CP1

Nonlinear Controller Design Based on Piecewise Linear Approximations

In this paper a general approach to the design of controllers for Nonlinear Control systems is presented. The methodology uses a Piecewise Linear (PWL) approximation of the Ordinary Differential Equations (ODEs) vector field which describes the dynamics of a system parameterized by the control inputs in order to exploit the linear properties of the PWL vector field facilitating the design of an stabilizing controller. The controller design can be carried out into the PWL approximation and with mild assumptions is possible to ensure the same asymptotic properties for real and approximate vector fields. A measure of the dynamics approximation error is used to estimate upper and lower bounds for the error between the actual and the approximated trajectories once the control vector calculated with the PWL system is replaced into the real one. A case study is presented in order to contrast the theoretical results along the paper.

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CP1

Impulsive Synchronization of Lipschitz Chaotic Systems

Impulsive method is suitable for digital implementation of secure communication based on chaos synchronization. In the present study, we assume that the system satisfies the locally Lipschitz condition and the Lipschitz constant is estimated a priori. We propose an impulsive controller to achieve synchronization of chaotic systems. Moreover, we discuss the relation between the impulsive intervals and the controlling gain. The Chua circuit system is simulated to illustrate the theoretical analysis.

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CP1

The Existence of a Solution to a Free-Boundary Problem Arising in Blood Flow Modeling

We prove the existence of a solution to a free boundary problem modeling blood flow in viscoelastic arteries. The model equations are obtained using asymptotic reduction from the incompressible, viscous Navier-Stokes equations, coupled with the linearly viscoelastic membrane equations. The reduced, effective equations are defined on the cylindrical geometry. The resulting problem is nonlinear with a free boundary. The existence of a weak solution is obtained by using the fixed point arguments.

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CP1

Constrained Maneuvering of Autonomous Spacecraft Using Potential Function Guidance

Autonomous spacecraft guidance laws constructed from functions that satisfy Lyapunov's second theorem of stability or Laplace's equation are presented. Constrained motion is specified by using the linear superposition of functions that describe goal points and regions to avoid. The methods are appealing since the motion can be visualised as either that of a particle on an energy surface or in an ideal fluid and are suitable for safety–critical applications. Numerical simulations illustrate the methods.

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CP1

Delayed State Feedback Induced Periodic Motions

This paper consider a state self-feedback system where the time delay comes from the transfer signal of the feedback.To investigate delay-induced periodic motion derived from a Hopf bifurcation both quantitatively and qualitatively, a called perturbation-incremental scheme (PIS), is proposed. Two example are used to demonstrate the present method. The validity of the results is shown by their consistency with the numerical simulation. Furthermore, an approximate solution can be calculated to any required accuracy.

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CP2

Hereditary Portfolio Optimization in Infinite Dimensions

This paper treats an infinite time horizon hereditary portfolio optimization problem in a market that consists of one savings account and one stock account. The savings account compounds continuously with a fixed interest rate and the stock account keeps track of the inventories of one underlying stock whose unit price follows a nonlinear stochastic hereditary differential equation. Within the solvency region the investor is allowed to consume from the savings account and can make transactions between the two assets subject to paying capital-gain taxes as well as a fixed plus proportional transaction cost. The investor is to seek an optimal consumption-trading strategy in order to maximize the expected utility from the total discounted consumption. The portfolio optimization problem is formulated as an infinite dimensional stochastic classical-impulse control problem due to the hereditary nature of the stock price dynamics and inventories. The quasi-variational HJB inequality (QVHJBI) for the value function is derived and the verification theorem for the optimal strategy is obtained. It is also shown that the value function is a viscosity solution of the QVHJBI.

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CP2
Differential Game Between Manufacturer, Retailer, and Bank

We consider a differential game between manufacturer, retailer, and bank. The model is a nonlinear system of three differential equations with five controls. The first equation describes the rate of change of the total assets of the manufacturer consisting of loan, value of the inventory, and accounts receivable. The second equation describes the rate of change of the manufacturer's inventory. The last equation describes a retailer's inventory.

$$\begin{cases} \dot{x}(t) = K(t) + p_2 u_1(t)\pi(x(t)) - \gamma x(t), \\ \dot{y}(t) = -v(t)y(t) + u_2(t)\pi(x(t)), \\ \dot{z}(t) = -w(t)z(t) + v(t)y(t),\ t \in [0,T], \end{cases} \quad (1)$$

Problems of profit maximization are stated and solved. Optimal strategy for each player is obtained using Maximum Principle and is also recognized as Stackelberg equilibrium.

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CP2
Scheduling Multiskill Call Centers Using Dynamic Routing

In this talk, we address the shift-scheduling problem in a multi-skill call centre. We propos a decision approach plan-operation into two models: plan and operation. The planning step we use the queuing theory models to plan the number of agents of each type needed on each period. Then, the operation step tries to produce the planned expectations, this is done by developing a dynamic routing rules. Finally, we develop a simulation model to evaluate the service level for each call type. Computation results obtained from real-life instances are reported

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CP2
Lowering Expected Transaction Costs Via Options

A portfolio with stock and cash cannot be improved by the addition of an option under the Black Scholes model. We show, however, that options are useful if we add transaction costs to the model. Specifically, for small transaction costs of size ε, the optimal rate for transaction costs without options is $O\left(\varepsilon^{\frac{2}{3}}\right)$. With options, however, we explicitly show the optimal stock/cash/options ratio, which reduces the optimal cost rate to $O\left(\varepsilon^{\frac{6}{7}}\right)$.

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CP3
Bases for the Shuffle Algebra

Combinatorics and free Lie algebras have been used to describe nonlinear control systems. Of interest are the canonical projection maps defined using the convolution product in $End(A(Z))$, where $A(Z)$ denotes the free associative algebra over the alphabet Z. Also of interest are the adjoint projection maps. The kernel of these adjoint maps have many properties that provide, in part, a change of basis from that associated with the *coordinates of the first kind* and the shuffle algebra.

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CP3
Convex Matrix Inequalities in Matrix Unknowns

The talk concerns the question of which Matrix Inequalities MIs convert to Linear Matrix Inequalities LMIs or to Convex Matrix Inequalities CMIs. The are two situations which behave differently: one whose structure does not depend on the dimension of the problem (called dimension free) and one which does. A well supported conjecture is: for dimension free problems every CMI results from an associated LMI. The talk will discuss this and whether or not one can determine which MIs transform to CMIs.

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CP3
Cross Gramians for Approximate Balancing of Nonlinear Systems

We extend the cross-Gramian method for approximating linear symmetric systems, see [D. C. Sorensen, A. C. Antoulas, "The Sylvester equation and approximate balanced truncation", *Linear Algebra and Its Applications*, vol. 351-352, p. 671-700, 2002.], to nonlinear symmetric systems. We study the concept of duality and symmetry for nonlinear systems, see [J. M. A. Scherpen, "Duality and singular value functions of the nonlinear normalized right and left coprime factorizations.", *Proceedings of the 44th IEEE CDC-ECC*, p. 2254-2259, 2005.]. A square nonlinear system is called symmetric if it is equivalent to its dual via a change of coordinates. The duality and symmetry of nonlinear systems are studied here in the context of a non-trivial extension of the linear case. For symmetric systems we define a cross-operator and cross-energy (Gramian) function related to a nonlinear Sylvester equation. We study the relation between the singular value functions of the cross-energy/operator and the Hankel singular values of the system, starting from [K. Fujimoto, J. M. A. Scherpen, "Nonlinear Input-Normal Realizations Based on the Differential Eigenstructure of Hankel Operators", *IEEE Trans. On Aut. Control*, vol. 50, 2005.].

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CP3

H-Infnity for Uncertain Systems

Abstract not available at time of publication.

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CP4

Viscosity Solutions for Max-Concave Hamiltonians and Singular Characteristics

Hamilton-Jacobi equations of the form $-\min_i H_i(x, \nabla u(x)) = 0$ arise in differential games where the minimizing player has only a finite number of options. We consider "co-dimension 1" singularities for viscosity solutions, in which discontinuities in the derivative occur across a smooth surface. These can be classified in a simple way, and described using Melikyan's singular characteristics. An example will illustrate how singular characteristics can be used to construct the desired solution.

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CP4

Natural Observers for Second-Order Bilinear Infinite-Dimensional Systems

We consider the observer design for a class of second order bilinear infinite dimensional systems. In order to preserve the physical interpretation of the second order system, namely that the derivative of the estimated position is the estimated velocity, we consider the observer in the second order setting. We extend earlier results on the natural observers for second order linear infinite dimensional systems. Within the arguments for well-posedness for the proposed natural observer, we provide the class of second order systems for which the proposed observer design is applicable, and through a parameter-dependent Lyapunov function for second order systems, the stability and convergence of the resulting state estimation error (position and velocity) are established. Extensive simulation studies of a 1D elastic structure describing cable dynamics are included to further support the theoretical findings of the proposed observer design.

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CP4

Zero Dynamics Boundary Control for Viscous Burgers' Equation

In this talk we present our recent results on zero dynamics design applied to a viscous Burgers' equation. The main problem of interest is tracking of time dependent reference signals prescribed at the ends of a unit interval. The desired controls are obtained by application of a zero dynamics methodology which has proven to be quite useful for certain types of (co-located) boundary control problems. We also provide several interesting examples. The main obstacles encountered in obtaining our main results stem from the lack of global a priori estimates for the boundary controlled Burgers' equation.

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CP4

Control of Scalar Conservation Laws with Pointwise Sources

An explicit gradient-based algorithm is presented to steer the distributed state of a scalar conservation law, the control variable being a set of pointwise sources. First, the wellposedness of such equations and their linearized counterparts are adressed. A specific adjoint calculus framework is then developed for BV fields, nonlinear conservation laws being known to generate such irregular flows. The efficiency of an adjoint-based gradient scheme is shown on an application in freeway traffic management.

