IC1

Stochastic Theory of Molecular Interactions Related to Intracellular Regulations

The molecular interaction is the fundamental feature of biological computations common to all intracellular regulations including transcription and metabolic regulations. We describe the molecular interaction as a finite state master equation and derived simple methods of computing its stationary state graphically. Our results not only gives a unified view of mathematical analysis of intracellular regulations, but also provides some novel interpretations to classical results in biochemistry. The classical Wegscheider condition which is concerned with the reversibility of the bio-chemical process is mathematically represented in terms of probability flow which is introduced by us. We also give a stochastic interpretation to the classical Michelis-Menten formula which is used extensively to represents the enzyme actions.

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IC3

Control of Systems Governed by Partial Differential Equations

Many control problems, such as active control of acoustic noise and vibration suppression, involve systems modelled by a partial differential equation. There are essentially two approaches to controller design for systems modelled by partial differential equations. In the first approach, the full model of the system is used in controller design. The designed controller is generally infinite-dimensional and is often subsequently reduced before implementation. This approach is generally not feasible, since a closed-form expression for the solution is not available. For most practical examples, a finite-dimensional approximation of the system is obtained and the controller is designed using this finite-dimensional approximation. The hope is that the controller has the desired effect when implemented on the original system. That this method is not always successful was first documented more than 30 years ago. A controller that stabilizes a reduced-order model need not necessarily stabilize the original model; or some other aspect of the system performance may be unacceptable. Systems with infinitely many eigenvalues either on or asymptotic to the imaginary axis are notorious candidates for problems. In this talk, some issues associated with approximation of systems for the purpose of controller design are discussed along with conditions under which satisfactory controllers can be obtained using approximations.

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IC4

A Guided Tour of Max-plus Algebra

Max-plus or tropical algebra deals with structures in which the addition is replaced by the maximum and the multiplication is replaced by the addition. I will present a guided tour of max-plus algebra, emphasizing the algorithmic tools that they provide to solve optimal control or zero-sum games problems via the dynamic programming method, and shedding light on some relations which have recently emerged with other fields, like discrete convexity and combinatorial matrix theory. I will illustrate the approach by a recent unexpected application of max-plus and control theory ideas to a basic problem in computer science: static analysis of programs.

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IC5

The Pontryagin Maxmimum Principle, Five Decades Later

Since the discovery of the Pontryagin Maximum Principle in the late 1950's, the original result has been extended and improved in many different directions. This talk will focus on new perspectives and developments about the finite-dimensional deterministic principle, especially the view of the principle as a statement about flows, and the emergence of new geometric insights, connections with nonsmooth analysis, and new theories of generalized differentials of maps.

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IP0

AWM-SIAM Sonia Kovalevsky Lecture: Swarming by Nature and by Design

The cohesive movement of a biological population is a commonly observed natural phenomenon. With the advent of platforms of unmanned vehicles, such phenomena has attracted a renewed interest from the engineering community. This talk will cover a survey of the speaker's research and related work in this area ranging from aggregation models in nonlinear PDE to control algorithms and robotic testbed experiments. We conclude with a discussion of some interesting problems for the applied mathematics community.

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IP0

The John Von Neumann Lecture

To follow.

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IP0

W. T. and Idalia Reid Prize in Mathematics Lecture: The Moment Problem for Positive Rational Measures: Convexity in the Spirit of Krein

The moment problem as formulated by Krein and Nudel'man is a beautiful generalization of several important classical moment problems. However, the importance of rational functions in systems and control and other engineering applications imposes certain complexity constraints. In this talk we present a new formulation of the moment problem which respects these constraints. While this version of the problem is decidedly nonlinear, the basic tools still rely on convexity. In particular, we present a solution in terms of a convex optimization problem that generalizes the maximum entropy approach used in several classical special cases.

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IP0

I.E. Block Community Lecture: "Kill All The Quants?": Models vs. Mania In The Current Financial Crisis

As the shockwaves of the financial crisis of 2008 propagate throughout the global economy, the "blame game" has begun in earnest, with some fingers pointing to the complexity of certain financial securities, and the mathematical models used to manage them. In this talk, I will review the evidence for and against this view, and argue that a broader perspective will show a much different picture. Blaming quantitative analysis for the financial crisis is akin to blaming $E = MC^2$ for nuclear meltdowns. A more productive line of inquiry might be to look deeper into the underlying causes of financial crisis, which ultimately leads to the conclusion that bubbles, crashes, and market dislocation are unavoidable consequences of hardwired human behavior coupled with free enterprise and modern capitalism. However, even though crises cannot be legislated away, there are many ways to reduce their disruptive effects, and I will conclude with a set of proposals for regulatory reform.

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IP0

Past Presidents Address: Parallelism and Puzzles

Every talk that Ive given at a SIAM meeting for the past 30 years has included some material about parallel computing. This talk will be no exception. In addition, I want to demonstrate some of our Experiments with MATLAB project intended for younger students.

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JP1

Semi-smooth Newton Methods in Function Spaces and Applications to Variational Problems in Optimal Control and Imaging

Non-differentiable variational problems arise in diverse areas of current interest, as for instance in optimal control governed by partial differential equations with constraints on the controls or the state, in mathematical imaging with bounded variation (BV) type regularization or sparsity constraints, in mathematical finance, and control of variational inequalities. At first, second order Newton type methods appear to be out of scope, and therefore (conjugate-) gradient methods are often used to solve such problems in practice. Exploiting the special structure, however, frequently *Newton-differentiability* can still be ascertained. This guarantees super-linear convergence of Newton-type methods. In case Newton-differentiability fails this is a phenomenon of the infinite dimensional setting and can be remedied by a regularization process. For the choice of the regularization parameter a model-based path-following strategy is proposed.

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CP1

Comparison Between Open Loop Optimization and Closed Loop Feedback Control for a Jet Flow Problem

Two different approaches to a fluid flow optimization problem are compared. Approach 1: The classical gradient-based optimization method is used where the gradient of the objective function is calculated through the sensitivity equations. Approach 2: A nonlinear POD/Galerkin model is used as an approximation to the flow governing equations, and a feedback controller based on gap-metric robust control is designed for the linear dynamics of the model and applied to the nonlinear one.

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CP1

Effects of Secondary Flows on the Transverse Distribution of the Depth Average Velocity in Free Surface Flows

In this study we analyzed the effects of secondary flows on the transverse distribution of the depth average velocity in free surface flows above non-uniform bottom roughness. In a first preliminary step, 3D-simulations were achieved using an anisotropic algebraic Reynolds stress model to determine the wall friction and the dispersion terms present in the depth averaged momentum equation. In a second and fundamental step closure assumptions of these terms were tested to define a 2D-Saint Venant model which is solved to calculate the transverse profile of the depth-averaged velocity. This approach was applied to opened channels with periodic transverse variation of the roughness with reference to some available experimental results. This process could allow analyze of scale change problems.

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CP1

Modeling the Dispersion in the Free Surface Flows

In this study we analyzed the effects of secondary flows on the transverse distribution of the depth average velocity in free surface flows above non-uniform bottom roughness. In a first preliminary step, 3D-simulations were achieved using an anisotropic algebraic Reynolds stress model to determine the wall friction and the dispersion terms present in the depth averaged momentum equation. In a second and fundamental step closure assumptions of these terms were tested to define a 2D-Saint Venant model which is solved to calculate the transverse profile of the depth-averaged velocity. This approach was applied to opened channels with periodic transverse variation of the roughness with reference to some available experimental results. This process could allow analyze of scale change problems.

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CP1

Non Standard Homgenization Theory For the Advection Diffusion Equation

The transport of passive scalars has been well studied using the advection diffusion equation in the case of periodic fluctuations with a weak or equal strength mean flow using homogenization theory. Homogenization seems to breakdown in the strong mean flow regime. Numerics however seem to suggest that homogenization theory still works. We develop a framework of non standard homogenization theory to study this case.

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CP2

Quantum Optimal Control Via Fluctuation Free Integration

This work deals with the expectation value equations of an optimally controlled univariate system. Position, momentum and certain control operators are taken into consideration via their expectation values as temporal unknowns. The resulting equations contain certain unknown terms over matrix representations of these operators. The matrix representations are approximated by the images of these operators under certain functions. The resulting equations become boundary value problems in time.

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CP2

An Iterative Procedure for Constructing Subsolutions of Discrete-Time Optimal Control Problems

We introduce an iterative procedure for constructing subsolutions of deterministic or stochastic optimal control problems in discrete time with continuous state space. The procedure generates a non-decreasing sequence of subsolutions, giving true lower bounds on the minimal costs. In each step, state trajectories are computed which serve to update the current subsolution.

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CP2

Moderation Incentives in Optimal Control

When something needs to be done as quickly as possible, the bounds on the possible are crucial in determining the optimal strategy. Moderation incentives—control-dependent cost function modifications rewarding avoidance of the admissible control region boundary and equaling zero on that boundary—can be used to construct smooth solutions of constrained optimal control problems. Subtracting a control-dependent moderation incentive scaled by a moderation parameter from a purely state-dependent cost term generates a one-parameter family of cost functions.

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CP2

Continuous-Time Dynamic Shortest Path Problem

The continuous-time dynamic shortest path problem is a generalization of the shortest path problem for a network in which arc costs can vary over time, each arc has a transit time, and parking is allowed at nodes. This problem is formulated as an infinite-dimensional linear program (LP) problem over a space of measures. In this study, we consider a general class of continuous-time dynamic shortest path problems for which problem data (e.g., arc costs, transit time and parking costs) can take negative values. We characterize extreme-point solutions of the LP formulation and derive a one-to-one correspondence between extreme-points and continuous-time dynamic shortest paths. Moreover, we define a dual problem and establish a strong duality result in the case where costs are piecewise analytic.

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CP2

The Maximum Principle for Problems with Delay in the Control: A Multiprocess Approach

We use the theory of multiprocesses to derive necessary conditions for the optimal control problem of minimizing the functional

$$\ell(x(T)) + \int_0^T L(x(t), u(t), u(t-\delta))\, dt$$

over all functions $x(\cdot)$ satisfying the dynamics $\dot{x}(t) = f(x(t), u(t), u(t-\delta))$ a.e. $t \in [0, T]$. In a more general sense, our results also introduce necessary conditions for certain multiprocess problems with constraints. Multiprocesses can be used to treat hybrid control problems and we believe our results constitute a first step for treating new classes of these.

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CP2

Value Functions and Transversality Conditions for Infinite-Horizon Optimal Control Problems

This paper investigates a relationship between the maximum principle with an infinite horizon and dynamic programming and sheds new light upon the role of the transversality condition at infinity as necessary and sufficient conditions for optimality with or without convexity assumptions. We first derive the nonsmooth maximum principle and the adjoint inclusion for the value function as necessary conditions for optimality that exhibit a relationship between the maximum principle and dynamic programming. We then present sufficiency theorems that are consistent with the strengthened maximum principle, employing the adjoint inequalities for the Hamiltonian and the value function. Synthesizing these results, necessary and sufficient conditions for optimality are provided for the convex case. In particular, the role of the transversality conditions at infinity is clarified.

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CP3

Adaptive Estimation of Fuzzy Cognitive Maps with Proven Stability and Parameter Convergence

Fuzzy Cognitive Maps (FCM) are signed directed graphs that model complex behavioral systems in various scientific areas. Current literature on estimating their weight interconnections do not consider conditions on the existence and uniqueness of their points of equilibrium (FCM solutions). In this paper we propose an adaptive weight estimation algorithm which guarantees exponentially fast error convergence to zero and uses the obtained conditions to construct appropriate weight updating rules.

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CP3

A Two-Patch Model for Plant-Herbivore Interactions

Our objective is to understand how insect (parasite) migration is impacted by the local population dynamics. We formulate and study a simple two patch discrete time plant herbivore (parasite) model. A fundamental feature of the model is the occurrence of three different time separated phases: Plant growth is followed by a parasite attack which is followed by a dispersal of the parasite. Our model incorporates intra-plant competition as well as nutrient recycling. We explore the existence and stability of synchronized dynamics between the two patches and the existence of interior equilibria at different levels of the herbivore. We show that for moderate coupling between the two patches, the infestation may actually disappear in both patches, suggesting a possible biology control strategy to stop the invasion of a pest by controlling its migration between patches.

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CP3

Controlling Clustering Behavior in Neural Networks

Coupled Hodgkin-Huxley neurons are considered when finite signal transmission times introduce time delays into the couplings. Stability of the fully synchronous and partially synchronized cluster states are studied by varying the coupling delay. Based on these investigations an act-and-wait controller is constructed that uses delayed inputs to destroy full synchrony and stabilize clustering. Such a controller may be useful to drive neural systems away from pathological synchronous states associated with Parkinson's disease.

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CP3

Customizing Drug Regimes Using Robust Nonlinear Model Predictive Control

Robust nonlinear model predictive control with sparse grid-based optimization is applied to personalize the scheduled dosing of pharmaceuticals based on recurrent observations. As an example, maintenance chemotherapy for childhood acute lymphoblastic leukemia is tuned using routine mean corpuscular volume measurements. Employing a model that reflects the action of 6-mercaptopurine on the cell cycle, robust controller parameters (drug doses and timing) were selected to sustain desired cell volumes while mini-

mizing outcome sensitivity to model uncertainties.

