMI) approach for a class of uncertain nonlinear multiple time-delay systems. First, using a non-Isidori-Bynes canonical form of dynamics, multiple time-delay, and mismatched uncertainties, a novel sliding surface design is derived based on Lyapunov-Krasoviskii method. Meanwhile, the asymptotic stability condition of the sliding motion is formulated into solving a LMI problem which is independent on the delay. Second, an adaptive Takagi-Sugeno FNN controller is proposed to cope with high uncertainties, while a switching law compensates the effect of using TS-FNN reaching law. Overall, advantages of the controller includes: i) asymptotic stability of sliding motion is independent on the delay; ii) the sufficient condition of the sliding surface design formulated into LMIs is more simple and feasible; and iii) we obtain a simpler structure of FNN. Simulation results demonstrate the validity of the proposed control scheme.

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PP1

A Barrier Algorithm for Nonlinear Control Problem

In this presentation we have proposed a barrier algorithm for a set of nonlinear control problems.The nonconvex models are considered on Banach spaces.Elementary theoretical results have been established.Necessary optimality conditions are found and the stability of solutions is analysed.

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PP1

Optimal Control of Rotor Containing Liquid

The body rotating around its main axis is considered. It is filled with ideal or viscous liquid, fully or partly. Moments of forces are perpendicular to main axis. An integral dependence of angular velocity on these moments is obtained, which is equivalent to an ordinary differential set. After that the optimal control problems are formulated. Hamilton-Pontryagin theory and Bellman principle are used.

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