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CP4

The Heat and Schrödinger Equations: Null Bound-

ary Control in One Shot

We discuss the null boundary controllability of the heat and Schrödinger equations with a potential. This unified approach applies not just to both of these PDEs, but also to a one-parameter family of PDEs that they belong to.

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CP4

Determining Mechanism from Quantum Control Data

Optimal control by closed-loop procedures produces laser pulses which control the dynamic behavior of quantum systems in simulations and experiments. The mechanism of interaction between laser and system is not well understood. Mechanism may be quantified through an expansion of the time propagation operator, and we have proposed Hamiltonian encoding to calculate it. We present the method, and recent analysis of fundamental limits to, and the feasibility of, an extension suitable for laboratory use.

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CP5

Circuit Modeling Approach to Analyze the Effect of High Heat on Thermoregulatory Control Mechanism in Human

Physiological control mechanism cannot be understood until its receptor, center of coordination and effector organs have been identified, and until the quantitative relations between the physical stimuli and physiological responses, have been confirmed. The present model circuit has been simulated using the software MULTISIM that mimics the vasomotor control of human under heat stress. The input has been taken as voltage source V2. The minimum skin blood flow (SkBF) has been observed at 35C i.e., 0 ml.100ml-1.min-1 and the maximum at 42C i.e., 18.6 ml.100ml-1.min-1. SkBF found to be in accordance with the physiological process. Hence, modeling using circuit technique could serve reasonable output.

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CP5

Reduced Models for Neural Control of Respiration in Mammals

We have developed reduced mathematical models for control of respiration in mammals. The neural controller is described mathematically by a set of differential equations that represent respiratory rhythm generation in the brainstem and was coupled to simplified models of the lungs incorporating oxygen and carbon dioxide transport. Both frequency and amplitude of breathing are regulated in response to physiological control signals (oxygen and carbon dioxide). Some features of experimental data are captured by the model.

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CP5

Optimal Treatment Planning in Radiotherapy Based on Boltzmann Transport Equations

A Boltzmann transport model for dose calculation in external radiotherapy is considered. We formulate an optimal control problem for the desired dose. Based on this model we develop a direct optimization approach based on adjoint equations. We prove existence and uniqueness of the minimizer. Numerical results in one and two dimensions are presented.

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CP5

Parameter Identification for Reaction-Diffusion Equations Modeling Turing Patterns

This talk focuses on a reaction-diffusion system modeling pattern formation in developmental biology (morphogenesis). Optimal control theory is used to find the parameters that lead to patterns mimicking those found in nature, which is an improvement on the common ad hoc approaches applied previously. The basic approach is to minimize a cost functional that measures the discrepancies between a given state called the 'target', in this case a pattern found in nature, and the solution of the reaction-diffusion system. The parameters of the system are treated as distributed controls. The results of some numerical experiments in 2-D are presented using the finite element method, which illustrates the convergence of a variable-step gradient algorithm for finding the optimal controls of the system.

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CP5

Dynamics and Impact of the Immune Response to Chronic Myelogenous Leukemia

Patients taking Gleevec have a brief but significant immune response against chronic myelogenous leukemia (CML). Our experiments show that these immune cells can be expanded in vitro via stimulation with autologous cryopreserved leukemia cells. We formulate a delay differential equation model of immune and leukemia dynamics, and devise optimal strategies of vaccination with cryopreserved leukemia cells. We show that vaccinations in combination with Gleevec treatment, may significantly increase patients immune responses and eliminate CML.

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CP5

Optimal Management of Drug Resistance in Suppressive Therapy

Drug resistance in HIV is overwhelmingly likely to preexist the start of treatment, and the risk of resistance is proportional to the population of the virus at the start of drug treatment. We use models which track populations of wild-type and drug-resistant virus to show that the current method of replacing a failing drug regimen is non-optimal, and may increase the risk of resistance emerging to the new regimen. Treatment interruptions using the failing drug regimen can be used to decrease this risk.

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CP6

Study of the Dynamic Performance of Pem Fuel Cells

This paper presents a dynamic nonlinear model for Polymer Electrolyte Membrane (PEM) Fuel Cells. A nonlinear controller is designed based on the proposed model to prolong the stack life of PEM fuel cells. Since it has been known that large deviation between hydrogen and oxygen partial pressures can cause severe membrane damages in the fuel cell, feedback linearization is applied to the PEM fuel cell system such that the deviation can be kept as small as possible during disturbances or load variations. Dynamic PEM Fuel Cell model is proposed as a nonlinear multiple-input multiple-output (MIMO) system so that feedback linearization can be directly utilized. During the control design, hydrogen and oxygen inlet flow rates are defined as the control variables, and pressures of hydrogen and oxygen are appropriately defined as the control objectives. The proposed dynamic model was tested by comparing the simulation results and the experimental data previously published. Simulation results show that the proposed dynamic nonlinear PEMFC model has better transient performances comparing with the linear control of PEMFC.

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CP6

An Adaptive Control of Automated Guided Vehicle in Consideration of Mass Change

In this presentation, an adaptive control design of Automated Guided Vehicle (AGV) is proposed. This AGV can move to all directions by using two active dual-wheel caster assemblies. For the driving construction, the number of input is larger than the number of output. The proposed method can make an adaptive controller to the redundant system. We show that this controller is valid for a change of loading weight by simulation.

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CP6

Fractional Derivative Model of Edfa with Ase

The present work introduces fractional derivative type model into the light amplification in Erbium-doped fiber amplifiers area describing amplified spontaneous emission of ions. Fractional derivative type model provides a natural framework for generalization of a Bononi type nonlinear model in the controllable form. Simulation results of nonlinear fractional differential equations based on expansion formula obtained by Atanackovic and Stankovic are also presented.

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CP6

Comparison of Control Methodologies for a Bench Mark Line of Sight Stabilization Application

This work presents control law designs for a benchmark, line-of-sight stabilization application for Electro-optical systems mounted on mobile platform, using representative methodologies like Open loop shaping, H-infinity control

method and Fuzzy Knowledge based controller. All the controllers meet the stringent requirements of disturbance attenuation and command following. Different methodologies are compared for their relative merits and demerits with respect to ease of design, implementation and performance in presence of practically unavoidable nonlinearities.

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CP6

A Study on Thermal Control in Small-Scale Electricity Furnace by Thermal Regulator E5EN-R1T

In this paper, thermal control result of the small-scale electric furnace model by the thermal regulator E5EN-R1T is described. Based on results of ON-OFF control in this model, proportional band can be adjusted the first thing. Then, the authors set the values of P(proportion), Ti(Integration)and Td(Differential) by trial-error method on the theory(Marginal sensitivity theorem),and P control, PI control and PID control are carried out. A pretty good control result(P:60C,Ti:60sec, Td:30sec) has been obtained and it is reported.

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CP7

On the Stability of Some Stochastic Integral Equations

Stochastic Volterra equations of the form:

$$dx(t) = f(x(t))dt + \int_0^t K(t-s)x(s)ds\ dt + g(x(t))dB(t),$$

are considered, where $\{B(t) : t \geq 0\}$ is standard one - dimensional Brownian motion and the kernel K decreases to zero non-exponentially. We study the convergence rate to zero of the stochastic solutions of the considered equation. It is proved under suitable conditions that :

$$\lim_{t\to\infty} \frac{|x(t)|}{K(t)} = \infty, \quad \text{almost surely.}$$

The considered stochastic integral equations arise if we consider the Black-Scholes market consists of a Bank account or a bond and a stock. These stochastic models can also be applied to population dynamics in biology.

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CP7

A Forward-Backward Algorithm for Perturbed Stochastic Linear-Quadratic Regulator Problems

We consider a nonlinear perturbation in the drift coefficient of the state equation for a linear-quadratic regulator (LQR) problem. We propose a forward-backward numerical algorithm to solve this optimization problem using the representation theorems between forward-backward SDEs and stochastic control problems. We identify certain regularity and growth conditions for a smooth solution to the corresponding HJB equation as well as to the FBSDE system. We also discuss convergence and regularity properties of the proposed scheme.

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CP7

On a Stochastic Robust Control

We consider some stochastic dynamical systems,which represents robustness that arise in controller and filter designs and also represent a remote control system in the presence of a network cable. The flexible arms connected by elastic joints of the robot is also studied. In addition we introduce a theory about the artificial intelligence. Some deterministic fractional dynamical systems is studied. These systems have many applications in robot and industry.

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CP8

Linear Quadratic Analysis of Tcp/ip Networks Transients

In this paper we consider a transient regime analysis for linearized models of TCP/IP networks in terms of their congestion signaling and queueing dynamics. Assuming the network information is known when compensating for delays, a linear quadratic control framework is invoked to calculate the robust control gains. The delay independent control has performance limits for large network delays, whereas the delay dependent control used in this paper regulates the delay closed loop dynamics arbitrarily close.

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CP8

Hierarchical Fault Tolerant Control of Network Service Availability

This paper is concerned with the mathematical analysis of a hierarchical Fault Tolerant Control (FTC) framework for service availability in communication systems. Following a control and optimization perspective, a modular design procedure for diagnostic and reconfiguration algorithms running at different levels of the hierarchy is described. A hierarchical decision logic algorithm is obtained by invoking the theoretical devices of the supervisory control theory of discrete event systems. Numerical results supporting the theoretical findings are provided.