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CP4

Sub-Optimal Risk-Sensitive Filter Design for Polynomial Stochastic Systems

The risk-sensitive filter design problem with respect to the exponential mean-square criterion is considered for stochastic Gaussian systems with polynomial drift terms and intensity parameters multiplying diffusion terms in the state and observations equations. The closed-form suboptimal filtering algorithm is obtained linearizing a nonlinear third degree polynomial system at the operating point and reducing the original problem to the optimal filter design for a first degree polynomial system. The reduced filtering problem is solved using quadratic value functions as solutions to the corresponding Hamilton-Jacobi-Bellman equation. The performance of the obtained risk-sensitive filter for stochastic third degree polynomial systems is verified in a numerical example against the mean-square optimal third degree polynomial filter and extended Kalman-Bucy filter, through comparing the exponential mean-square criteria values. The simulation results reveal strong advantages in favor of the designed risk-sensitive algorithm for large values of the intensity parameters.

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CP4

A Numerical Scheme for Certain Perturbed Stochastic Control Problems

We start with a stochastic control problem which has a smooth solution together with its PDE representation. Then we study how some nonlinear perturbation terms change the properties of the solutions and how to compute the corresponding value functions. We use forward-backward SDEs and their connections with PDEs to construct a numerical scheme and study its regularity and convergence properties. We use stochastic LQR problem as a benchmark and state sufficent conditions for the procedure.

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CP4

Numerical Methods for Optimal Controls for Nonlinear Stochastic Systems With Delays: Algorithms and Data

The Markov chain approximation methods, widely used to compute optimal value functions and controls for stochastic systems, was extended to general controlled nonlinear diffusions with delays in a recent monograph of the author. The path, control and/or reflection terms can all be delayed, and the memory requirements can be huge. Recasting the problem in terms of a "wave equation' yields algorithms with considerably reduced memory requirements. We concentrate on the algorithmic details and present numerical data showing that the methods work well.

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CP4

Multi-Player Stochastic Game of Defending a Target: A Risk-Averse and Pareto Strategy Approach

The problem of pursuit and evasion is extended to a problem of defending targets, where the roles of the teams are interchanged. In particular, the evading team of aggressors is to approach some either stationary, moving, or escaping targets, whereas the pursuing team is to defend the targets by intercepting the evading team. For the linear-quadratic problem class, an end-game engagement of risk-averse and non-inferior strategy is proposed to allow performance assessment with high confidence for the teams on the basis of non-cooperative interactions. Furthermore, the conceptual solution is enabled by three prerequisites: 1) the Know-How related to competencies, 2) the Know-How-to-Cooperate related to coordination between activities, and 3) the Need-to-Cooperate to justify the activities of cooperation under the presence of competition and mixed random behaviors from adversarial teams and a stationary stochastic environment, respectively.

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CP4

A Combined Linear/Integer Programming Heuristic to Control Multi-Action Restless Bandits

We develop a two-step heuristic to control a network of Markov decision processes (MDPs) to which multiple varied actions may be applied. An MDP linear program obtains optimal policies and reduced cost coefficients for individual projects. Integer programming, using the reduced cost coefficients, is then used to assign resources to projects. We compare the performance of this approach with the optimal policy when computationally feasible and, for larger problems, the greedy policy.

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CP4

Multi-Target Tracking Via Restless Bandits' Marginal Productivity Index and Kalman Filter in Discrete Time

Using the Kalman Filter, we formulate as a discrete-time multi-armed restless bandit model the problem of tracking a collection of independent targets moving along one dimension by several sensors. We propose a tractable scheduling policy that nearly-minimizes the sum of the

measurement and observation cost. Using indexation theory, we establish indexability and derive a bound on the system's optimal performance. Computational results indicate that our policy outperforms the conventional greedy policy.

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CP5

The Back and Forth Nudging Algorithm for Controlling a Backward System and Estimating An Initial Condition

We consider the Back and Forth Nudging algorithm for estimating the initial condition of a geophysical system. This scheme does not require any linearization, or adjoint equation (unlike variational schemes). However it iteratively provides new estimations of the initial condition. We study its convergence properties and efficiency on a shallow water model. We show that it is possible to control the backward (in time) trajectory, and the error decreases exponentially with the number of iterations.

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CP5

Dynamic Distributed Control over Semirings and Applications

We demonstrate that many constrained dynamic control problems involving hybrid systems are control problems for dynamical systems over partially ordered semirings. Applications include biological-social-communication networks, collaborative robotics, consensus, flocking, trust, swarms. We next show that when time is discrete and inputs, outputs and states take values in finite sets, these problems are equivalent to constrained shortest path problems. We then develop algorithms, mostly distributed ones, for solving these dynamic constrained shortest path problems over semirings.

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CP5

Distributed Semistable LQR Control for Discrete-Time Dynamically Coupled Systems

A distributed linear-quadratic-regulator (LQR) semistability theory for discrete-time systems is developed for designing optimal semistable controllers for discrete-time coupled systems. Unlike the standard LQR control problem, a complicating feature of the proposed optimal control problem is that the closed-loop discrete-time semistable Lyapunov equation can admit multiple solutions. Necessary and sufficient conditions for existence of solutions to the discrete-time semistable Lyapunov equation are derived and a design framework for distributed optimal controllers is presented.

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CP5

Dynamics of a Model of a TCP Protocol with Randomized Routing

The Internet has become a central means of communication on a global scale. Its emergence over the last two decades has been facilitated by the introduction of congestion control methodologies such as TCP, that allow millions of users to share network resources without causing congestion collapse. We will discuss a mathematical model of such a protocol that maximizes network utility by joint control of congestion and routing of traffic. If multiple routes between locations in a network are available, there is a trade-off between utility and the diversity of paths available to users who want to transmit with minimum cost. The entropy of the probability distribution associated with a random route allocation scheme can be used analyze this trade-off when the dependence of the utility on the link capacities and the topology of the network is shown. We illustrate this with two examples.

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CP5

Optimal Control of Switched Systems

We consider optimal control of switched systems. In such systems, the control consists of continuous as well as discrete signals where the discrete input represents switches between finitely many dynamic subsystems. We will derive conditions on finding the optimal switching sequence and switching times between the subsystems, as well as finding the optimal continuous input. We illustrate our results using an air traffic control application in which the optimal switch time between allowable runway configurations needs to be determined.

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CP5

Performance Limitation on Nonlinear Stabilization with Uncertainty

The problem of performance limitation on the stabilization of nonlinear dynamical system in the presence of uncertainty is studied. Necessary and sufficient conditions for the stabilization are expressed in terms of global expansion rate, as captured using the characteristic exponents, of the system.

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CP6

An Obstacle Avoidance Scheme Using Cubic Spline

Functions from Real Robotic Vehicle Sensory Measurements

A generalisable real-time obstacle avoidance method for robotic vehicles equipped with sensory perception using cubic spline functions generated from sensory measurements. The proposed method uses cubic spline functions generated from the normalized sensory measurements at the momentary location of the robotic vehicle to compute a steering actuation. The steering actuation is then combined with the overall robot control steering function allowing the robots to avoid obstacles while being steered towards a goal position.

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CP6

Particle Swarm Optimization Based Robust Predictive Control: Application to Guidance

This paper proposes a novel approach of model predictive guidance by implementing a new Particle Swarm Optimization (PSO) method, Hybrid Gradient Descent PSO. The models of the plant and predictor used include random target maneuvers, actuator saturation, rate of change of commanded acceleration saturation, very high measurement noise ($\geq$ 50% of signal) and unknown target acceleration (η_T) model, thus presenting a realistic engagement scenario. The final lateral miss and energy expended are minimized.

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CP6

Sensor Guided Flight for Fixed-Wing Uavs

Sensor Guided Flight describes the ability for a UAV's sensing system to automatically request a platform position and attitude that maximizes sensor performance. This is a particularly difficult problem for slow, fixed-wing UAVs. Toyon's Sensor Guided Flight algorithm tightly couples the platform and sensor control: optimal sensor footprints are determined from a target pdf, then optimal viewing angles for those footprints are selected to respect environmental conditions and line-of-sight to the ground and targets.

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CP6

A New Algorithm for Automated Aircraft Conflict Resolution

The growth of the traffic is a major challenge for the next twenty years. Future air traffic management systems will incorporate automatic conflict solvers to allow more flexible use of airspace (4D trajectories generation). In this lecture we will present a new approach based on an analogy with light propagation. The resulting trajectories are guaranteed conflict free. Furthermore, they are approximate geodesics with respect to a metric linked with congestion of airspace and allow for feasible aircraft velocities.

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CP6

Complexity in Air Traffic Management

Growth of the air traffic is a challenge for the next twenty years. Major innovative projects (SESAR in Europe, NexGen in US) have been launched to develop new concepts. Among these, a definition of the complexity of a traffic configuration is required. We will present a new approach based on fitting a dynamical system to observed aircraft positions and velocities then computing Lyapunov exponents on a regular grid to produce a complexity map. A new kind of interpolating splines will be introduced for time-dependent vector field fitting.

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CP6

An Inertial Navigation System Based on a Simple Apposition Eye

In recent work with collaborators, we showed that it is possible to build a strap-down type inertial navigation system (that we call an Optical inertial Navigation System (ONS)) using a simple apposition eye, which is a type of compound eye found in insects. The ONS is assumed to be rigidly mounted on a micro unmanned aircraft. Using a Fourier optics model for a lens-optical fiber system, we showed that each lens-fiber system in the eye behaves as a low pass spatial filter, with a very low bandwidth. This fact is an important distinguising feature from simple eyes such as those found in humans. Considering a mathematical idealization of a continuum of lens-fiber systems on a regular corneal surface, we show that the ego-motion estimation problem is well-posed, for sufficiently rich quasi-monochromatic, incoherent excitation on an allowable, regular corneal surface. A significant result of practical importance, is that the solution to the ego-motion problem does not depend on the parametrization of the surfaces, or the parameters of the aircraft (such as mass and moment of inertia) on which the

ONS is mounted.

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CP7

Optimal Stopping Games for Stochastic Systems with Memory

In this paper, an optimal stopping game for a system of stochastic functional differential equations with a bounded memory is considered. The game consists of two players with conflicting objectives. Player I (respectively, Player II) wants to maximize (respectively, minimize) an objective function by choosing an appropriate stopping time. Under some conditions, Hamilton-Jacobi-Isaacs (HJI) variational inequalities for the upper and lower value functions are derived via dynamical programming principle. It is shown that each of the value functions is the unique viscosity solution of the corresponding HJI variational inequality.

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CP7

Invariance Entropy for Systems with Output

The purpose of this contribution is to study the information needed to achieve controlled invariance. Following a proposal by Nair, Evans, Mareels and Moran (2004), this is achieved using a measure similar to the notion of topological entropy in the theory of dynamical systems. More specifically, an approach introduced earlier for subsets of the state space is generalized for controlled invariance of subsets in the output space. Results for linear and nonlinear control systems are presented.

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CP7

An Optimal Trading Rules of a Mean-Reverting Asset

This work provides an optimal trading rule that allows buying, selling and selling short of an asset when its price is governed by mean-reverting model. The goal is to find the buy and sell prices such that the overall return (with slippage cost imposed) is maximized. The associated HJB equations are used to characterize value functions. The solution of the original optimal stopping problem is presented by solving four algebraic equations. Examples are given.

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CP7

Feedback Control for a Weakly Perturbed Stochastic Oscillator with a Guaranteed Escape Rate

A control strategy for a Lagrangian system with small noise is suggested. The control task is to build a system with a noise-independent escape rate (in the small noise limit). The results employ the large deviations approximations of escape rate for Lagrangian systems. An explicit asymptotic formula allows us to design a regulator ensuring a noise-independent escape rate in the controlled system. Applications to physically meaningful problems illustrate the theory.

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CP7

Showing Existence of a Converging State Estimate for Quantized Control System Using Entropy and Total Variation

Consider discrete-time continuous-state unstable dynamical systems. An asymptotically converging state estimate using limited data-rate information is possible, if and only the informations entropy is larger then the increase at every time step of the differential entropy of the states probability distribution function. As opposed to showing necessity, differential entropy alone is not enough to show sufficiency. However, using also the notion of total variation we are able to prove the sufficiency direction.

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CP8

A Simple Characterization of the Normal Forms for Nonlinear Control Systems

In this paper we propose a methodology to derive normal forms for nonlinear control systems around equilibria and relative equilibria. This approach extends to control systems with special structure.

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CP8

Convergence of Gradient-Type Observers for Invariant Systems on SO(n)

Applications in robotic autonomous systems have motivated the recently increasing interest in observers for invariant systems on Lie groups. Here, we consider an observer for left-invariant systems on the special orthogonal group $SO(n)$ with outputs invariant under the left action of $SO(n)$ on the output space S^{n-1}. We propose an observer construction for these systems based on a gradient law. We give a criterion on the inputs for almost global convergence of this observer.

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CP8

Fast Regulation for A Class of Nonholonomic Systems Using Virtual Trajectories

This talk concerns the regulation problem for a class of nonholonomic systems that includes of rolling sphere as a special case. The basic ideal is to first introduce a virtual moving periodic trajectory. Under a full rank condition, the associated tracking problem with fast convergence is then solved and used to achieve practical stability for the regulation problem. To verify the effectiveness of the proposed results, an interesting simulation result is also presented.

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CP8

An Equation-free Approach Towards Closed-loop Non-linear Control of the Flow Around a Cylinder

We present an approach towards efficient closed-loop nonlinear control of the flow around a cylinder. An equation-free approach is employed by determining the mapping of the control law to apply based on the current system state. An approximation of the mapping is derived by projection as a preprocessing step. The control is then simply evaluated in real-time at no cost by application of the mapping to the vector state.