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CP8

Stabilizing Controllers over Networks

This talk considers the problem of finding decentralized controllers which stabilize a network of subsystems when the controllers may communicate, but subject to delays. When all of the subsystems and associated controllers under consideration are linear time-invariant, a condition called quadratic invariance allows for the parameterization of all stabilizing controllers, and it is shown that for this problem, that condition reduces to controllers being able to communicate information faster than dynamics propagate. A new invariance condition has been shown to similarly allow for the parameterization of all possibly nonlinear, possibly time-varying stabilizing controllers. It is shown that this also reduces to the controllers being able to share information faster than dynamics propagate, so that if they do, one may find all causal stablizing controllers over the network.

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CP9

Control of a Three-Joint Underactuated Planar Manipulator by Interconnection and Damping Assignment Passivity-Based Control Method

We apply Interconnection and Damping Assignment Passivity-Based Control (IDA-PBC) method to an underactuated planar manipulator with the third joint unactuated which is under second-order nonholonomic constraints. We give a port-Hamiltonian representation of the system and present the applicable condition of IDA-PBC. We also design a desired inertia matrix and potential energy function of the closed Hamiltonian system to derive a concrete control law. Numerical experiments show the effectiveness of the controller.

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CP9

Vibration and Control of a Flexible Structure with Variable Joint Stiffness

In most structure analyses, the joint stiffness is typically neglected. For structures operating in a harsh environment; e.g., the landing gears of an aircraft, or structures of off-shore oil platform, once the joint stiffness is reduced to the level of links, it provides almost no support to the system, and ensuing failure is expected. In this study, we investigate the effects of variable joint stiffness on the vibration of a simple beam structure. The natural frequency of the beam structure is first examined at different level of joint stiffness, from which a functional relationship can be established and feasible control algorithms are proposed for the future design of smart structures.

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CP9

Variational Principles and Geometry of Nonholonomic and Vakonomic Mechanical Systems

We explore mechanical systems with nonholonomic constraints that either satisfy i) The Principle of Virtual Work (Dynamics) or ii) Hamilton's Principle (Vakonomics). We will discuss the difference between these two systems in a geometric context, and show how either system can be described in terms of quasi-velocities. As an illustration of vakonomic dynamics we consider the fourth order dynamical systems that arise from the optimal control of second order nonholonomic systems.

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CP9

Task Encoding and Control of Metamorphic Robots

Controlled shape change is an important requirement in many metamorphic systems, including reconfigurable robots and biological systems. We are interested in the problem of encoding this task in a dynamical systems setting, so as to enable robust behaviors. Towards this end, we present two technical contributions: (a) a technique for characterizing the geometry of shape spaces of metamorphic robots that allows us to design dynamical control strategies as vector fields in this space and (b) techniques for optimally sampling such spaces, which admit a manifold structure, enabling the application of efficient approximation algorithms for computing geodesics.

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CP9

Adaptive Backstepping Design of a Two Dof Flexible-Joint Robot Based on Function Approximation Technique

In this paper a function approximation technique is proposed for adaptive backstepping design of a two-link flexible-joint robot manipulator. The dynamics of the robot manipulator are derived with the assumption that all matrices in this robot model are unknown. Using the Lyapunov stability theory, a set of update law is derived to give closed loop stability with proper tracking performance.

The computer simulation is shown to verify validity and effectiveness of the proposed control law.

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CP9

Stability Analysis of a Non-Autonomous Control System Using the Concept of Lyapunov Exponents

A bipedal robot trajectory tracking control system is investigated. Since the biped is subjected to constraints, the value of control torque cannot be chosen arbitrarily. A simple harmonic motion is chosen as desired trajectory, which leads the tracking control system to non-autonomous. The stability of such non-autonomous system is analyzed using the concept of Lyapunov exponents. Lyapunov exponents spectrum is calculated based on mathematical models (of both non-autonomous and autonomous systems) and a time series.

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CP10

An Efficient Computational Algorithm for the Solution of Control Problems with Ill-Posed Model

The solution and analysis of a control problem involves the solution and analysis of the mathematical model of the related system. Quite often, one can not obtain a closed form solution/analysis for the model, and thus computational methods are to be used. The resulting discrete system is normally ill-conditioned. In this work, we develop a multilevel computational approach for the solution of these types of control problems, leading to significant improvements in the results.

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CP10

Using The Method of Subdomains in the Solution of Control Problems

In this work, we divide the domain of the solution into different subdomains, based on the common features of the subdomain. This would allow us to use an adaptive numerical algorithm in the solution of the control problems. This algorithm would let us to take into the account the specific features of each subdomain and treat the problem locally. We have obtained better results using our method, as compared to the similar results of the classical global methods.

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CP10

Trust Region Spectral Bundle Method for Nonconvex Eigenvalue Optimization

We present a nonsmooth optimization technique for nonconvex maximum eigenvalue functions and for nonsmooth functions which are infinite maxima of eigenvalue functions. We prove global convergence of our method in the sense that for an arbitrary starting point, every accumulation point of the sequence of iterates is critical. The method is tested for the H_∞ controller synthesis on some classical plants. Results are compared with those previously obtained by other techniques.

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CP10

Circuit Design Problem Formulation on Basis of the Control Theory Approach

The design process of any analog circuit design was formulated on the basis of the control theory application. This approach produces the infinite set of different design strategies inside the same optimization procedure. The problem of minimal-time design algorithm construction is defined as the problem of a functional minimization of the control theory. The design process is defined as a controllable dynamic system and the Lyapunov function of this system serves to minimize the computer design time. Numerical results of some electronic circuit design demonstrate the efficiency of the proposed methodology.

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CP10

Numerical Optimization Assisted by Noncommutative Symbolic Algebra

We describe how a symbolic computer algebra tool (NCAlgebra) that can handle symbolic matrix (noncommutative) products is used to numerically solve systems and control problems. Our current focus is on semidefinite programs arising from control theory, where matrix variables appear naturally. Our tools keep matrix variables aggregated at all steps of a primal-dual interior-point algorithm. Symbolic matrix expressions are automatically generated and used on numerical iterative procedures for the determination of search directions, showing promising results.

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CP11

Large-Scale Control in Porous Media Flow

Control of porous media flow, such as reservoir management, is not a new area of research. Since the foundations of reservoir simulation and management some kind of optimization has been used in practice. However, flow control in porous media flow has been facing remarkable new challenges in a theoretical and practical point of view. In this talk, issues in large-scale closed-loop control will be discussed emphasizing model reduction applied to improvements in oil recovery.

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CP11

Curvature of Optimal Control: Deformation of Planar Systems

The Maximum Principle provides necessary conditions for a trajectory-control-pair to be optimal. Classical sufficient conditions test for definiteness of second order derivatives. Recently Agrachev introduced a curvature of optimal control, which yields elegant sufficient conditions for systems whose control take values in a circle. We present initial studies of this curvature as this circle continuously deforms into a closed interval. Of particular interest is its behavior at parameter values where conjugate points emerge with associated loss of optimality.

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CP11

A Dual Method for the Two-Target Distributed Optimal Control of a Parabolic System

We consider the problem of finding an optimal control that drives the solution of the given parabolic PDE to a specified target at some fixed time. Meanwhile it is desired to keep the variation of the solution from a second target as small as possible. We treat this problem as a multi-objective optimization and consider three different approaches for the solution. We compare these approaches and propose an efficient algorithm based on the duality.

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CP11

Boundary Control Schemes for Nonlinear Kirchhoff String

A nonlinear Kirchhoff string is given as

$$\frac{\partial^2 z(x,t)}{\partial t^2} = M(\|\frac{\partial z(x,t)}{\partial x}\|^2)\frac{\partial^2 z(x,t)}{\partial x^2}\ , \quad x \in (0\ ,\ 1)\ , \quad t \geq 0\ ,$$

$$z(0,t) = 0\ , \qquad M(\|\frac{\partial z(x,t)}{\partial x}\|^2)\frac{\partial z}{\partial x}(1,t) = u(t)\ , \qquad t \geq 0\ ,$$

here $M(\cdot) \in C^1(\mathbf{R}_+)$, $\|\cdot\|$ represents L_2 norm, $u(t)$ is the boundary control force. We propose two new stabilizing controllers by using $z(1,t)$, which are related to the positive real controllers. One of these classes generalizes a class already proposed in the literature and the other one is new.

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CP11

On the Controllability of Maxwell Fluids

We study the controllability of viscolastic fluids governed by the upper convected Maxwell equation. The effects of different fluid geometries are investigated. This is a joint work with Professors Wei Kang and Arthur Krener.

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CP12

A Piecewise Linear Output Error Identification Algorithm

We present a novel BIBO stable Nonlinear Output Error (NOE) identification algorithm based on High Level Canonical Piecewise Linear (HL CPWL) functions. Starting from a linear OE approximation, the model structure allows the implementation of an identification algorithm in which the order of the model can be easily increased during the identification process retaining the previous achieved approximation. We also describe the possibilities of the hardware implementation of the identification algorithm.

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CP12

On the Implementation of a Wavelet-Based Iterative Learning Controller Using Cpld/fpga

The implementation of a wavelet-based iterative learning controller (WILC) is presented in this paper. To meet the requirements of simple hardware, fast rapid prototyping and cost-effectiveness, we present a servo-chip design with a wavelet-based iterative learning control scheme which is implemented on a single Altera FLEX 10KRC-240 FPGA (Field Programmable Gate Array). Three sub-systems are built inside this FPGA-based servo-chip, including a feedback controller module, a discrete wavelet transform (DWT) module and an inverse discrete wavelet transform (IDWT) module. To verify the efficacy of this design, an ink-jet printer is adopted as the control target and a much improved speed-tracking performance is observed from the experimental verification. Simulations on Matlab are also presented for comparison.