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CP8

Numerical Simulation of An Almost Global Attitude Tracking Control Scheme Using a Lie Group Variational Integrator

We obtain a variational integrator to numerically simulate an almost global attitude tracking control scheme that was recently reported. Instead of discretizing the equations of motion governing the feedback attitude dynamics, we use the discrete equations obtained from the discrete Lagrange-dAlembert principle. The resulting Lie group variational integrator numerically implements the feedback attitude dynamics in the presence of control and external moments. We give numerical simulation results for the attitude tracking of an AUV.

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CP9

Existence of Solutions for Some Functional Integral Equation

In this paper, we present an existence of solutions for some nonlinear functional-integral equations which include many key integral and functional equations that appear in nonlinear analysis and its applications. This functional-integral equation produces many integral equations which have arisen in different science fields such as theory of optimal control, economics and etc. Also we prove that the solution of this type equation is bounded and continuous. For getting these results, we employ the fixed point theorem and Darbo condition with respect to a measure of noncompactness in the Banach algebra.

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CP9

Stability Analysis of Uncertain Dynamical Systems

The problem of stability verification of uncertain dynamical systems is studied. Lyapunov measure, developed for stability verification of deterministic dynamical systems, is used to verify the hierarchy of stability notions as defined by Lyapunov and moment Lyapunov exponents in uncertain dynamical systems. Transfer operator based framework and its finite dimensional approximation using set-oriented numerical method is used for the computation of Lyapunov measure. Simulation results on the consequence of instability as verified using Lyapunov measure in uncertain dynamical systems are presented.

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CP9

Stability Results for Coupled Subsystems with Applications to Distributed Control of Heterogeneous Vehicles Platoons

We study the stability of a possibly infinite string of coupled stable subsystems, characterized by a DC gain condition (Angeli 2006, Lanzon and Petersen 2008) which is expressed as a continued fraction with verifiable convergence properties. Through analysis of the convergence of the continued fraction, we establish both stability and robustness for the infinite string under arbitrary coupling patterns. The derived stability results are used to achieve locally distributed control of heterogeneous vehicle platoons.

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CP9

Computation of Minimal Collision Time for Switching Control between Trajectory Tracking and Avoiding Collision with a Non-Cooperative Vehicle

A autonomous vehicles are requested to achieve their own tasks like trajectory tracking without collision with the other ones. Then, we consider a method that the controlled vehicle tracks the reference trajectory and avoids the collision with the non-cooperative vehicle which is the model of the other vehicle. We propose a switching control which switches between the collision avoidance and the trajectory tracking modes, based on the minimal collision time.

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CP9

Flocking of Swarms Under Bounded Disturbance

We will present a decentralized controller for a swarm of mobile agents to flock at presence of unknown disturbance. The proposed controller is general and only needs local sensing information for the swarm to achieve collective behaviors. We assume that during the swarms motion, each agent can sense and interact with its neighbors while follow the gradient force of the environment. The disturbances on the agents are unknown but assumed to be bounded by a known bound. We show that the controller can make the velocities of all agents ultimately bounded converge to a common value under bounded disturbance.

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CP9

Parameter Identification from Dilatometric Investigations

Dilatometric investigations are often employed in the metallurgy for the analysis of the phase transformations in steel during the heat treatments. The goal is a mathematical investigation of dilatometer experiments to measure the kinetics of solid-solid phase transitions in steel upon cooling from the high temperature phase. One can show that the complete phase transition kinetics are uniquely determined by the dilatometer data and present some numerical identification results.

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CP10

Some Properties of Modal Trajectories of Systems Which Measure Diffraction Intensity from a Spherical Object Whose Motion Is Known

I consider point-like object, whose non-random motion is disturbed by linear noise, as the field measurements also. The sequences of probability densities for position, velocity and measurement variables are calculated numerically for various cases of parameters. General properties of the behaviour of these systems are obtained. Suggestions in case of unknown target motion are made. The results are presented in, about, 35 pages of text and 100 diagrams.

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CP10

Robust Discrete Generalized Proportional Integral

Control for Induction Motors

The problem of controlling induction motors is tackled by means of an observer based robust discrete-time linear approach. Model uncertainties and external disturbances are assumed to be bounded and band limited, represented by an entire family of local polynomial approximations. The observer carries out the disturbance estimation reducing the complexity of the controller design. The controller efficiency is tested with experimental results, performing a trajectory tracking task under load variations.

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CP10
Multi-Criteria Optimization for Adaptive Resource Management in Phase Array Radars

As Phase Array Radars can be programmed for a variety of tasks in real time, these radars are required to carry out multiple functions (*volume search*, *tracking*, ...). In a constantly changing environment, they require adaptive resource management to select and prioritize tasks while their performance is measured on many criteria (coverage, time, energy,...). To resolve this multi-objective problem, Multi-criteria Analysis is applied to generate algorithms providing Optimized control solutions to tasks assignment.

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CP10
Optimal Control of a Thermomechanical Model Including Transformation Induced Plasticity

Metallurgical phase transitions may invoke shape alterations of steel workpieces in different ways, e.g. by the phases' different densities or by means of transformation induced plasticity, which occurs even for small stresses below yield if phase transitions take place. We investigate an optimal control problem for a thermomechanical model of phase transitions in steel and present numerical results achieved by finite element computations.

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CP10
A Hysteresis Hybrid Cascade Observer for Sensorless Valve Control in Camless Internal Combustion Engine

Camless internal combustion engines offer improvements over traditional engines in terms of torque performance, reduction of emissions, reduction of pumping losses, fuel economy. Theoretically, electromagnetic valve actuators offer the highest potentials for improving efficiency due to their control flexibility. Sensorless control is one of the most important issues with regard to implementation in real cases of this new technology. This paper proposes a hysteresis hybrid cascade observer to realize a sensorless control. The proposed observer consists of two parts, a switching velocity observer combined in cascade with a Luenberger observer. A hysteresis strategy is introduced which allows the avoidance of not only chattering problems but to trade with not observable sets. The proposed structure consists of two models and, each model, of two embedded functioning ones. Current is measured and position as well as velocity of the electromagnetic valve are estimated. Real measured data by means of an innovative electromagnetic valve actuator as an experimental setup are used to show the effectiveness of the proposed method.

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CP10
Sparse Dynamic Texture Modeling

A dynamic texture is a sequence of images that exhibit a certain regularity and that can be modeled by a reduced order linear time-invariant model. In this paper, we extend the idea to cases where images in the sequence have a sparse representation with respect to an over-complete dictionary of basis functions, in which case a piece-wise linear model is estimated. We propose a model estimation algorithm based on K-SVD, for optimizing the over-complete dictionary and present an initialization step that lends itself to an alignment algorithm used for obtaining a reduced order system.

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CP11
LMI Based Sliding Mode Control Design for Twin Rotor System

A new linear sliding manifold for twin rotor system has been proposed which assures the system performance and the control effort required to maintain sliding, in an optimal way. The convex optimization problem has been developed based on structural assumption on the Lyapunov matrix for the closed-loop system. The feedback control law designed from sliding surface delivered the simulation results, which show the effectiveness of the algorithm for regulation control of twin rotor system.

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CP11
Closed Range Operators and Minimization Problems

The goal of the talk is to give some first order necessary conditions for the following problem

$$L(y_o,u_o) = \text{Local Minimum}\, L(y,u) = g(y) + h(u),$$
$$\text{subject to } (y,u) \in M = \{(y,u), Ay = Bu + f\}, \qquad (P)$$

where H is a Hilbert space, $f \in H$, g, $h : U_{\text{open}} \subseteq H \to \mathbf{R}$ are Fréchet differentiable, or locally Lipschitz continuous,

$A : D(A) \subset H \to H$, and $B : D(B) \subset H \to H$ are linear densely defined operators, and the hypothesis (H_1) below holds. (H_1): $R(B)$ is closed and $S^{AB} = \{v \in D(A);\ Av \in R(B)\}$ is dense in H. Our result is derived using Bouligand's tangent cone. The range condition (H_1) may not be necessary for our optimality conditions to be verified and we show that such a situation is where A and B are linear bounded operators.

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CP11

Hybrid Model for Process Control

A hybrid model integrates a second-order process model and ARIMA (0, 1, 1) model that describes the stochastic output, when i.i.d Normal (0,1) random shocks pass through a filter by means of a feedback control algorithm. The algorithm simulation gives the input adjustment to bring the control error standard deviation of the outgoing product quality control variable as close to the controller set point and to minimise its control error variance. It also provides data for the adjustment intervals within the constraints of feedback control stability, controller gain, and process gain. The algorithm can be applied to paper and food industries and implemented through a parallel processing architecture.

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CP11

Necessary and Sufficient Controllability Conditions for a Continuum of Time-Varying Linear Systems

We study a new class of control problems which involves controlling a continuum of parameterized dynamical systems with the same open-loop control input. We call such problems Ensemble Control. We derive the necessary and sufficient controllability conditions and an accompanying analytical optimal control law for a continuum of finite dimensional time-varying linear systems. We show that ensemble controllability is related to the singular values of the linear operator characterizing system dynamics.

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CP12

Nonlinear Filtering and Estimation: Application to a Cardiovascular Control Model

In this talk we discuss state and parameter estimation using nonlinear Kalman Filtering as applied to a nonlinear cardiovascular control model. The model is sufficiently detailed so that it can be used to study control interactions and perhaps shed light on the underlying physiology. However, many aspects of the dynamical system and measurement affect the performance of the estimation algorithm and determine the accuracy of the computed estimates. These aspects will also be discussed.

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CP12

Indirect Adaptive Control of Unknown Mimo Nonlinear Systems Using a New Neuro-Fuzzy Representation

The indirect adaptive regulation of unknown nonlinear dynamical systems under the presence of dynamic and parameter uncertainties, is considered in this paper. The method is based on a new Neuro-Fuzzy Dynamical Systems definition, which uses the concept of Fuzzy Dynamical Systems (FDS) operating in conjunction with High Order Neural Network Functions (F-HONNFs). Once the system is identified around an operation point, it is regulated to zero adaptively.

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CP12

Regularization and Parameter Identification for Ill-Posed Quasi-Variational Inequalities

This talk will focus on the stability issues for ill-posed quasi-variational inequalities. As a regularization tool the so-called elliptic super regularization will be employed to a quasi-variational inequality with multi-valued monotone operators. Regularization will be used to handle the data perturbation as well as non-coercive operators. Applications of our results to the identification of variable parameters in partial differential equations will be discussed. We will also discuss the case when the set of admissible coefficients are also coefficient-dependent. Finite element based numerical examples will be presented.

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CP12

Comparison of Coupled Harmonic Oscillators and Finite Difference Approximations of the Wave and

Schrodinger Equations for Control

Solutions of the equations for coupled harmonic oscillators and separation of variables solutions of finite difference (space/time) equations for the wave equation are well-known. Separation of variables solutions of finite difference equations for the Schrodinger equation having the same spatial part as the above solutions have been obtained. We investigate these similarities for controlling the Schrodinger equation. Oscillator equations and space semi-discretizations of the wave equation are the same, modulo constants.

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CP12

A Numerical Method for Solving Time Optimal Control and Minimum Effort Control Problem

We present a numerical method to solve the time optimal and minimum effort control problem for nonlinear systems. Necessary optimality system is formulated using Lagrange multiplier theory. Shooting method with semismooth Newton method is developed to overcome the discontinuities in the control law. The Jacobian for the Newton method is computed based on second variation. The globalization of the shooting method is attained by solving a related minimum norm problem and using the standard line search strategy. Applications to control of quantum spin system and heat equation are demonstrated.

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MS1

Optimal Impedance Factor Under Uncertain Wavenumber

We consider the Helmholtz equation which models the acoustic wave propagation. We assume that wave number in the Helmholtz equation is random. The randomness of the wave number is due to inaccuracy in data collection as well as uncertain operating conditions. The goal of the optimization problem is to find the best impedance factor so that the noise radiation is minimized. Because of large amount of computing cost, the regular Monte Carlo method is prohibitively expense. In this talk, we will present an improved Monte Carlo and quasi Monte Carlo method to efficiently evaluate the cost function of the optimal control problem. Numerical results will also be presented.

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MS1

Stochastic Optimal Control and Optimization in Aerodynamics

Uncertainty occurs in virtually every aspect of our daily life. Uncertainty, for instance, governs the prices of fuels, the availability of electricity, the demand for chemicals, wind speed, traffic, stock market and much more. In the past half-dozen years, there have been several events that serve to increase awareness of uncertainty in computational fluid dynamics (CFD) such as the publication of the American Institute of Aeronautics and Astronautics (AIAA) guidelines on the verification and validation, the Drag Prediction Workshop sponsored by the AIAA Applied Aerodynamics Technical Committee, the pair of sessions on CFD uncertainty at the January 2003 AIAA Aerospace Sciences Meeting, and the September 2006 special issue, vol. 217, of the Journal of Computational Physics. In addition, the interest of controlling or optimizing CFD applications under uncertainty has increased rapidly; scientists have realized that deterministic optimal control and optimization are usually unreliable. Several different approaches on CFD stochastic optimal control and optimization applications can be found in the literature and will be presented in this talk.

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MS1

Fast Algoritms for Stochastic Inverse Problems

We present an efficient numerical strategy for inverse problems under uncertainty. Methods based on generalized polynomial chaos (gPC) are developed. The methods take advantage of the high order accuracy of the gPC methods to significantly speed up the forward problem solver. Furthermore, the gPC solution provides an accurate surrogate model that can be used in various aspects of the inverse simulation. We will illustrate the advantage of the gPC based methods via inverse parameter estimation problems.