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CP12

Game-Theoretic Model-Based Approach to Higher-Level Fusion with Application to Sensor Resource Management

We present a hierarchical game-theoretic approach to level 2 and level 3 fusion problems. Given level 1 data of observations of individual objects and prior knowledge of the composition of enemy grouping, we consider the level 2 problem by developing a Bayesian inference algorithm for determining the enemy identity. We then apply game theory toward the level 3 problem, inferring the intent of enemy groups, given the determined identities and prior knowledge of enemy strategies.

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CP12

Online Parameter Identification in Time Dependent Differential Equations

Online parameter identification becomes necessary whenever model parameters are needed in order to support decisions that have to be taken during the operation of the real system. Based on ideas from adaptive control and regularization of inverse problems we suggest an online method that works both for ODEs and time-dependent PDEs. It allows for partial state observations and does neither require a linear parameterization nor data differentiation or filtering. Numerical examples in context of aircraft control are presented.

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CP12

Temperature Data Assimilation Based on Pointwise Transient Measurements: High Speed Variational Reconstruction

The inverse problem of temperature identification based on pointwise transient measurements is considered. The problem is set in a model-based data assimilation approach that builds upon optimal control theory. The well-known convergence difficulty of the adjoint technique near the final instant is eliminated here by minimizing the regularized performance index in a smooth enough functional space. A dual formulation of the problem constructs a high-speed algorithm well suited for real-time applications and enabling parallel computations.

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CP12

Explaining Learning and Its Various Types by a Multi-Feedback Control Model

In this paper, well clarify relations existing between control, learning and modeling by presenting a computable model integrating a set of nested loops of control. Well first explain a 2-loops model, which will be generalized to n loops afterwards. This will allow us to define various categories of learning. The specific role of recursivity will be analyzed. Well illustrate the use of this model on human learning as well as on auto-optimized microelectronics digital chips.

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MS1

On Regularization Concepts for Parabolic Boundary Control Problems with Pointwise State Constraints

The presence of pointwise state constraints presents a challenge for the analysis as well as the numerical treatment of optimal control problems. It is known that the Lagrange multipliers associated with the constraints are regular Borel measures, if the states are considered in spaces of continuous functions. On the one hand, this restriction to continuous state functions requires sufficient regularity of the controls. Without box constraints on the control, this leads to severe restrictions on the spatial domain when considering controls in L^2-spaces. In parabolic boundary control problems, first order necessary optimality conditions of Karush-Kuhn-Tucker type cannot be shown at all in useful spaces. On the other hand, solving state-constrained optimal control problems numerically leads to specific difficulties. For example, measures appear in the right-hand-side of associated adjoint equations. In recent years, many regularization approaches have been studied in order to improve both the analysis and the numerical treatment of these problems. In this talk, we apply different regularization methods to parabolic boundary control problems with pointwise state constraints in the whole domain and compare the results.

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MS1

Optimal Control Problems for PDEs with Mixed Control-State Constraints – Multiplier Regularity and Numerical Applications

In the optimal control of ordinary differential equations it is a well known fact that problems with mixed control-state constraints exhibit better properties than those with pure pointwise state constraints. A similar behaviour was observed for the optimal control of elliptic and parabolic partial differential equations, (M. Bergounioux and F. Tröltzsch. Optimal control of semilinear parabolic equations with state-constraints of bottleneck type. *ESAIM, Control, Optimisation and Calculus of Variations*, 4:595–608, 1999.), (N. Arada and J. P. Raymond. Optimal control problems with mixed control-state constraints. *SIAM J. Control*, 39:1391–1407, 2000.), (A. Rösch and F. Tröltzsch. Existence of regular Lagrange multipliers for a nonlinear elliptic optimal control problem with pointwise control-state constraints. *SIAM J. Control and Optimization*, xx(x):548–564, 2006.). For instance, the Lagrange multipliers associated with certain mixed control state constraints are functions of L^p-spaces. Following an approach suggested in (A. Dmitruk. Maximum principle for the general optimal control problem with phase and regular mixed constraints. *Computational Mathematics and Modeling*, 4:364–377, 1993.) for ODEs, the talk reports on a new and simplified technique to prove L^1-regularity in the case of elliptic PDEs. Moreover, an idea of (A. Rösch and D. Wachsmuth. Regularity of solutions for an optimal control problem with mixed control-state constraints. 2006, submitted.) is extended to derive L^∞-estimates for the multipliers, along with the proof of Lipschitz regularity of optimal controls. The potential application to the numerical regularization of problems with pure pointwise state constraints is briefly sketched.

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MS1

Error Estimates for Finite Element Discretization of Parabolic Optimal Control Problems

In this talk we discuss space-time finite element discretization of parabolic optimal control problems with control constraints. We develop a priori error analysis taking into account space and time regularity of the optimal solution. For the treatment of control constraints we generalize and compare different approaches known from elliptic control problems. Numerical results confirm theoretical investigations.

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MS1

Adaptive Finite Element Methods for Optimal Control Problems with Control Constraints

We present our work on a posteriori error estimators for the discretization- error in the cost functional or a given quantity of interest, for optimal control problems governed by partial differential equations with additional inequality constraints on the controls. Afterwards we discuss evaluation of local indicators obtained from the estimation for adaptive mesh refinement. Finally we will demonstrate our results with some numerical examples.

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MS2

Correction of Perturbed Optimal Feedback Controllers in Real-Time

Open-loop solution of a optimal control problems are just the first step to cope with the practical realization of real life applications. Closed-loop (feedback) controllers, like the classical Linear Quadratic Regulator (LQR), are needed to compensate perturbations appearing in reality. Although these controllers have proved to be a powerful tool in many applications and to be robust enough to countervail most differences between simulation and practice, they are not optimal if disturbances in the system data occur. If these controllers are applied in a real process, the possibility of data disturbances force recomputing the feedback control law in real-time to preserve stability and optimality, at least approximately. For this purpose, a numerical method based on the parametric sensitivity analysis of nonlinear optimization problems is suggested to calculate higher order approximations of the feedback control law in real-time. Using this method, the optimal controller can be adapted within a few nanoseconds on an typical personal computer. The method is illustrated by the adaptive optimal control of the classical inverted pendulum and a crane system.

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MS2

Steady State and Turnpike of Infinite Dimensional Optimal Control Systems

In this talk we are concerned with the long-run behavior of solutions to infinite horizon optimal control problems. We consider optimal control systems where the state equation is a semi-linear parabolic equation and the cost integrand is convex. The goal is to establish convergence to steady state and turnpike property of solutions to infinite horizon, optimal control systems.

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MS2

Optimal Control of a Servo Drive System with Coulombic Friction and State Constraints

We consider a servo drive system that represents a typical electrodynamic actuator. As such an actuator is very common for loudspeakers, it is called a voice-coil-motor. The basic dynamical model comprises five ODEs for the motor, resp., load mass positions and velocities as well as the coil current. The control function is given by the voltage input. The system involves static Coulombic friction that causes discontinuities in the dynamic equation for the motor mass velocity. We study both time-minimal and energy-minimal controls imposing state constraints for the velocities. The computed optimal controls were implemented on a real system and turned out to be in perfect agreement with measured test bench results.

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MS2

Suboptimal Feedback Control Design of Constrained Parabolic Systems in Uncertainty Conditions

The talk concerns minimax control problems for linear parabolic systems with uncertain perturbations and control functions acting in the Dirichlet boundary conditions. The parabolic control system is functioning under pointwise constraints on control and state variables. The main goal is to design a feedback control that ensures the required state performance and robust stability under any feasible perturbations and minimize an energy-type functional under the worst perturbations from the given area. We develop an efficient approach to the minimax control design of parabolic systems that is based on certain properties of the parabolic dynamics. In this way we justify a suboptimal structure of the feedback regulator and compute its optimal parameters ensuring robust stability of the closed-loop, highly nonlinear parabolic control system on the infinite horizon.

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MS3

Well-Posedness of a Fluid-Structure Interaction Problem Arising in Blood Flow

The speaker will talk about the existence of a unique solution to an initial-boundary value problem arising in modeling blood flow through viscoelastic arteries. The problem describes the coupling between the axially symmetric flow of an incompressible, viscous fluid modeled by the Navier-Stokes equations and the motion of the vessel walls modeled by the linearly viscoelastic membrane equations. Assuming the physiologically relevant flow and vessel wall data with the physiologically relevant inlet and outlet pressures, this become a difficult problem to analyze due to the competition between the hyperbolic and parabolic effects driving the wave propagation in arterial walls smoothed out by the small vessel wall viscosity and the viscous fluid effects. As a first step toward analysing this problem, we derived a closed system of effective, reduced two-dimensional equations that capture the main features of the original problem to a certain accuracy. The resulting problem is a two-dimensional, non-linear version of the Biot equations arising in porous media flows. Using energy methods and fixed-point arguments, we obtained the existence of a unique solution to the resulting non-linear free-boundary problem. The numerical solutions were compared with the experimental flow measurements, performed at the Texas Heart Institute, showing excellent agreement between the experiment and the solutions of the reduced problem.

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MS3

Finite Element Analysis of a Coupled Fluid-Structure System

In this talk, we will consider the numerical analysis of a fluid-structure interactive partial differential equation (PDE) system, comprising the Stokes (or Navier-Stokes) equations coupled to the equations of linear elasticity. The coupling between the two distinct dynamics is accomplished on the boundary interface between respective fluid and structure geometries. Solutions of this fluid-structure PDE are approximated by means of a certain Finite Element Method (FEM), a FEM which in part incorporates a nonstandard usage of the Babuška-Brezzi "inf-sup" Theory.