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MS1

Groundwater Model Calibration and Uncertainty Quantification

Since groundwater systems are open and complex, groundwater modeling results are inherently uncertain. For scientifically defensible water resources management and decision making, it is thus indispensible to quantify uncertainty in predictions of groundwater flow and contaminant transport. In this presentation, parametric and conceptual model uncertainties are jointly assessed using a Bayesian method, which entails model calibration for estimating the jointly likelihood function of models and model parameters. Model uncertainty refers to a situation where multiple models are all acceptable given available data and information. It has been shown that model uncertainty dominates parametric uncertainty in groundwater modeling.

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MS2

Toward a Theory of Rapid Exploration of Unknown Spatial Fields

Problems of using mobile sensors to explore an unknown spatial domain can be formulated in terms of sampling values of an unknown function. We discuss exploration procedures based on this formulation. The goal is: (i) to determine important qualitative features (e.g. critical points and topological features), (ii) to provide a running assessment of the value of the information that has been acquired, and (iii) to emphasize qualitative features over an asymptotically accurate pointwise description.

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MS2

POMDP Approaches for Multiagent Exploration

This paper studies the problem of dynamic adaptive scheduling of sensors for the problem of search and classification of multiple objects. The problem is cast as a partially observed Markov decision problem (POMDP). While the exact POMDP problem is intractable, the paper describes a relaxed formulation that leads to a hierarchical decomposition that can be solved with mathematical programming techniques. The paper includes simulations of the achieved performance and comparison with performance bounds.

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MS2

A Decision Task in a Social Context: Experiments, Modeling, and Preliminary Analyses of Behavioral and Brain Imaging Data

To investigate the influence of group input in decision-making, we consider gambling tasks in which individuals, playing against algorithms based on past choices, attempt to maximize their rewards. Algorithms are chosen such that global optima are hard to identify when playing alone. We generalize a drift-diffusion model for individual decisions to include feedback on other group members' rewards and choices, and use brain imaging data to inform on individual variations in susceptibility to such feedback.

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MS2

Modeling, Analysis and Evaluation of Dynamic Decision Making in Sequential Two-choice Tasks

We present the construction, analysis and evaluation of a dynamical system model for human decision making in sequential two-choice tasks. For a nominal decision making policy inspired by behavioral aspects of humans, we show analytical asymptotic behavior of such decision making process in sequential two-choice tasks for various types of reward structures. These analytical results are compared to human subjects data from experiments being carried out by cognitive scientists.

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MS3

Energy Shaping Control of Distributed Parameter port-Hamiltonian Systems Based on Finite Elements Approximation

In this paper, the control by energy shaping developed for finite dimensional port Hamiltonian systems is applied to the finite element approximation of the distributed parameter plant. In this way, standard tools for studying the stability of finite dimensional port Hamiltonian systems can be used to prove the validity of the boundary controller. Since the finite element model is generally given in terms of a Dirac structure and of discrete constitutive equations, and it is completely a-causal, the plant dynamics is not given in standard input-state-output form, but as a set of DAEs. Consequently, the classical energy-based methods have to be extended in order to deal with dynamical systems with constraints, usually appearing in the form of Lagrangian multipliers. The general methodology is illustrated with reference to a particular example, i.e. an hinged-hinged Timoshenko beam with torque actuators at both sides. With this particular choice of the boundary conditions, the finite elements approximation cannot be written in standard input-state-output form.

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MS3

Colocation Methods for the Discretization of Infinite-dimensional Port Hamiltonian Systems

IIn this paper we present a pseudo-spectral discretization method of infinite-dimensional port-Hamiltonian systems defined on two-dimensional spatial domains by using Lagrange polynomials. Extending the mixed-finite element method we suggest a way for the exact discretization not only of the co-boundary operator and the associated Stokes-Dirac structure but also discuss the discretization of the boundary operator.

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MS3

Port-Hamiltonian Structure Preserving Discretization of a 1-D Inflatable Space Reflector

We treat the application of existing structure preserving discretization methods to the distributed model of the dynamics of a 1D inflatable space reflector with piezo actuation in port-Hamiltonian (pH) form. The resulting lumped port-Hamiltonian model can then be used for designing an highly accurate inflatable reflector shape controller. We show how a nonlinear finite dimensional pH model can be obtained in the 1D case and discuss the possibilities of extending the results to the 2D case.

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MS3

Structure Preserving Spatial Discretization of Distributed Conservation Laws

After recalling the abstract formulation of Kirchhoff's laws on graphs we discuss a framework for the spatial discretization of distributed-parameter systems described by systems of conservation laws as finite-dimensional port-Hamiltonian systems defined on open k-complexes, with inputs and outputs corresponding to a selected set of boundary cells. The approach will be illustrated by some examples including heat transfer on a 2-dimensional domain.

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MS4

Computational Experiments on Localized Large Population Mean Field Stochastic Control

We study large population stochastic dynamic games with agent specific cost coupling resulting in locality related interactions. The Mean Field (MF) methodology (Huang, Caines, Malhame, IEEE-TAC'07) is used to compare the effectiveness of decentralized (MF-Nash equilibrium) and centralized (global optimization) strategies, and to measure the impact of perfect information on the cost function. The main conclusion from the numerical simulations is the high level of robustness of the MF Nash equilibria with respect to all the variations under study.

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MS4

On the Value of Stochastic Differential Games

Stochastic differential games on a fixed finite time interval are considered. Upper and lower value functions are considered and are shown to be unique viscosity solutions to the corresponding Isaacs PDEs. The strategies for the two controllers are not the same as the usual Elliott-Kalton strategies. Admissible strategies depend in a progressively measurable way on both the opponent's past control choices and on the past of the Brownian motions in the game dynamics. For deterministic differential games of a particular structure, there is an interpretation in terms of "max-plus stochastic control."

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MS4

The Locality Dependent Nash Certainty Equivalence (Mean Field) Principle in Large Population Stochastic Dynamic Games

We study large population stochastic dynamic games where each agent assigns individually determined coupling strengths (with spatial interpretation) with respect to other agents in its cost. The Mean Field methodology (HCM, IEEE-TAC07) yields decentralized controls as an $epsilon(N)$-Nash equilibrium for the N agents. A key feature of the mean field approximation with localized interactions is that each agents control law depends upon its own state and the precomputable locally received aggregate effect of other agents, which in turn apply their own decentralized control laws.

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MS4

Finite Element Approximation of Stochastic Differential Games with Discount Control and Nonmarket Interactions for N Players

We consider a discretization of non-linear systems corresponding to discounted stochastic differential games, assuming that the resulting Hamiltonian has quadratic growth in the gradient. The solution represents a Nash equilibrium point of the stochastic game. This model includes cases where the player can influence the discount factor and where non-market interaction can take place. A fully discrete Galerkin approximation is considered using continuous piecewise linear finite elements in space and a backward Euler time discretization. A priori error estimates are shown.

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MS5

On an Algorithm for Anytime Control

We consider an anytime control algorithm that is suitable for situations where the availability of processing resources is time-varying. In the approach, at every time step, the components of the control input vector are calculated sequentially to maximally utilize the available processing resources. Alternatively, the algorithm can be viewed as using a sequence of process models with increasing fidelity to refine the control input. Through a combination of analytical and numerical results, we show that the increase in performance due to the proposed algorithm can be significant.

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MS5

Control of Multiple Networked Plants Subject to Delays and Data Dropouts

The integration of physical systems through computing and networking has become the most pervasive application of networking and information technology, a trend now known as Cyber-Physical Systems (CPS). Our work is inspired by the rapidly increasing use of networked control system architectures in constructing real-world CPS and aims at addressing the fundamental problems caused by network uncertainties, such as time varying delay and packet loss. To address these implementation uncertainties, we use passivity for control design of CPS. We develop a theoretical framework that provides an effective way to interconnect multiple passive plants and controllers together and preserve stability in the presence of time-varying delays and data dropouts. We demonstrate the design using a networked teleoperated robotic platform. The proposed architecture is flexible and reconfigurable to allow adding or removing passive systems at runtime.

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MS5

Event-triggered and Self-triggered Real-time Control

Control task have been traditionally treated as periodic for the purposes of real-time scheduling. This periodicity assumption results in a separation of concerns that has been very successful over the years: control engineers can safely ignore implementation details when designing feedback controllers and software engineers can safely ignore stability and other control considerations when scheduling control tasks on concrete platforms. However, the periodicity assumption also leads to conservative designs that are inadequate for existing resource limited platforms such as the ones used in sensor-actuator networks. In this talk I will revisit real-time scheduling of control tasks with the purpose of illustrating the benefits of relaxing periodicity. I will propose event-triggered and self-triggered scheduling policies with guaranteed performance and improved usage of computational resources with respect to traditional periodic schedules.

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MS5

Automata Based Interfaces for Control and Scheduling

We propose the use of formal languages of infinite words over the alphabet of task identifiers as an interface between control designs and software implementations. We argue that this approach is more flexible than the classical real-time scheduling framework based on periodic tasks, and allows composition of interfaces by language-theoretic operations. We show that finite automata over infinite words offer analyzable representation and can capture many interesting interface specifications such as exponential stability of switched linear systems. The practicality of the approach is demonstrated with a tool for compositional real-time Java development called RTComposer.

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MS6

Optimal Control in Glucose Regulation

The glucose metabolism is a tight regulated system providing energy in humans. Dysfunctions of this system may lead to pathologies like diabetes. Establishing mathematical control algorithms is therefore essential in imbalanced glucose metabolisms. We will present new combined computational methods for ODE systems, optimization, parameter estimation, optimal design, and control to target this problem. The goal is to monitor the glucose metabolism via mathematical optimal control and the design of minimal invasive methods.

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MS6
Control and Design in Inverse Problems

Designing experiments and appropriate regularization operators in inverse problems is crucial in order to obtain better recovery of the parameters. In this talk we will present an optimal control framework for the computation of these quantities. We show that by appropriate design, better results can be obtained. We then apply the methodology to medical imaging applications.

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MS6
Inverse Problems in Medical Image Registration

The goal of image registration is to find a geometric alignment of corresponding structures for two given images. I will present a variational approach for minimizing a suitable distance between images with respect to a spatial mapping. In addition, a second building block is regularization which is crucial to avoid non-physical mappings and to force smoothness properties of the deformation.

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MS6
Optimal Mass Transport Registration

Abstract not available at time of publication.

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MS6
Investigating the Order of Events in Optimal Control of Harvesting

An optimal control harvesting problem for a population modeled by an integrodifference equation model is considered. The proportion to be harvested is taken to be control. The harvesting occurs after the growth of the population but before the dispersal. The goal is to find the optimal harvesting control to maximize the profit. Existence and characterization of the optimal control are established. The case with harvesting after growth and dispersal is then compared with the case treated here.

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MS7
A Unified View of Legendre Pseudospectral Methods for Solving Optimal Control Problems

The Legendre PS methods are most thoroughly studied for optimal control and trajectory optimization applications. In particular, the Legendre-Gauss-Lobatto method is widely used for boundary-value type Problems. Recently, other methods based on other quadrature points such as Legendre-Radau and Legendre-Gauss have been proposed for solving optimal control problems. In this talk, we present a unified view of these various methods and for each case discuss the Covector Mapping Principle which is associated with the consistency of approximations that allows one to generate dual maps (such as Hamiltonians, adjoints etc) without resorting to solving difficult two-point boundary-value problems.

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MS7
The Evolution of Satellite Slew Maneuver Design and Control

We examine how recent advances in pseudospectral methods and techniques have allowed us to advance from the minimum time reorientation of a tri-axisymmetric spacecraft to the minimum-time reorientation of an asymmetric spacecraft equipped with control moment gyros. Key techniques include identifying the system control, applying the principles of Bellman and Pontryagin to validate the control solutions optimality, and the Carathodory-p solution concept which allows us to generate practical closed-loop solutions to dynamical systems.

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MS7
Practical Stabilization of Infinite Horizon Nonlinear Optimal Control Problems by Pseudospectral Methods

We present a feedback solution for infinite horizon nonlinear optimal control based on real-time computational optimal control. The central idea is to perform feedback implementations through pseudospectral methods. Two algorithms are considered: free sampling frequency and fixed sampling frequency. For both algorithms, we provide a theoretical analysis on the stability and the robustness of the closed-loop system. Under reasonable conditions, the closed-loop system is proved to be practically stable under both computational delay and computational errors/disturbances.

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MS7
On the Rate of Convergence for the Pseudospectral Optimal Control of Feedback Linearizable Systems

We prove that the Pseudospectral (PS) optimal control has a high-order rate of convergence. More specifically, the optimal cost converges at the order of 2m/3-1, where m is defined by the smoothness of the optimal trajectory. If the cost function can be accurately computed, then the convergence rate is improved to the order of 3m-1. If the optimal control is C-infinity, then the convergence rate can be made faster than any given polynomial rate.

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MS7

Direct Trajectory Optimization and Costate Estimation of General Optimal Control Problems Using a Radau Pseudospectral Method

A method is presented for direct trajectory optimization and costate estimation using global collocation at Legendre-Gauss-Radau (LGR) points. We show how the first-order optimality conditions for the discrete optimization problem can be reformulated as a lower order collocation scheme applied to the continuous adjoint equation. Numerical results show that the use of LGR collocation leads to the ability to determine accurate primal and dual solutions for both finite and infinite-horizon optimal control problems.