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MS3
The Coupled PDE System Arising in Fluid-Structure Interaction

In this talk, a fluid-structure interactive partial differential equation (PDE) model is considered. The PDE comprises a coupling of the linearized Stokes equations to a vector-valued wave equation, with this wave equation constituting a (simplified) model for the structural component of the dynamics. The coupling between the disparate PDEs occurs on the boundary interface between the fluid and solid media. We shall discuss how an explicit semigroup formulation may be given to these linearized dynamics, by virtue of a novel elimination of the associated pressure. We subsequently proceed to give a precise characterization of the spectrum of the fluid-structure semigroup generator; besides being of acute interest in its own right, this spectral characterization allows an appeal to the well-known criterion of Arendt-Batty and Lyubich-Phong, so as to infer strong stability of the fluid-structure semigroup; thus the solutions to the fluid-structure PDE decay asymptotically. (During the course of this talk, it will be shown that the resolvent of the fluid-structure generator is not a compact operator; thus strong stability cannot be inferred by the classical approach of Nagy-Foias).

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MS4
Application of Sparse Optimal Control Techniques in the Aerospace Industry

Combing modern nonlinear programming algorithms that exploit matrix sparsity with discretization techniques for ordinary differential equations has resulted in powerful new computational techniques for optimal control. This presentation will deal with some of the important algorithmic issues that must be addressed when applying these new methods to realistic applications in the aerospace industry.

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MS4
Towards Accurate Costates Estimation Using Pseudospectral Methods

Costates estimation is an important issue in computational optimal control. Accurate costates facilitate convergence analysis, optimality verification, sensitivity analysis and a design of robust feedback control systems. In this talk, we analysis the relation between the discrete KKT multiplies and the continuous costates in the pseudospectral direct approximation of continuous constrained optimal control problems. Closure conditions previously discovered are clarified. The effect of primal optimality/feasibility tolerances to the costate estimation is explained and demonstrated via examples. The results provide guidelines to design accurate costates estimation algorithms.

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MS4
Discrete Approximations in Optimal Control

In this talk we discuss several issues on discrete approximation of optimal control systems governed by controlled differential equations and differential inclusions with finite-dimensional and infinite-dimensional state spaces. 1. The first issue is about well-posedness of discrete approximations of constrained optimal control problems. We discuss new results on consistent approximations of endpoint and state constraints matched with the stepsize of discretization ensuring the value convergence as well as the strong (in Sobolev spaces) convergence of optimal solutions of discrete approximations. 2. The second issue concerns the fulfillment of the necessary optimality conditions in the form of the Approximate Maximum Principle for discrete approximations of constrained optimal control problem with no convexity assumptions. There are positive and negative results in this direction, both are rather surprising. 3. Finally, we discuss the possibility to use discrete approximations as the driving force to derive new results (necessary optimality, local controllability conditions, etc.) for continuous-time systems by the limiting procedure from the corresponding problems of mathematical programming.

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MS5
Adaptive Nash Strategies of Dynamic Games in High Level Information Fusion

Recent advances in applying game theory to high level information fusion are promising. In those game theoretic frameworks, adaptive techniques are important when there are unknown parameters in the cost functions of the opponents. Existing adaptations are usually considered from a perspective of systems, for an example, evolutionary games. In this paper, we propose a new adaptive approach for linear quadratic discrete-time games, including simultaneous and sequential games, with scalar inputs and state feedback Nash strategies. We consider the effort of adaptation under a Fictitious Play (FP) framework with learning algorithms derived from conventional adaptive control methods. Convergence to Nash strategies is proved with the condition that there exists a unique state feedback strategy, which implies that the associated coupled discrete-time algebraic Riccati equations (DAREs) have a unique positive semi-definite solution. Piece-wise linearization is used to transform general high level information fusion problems to linear quadratic discrete-time games.

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MS5

Game Theoretic Sensor Resource Management for High-Level Distributed Fusion

We present a hierarchical game-theoretic approach to level 2 and level 3 fusion problems. Given level 1 data of observations of individual objects and prior knowledge of the composition of enemy grouping, we consider the level 2 problem by developing a Bayesian inference algorithm for determining the enemy identity. We then apply game theory toward the level 3 problem, inferring the intent of enemy groups, given the determined identities and prior knowledge of enemy strategies.

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MS5

Disturbance Attenuation Analysis of Sequential Games in High Level Data Fusion

Recently, there have been increasing needs for research in game theoretic approaches for high level information fusion. In this paper, we use a zero-sum game theoretical approach to address the robust disturbance attenuation analysis of state feedback Nash strategies for Dynamic Linear Quadratic Sequential Games (LQSGs) with uncertainties or disturbances. For finite-horizon LQSGs, we first provide state feedback Nash strategies with optimal attenuation levels. Then we extend the approach to infinite-horizon LQSGs. We prove that the feedback system is Bounded Input Bounded Output (BIBO) stable with respect to the disturbances. For the general dynamic games for high level information fusion, piece-wise linearization is carried out to transform them to linear quadratic discrete-time games.

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MS5

Cooperative Outcomes for Stochastic Multi-Player Nash Games: Performance-Measure Statistics and State-Feedback Paradigm

Recent theory of cost cumulant control has been used successfully in the area of stochastic regulator problems with nontrivial structural control benchmarks. Since optimal stochastic regulator problems can be seen as the one-player special case of stochastic differential games, it is interesting to explore the idea of applying this new control paradigm to the linear-quadratic class of nonzero-sum stochastic differential games where there are more than two players and each player tries to minimize his individual performance measure. The utility of this newly developed control paradigm can be applied to multi-person and multi-decision objective problems. For instance, a dynamic sensor allocation can be cast into a stochastic multi-player Nash game where multiple players are sensors. In this setting, each sensor has ability to selfishly seek to optimize its own local objective. As a result, one can guarantee that the sensors will collectively operate efficiently.

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MS6

Optimal Control of Mixed Immunotherapy and Chemotherapy of Tumors

Abstract not available at time of publication.

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MS6

Parameter Estimation for a Model of Baroreflex Regulation of Heart Rate

The baroreflex is an important homeostatic mechanism of the cardiovascular system. Its purpose is to control and maintain blood pressure by regulating heart rate, particularly during orthostatic stress (i.e. sitting or standing). In this talk, we will give a basic outline of a mathematical model that was designed to predict the dynamics of heart rate regulation with respect to postural changes from sitting to standing (Olufsen et al.). We will describe the process of calibrating the unknown parameters of this model using experimental data. In addition, we will include some sensitivity analysis results that lend some insight into the mechanism and its predictive capabilities.

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MS6

Title Not Available at Time of Publication.

Abstract not available at time of publication.

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MS6

A Mathematical Model Separates Quantitatively the Cytostatic and Cytotoxic Effects of a HER2 Tyrosine Kinase Inhibitor

Oncogene signaling deregulates cell proliferation resulting in uncontrolled growth. Amplification and mutations of the HER2 proto-oncogene occur in approximately 20% of breast cancers. A therapeutic strategy that blocks HER2 function is the kinase inhibitor lapatinib. We determined experimentally the anti-proliferative effect of lapatinib combined with a mathematical model to interpret the data. The model suggests that lapatinib acts by slowing the transition through G1 phase whle we also find a previously unreported late cytotoxic effect.

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MS7

Fast Solution of Nonlinear Optimal Control Problems

We discus a class of optimization algorithms for nonlinear optimal control problems. The optimization algorithms are based on the all-at-once approach, use interior-point techniques for handling of classes of inequality constraints, employ trust-region methods for globalization, and allow a rigorous integration of iterative linear system solvers for the approximate solution of optimization subproblems. We present theoretical convergence results. In addition, the numerical performance of these methods is illustrated on test problems in which optimization subproblems are solved iteratively using multigrid or domain decomposition methods.

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MS7

Regularization Approaches in State Constrained Optimal Control of PDEs

In this talk Moreau-Yosida-based as well as Lavrentiev-based regularization for state constrained optimal control problems for partial differential equations are considered. The regularization is necessary due to the poor Lagrange multiplier regularity. We investigate convergence properties w.r.t. the regularization parameter and introduce path-following methods for the numerical solution. For a fixed parameter setting the proposed methods are mesh-independent and converge locally superlinearly (the latter in function space). The talk ends by a report on test runs including a comparison with interior point solvers.

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MS7

Fast Optimized Wavelet Methods for Stationary PDE-Constrained Control Problems

We employ wavelet methods for control problems constrained by non-linear stationary PDEs. The emphasis is placed on the fast numerical solution of the optimality conditions leading to a coupled system of PDEs. Optimized wavelet discretizations allow to employ fast iterative solution schemes of optimal computational complexity with small absolute iteration numbers. We also demonstrate how to employ norm equivalences in terms of wavelet bases to evaluate Sobolev norms of any order as accurately as possible.

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MS7

Semismooth Newton Method for an Optimal Control Problem with Control and Mixed Control-State Constraints

A class of optimal control problems for a semilinear parabolic partial differential equation with control and mixed control-state constraints is considered. For this problem, a projection formula is derived that is equivalent to the necessary optimality conditions. As main result, the superlinear convergence of a semismooth Newton method is shown. Moreover we show the numerical treatment and several numerical experiments.

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MS8

Higher-Order Optimality Conditions for Nonregular Constrained Optimization Problems

We start with considering higher-order optimality conditions for nonregular optimization problems with equality constraints given in the operator form as $F(x) = 0$, where $F : X \to Y$ is an operator between Banach spaces and the Frechet derivative $F'(x^*)$ is not onto. Then we present optimality conditions for nonregular problems with inequality constraints in finite dimensional spaces when the active constraint gradients are linearly dependent at the solution of the problem.

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MS8

Generalized Jacobians and the Variational Differential Inclusion

In the nonsmooth Maximum Principle, the classical variational equation is replaced by a differential inclusion whose right-hand side is the Clarke Generalized Jacobian of the reference vectorfield with respect to the state. The solutions then lead to a compact (usually nonconvex) set of linear maps which is a Warga derivate container of the reference flow map. We extend this result to more general "generalized Jacobians" and more general concepts of multivalued differential.