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MS8

Adaptive Estimation of Second Order Bilinear Infinite Dimensional Systems Using Natural Adaptive Observers

We extend our previous work on the use of natural observers for state estimation of second order infinite dimensional linear systems and that on natural observers for bilinear second order infinite dimensional systems to the case of adaptive estimation of bilinear second order infinite dimensional systems. In this case the adaptive observer along with the parameter adaptation rules provide estimates of both the process state and of the unknown plant parameters. The proposed natural adaptive observer retains the second order structure of the system, thereby preserving the physical interpretation of the observer states, namely that the derivative of the estimated position term is indeed the estimated velocity, something that standard first order adaptive observers cannot provide. The parameter estimates are derived using a parameter-dependent Lyapunov functional. The proposed Lyapunov analysis provides convergence of the state estimates and under additional conditions, convergence of the parameter estimates.

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MS8

Pod Based Observer for Contaminant Flow Estimation in Building Systems

In this paper, we propose a POD-based technique that is suitable for the design of reliable observers for the estimation of velocity field and contaminant flow for Navier-Stokes flow. POD modes are constructed using the method snapshot. Karhunen-Loeve (Galerkin) projection to develop a reduced-order model obtained by projecting the velocity field onto the most important POD modes. The resulting finite-dimensional dynamical system is suitable for the design of nonlinear observers. The estimate of the velocity field is then used to estimate the concentration field of a contaminant from the 2D and 3D advection-diffusion equations. The prime application considered is the estimation of airflow and contaminant flow in building systems. 2D and 3D simulation examples are provided to demonstrate the applicability of the technique.

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MS8

Unstable and Anti-Stable Wave Equations: New Benchmarks for Boundary Control

Typical boundary control problems for wave equations, beams, and other hyperbolic-like PDEs are neutrally stable, with all eigenvalues on the imaginary axis. We introduce control problems and solutions for wave equations that have all eigenvalues in the right half-plane. These problems incorporate 'anti-damping,' either on the boundary opposite from the controlled boundary, or in the domain. Explicit feedback laws are obtained using the backstepping method to achieve exponential stability.

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MS8

Monotonicity Preserving Inexact Newtons Method

It is well known that the Kleinman-Newton method for solving algebraic Riccati equations exhibits a monotone convergence behaviour. This method can be extended to cover more general equations like nonsymmetric Riccati equations, algebraic stochastic Riccati equations and Riccati equations in Hilbert space. In this talk we show how the concept of inexact solves for the Newton steps in the general case still leads to a monotone convergent sequence.

It clearly shows which type of properties (convexity, monotonicity etc.) are needed to provide a rigorous convergence theory.

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MS9

Optimal Portfolio Problem for Stochastic-Volatility, Jump-Diffusion Models and Jump-Bankruptcy Conditions

This paper treats the risk-averse optimal portfolio problem with consumption in continuous time with a stochastic-volatility, jump-diffusion (SVJD) model of the underlying risky asset and the volatility. The new developments are the use of the SVJD model with double-uniform jump-amplitude distributions and time-varying market parameters for the optimal portfolio problem. Although unlimited borrowing and short-selling play an important role in pure diffusion models, it is shown that borrowing and short-selling are severely constrained for infinite-range jump-amplitude models, while the constraints are much more flexible with finite-support models. Also, a formulation of Heston's stochastic Volatility model is given that is better posed for stochastic and computational analysis.

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MS9

Refined and Enhanced FFT Techniques, with Applications to Pricing Barrier Options and Their Sensitivities

The fast Fourier transform (FFT) technique is now a standard tool for the numerical calculation of prices of derivative securities. Unfortunately, in many important situations, such as the pricing of contingent claims of European type near expiry, and the pricing of barrier options close to the barrier, the standard implementation of this technique leads to serious systematic errors. We propose a new, fast and efficient, variant of the FFT technique, which is free of these problems, and is as easy to implement as the most common version of FFT. We apply this techniques to computing the prices and sensitivities of barrier options and first-touch digital options on stocks whose log-price follows a Lévy process. The numerical results obtained via our approach are demonstrated to be in good agreement with the results obtained using other (sometimes fundamentally different) approaches that exist in the literature. However, our method is computationally much faster (often, dozens of times faster). Moreover, our technique has the advantage that its application does not entail a detailed analysis of the underlying Lévy process: one only needs an explicit analytic formula for the characteristic exponent of the process. Thus our algorithm is very easy to implement in practice. Finally, our method yields accurate results for a wide range of values of the spot price, including those that are very close to the barrier, regardless of whether the maturity period of the option is long or short.

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MS9

Stochastic Control and Option Hedging in the Presence of Transaction Costs

After a review of the theory of option hedging theory in the presence of transaction costs and the associated tools of singular stochastic control, we present an empirical study of stock, bond and option prices, showing substantial discrepancies between the theory and market data. We then describe a new approach using ideas from stochastic adaptive control to resolve this difficulty.

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MS9

Growth Optimal Portfolio Under Proportional Transaction Costs with Obligatory Diversification

A continuous time long run growth optimal portfolio with proportional cost consisting of the sum of a fixed proportional cost and a cost proportional to the volume of transactions is considered. An obligatory portfolio diversification is introduced according to which it is required to invest at least a fixed small portion of the wealth in each asset.

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MS10

Recent Advances on Chebyshev Pseudospectral Methods for Nonlinear Optimal Control Problems

Chebyshev pseudospectral methods are attractive for solving nonlinear optimal control problems due to various computational advantages. However, unlike Legendre polynomials, Chebyshev polynomials are orthogonal with respect to a non-uniform weight function. This fact generates difficulties in costate computation because of the discrepancy between the numerical integration and the discretization of differential constrains. We will present some recent advances that resolve such discrepancy and produce accurate costate computation using Chebyshev pseudospectral methods. Several examples in engineering applications will also be presented to illustrate our results.

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MS10

Observability and Its Computation for Nonlinear Systems

A measure of observability is introduced for general nonlinear systems. The observability of state variables and unknown parameters relative to measurement data is quantitatively defined; and this measure of observability can be numerically computed using computational dynamic optimization. This concept is applicable to a broad family of problems of estimation. Numerous examples are given to illustrate the usefulness of the concept. In one example, the concepts of weakly observable and strongly observable are rigorously and quantitatively illustrated.

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MS10

Measures of Unobservability

An observed nonlinear dynamics is observable if the mapping from initial condition to output trajectory is one to one. The standard tool for checking observability is the observability rank condition but this only gives a yes or no answer. It does not measure how observable or unobservable the system is. Moreover it requires the ability to differentiate the dynamics and the observations. We introduce a new tool, the local observability gramian, to measure the degree of observability or unobservability of a system. To compute the local observability gramian, one only needs the ability to simulate the system. We apply this tool to find the best location to put a sensor to observe the flow induced by two point vortices.

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MS10

Idempotent Numerical Methods for Stochastic Control

It is now well-known that many classes of deterministic control problems may be solved by max-plus (more generally, idempotent) numerical methods. It has now been discovered that idempotent methods are also applicable to stochastic control problems. The key tool that had been missing previously was simply the idempotent distributive property. It was also necessary to realize that idempotent linearity of the associated semigroup was not required. Instead, it is sufficient that certain solution forms are retained through application of the dynamic programming principle operator.

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MS11

Quantum Estimation and Control

This minitutorial will provide an introduction to fundamental ideas concerning quantum feedback control and the application of convex optimization to quantum estimation problems. After motivating the need for quantum estimation and control arising from emerging quantum technologies, we discuss the various types of control that have been considered for quantum systems, and why feedback and estimation play important roles. The underlying mathematical models from quantum mechanics are summarized in a way that is suitable for estimation and feedback control. Examples of recent work in quantum feedback and estimation are provided.

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MS12

Surrogate and Reduced-order Models for Statistical Inverse Problems

The Bayesian approach to nonlinear inverse problems requires repeated solutions of a forward model, typically a computationally intensive set of PDEs. We present two strategies for more efficient posterior sampling in this context. The first strategy uses generalized polynomial chaos to approximate the forward solution over the support of the prior distribution, thus defining a surrogate posterior density that can be evaluated at minimal computational cost. The second strategy uses projection-based model reduction to construct a lower- dimensional dynamical model, preserving input-output relationships over a parameter set of interest. These strategies are contrasted on inverse problems of varying complexity and dimension.

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MS12

Optimal Control Under SPDE Constraint

We study the control and parameter identification problem for a stochastic elliptic boundary value problem. Error estimates are established. Numerical examples are also presented to examine our theoretical results.

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MS12

A Stochastic Collocation Based Kalman Filter for Data Assimilation

In this work, a stochastic collocation based Kalman filter (SCKF) is developed to estimate model parameters such as permeability and porosity from direct and indirect measurements. It combines the advantages of the ensemble Kalman filter (EnKF) for dynamic data assimilation and the polynomial chaos expansion (PCE) for efficient uncertainty quantification. In this approach, the model parameters are represented by the Karhunen-Loeve expansions and the model responses such as pressure and saturation are expressed by the PCE. The coefficients of PCE are solved with a collocation technique. Realizations are constructed by choosing collocation point sets in random space. The stochastic collocation method is nonintrusive in that such realizations are solved forward in time via existing deterministic solver independently as in the Monte Carlo method. The needed entries of the state covariance matrix are approximated with the coefficients of PCE, which can be recovered from the collocation results. The system state is updated by separately updating each stochastic spectral component. Two-dimensional single and two-phase flow examples are used to demonstrate the applicability of the SCKF with respect to different factors such as initial statistics (variance, correlation length), and the number of observations. The results are compared with those from the EnKF method. It is shown that the SCKF is computationally more efficient than the EnKF. It provides a satisfactory estimation of the model parameters with dynamic measurements.

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MS13

Multi-Agent Collision Avoidance with Acceleration Constraints

A switching control law is derived using optimal control techniques to guarantee separation between acceleration constrained vehicles. The method augments existing multi-agent control algorithms with the capability to switch to provably safe collision avoidance maneuvers when required. It is extended to the control of arbitrarily many vehicles, limited only by communication of vehicle states. These methods are demonstrated in simulations where existing techniques are prohibitively slow or fail, and in quadrotor helicopter flight experiments.

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MS13

Constructive Methods for High Confidence Networked Control Systems

Network control systems (NCS) abound in industrial, aeronautical, and robotics applications. NCS typically consist of both discrete and continuous time interactions between nodes. Various methods will be discussed which construct a NCS with nodes which have certain (geometrical) properties - resulting in a robust, stable, and scalable NCS. We conclude by showing a novel l_2^m-stable NCS architecture for conic systems, and point to future research directions.

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MS13

Passivity-Based Control for Distributed Hybrid Systems

The traditional strengths of passive control can be further extended when applied to hybrid systems using multiple storage functions. In this talk, we cover a new method of passivity-based control for distributed hybrid systems. To apply our results, we present a constructive method to solve the output synchronization problem for networked mechanical systems with nonholonomic constraints. We also show that the general problem of multi-robot coordination can be handled using these results.

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MS13

Wireless-Controlled Distributed Agents

This talk presents theorems for convergence and stability of distributed control systems in which agents communicate with each other by wireless messages which may be lost, duplicated or delivered out-of-order. The theorems have been proved in an automatic theorem proving system (PVS). The theorems are applied to mobile robots communicating with each other by wireless to carry out group operations.

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MS14

Periodic Antiviral Therapies for Within-Host Virus Models

We investigate the effect of drug treatment on the standard within-host virus model, assuming that therapy occurs periodically. It is shown that eradication is possible under these periodic regimens, and we quantitatively characterize successful drugs or drug combinations, both theoretically and numerically. We also consider certain optimization problems, motivated for instance, by the fact that eradication should be achieved at acceptable toxicity levels to the patient. It turns out that these optimization problems can be simplified considerably, and this makes calculations of the optima a fairly straightforward task.

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MS14

Optimal Control for a Discrete Time Rabies Model on a Spatial Grid

An epidemic model for rabies in raccoons is formulated with discrete time and spatial features. The goal is to analyze the strategies for optimal distribution of vaccine baits to minimize the spread of the disease and the cost of implementing of the control. Discrete optimal control techniques are used to derive the optimality system, which is then solved numerically to illustrate various scenarios.

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MS14

Mitigating the Spread of Antibiotic Resistance: From Communities to Clinics

The development and spread of bacteria that are resistance to broad classes of antibiotics is a prevalent health threat today, not only to patients with compromised immune systems, but also to healthy children and adults. Bacteria such as methicillin-resistant *Staphylococcus aureus* (MRSA) are now not only seen in hospital settings, but strains have more recently appeared in community settings, particularly in situations where people spend significant time in groups, such as in schools or college dorms. Those infected then enter clinical settings, bringing new resistant bacterial strains into the hospital. Because treatment options are limited, the mathematical model developed allows us to explore control strategies to contain the spread and reduce the threat of the disease. This talk will explore which strategies have the highest impact.

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MS14

Variations on a Model for Cholera

Cholera was responsible for the deaths of millions of people across the globe in the 1800's. While the disease is no longer a threat to populations who have access to proper sanitation, we do not know how to eliminate the pathogens that cause cholera from the environment and, as a result, the growing numbers of people who are forced to live without adequate sanitation are resulting in increasing outbreaks of this deadly disease. In fact, according to the World Health Organization, some 2,755 have died and 48,623 people are suspected to have been infected with cholera since last year In this talk, an initial model describing a cholera outbreak and considering an optimal mitigation strategy for an outbreak is discussed. Variations of the model and the optimal control schemes are considered, identifying model sensitivities and suggesting which aspects of cholera outbreaks are most important to understand in treating future cholera epidemics.

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MS15

Optimal Placement of Temperature Sensors in Buildings

In this talk, we describe an optimization-based approach to placing temperature sensors in the design of energy efficient buildings. The Navier-Stokes equations are used to model the advective flow in a two-bed hospital room. The sensor placement problem is solved by optimizing the observer gains associated with the advection-diffusion (energy) equation. The problem is considered under several configurations of vent locations and open/closed doors.

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MS15

Towards Optimal Actuator Placement for Dissipative PDE Systems in the Presence of Uncertainty

We consider the issue of actuator placement for noisy transport-reaction processes, which are mathematically modelled by perturbed linear dissipative partial differential equations (PDEs). The proposed method is based on previous work by the authors on actuator placement for PDEs, however the presence of noise and/or model uncertainty precludes their direct application. Using modal decomposition for space discretization, we formulate an optimization problem that considers the controllability of specific modes, minimizes the spillover effects to the fast modes and takes explicitly into consideration the spatial distribution of noise or model uncertainty. Specifically, we project the PDE in an appropriate Sobolev space and employ the concept of spatial and modal norms to formulate a nonlinear stochastic optimization problem that can be solved efficiently using standard search algorithms. The proposed is successfully applied to a representative one-dimensional parabolic PDE, where the optimal location of multiple actuators is computed.

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MS15

Resource-aware Control of Spatially Distributed Systems Over Wireless Sensor Networks: Integrating Feedback and Scheduling

This paper presents an integrated model-based control and scheduling approach for spatially distributed systems controlled over a resource-constrained wireless sensor network. The approach is resource-aware in that it minimizes the rate at which each node in the network collects and transmits measurements to the controller without jeopardizing closed-loop stability. Hybrid system and singular perturbation techniques are used to characterize the minimum allowable communication rate in the infinite-dimensional system. The results are illustrated through numerical simulations.

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MS15

Frequency Domain Methods for the Optimal Placement of Actuators and Sensors in Systems Governed by Partial Differential Equations

In our work, we revisit the problem of actuator and sensor selection for a class of distributed parameter systems in the context of frequency domain considerations. In addition to considering sensors and actuators that would enhance certain performance, quantified in terms of an LQR or H2 index, we impose additional conditions for the said location optimization that would provide robustness with respect to spatial disturbances. An appropriate measure to optimization is given by the closed loop transfer function and a double optimization procedure provides the optimal actuator and sensor location while at the same time ensures that a certain robustness level is attained. Numerical studies of representative 1D and 2D systems are provided to demonstrate the effectiveness of the proposed approach.

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MS16

Efficient Connectivity Topologies for Networked Control Systems

We develop a unifying analytical framework for networked systems, capturing the essential tradeoff between agent collaboration benefits and costs. We show the critical role of agent connectivity topologies in this tradeoff. We demonstrate that connectivities related to small world and expander graphs offer dramatic advantages for networked systems problems that need a distributed solution. These topologies are efficient from the perspective of costs yet lead to fast convergence of distributed algorithms from the benefits perspective.

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MS16

Short Maturity Symptotics for a Fast Mean Reverting Heston Stochastic Volatility Model

We study Heston stochastic volatility model in the regime

where the maturity is small but large compared to the mean-reversion time of the stochastic volatility factor. We derive a large deviation principle and compute its rate function. We obtain asymptotic prices for Out-of-The-Money call and put options and their corresponding implied volatilities.

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MS16
Incomplete Inventory Information-the Next Challenge

Inventory control is one of the most important topics in management science/operations research. A systematic analysis of inventory problems began with the development of the classical EOQ formula of Harris in 1913. Since then, an enormous amount of literature has accumulated on inventory control problems. One of the critical assumptions in this vast literature has been that the current level of inventory is fully observed. Some of the most celebrated results such as optimality of base-stock or (s,S) policies have been obtained under the assumption of full observation. Yet it is often the case in practice that the inventory level is only partially observed. Most of the well-known inventory policies are not only non-optimal, but are also not applicable in the partial observation environment. The reasons for partial observation of the current inventory level are many. Inventory records or cash register information differ from actual inventory because of a variety of factors including transaction errors, theft, spoilage, misplacement, unobserved lost demands, and information delays. As a result, what are usually observed are some events or surrogate measures, called signals, related to the inventory level. At best, these relationships may provide only the distribution of current inventory levels. In the best case, therefore, the relevant state in the inventory control problems is not the current inventory level, but rather its distribution given the observed signals. Thus, the analysis for finding optimal production or ordering policies takes place generally in the space of infinite-dimensional probability distributions. The purpose of this talk is to review recent developments in the analysis of partially observed optimal control problems that arise in the management of inventory systems.

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MS16
A New Approach to the Harvest and Thinning of Stochastic Renewable Resource Models

This paper considers both the Wicksell single-period harvest problem and the Faustmann on-going rotation problem for stochastic renewable resource models. It also investigates a model in which the growth is affected by natural disasters and a model in which the resource manager elects to manage the resource so as to promote quicker growth that results in larger and more valuable units. A new methodology is introduced that imbeds the problem in an infinite-dimensional linear program. A related auxiliary linear program then leads to a tractable nonlinear optimization problem. This new approach provides a straightforward method by which to determine the optimal harvesting rule. Several specific resource models are examined, which allows one to compare the resulting values and optimal policies and observe the sensitivity of the optimal harvesting rule to the stochastic model adopted.

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MS17
A Multiplay Model for Rate-Independent Hysteresis with Nonlocal Memory

A multiplay model consists of N mass/spring/dashpot with play systems connected in parallel. The limiting input-output map of the multiplay is a hysteretic map with nonlocal memory. The shape of this map is determined by the stiffness coefficients and the play widths of the mass/spring/dashpot with play systems. The multiplay can model any hysteretic system with a known hysteresis map because the stiffness coefficient and play widths can be adjusted to give the desired hysteresis map.

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MS17
Optimal Control for the Hysteretic Play Operator

In this paper, we study the stabilization of a second order differential equation with control occurring through a play operator. The play operator describes certain types of hysteretic behavior such as mechanical play between gears. An optimal control problem of minimizing a cost associated with these dynamics is considered. Through the viscosity solution of the Hamilton-Jacobi-Belman PDE, we can computationally construct the optimal continuous control that stabilizes the dynamics while minimizing the accrued cost.

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MS17
Adaptive Control Design for Hysteretic Systems Modeled by the Homogenized Energy Framework

Ferroelectric and ferromagnetic actuators are being considered for a range of industrial, aerospace, aeronautic and biomedical applications due to their unique transduction capabilities. However, they also exhibit hysteretic and nonlinear behavior that must be accommodated in models and control designs. If uncompensated, these effects can yield reduced system performance and, in the worst case, can produce unpredictable behavior of the control system. One technique for control design is to approximately linearize the actuator dynamics using an adaptive inverse compen-

sator that is also able to accommodate model uncertainties and error introduced by the inverse algorithm. This talk describes the design of an adaptive inverse control technique based on the homogenized energy model for hysteresis. The resulting inverse filter is incorporated in an L1 control theory to provide a robust control algorithm capable of providing high speed, high accuracy tracking in the presence of actuator hysteresis and nonlinearities. Properties of the control design are illustrated through numerical examples.

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MS17

Modeling the Nonlinear Behavior of Macro Fiber Composite Actuators

Macro Fiber Composites (MFC) are planar actuators comprised of PZT fibers embedded in an epoxy matrix that is sandwiched between electrodes. Due to their construction, they exhibit significant durability and flexibility in addition to being lightweight and providing broadband inputs. They are presently being considered for a range of applications including positioning and control of membrane mirrors and configurable aerospace structures. However, they also exhibit hysteresis and constitutive nonlinearities that must be incorporated in models and model-based control designs to achieve the full potential of the devices. In this talk, we discuss the development of models that quantify the hysteresis and constitutive nonlinearities in a manner that promotes subsequent control design. The constitutive models are constructed using the homogenized energy model for ferroelectric hysteresis and used to develop resulting system models. The performance of the models is illustrated validated with experimental data.

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MS18

Inexact Implementation of the Kleinman-Newton Method

We consider the applicabilty of inexact Newton methods in the context of algebraic Riccati equations. The following questions arise: Is it possible to maintain the global convergence behaviour and the monotonicity of the iterates also in the inexact case? Can all established implementations of the Kleinman-Newton method be expanded to an inexact version? Are there numerical benefits compared to exact Kleinman-Newton method? In this talk we address these issues and give numerical examples.

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MS18

A Fast Algorithm for Determining Optimal Feedback Gain

A fast algorithm to compute the optimal feedback gain for the linear quadratic regulator problem is developed and analyzed. The algorithm utilizes the relation between an invariant subspace of the corresponding Hamiltonian operator and the solution to the Riccati equation and the reduced order methods. It is based on the inverse of the Hamiltonian operator on the reduced order subspace. Large scale control systems that arise from a discretization of a class of control problems governed by partial differential equations is used to demonstrate the feasibility and applicability of Algorithm. A sparsity and structural property of system matrices are incorporated in Algorithm and it enables us to compute a stabilizing feedback law for a large class of distributed control systems.

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MS18

Regularization of the Riccati Equation

Current numerical methods are infeasible for calculating the solution to optimal control problems for hyperbolic PDEs. In this paper, we study two types of regularization techniques which lead to numerically stable algorithms for solving the Riccati equation. The first technique involves a regularization parameter in the model; e.g. the Euler-Bernoulli beam model with a damping term. In the second approach, we look the weak solution of the Riccati equation obtained by adding a viscous term to the original equation.

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MS18

Mesh Independence for a Newton Based Riccati Solver

We consider the convergence of the infinite dimensional version of the Kleinman-Newton algorithm for solving the algebraic Riccati operator equation associated with the linear quadratic regulator(LQR) problem. We establish mesh independence for this algorithm. The importance of dual convergence and preservation of exponential stability (POES) with regard to strong convergence of the functional gains and mesh independence of the algorithm are discussed. Numerical results are presented.

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MS19

An Additive D-Stability Criterion and Application to Reaction-Diffusion Systems

Matrix A is said to be additively D-stable if A-D remains Hurwitz for all nonnegative diagonal matrices D. In reaction-diffusion models, additive D-stability of the matrix describing the reaction dynamics guarantees stability of the homogeneous steady-state, thus ruling out the possibility of diffusion-driven instabilities. We present a new criterion for additive D-stability using the concept of compound matrices. We first give conditions under which the second additive compound matrix has nonnegative off-diagonal entries. We then use this Metzler property of the compound matrix to prove additive D-stability with the help of an additional determinant condition. This result is then applied to investigate the stability of several biological circuits in the presence of diffusion.

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MS19

Modular Cell Biology: Retroactivity and Insulation

Modularity plays a fundamental role in the prediction of the behavior of a system from the behavior of its components, guaranteeing that the properties of individual components do not change upon interconnection. Just as several engineering systems do not display modularity, nor do many bio-molecular systems due to impedance-like effects, called retroactivity, at interconnections. We study the effect of interconnections on the input/output dynamic characteristics of transcriptional components and introduce insulation devices to enforce modularity.

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MS19

Nutritional Signal Integration by the Spo0A Phosphorelay in Bacillus Subtilis

Many *Bacillus subtilis* stress responses are under the control of a signal integration phosphorelay, which integrates many different signals into a single active Spo0A concentration. Using an ordinary differential equation model in conjunction with single cell fluorescent microscopy experiments, we suggest that the phosphorelay may be performing a division operation, giving each cell a measure of the available nutrients normalized by the number of growing cells competing for this same food. We also consider the design principles for the observed phosphorelay architecture.

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MS19

Nonlinear Fluctuation Theorems for Biological Control Systems

Life in the cell is a complex battle between randomizing and correcting statistical forces: Births and deaths of individual molecules create spontaneous fluctuations in abundances - noise - while many control circuits have evolved to eliminate, tolerate or exploit the noise. The net effect is also complicated by the fact that the control circuits in turn are made up of poorly characterized probabilistic chemical reactions, with nonlinear interactions and delays. I will present analytical mathematical methods for predicting fluctuations in complex nonlinear systems, drawing on a range of areas in applied mathematics, from information theory, non-equilibrium nonlinear fluctuation-dissipation theory, and chemical reaction network theory. The biological examples will focus on homeostatic feedback control, that supposedly increases a system's stability to internal and external perturbations. In particular I will show how seemingly mild constraints on the birth rates–or short delays–place severe limits on homeostasis and molecular fluctuations that no type of control system could overcome in any context. I also discuss how limits become dramatically more restrictive in chemical cascades, where information is inevitably lost at each step. The results are formulated in terms of biological observables that were measured for many systems. Finally, I will briefly discuss some experimental results for bacterial plasmids, based on methods for counting the exact number of molecules per individual cell.

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MS20

Robust Control of Parabolic PDE Systems via Adaptive Model Reduction

We consider the problem of feedback control of distributed processes that are modeled by parabolic PDE systems with uncertainty. To circumvent the limitations of model reduction based methodologies we develop a computationally-efficient methodology called adaptive Karhunen Loève expansion (AKLE). We employ AKLE to synthesize robust controllers that can account for complex process behavior, model uncertainty and irregular process domains. The proposed approach is successfully applied to stabilize an open-loop unstable chemical reactor.