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MS8

A Sufficient Condition for Exact Penalty in Constrained Optimization

We use the penalty approach in order to study constraint minimization problems in a Banach space with Lipschitzian constraints. We discuss sufficient conditions for the existence of the exact penalty.

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MS8

New Generalized Jacobians in Infinite Dimensional Optimzation Problems

In this talk a concept of generalized Jacobians for Lipschitz functions defined on infinite dimensional spaces wil be introduced. This notion extends to the infinite dimensional setting Clarke's generalized Jacobian which is defined for Lipschitz functions over finite dimensional spaces. Several properties and calculus rules are presented.

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MS9

Comparison of Full- and Reduced-Order Models for Feedback Control of Fluids

The feedback control of fluid flows using model reduction techniques has been studied for the past decade. In this study, we investigate the effectiveness of the proper orthogonal decomposition (POD/Galerkin) and a controller reduction approach. Numerical results comparing these popular approaches with Riccati equation-based linear state feedback for control past circular cylinders and over a backward-facing step will be presented.

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MS9

On Global Controllability Properties of a Swimming Model in a Nonstationary Stokes Fluid

We study the motion capabilities ("straight line motion" and "turns") of an abstract object consisting of several "narrow" rectangles, subsequently connected by elastic links, which "swims" (as opposed to "being pushed or pulled") in the 2-D Stokes fluid. We assume that the means by which we can affect the swimming process are the change of spatial orientations of the aforementioned rectangles and the direction and strength of the rotation forces acting between them.

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MS9

Issues in Control of Viscoelastic Flows

The lecture will present recent results on controllability of viscoelastic flows. Constitutive models are assumed to be of Maxwell or Jeffreys type. Both linear and nonlinear situations are examined. In contrast to the analogous situation in elasticity or Newtonian fluid mechanics, the linear problem is controllable only within a subspace, and therefore the linear results give no insights regarding controllability in the nonlinear case. I shall review a number of special cases which are accessible to analysis.

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MS9

Regularity of Weak Solutions to a System of Fluid Structure Interaction

A 3D fluid-structure interaction model in which an elastic body is fully immersed in a viscous incompressible fluid is studied. The interaction is realized through an interface, i.e., the boundary of the elastic body.We establish existence of global weak solutions to this nonlinear model of fluid structure interaction. We also establish existence of smooth solutions in both two and three dimensions given more regular initial data satisfying natural compatibility conditions on the interface. This is joint work with V. Barbu, I . Lasiecka and Z. Grujic.

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MS10

Numerical Approximation of Pursuit-Evasion Games with State Constraints

We present a new convergence result for the convergence of a dynamic programming scheme to the viscosity solution of the Isaacs equation related to pursuit-evasion games with state constraints in R^n. We will also give some details on the implementation of the approximation scheme and of the numerical synthesis of optimal controls. Finally, several tests on the classical tag-chase game in a court with internal obstacles will be presented.

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MS10

Convergence for a Curse-of-Dimensionality-Free Method for HJB PDEs

Nonlinear, steady-sate HJB PDEs with Hamiltonians formed by (or well-approximated by) pointwise maxima of quadratic forms are considered. (This includes switched linear systems.) A recent development is the discovery of numerical methods for such PDEs, which are not subject to the curse-of-dimensionality. These methods work through an approximation of the associated (max-plus linear) semigroup as a max-plus sum of semigroups associated with linear/quadratic problems. A convergence rate is obtained indicating the number of iterations required to obtain a given error (scaled by the norm squared) over the entire space. Neither the number of iterations or the the computations per iterations are subject to the curse-of-dimensionality. In particular, the computational growth as a function of dimension is at a cubic rate. There is a "curse of complexity" which must be addressed. Nevertheless, these new methods are of both theoretical and practical interest.

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MS10

Optimal Trajectory Solutions Using Higher Order Implicit Integration and Nonlinear Programming

Implicit integration combined with modern nonlinear programming packages has proven to be an effective technique for trajectory optimization. To provide greater fidelity and robustness, enhanced procedures have been developed. General procedures are presented for implicit integration schemes of arbitrary order, automatic variable scaling and grid refinement.. Computation experiences applying and comparing these methods to interplanetary spacecraft and aircraft problems are given. These procedures have demonstrated substantial improvements in integration accuracy and robust operations.

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MS10

The Role of Convexity in Optimal Control Theory

We consider a variational problem of the form

$$\min l(x(0)) + \int_0^\tau L(x(t), dx/dt)dt$$

where the minimization is over the absolutely continuous arcs $x(.)$ that satisfy $x(\tau) = \xi$. This talk explores properties of the Fully Convex Control (FCC) problem in which both $l(.)$ and $L(.,.)$ are convex, but possibly nonsmooth and extended real-valued. The strong convexity hypotheses make the problem somewhat special, but as will be explained, the FCC formulation still covers Linear Quadratic Regulator and its extensions with hard control constraints. The FCC problem plays roughly the role that linear systems enjoy in nonlinear systems theory, and we shall explore this analogy by presenting a unifying theory of necessary and sufficient conditions, duality, and a Hamilton-Jacobi theory. New research results and directions will also be presented.

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MS11

Hybrid Monolithic Shape Memory Alloy Actuators

Abstract not available at time of publication.

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MS11

Robust Controller Design for Magnetostrictive Actuators

Magnetostrictive materials have many advantages for use in micro- positioning devices, but are difficult to control due to their hysteresis and other nonlinearities. These materials are passive and this property is used to identify a class of stabilizing controllers. A controller in this class that optimizes tracking performance is found. The controller is evaluated experimentally. The use of a similar approach for control of other smart materials is discussed.

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MS11

Perturbation Control Techniques for Magnetic Transducers

Abstract not available at time of publication.

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MS11

Robust Adaptive Control of Conjugated Polymer Actuators

Abstract not available at time of publication.

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MS12

LQG Balanced POD for Distributed Parameter

Systems

Developing reduced order models for use in design of closed-loop controllers has attracted much attention in the last five to ten years. Methods such as proper orthogonal decomposition (POD), balanced truncation, and LQG balancing have been applied with varying degrees of success. A method was recently proposed, termed Balanced Proper Orthogonal Decomposition, where two of the reduction techniques are combined to utilize positive attributes of each. POD is well-suited to developing a model from experimental or computational data. Balanced truncation preserves system properties such as controllability and observability. In this paper, we explore combining POD with LQG balanced truncation. The latter method preserves properties of the solutions to the control and filter Riccati equations. We report on the performance of this method for systems modeled by partial differential equations.

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MS12

Sensitivity Analysis for Sensor/Actuator Placement

This talk surveys some results for sensitivity analysis related to sensor/actuator placement for control design in systems governed by partial differential equations. When sensor or actuator placement is parametrized as part of the control design problem, the regularity of the solutions to the governing mathematical models should be carefully examined prior to sensitivity calculations. When the parameter of interest determines location of sensors or actuators, the resulting sensitivity equations suffer from a loss of regularity as compared with that of the original PDE model. This can have serious consequences if black box approaches to sensitivity computations are used. Model problems that illustrate some of these issues are discussed.

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MS12

Optimal Damping Design: An Eigenvalue Sensitivity Approach

We consider a sensitivity approach for the optimal absorption design for damped elastic systems. These systems are generally represented by abstract wave equations with variable damping coefficients. Using the sensitivity equation of eigenvalues of the corresponding system generator, a solution method is developed and analyzed for determining the optimal design with respect to the design parameter. Based on such a solution method, approximation methods are also developed for construction of the optimal design. Numerical examples are presented to demonstrate the feasibility of our proposed method.

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MS12

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. In particular, 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. These results are applied to systems governed by delay equations and numerical results are presented using different approximation schemes.

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MS13

Feedback Stabilisation of Navier-Stokes System: Approximation and Error Estimates for the Riccati Approach

Errors estimates related to general approximation of closed-loop systems are provided. The feedback law in the closed-loop system is expressed with the solution of an infinite dimensional algebraic Riccati equation, which is provided by an optimal control problem stated over an infinite time horizon. The case of nonconform and semidiscrete approximation is investigated. We give examples of applications dealing with the closed-loop Oseen equations, where the feedback law is chosen so that it locally stabilizes, near a given steady-state flow, the solutions of the Navier-Stokes equations in a bounded domain.

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MS13

Optimal Control of Heat Transfer with Radiation Interface Conditions and Pointwise State-Constraints

The talk is concerned with an optimal control problem arising from the optimization of the temperature distribution within the sublimation growth of semiconductor single-crystals. The problem consists of a semilinear elliptic partial differential equation with nonlocal radiation interface conditions and pointwise control and state constraints. First, the existence of a unique continuous solution of the semilinear state equation is established. Moreover, it is shown that the associated solution operator is continuously Fréchet-differentiable. Based on this and the continuity of the solution, it is possible to establish the existence of Lagrange mutlipliers in the space of regular Borel measures by means of the Karush-Kuhn-Tucker theory. Furthermore, the associated adjoint equation with these measures as inhomogeneity is discussed. It is shown that this equation admits a solution in $W^{1,q}$ with some $q < N/(N-1)$, where N denotes the spacial dimension. This allows to establish necessary and sufficient optimality conditions. The theoretical results are illustrated by numerical examples.