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MS20

A Comparison of Nonlinear Filtering Approaches in the Context of an HIV Model

Three different filtering methods, the Extended Kalman Filter (EKF), the Gauss-Hermite Filter (GHF), and the Unscented Kalman Filter (UKF), are compared when applied to log state variables of a model of the immunologic response of the human immunodeciency virus (HIV) in individuals, as part of real time feedback control methodology for this HIV model. The filters are implemented to estimate model states from simulated noisy data, and compared in terms of estimation accuracy and computational time. Our initial numerical experiments reveal that the GHF is the most computationally expensive algorithm, the EKF is the least expensive, and the UKF computation time is greater than that of the EKF but still inexpensive relative to the GHF. Computational experiments also show that the GHF and UKF are better filters than the EKF, and their performance is similar. Since the UKF increases accuracy with a reasonable amount of increased computation expense, it is determined to be the most effective algorithm for this particular problem.

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MS20

On Commutation of Reduction and Control

Feedback control design for complex PDEs often follows the sequence of model reduction followed by control design. This then requires good sampling strategies for the model reduction phase. An alternative strategy is to formulate the controller approximation problem with a high order discretization, then introduce model reduction as a means for solving the associated high rank matrix problems. We investigate the trade-offs between these two approaches using numerical experiments involving feedback control of the Stokes and Oseen equations (linearized Navier-Stokes equations) in complex domains.

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MS20

Global Asymptotic Stability of Nonlinear Population Systems with Discrete Time and Continuous Structure

We consider a class of structured population systems with discrete time and continuous structure. These systems are nonlinear and have an infinite dimensional state space. In our applications, the system is an integro-difference model. We prove a global asymptotic stability result for these systems, and obtain a formula for the limiting population in terms of the life history parameters. We apply this to a new model for the endangered plant species blowout penstemon.

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MS21

Max-plus Stochastic Control and Risk-sensitivity

In Wentzell-Freidlin large deviation theory, limits on small perturbations can be understood as expectations of random variables under max-plus probability and they still retain stochastic natures in max-plus sense. In this talk, we consider optimal max-plus stochastic control with max-plus additive functionals. We show that the value function is the unique viscosity solution of the dynamic programming PDE of a quasi-variational type. We also derive the value function from a risk-sensitive control via risk-averse limit. Applications to optimal consumption problems will be discussed.

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MS21

Non-expansive Mappings and Dynamics of Topical Functions

Topical functions are a natural non-linear generalisation of linear mappings over the max-plus semi-ring. They appear in variety of contexts in mathematics, computer science, and engineering. For instance, in the analysis of zero-sum two-player games, topical functions arise as dynamic programming operators. They also play a role in the perfor-

mance analysis of certain discrete event systems, which are used to model computer networks and manufacturing systems. For many applications it is important to understand their dynamics, stability, equilibrium states, and cyclic behaviour. Topical functions are non-expansive under the supremum-norm. In this talk I will explain how this crucial property can be used to gain insight into the nature of the dynamics of topical functions.

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MS21

The Min-max Algebra and Complexity Reduction in a New Method for Game Problems

Deterministic game problems may be solvable (in a curse-of-dimensionality-free manner) through use of the min-max and max-plus algebras. Suppose the value function is a max-plus convex function. The space of max-plus convex functions is a vector space over the min-max algebra. Any max-plus convex function has a countable min-max basis expansion. The problem of finding the optimal min-max linear combination approximation with n elements to a min-max linear combination with m elements (m greater than n) is reduced to pruning.

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MS21

The Boundary at Infinity of Optimal Control Problems

Consider a deterministic optimal control problem with additive reward and infinite time horizon. Its solutions can be constructed from the associated set of max-plus "harmonic" functions. To describe these functions, we develop a max-plus version of the Martin boundary. This boundary turns out to be a generalisation of the horofunction boundary appearing in metric geometry, and we discuss some of its applications there.

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MS22

Analytical and Numerical Constructions in Pursuit Evasion Games on 2D Surfaces

We consider games with simple motions of the players on 2D surfaces (manifolds), like surfaces of revolution, two-sided plane figures, Euclidean plane with an obstacle. Generally, due to nonunique geodesic lines connecting players at some positions, singular trajectories arise in the game. We formulate sufficient conditions for a game space for which no singular paths arise. We describe the main singularity in the problem - a bifurcation of a dispersal surface into two branches of an equivocal surface and give the list of singularities so far found in the considered class of games. We give some numerical illustrations and discuss possible applications.

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MS22

Two-Player Evasion-Interrogation Games with Uncertainty

We consider interrogation in the context of evader-interrogator games where each player has uncertain information about the adversary's capabilities. The mathematical formulation results in a minmax problem over spaces of probability measures. Computational and theoretical results for this problem will be discussed.

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MS22

Disturbance Rejection Using a Dynamic Game Formulation

The application of the theory of dynamic games to disturbance rejection in dynamical systems is naturally appealing. Finite-dimensional, time invariant, linear quadratic dynamic games are perhaps the best understood and researched class of dynamic games. This is particularly true for continuous-time linear quadratic differential games. In this paper, the discrete-time Linear-Quadratic Dynamic Game (LQDG) is discussed. Conditions for the existence of a solution to the discrete-time LQDG are provided, and its explicit, closed form, solution is worked out. This opens the way to designing novel digital signal processing algorithms for disturbance rejection.

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MS22

Revisiting Log-Linear Learning: Asynchrony, Completeness and Payoff-Based Implementation

Log-linear learning is a learning algorithm with equilibrium selection properties. In potential games, log-linear learning provides guarantees on the percentage of time that the joint action profile will be at a potential maximizer. The traditional analysis of log-linear learning has centered around explicitly computing the stationary distribution. This analysis relied on a highly structured setting: i) players utility functions constitute an exact potential game, ii) players update their strategies one at a time (asynchrony), iii) at any stage, a player can select any action in the action set (completeness), and iv) each player is endowed with the ability to assess the utility he would have received for any alternative action provided that the actions of all other players remain fixed. Since the appeal of log-linear learning is not solely the explicit form of the stationary distribution, we seek to address to what degree one can relax the structural assumptions while maintaining that only potential function maximizers are the stochastically stable action profiles. In this talk, we introduce variants of log-linear learning motivated by relaxing these assumptions. Using the theory of resistance trees for regular perturbed Markov chains, we prove that only potential function maximizers are stochastically stable.

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MS23

Detection of Zeno Behavior and Completion of Hybrid Systems applied to a Bipedal Walking Robot

Bipedal walking robots are naturally modeled by hybrid systems and thus provide a very interesting class of models in which to better understand hybrid phenomena. Of particular interest is Zeno behavior, which occurs in a hybrid system when there are an infinite number of transitions in a finite amount of time. This talk will present results on the detection of Zeno behavior and the completion of hybrid systems in the context of bipedal walking.

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MS23

Homogeneity and Tangent Cones in Approximation of Hybrid Dynamical Systems

Hybrid inclusions model hybrid dynamical systems through the combination of differential inclusions, difference inclusions, and constraints. A fundamental result in differential or difference equations concludes asymptotic stability for a system from asymptotic stability for its linear approximation. The talk will show a generalization of this result to hybrid inclusions. Approximations of hybrid inclusions will involve linearization, tangent cones, homogeneous approximation of functions and set-valued mappings, and tangent homogeneous cones, where homogeneity is considered with respect to general dilations.

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MS23

Necessary Conditions for Measure-Driven Differential Inclusions

We extend Clarke's recent stratified necessary conditions for non-convex differential inclusions. Our dynamic models include a vector-valued measure and provide a general structure that includes impulsive systems. A "time-stretching' transformation is the central ingredient of the proofs. We will describe our methods, possible extensions, and applications.

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MS23

Positive Invariance of Constrained Linear/Affine Dynamics and Its Applications to Hybrid Systems

This talk addresses global long-time behaviors of constrained linear/affine dynamics, motivated by recent work on piecewise linear/affine systems (PLSs/PASs). We will start with a review of local and finite-time switching properties of (Lipschitz continuous) PASs, e.g., non-Zenoness and simple switching behavior, and discuss their applications to complementarity systems. We then focus on long-time switching behaviors of PASs. We show that the positively invariant set associated with each linear/affine dynamics plays an important role in characterization of long-time switching dynamics. Necessary and sufficient conditions are developed for the existence of such a positively invariant set. We will further discuss its applications in finite-time/long-time observability analysis and safety verification of affine dynamics.

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MS24

Intrinsic Methods in the Theory of Thin and Asymptotic Shells

In the theory of thin shells, the asymptotic model, when it exists, only depends on the choice of the *constitutive law*, the *midsurface*, and the subspace of the space of solutions that properly handles the loading applied to the shell. A central issue is how rough this midsurface can be to still make sense of asymptotic *membrane shell* and *bending equations* without ad hoc mechanical or mathematical assumptions. It is possible for a general $C^{1,1}$-midsurface with or without boundary such as a sphere, a donut, or a closed reservoir. Moreover, it can be done without local maps, local bases, and Christoffel symbols via the purely intrinsic methods developed by Delfour and Zolésio starting in 1992 and in a number of subsequent papers.

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MS24

Existence of Minimizer of Some Curve Functionnals

We prove the existence of a minimum of a functionnal defined on a space of curves. This functionnal comes from some radar optimisation problems and consists in some specific integral over the curve. We search the curve in a sobolev space. We also prove a compactness result on shape spaces with local constraints.

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MS24

A New Algorithm for Harmonic Solution in 3D Electromagnetic

We consider the problem of finding the harmonic solutions for the external body problem governed by the 3D Maxwell equations. As well known, this solution are related to the solution of a Helmholz equation. Unfortunately, in concrate situations this solution may be difficult to compute. Our approach is based to looking for the solution as the minimizer of a given functional, so that the initial problem becomes a control problem.

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MS24

Tube Variational Euler Solution

Abstract not available at time of publication.

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MS25

Comparison of Truncation Methods for Low Order Estimators

In this talk, we compare two balanced truncation methods as a means of designing low order compensators for a PDE system. The first is the application of balanced truncation to the estimator dynamics, rather than the state dynamics, as is typical. The second, LQG balanced truncation, applies the balancing technique to the Riccati operators obtained from a specific LQG design. Performance and robustness properties of the reduced order compensators are investigated.

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MS25

Reduced-Order Modeling and Concentration Regulation for a Reaction Transport Network

Reaction transport processes have fundamental importance in the realms of ground water systems and hydrogeology. We develop a reduced-order dynamical model for a reaction transport network comprised of coupled chemical concentrations, with accuracy validated in simulation. The reduced-order model is utilized to develop boundary injections of parent concentrations that optimally regulate daughter products to target profiles. Optimal concentration injection is demonstrated for the reduced and full-order reaction transport network models.

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MS25

Optimal Model Reduction with Application to Nonlinear Convection

In the first part of this presentation two popular model reduction techniques, the proper orthogonal decomposition (POD) and balanced truncation, are shown to be optimal in the sense of distance minimizations in spaces of Hilbert- Schmidt operators. Optimality of balanced truncation seems to have been overlooked in the literature. In the second part POD is applied in conjunction with empirical balanced truncation to a nonlinear convective flow modeled by the two-dimensional Burgers equation.

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MS25

An Algorithm for H_∞ Control Using Sensitivity Analysis

A necessary and sufficient condition for the existence of a controller for which the H_∞-norm of the transfer function is less than γ, leads to an algorithm to determine the optimal attenuation γ^*. This algorithm relies on the sensitivity of the eigenvalues of the coupling matrix. We present numerical results that illustrate an algorithm where the sensitivity of an eigenvalue is used to determine γ^*.

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MS26

Analysis of Brain Data

EEG data are recorded from patients with epilepsy, and they can also be analyzed to determine information about how brains function. Large-scale networks may play a role in the generation of seizures and their spread. If they can be reliably defined, then they may suggest alternate methods for controlling seizures. Several methods are available to use in the determination of synchronization of neurons in the brain. Epilepsy is an extreme example of synchronization, so it is natural to consider patients with epilepsy when studying how the synchronization of neurons develops. In particular, it is important to determine if a seizure starts from a focus or a network as it is critical to determine treatment possibilities. A powerful way of analyzing data is by using diffusion mapping. Eigenfunctions of Markov matrices are used to construct coordinates called diffusion maps that generate efficient representations of complex geometric structures. Not only does diffusion mapping allow for dimensionality reduction of the data, but this method also provides pattern recognition in the data so that certain parts of the data may be analyzed more closely. It is a useful tool in detecting anomalies in EEG data and determining whether a brain is functioning normally or not. Principal components analysis is a transform that allows for more dimensionality reduction and to determine if data signals are behaving similarly or not. Using this from the parts of the data taken to be studied after diffusion mapping, a better idea of which parts of the brain are behaving similarly and which are not may be obtained. This method is used in addition to diffusion mapping in detecting anomalies in the data, but moreover, it allows for detailed analysis of the data. Thus, for instance, the preseizure data in patients with epilepsy may be analyzed to determine if there are any anomalies that may help predict the occurrence of a seizure.

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MS26

A Hamilton-Jacobi Equation in Compressible Euler Equations

We formulate a special system of conservation law equation as minimizer from a variational problem defined on space of measure-valued path. The associated Hamilton-Jacobi equation is defined on a measure-valued state space and has a unique solution in appropriately extended viscosity sense.

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MS26

Systems of Kolmogorov Backward Equations for Switching Diffusions with Two-time Scales

This talk is concerned with switching diffusions having two-time scales. The underlying systems involve both continuous dynamics that are in the form of diffusions and discrete events that are represented by continuous-state-dependent jump processes. The jump process is not a Markov chain, but only the joint pair of the continuous and discrete components is a Markov process. The motivation of our study stems from emerging applications in communication networks, financial economics, and chemical engineering. Our effort is devoted to developing asymptotic expansions of the systems of the Kolmogorov backward equations. These expansions will help us to reduce computational complexity in subsequent study for related near-optimal control and stabilization problems.