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MS13

On the Finite Element Approximation of Elliptic Optimal Control Problems with Neumann Boundary Control

A Neumann boundary control problem for a linear-quadratic elliptic optimal control problem in a convex and polygonal domain is investigated. The main goal is to show an optimal approximation order for discretized problems after a postprocessing process. It turns out that two saturation processes occur: The regularity of the boundary data of the adjoint is limited if the largest angle of the polygon is at least $2\pi/3$. For piecewise linear finite elements, the theory cannot deliver optimal approximation rates for convex domains. We will derive error estimates of order h^σ with $\sigma \in [3/2, 2]$ depending on the largest angle and properties of the finite elements. Moreover, we will investigate also the case of domains with a reentrant corner. Here, we obtain error estimates of order h^σ with $\sigma \in [1, 3/2]$ Finally, numerical tests illustrate the theoretical results.

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MS13

Homotopy Methods for State Constrained Optimal Control

We consider homotopy methods in function space for optimal control problems subject to PDE constraints and bounds on the state. Our main focus here is on interior point methods. We study structure and convergence of homotopy paths generated by logarithmic and rational barrier functions. It turns out that the proper type of barrier function has to be chosen in order to guaranty existence and strict feasibility of solutions in function space. Then, for the right type of barrier functions, the convergence of a Newton path-following scheme to the solution of the original state constrained problem can be established.

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MS14

Mangasarian-Fromowitz Assumptions and Optimality Conditions for Mixed Constrained Problems

The focus of this paper is on Mangasarian-Fromowitz type conditions for mixed constrained optimal control problems with possibly nonsmooth dynamics. We show how necessary conditions of optimality in the form of unmaximized Hamiltonian type conditions can be derived under such assumptions. The Unmaximized Hamiltonian inclusion type conditions we obtain here are distinct from well known versions of weak nonsmooth maximum principle because they employ a joint subdifferential instead of the customary product of partial subdifferentials.

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MS14

Optimality Conditions for Asymptotically Stable Control Systems

We consider infinite horizon optimal impulsive control problems for which a performance criteria is minimized by choosing asymptotically stable control strategies. We present necessary optimality conditions in the form of maximum principle and show how they can be derived from an auxiliary conventional (nonimpulsive) optimal control problem with mixed constraints. As far as we know, results of this kind have not been previously derived for problems with trajectories restricted to the set of stabilizing ones.

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MS14

Regularity Properties of Optimal Control for Mixed Constrained Problems

In this paper we investigate regularity properties (Lipschitz continuity and differentiability) of the optimal control in linear-quadratic problems with mixed control/state constraints of equality and inequality type. It is shown that under appropriate hypotheses the optimal control possesses the indicated regularity.

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MS14

Invariance Properties for Impulsive Systems

This talk will consider a dynamical system in which the righthand side contains a measure with state-dependent coefficients. A solution concept that involves a graph completion will be introduced, and characterizations of the system's weak and strong invariance properties will be provided.

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MS15

Structure of Solutions for Ergodic Type Bellman

Equations of First Order

Ergodic type Bellman equations of first order with a quadratic Hamiltonian are considered in the framework of viscosity solutions. It is known that the equations have multiple solutions even if the solutions are identified under additive constants. We will show that there exists a critical solution. We will also deduce the min-max type representation for the critical value, which is motivated from Donsker-Varadhan min-max formula of the principal eigenvalue for the second order linear differential operators.

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MS15

Max-Plus Integral Kernels and a Fundamental Solution for Differential Riccati Equations

The semigroups associated with Bellman equations are max-plus linear. The semigroup operators have semiconvex dual operators with representations as max-plus integral operators. In the linear-quadratic case, the kernel of the semiconvex dual operator is a quadratic function. Propagation in the dual space is through composition of these operators, and hence max-plus integral convolutions. This leads to a surprising new understanding of Riccati equations where the quadratic term is sign-definite, and a new fundamental solution for them. This fundamental solution has a very nice control interpretation, and so leads to a more satisfying understanding of Riccati equations.

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MS15

Aronsson Equation and Deterministic Optimal Control

Aronsson equation is a second order degenerate elliptic equation that appears in L^∞ minimization problems and is satisfied by the so called absolute minimizers. We will discuss the fact that value functions in deterministic optimal control are absolute minimizers in regions where they are *bilateral viscosity solutions* of the classical Bellman equation. We will then derive Aronsson equation for value functions under weaker assumptions than the standard theory.

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MS15

An Overview of the Applications of Game Theory to Importance Sampling

Importance sampling (IS) algorithms for estimating rare-event probabilities are intimately connected with two-person zero-sum differential games. This game interpretation shows that state-dependent schemes are needed in order to attain asymptotic optimality in a general setting. We show that the classical subsolutions of the associated Isaacs equation can be used as a basic and flexible tool for the construction and analysis of efficient IS schemes. We also present some numerical examples of rare event simulation in queueing networks.

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MS16

Closed-loop Control of Channel Flow Using Balanced Proper Orthogonal Decomposition

Reduced-order models of linearized channel flow obtained using balanced proper orthogonal decomposition (BPOD), a close numerical approximation to balanced truncation, are used to develop optimal closed-loop controllers. The models are better at capturing the input-output behavior of the system compared to standard POD/Galerkin models. We use these models to design closed-loop controllers to suppress transition to turbulence in channel flow, using body forces and wall blowing/suction for actuation.

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MS16

Model Reduction of Nonlinear Control Systems

We review methods for model reduction for linear and nonlinear control systems and offer a new method for nonlinear control systems. We also present new error estimates for both linear and nonlinear model reduction.

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MS16

Cross Gramians and Riccatians for Approximate Balancing of Nonlinear Systems

Abstract not available at time of publication.

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MS16

Nonlinear Balanced Realizations

Abstract not available at time of publication.

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MS17

Multigrid Algorithms for Distributed Parameter Estimation Problems

Here I consider distributed parameter estimation related to the inverse medium problem for elliptic, parabolic, and hyperbolic PDEs. In this talk I will present three representative examples, for a Helmholtz, a reaction-diffusion,

and an acoustic wave propagation PDE. I will present the inverse operator, and discuss the spectral properties. I will conclude with a list of recently proposed multilevel algorithms that are robust as the regularization is reduced, achieve optimal algorithmic complexity, and can scale to parallel computing architectures.

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MS17

Towards an Optimal Control Approach for Drinking Water Decontamination

When a drinking water network is contaminated, harmful particles and chemicals in the fluid may be transported into biofilms present on pipe surfaces. Effective decontamination of a system with biofilms is not well understood. We will discuss an approach for removing contaminants in biofilms by controlling the fluid flow profile. Our control methodology makes use of a multiscale and multi-physics model of a biofilm coupled to a continuum model for fluid flow.

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MS17

Inexact Null-Space Iterations in PDE-Constrained Optimization

Upon discretization, PDE-constrained minimization problems lead to large scale finite dimensional mathematical programs. In this talk, we focus on preconditioned iterative solvers for such optimization problems. The solver concept is based on user chosen iterative forward and adjoint solvers, which might be only linearly convergent and which are intertwined with a suitable preconditioner for the overall KKT-system. Every step of the algorithm can be decomposed into feasibility restoration (null space restoration) and a step towards optimality. An exact L1-merit function operates as a progress measure. A convergence analysis is presented and a report on numerical tests is given.

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MS17

Optimal Control and Model Reduction of PDAE Fuel Cell Models

Molten carbonate fuel cells (MCFC) are especially well suited for stationary power plants if their process heat is used to increase their efficiency. MCFCs will become soon competitive compared with traditional power plants. The dynamic behaviour of MCFCs is governed by effects from gas dynamics, electrochemical reactions, electrodynamics and heat transfer. These effects can be modelled mathematically by a hierarchy of systems of partial differential algebraic equations (PDAE) in 1D or 2D of mixed parabolic-hyperbolic type. Integral terms appear and the nonlinear boundary conditions are given partly by a DAE system. These large PDAE systems of dimension between roughly 10 and 30 equations are discretized by the method of lines, yielding huge dimensional DAEs. In order to enable real time control of the system model reduction techniques are needed. We choose the snapshot form of proper orthogonal decomposition (POD). We will present new computationally expensive numerical results of (sub)optimal control during load changes for a 2D dynamical MCFC model.

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MS18

Scalable Nonlinear Multigrid Solvers for Inverse Reaction-Diffusion Problems

In this talk we present multigrid smoothers for saddle-point Euler Lagrange equations related to inverse problems for systems governed by parabolic PDEs. Due to the problem size of these problems, we have to devise matrix-free preconditioners. Due to the ill-conditioning, efficient multigrid solvers are required. The two key components of multigrid are the intergrid transfer operators, and the smoother. Here we restrict our attention to construction of efficient smoothers for full-space formulations of the inverse problem.

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MS18

Multilevel Optimization Methods for the Control of the Transport of Bose-Einstein Condensates

The optimal control of the transport of Bose-Einstein condensates in magnetic microtraps is formulated and solved efficiently by multilevel optimization schemes. The time evolution of the wavefunction of the Bose-Einstein condensates is governed by the Gross–Pitaevskii equation. This wavefunction is manipulated through variation of a controllable magnetic confinement potential and an efficient control strategy for this potential is determined within the framework of optimal control theory. To solve the resulting problem a cascadic nonlinear conjugate gradient scheme and a full multilevel optimization scheme are considered. For a variety of magnetic confinement potentials we study transport and wavefunction splitting of the condensate, and demonstrate that the optimal control theory approach allows to drastically outperform more simple schemes for the time variation of the microtrap control parameters.

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MS18

Adaptive Finite Elements for Parabolic Optimization Problems

In this talk we present a posteriori error estimates for space-time finite element discretizations of parabolic optimization problems developed in (D. Meidner and B. Vexler, Adaptive Space-Time Finite Element Methods for Parabolic Optimization Problems, to appear in SIAM J. Control Optim.). The provided error estimates assess the discretization error with respect to a given quantity of interest and separate the influences of different parts of the discretization (time, space, and control discretization). This allows to set up an efficient adaptive algorithm which successively improves the accuracy of the computed solution by construction of economical, locally refined meshes for each time step separately and of an adaptive time discretization. Numerical examples for nonlinear parabolic equations confirm the efficiency of our method.