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MS26

Computational Methods for Stochastic Differential Equations Involving Standard Brownian Motion and Fractional Brownian Motion

As more applied science researchers are attempting to use Stochastic Differential Equations (SDEs) in their modeling, especially when involving Fractional Brownian Motion (fBM), one common issue appears: an exact solution cannot be found. Therefore, in this paper, we test various Numerical methods in solving SDEs with standard BM that have non-linear coefficients. In addition we extend our results to SDEs with fBM.

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MS27

Global Motions for a Swimming Model

We study the global motion capabilities (or global controllability) of an abstract object consisting of small narrow rectangles connected by flexible links, which "swims' in a fishlike or rowing fashion in the nonstationary Stokes fluid. We assume that the means by which we can affect the swimming motion are the change of the spatial orientation of the aforementioned rectangles and the direction and strength of the rotation and elastic forces involved. The model of our interest is a hybrid system consisting of the fluid partial differential equation coupled with an (integro-)ordinary differential equation for the position of the object. It is governed via some coefficients in system's equations regarded as multiplicative controls. We illustrate our analytical results by a series of computational experiments.

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MS27

On the Use of Some Coordinates as Controls in a Mechanical System.

The simple idea of using some of the Lagrangian coordinates (q_i, u_α), say the u_α, "as controls" is here illustrated in its mechanical, geometrical, and analytical contents. A notion of curvature $\mathbf{c}$ of the foliation $\{u = cost\}$ is crucial to characterize the functional dependence of the equation on the controls u and their derivatives $\dot{u}$. While $\mathbf{c} = 0$ implies nice input-output continuity properties, the non vanishing of $\mathbf{c}$ is necessary for a certain vibrational stabilizability.

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MS27

Quasivelocities and Symmetries in Nonholonomic Systems

Quasivelocities are the components of a mechanical system's velocity relative to a set of vector fields that are not associated with configuration coordinates. This talk discusses how quasivelocities may be used in the formulation of nonholonomic systems with symmetry. In particular, the use of quasivelocities in understanding unusual momentum conservation laws is investigated, as is the applications of these conservation laws and discrete symmetries to the qualitative analysis of nonholonomic dynamics.

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MS27

A Geometrical Formulation of Open Thermodynamical Processes

It is known that the equilibrium properties of thermodynamic systems may be expressed by a Legendre submanifold of the Thermodynamic Phase Space, endowed with its canonical contact form. In this talk we discuss the formulation of open multi-physics systems subject to irreversible thermodynamic processes in terms of contact vector fields leaving invariant the Legendre submanifold and generated by contact Hamiltonian functions depending on external variables, which may be used for interconnection and control.

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MS28

Efficient Solution of Large Scale Differential Riccati Equations

The numerical treatment of linear quadratic regulator/gaussian design problems for parabolic partial differential equations requires solving large scale Riccati equations. In the finite time horizon case, the differential Riccati equation (DRE) arises. Typically the coefficient matrices of the resulting DRE there have a given structure (e.g. sparse, symmetric, low rank). We develop efficient numerical methods capable of exploiting this structure and discuss their implementation in the Matlab toolbox M.E.S.S (Matrix Equation Sparse Solver).

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MS28

Eigenspace Solutions for Lur'e Equations

Lur'e equations are generalizations of Riccati equations and occur especially in model reduction and linear-quadratic singular optimal control problems. It is well-known that the solutions of Riccati equations can be parametrized by Lagrangian eigenspaces of certain Hamiltonian matrices. In this talk, we present a generalization of this theory to Lur'e equations.

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MS28

Accelerating Solvers for Large Sparse Algebraic Riccati Equations

In the recent decade the Newton/Kleinman-ADI iteration has emerged to be an efficient tool for the solution of large sparse algebraic Riccati equations. It performs especially well in the context of linear quadratic regulator problems where it can be applied directly to the feedback operator searched for. On the other hand it is strongly dependent on the quality of the shift parameters in the inner ADI iteration. Here we investigate acceleration techniques, that are applicable, e.g., when these parameters produce slow convergence.

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MS28

Numerical Algorithms for Projected Riccati Equations

We consider the numerical solution of projected generalized Riccati equations using Newton's method. Such equations arise in positive real and bounded real balanced truncation model reduction of descriptor systems. The computation of the low-rank Cholesky factors of the solutions of projected Riccati equations is also discussed. Numerical examples are given.

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MS29

Using Sensitivity Analysis to Predict Transition for a Nonlinear Parabolic Partial Differential Equation

We illustrate how sensitivity calculations can provide a practical precursor to dynamic transitions in parameterized nonlinear parabolic partial differential equations. Numerical results for a reaction-diffusion equation show that sensitivity computations indicate a transition is about to occur well before the numerical simulation of the system indicates a transition. The ultimate goal is to use this type of sensitivity information to determine when to turn on a controller to prevent transition in the original PDE system.

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MS29

Observer Design for an Unsteady Oseen Flow with Hair Sensor Arrays

In closed-loop model-based flow control design, state information is often provided from impractical locations for measurements using generalized sensor models. In this work, we mathematically integrate a wall mounted bioinspired hair sensor array in an LQG observer design to test the detection of spatial and temporal changes in an unsteady Oseen flow field. Accurate state estimation could help realize closed-loop flow control designs where only measurements from surfaces are available.

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MS29

Convergent Snapshot Algorithms for Model Reduction and Feedback Control of PDE Systems

We present recent developments regarding accurate and efficient algorithms for computing feedback control laws and reduced order models for linear partial differential equation (PDE) systems. The algorithms are closely related to proper orthogonal decomposition, an optimal data reconstruction technique. POD is used systematically to provide convergence theory and error bounds for the algorithms. We will discuss a low storage algorithm for Lyapunov equations and multiple algorithms for balanced model reduction of PDE systems.

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MS29

Solvers for High Rank Matrix Equations Using Model Reduction Methods

A number of interesting control applications lead to large matrix equations with sparse, yet high rank matrices. We discuss a technique based on recent works by Benner and by Singler that reformulate Lyapunov and some Riccati equations as large scale differential equations where model reduction methods, such as the proper orthogonal decomposition, can be applied. Our numerical results show substantial computational savings over standard numerical libraries for control problems requiring high order discretizations.

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MS30

Mutual Information for Stochastic Signals and Levy Processes

Some relations between estimation and mutual information are given by expressing two mutual information calculations in terms of two distinct estimation errors. The mutual information between a stochastic signal and a pure jump Levy process whose rate function depends on the signal is expressed in terms of a filtering error and the rate of change of this mutual information with respect to a parameter multiplying the rate function of the Levy process is expressed in terms of a smoothing error.

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MS30

A Strong Duality Theorem for Optimal Stopping of One Dimensional Diffusions

We develop a new approach to the solution of optimal stopping problems for one-dimensional diffusions. It is based on imbedding the stopping problem in an infinite dimensional linear program (LP). We shall verify that a strong duality theorem holds for this LP. As a consequence one is able to construct the value function by either solving a family of 2-dimensional nonlinear optimization problems or by solving a family of semi-infinite linear programs. The procedure will be illustrated on a number of examples.

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MS30

Stochastic Averaging in Continuous Time and Applications to Extremum Seeking

We present new theorems for the study of local exponential practical stability via stochastic averaging and compare their conditions and statements to existing averaging theorems. We relax conditions on growth, equilibria, and global stability of the average system. This work is inspired by the problem of reconstructing the stochastic feedback law employed in chemotaxis locomotion of E. Coli bacteria.

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MS30

Cauchy Estimation for Linear Scalar Systems

An estimation paradigm is presented for scalar discrete linear systems entailing additive process and measurement noises that have Cauchy probability density functions (pdf). For systems with Gaussian noises, the Kalman filter has been the main estimation paradigm. However, many practical system uncertainties that have impulsive character, such as radar glint, are better described by stable non-Gaussian densities, for example, the Cauchy pdf. Although the Cauchy pdf does not have a well defined mean and does have an infinite second moment, the conditional density of a Cauchy random variable, given its linear measurements with an additive Cauchy noise, has a conditional mean and a *finite* conditional variance, both being functions of the measurement. For a single measurement, simple expressions are obtained for the conditional mean and variance, by deriving closed form expressions for the infinite integrals associated with the minimum variance estimation problem. To alleviate the complexity of the multi-stage estimator, the conditional pdf is represented in a special factored form. A recursion scheme is then developed based on this factored form and closed form integrations, allowing for the propagation of the conditional mean and variance over an arbitrary number of time stages. In simulations, the performance of the newly developed scalar discrete-time Cauchy estimator is significantly superior to a Kalman filter in the presence of Cauchy noise, whereas the Cauchy estimator deteriorates only slightly compared to the Kalman filter in the presence of Gaussian noise. Remarkably, this new recursive Cauchy conditional mean estimator has parameters that are generated by *linear* difference equations with stochastic coefficients, providing computational efficiency.

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MS31

On the Pre-Lie Magnus and Fer Expansions

We review recent work on the classical Magnus and Fer expansions, unveiling a new structure by using the language of dendriform and pre-Lie algebras as well as combinatorial Hopf algebras of rooted trees. We introduce a particular class of linear equations in dendriform algebras and provide their solutions. At the end we will also indicate new results on the use of combinatorial Hopf algebras in numerical methods and the general theory of pre-Lie Butcher series. Motivations as well as several applications are provided.

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MS31

On Nonlinear System Interconnections and Integer Sequences

Given two nonlinear input-output systems represented as Fliess operators, their cascade and feedback interconnections are described by certain formal power series products of their respective generating series. Sufficient conditions are given under which each interconnection is well-defined on a closed ball in an L_p space. Relationships are then derived between the radii of convergence and the asymptotic behavior of the Fibonacci sequence and the sequence of Catalan numbers.

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MS31

Some Applications of Hopf Algebras to Realization Theorems in Control and Machine Learning

We show how Hopf algebras can be used to prove formal realization theorems in control theory and machine learning. This is joint work with Richard Larson.

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MS31

Control Interpretations of Two Convolution Products in the Hopf Algebra

A Hopf-algebraic interpretation of the Chen-Fliess series identifies it as the image (under certain evaluation maps) of the identity map on the free associative algebra over a set of noncommuting symbols. Two distinct Hopf algebra structures on this space of formal series give rise to two distinct convolution products. This talk maps these two combinatorial objects to control settings, comparing them to products of compositions of systems and compositions of controls.

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PP0

Quadratic Stability of a Thermoforming Reheat Process with Two Time-Varying Uncertainties

Thermoforming is a 10B dollar industry in North America. The parameter-varying nature of its reheat stage has never been considered. The set-points are determined by trial and error. A control design can improve quality, reduce scrap and allow for temperature zoning. Quadratic stability analysis for this process, controlled by an output feedback controller, is addressed. A polytopic covering technique is used to perform this analysis. Region of stability is estimated for different parameter uncertainty sizes.

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PP0

Comparison of Various Optimization Approaches for Parameter Identification in Variational Prob-

lems

We aim to present a rigorous theoretical and numerical comparison among various optimization based approaches available for identifying variable coefficients in general variational problems. Finite element and adaptive finite element methods will be presented for the numerical solvability of the underlying variation problem. A particular emphasis will be given to the possible extension of these approaches for variational inequalities.

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PP0

Experimental Validation of Tracking Control with Collision Avoidance Using Rc Model Cars

This study presents some experimental results of the already proposed method that simultaneously achieve avoiding collisions and tracking to a reference trajectory. To validate its practicability through the experiment, we have prepared some radio-controlled toy model cars, set as an evador and a pursuer, and made a visual feedback control system to measure their position and to control the cars remotely. In the poster presenation we hope, we are going to use not only a indicated poster sheet but also some moives caputered from a camera.

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PP0

Robust Stabilization for Discretized Control Systems on a Grid Pattern

This paper deals with the stability problem of discrete-time and discrete-value (discretized /quantized) control systems in a frequency domain. The discretized (stepwise) nonlinear characteristic on a grid pattern is partitioned into two sections: bounded and sectorial areas. First, by considering a sectorial area over a specified threshold, the robust stability condition for nonlinear discrete-time systems is presented. Then, the method of robust stabilization using discretized PID control with transmission delay is described. Numerical examples for continuous plants are provided to verify the result.

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PP0

Exact Boundary Controllability Result for An Undamped Three-Layer Sandwich Beam by Hilbert Uniqueness Method

In this paper we consider the exact controllability of a three-layer sandwich beam consisting of a compliant middle layer and two stiff outer layers. Boundary controllability result is obtained by the observability inequality by using the multiplier method. Under some restrictions on the parameters and the sufficiently large T, we proved that the system is exactly controllable.

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PP0

A Control for a Rotor with a Cavity Containing Liquid

We consider the motion of a body with a cavity containing an ideal liquid. The motion is perturbed relative to uniform rotation. We propose the joint solution of hydrodynamical and mechanical equations. Based on the equations obtained, the stability of steady-state rotation of a body with liquid is investigated. We obtain the dependence of angular velocities on the perturbated moment of force. Then, the optimal control problems with different functionals are formulated and solved.

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PP0

Parallel Newton-Krylov-Schwarz Algorithms for Complementarity Problems

In this talk, we consider complementarity problems with PDE constrains. Using semismooth function, the solution of the optimization problem can be obtained by solving a large sparse nonlinear system of algebraic equations. We study some parallel Newton-Krylov-Schwarz algorithms consisting of a semi-smooth Newton, a Krylov subspace linear solver and a multilevel overlapping Schwarz preconditioner, and discuss their parallel performance for some obstacle problems.

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