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MS19

Riccati Synthesis for Structural Acoustic Control Problems

In this talk, we will discuss the feasibility of numerically approximating the minimal norm steering control, relative to the boundary null controllability of a structural acoustic interaction. This approximation of the optimal null control will be the result of a numerical analysis of the appropriate Riccati Equation. Results of convergence for approximations of both the null controller and the corresponding dynamics will be presented. This is joint work with Michael Gunderson.

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MS19

Hamiltonian Based Riccati Theory and Fast Riccati Solver

We develop a fast algorithm to compute the optimal feedback gain for the linear quadratic regulator problem. The algorithm utilizes the relation between an invariant subspace of the corresponding Hamiltonian operator and the solution to the Riccati equation and is based on the inverse of the Hamiltonian operator. 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 very large control systems.

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MS19

Controller Design for Infinite-Dimensional Systems

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 is known as direct controller design. In the second approach, indirect controller design, the model is reduced to obtain a finite-dimensional model. This finite-dimensional approximation is used for controller design. Both approaches will be examined in the context of several models for acoustic noise. The models vary in complexity and in how different aspects of the dynamics are modelled. The modelling has consequences has controller design.

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MS19

On Sampled-Data Controller Implementation for Spatially Distributed Systems

Consider a linear, infinite-dimensional, exponentially stable plant which has impulse response given by a matrix-valued Borel measure. Let r(t) be a vector-valued reference signal which is the linear combination of finitely many known sinusoidals, but otherwise unknown. Suppose the system is subject to disturbances which are asymptotic to finite sums of sinusoidals. We design a low-gain sampled-data controller which maintains the stability of closed-loop system and approximately tracks r(t).

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MS20

Progressive Strategies for Differential Games

Two controller, zero sum differential games on a fixed finite time horizon are considered. A lower game value is defined using strategies which depend in a progressively measurable way on past control choices for the maximizer. Results about viscosity solutions of the Isaacs PDE imply that this lower value function is the same as with the Elliott-Kalton definition. With a smaller class of "strictly progressive" strategies for the minimizing controller, the upper value is obtained instead of the lower value.

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MS20

Numerical Methods for Regime-Switching Stochastic Differential Games

This work is concerned with numerical methods for stochastic differential games of regime-switching diffusions. Procedures based on Markov chain approximation techniques are developed. A new proof of the existence of a saddle point for the stochastic differential game is presented,

which enables us to treat certain systems with nonseparable (in controls) cases. Convergence of the algorithms is derived by weak convergence methods. In addition, examples are also provided for demonstration.

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MS20

Liapunov-Like Sufficient Conditions for the Guaranteed Capture or Evasion in Multi-Player Differential Games

In this presentation, two sequences of continuously differentiable functions that represent convergent approximations of the min and the max function, respectively, are considered. Using these functions we design pursuers' and evaders' strategies that guarantee either capture or evasion of the evaders. These strategies are proven to achieve the corresponding goals using a Liapunov-like methodology. Dynamic models for the agents are assumed to be nonlinear which is particularly important if the agents represent vehicles.

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MS21

Model Order Reduction of Truly Large-Scale RCL Networks

Abstract not available at time of publication.

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MS21

A Proper Orthogonal Decomposition Approach for the Empirical Balancing of Nonlinear Systems with Unstable Linearization

Abstract not available at time of publication.

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MS21

Optimal H2 Model Reduction of MIMO Systems

Abstract not available at time of publication.

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MS21

Balancing for Infinite-Dimensional Linear Systems

We show that balancing methods can be generalized to infinite-dimensional linear systems. This is true for the usual Hankel-balancing, but also for variants such as LQG, H-infinity, bounded real and positive real balancing. The known error-bounds generalize to the infinite-dimensional case. However, the upperbound may now be infinite. We give conditions under which the upperbound is finite and one thus obtains convergence of finite-dimensional approximants in the desired metric.

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MS22

Path-Following Primal-Dual Interior-Point Methods for Shape Optimization of Stokes Flow Problems

We are concerned with shape optimization problems in channel fluid flow problems. The state variables are supposed to satisfy the Stokes system and the design variables are the control points of a Bezier curve representing the geometry of the channel subject to bilateral pointwise constraints. Within a primal-dual setting, we suggest an all-at-once approach based on interior-point methods. The resulting parameter dependent nonlinear system is solved by an adaptive path-following technique within the framework of an affine invariant convergence theory. The discretization is taken care of by Taylor-Hood elements with respect to a simplicial triangulation of the computational domain and automatic differentiation is used in the computation of first and second order derivatives. Numerical results illustrate the convergence behaviour of the adpative path-following interior-point method.

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MS22

Multiscale Optimization of Gas Networks

We are interested in gas flow in pipe networks. Several models for the dynamics inside the pipe are known which range from partial differential equations to purely algebraic relations. Usually, the dynamics of different pipes is coupled at pipe fittings and we discuss the mathematical and

physical reasonable coupling conditions in particular for nodes which model compressors. These nodes can be controlled by prescribing the applied compressor energy. We are interested in questions of well-posedness and existence of solutions and discuss optimization techniques relying on the given model hierarchy. Finally, we present numerical optimization results for sample networks.

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MS22

Path-Following Methods for a Class of MPCCs in Function Space

We consider Mathematical Programs with Complementarity Constraints in function space. Typical model problems are related to optimal control of variational inequalities (VIs) or parameter identification in VIs. Here we propose a relaxed Moreau-Yosida based path-following concept for the development of a first order optimality characterization as well as the design of a solution algorithm. Our first order conditions are close to strong stationarity in finite dimensions. The proposed algorithm uses a semismooth Newton method (with a locally superlinear convergence in function space) for solving the relaxed path-problems. The talk ends by a report on numerical tests.

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MS22

Model Reduction in Laser Welding

Laser welding is a modern joining technique for new metallic materials particularly aluminum alloys. However, there is a high risk of hot cracking. Therefore, the aim is to avoid this undesirable effect caused by several processes during the solidification. For modelling process there are three main aspects which have to be considered: The thermodynamical, the mechanical and the metallurgical effect by which the arising of the opening displacement caused by transverse tensile strains can be described. Because of the high complexity of this physical process a model reduction in the mathematical model has to be done. After that formulation a method can now be applied to prevent hot cracking. One possibility is to use the so called multi-beam technique. Thereby, additional laser beams are imposed to compensate for the strain induced by the main laser beam. Hereby, it is important to determine the optimal position, size and power of the additional laser beams in order to prevent hot cracking. Mathematically, this leads to a constraint nonlinear optimization problem where amongst other constraints a partial differential equation has to be solved.

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MS23

State and Output Feedback Control over Packet Dropping Network Links

We study a stabilization scheme for a discrete-time control system in which the feedback loop includes a network link that may suffer packet drops. We study state/output feedback stabilization schemes for linear systems of arbitrary dimension. We also compare it against an alternative control scheme that first uses Kalman filtering (with intermittent observations) to estimate the state and then applies state feedback based on this state estimate. We conclude that, under certain conditions, the two control schemes can have comparable performance but the proposed state/output feedback strategy is considerably simpler to implement.

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MS23

A Real-Time Distributed Priority-Based Protocol for CAN Networks based on Delay Impulsive Systems

We consider Networked Control Systems (NCSs) consisting of a LTI plant; a linear static or dynamic feedback controller; a collection of sensors that provide measurements to the controller; and a collection of actuators that are used to control the plant. The different elements of the control system are spatially distributed, but interconnected through a communication network. Due to the shared and unreliable channel used to connect the subsystems, the sampling intervals are uncertain and variable. Moreover, samples may be dropped and experience uncertain and variable delays before arriving at the destination. We show that the resulting NCSs can be viewed as a MIMO sampled-data system with variable sampling intervals and delay, which can be modeled by delay impulsive systems. We provide conditions for the stability of the closed-loop expressed in terms of LMIs. By solving these LMIs, one can determine positive constants that determine upper bounds between the sampling time and the next update time at the destination, for which stability of the closed-loop system is guaranteed. Based these results, we present a scheduling test based on Earlier Deadline First (EDF) algorithm for real-time systems. If the test passes, the stability of several control systems sharing a network is guaranteed. Then we present a Medium Access Control (MAC) protocol which can be implemented on Controller Area Networks (CAN) in real-time and in a distributed fashion which grants the access to the network to a node with the earliest deadline.

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MS23

Distributed Sensor Pre-Processing for Feedback Stabilization, In the Presence of Unreliable Interconnections

Consider an unstable discrete-time, linear and time-invariant plant, two sensors, with computational capabilities, and one controller. Each sensor collects noisy measurements of a linear combination of the state of the plant. This paper addresses the design of the controller and of the processing at the sensors so as to stabilize the plant. The sensors are connected to the controller via two stochastic links whose connectivity is modeled by two independent Bernouli processes, with loss probabilities p1 and p2. We show that it is a necessary and sufficient condition for stability that the pair (-log(p1),-log(p2)) lies in a two dimensional convex region, which is uniquely determined by the parameters of the plant.

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MS23

Feedback Control over Signal to Noise Ratio Constrained Communication Channels

Recently, there has been growing interest in stabilisability and performance problems in control over communication channels. Here we present an overview of recent results when a signal-to-noise ratio (SNR) constrained channel is considered. We discuss the linear time invariant (LTI) output feedback discrete-time case. Our analysis closely parallels results in bit rate limited control. The SNR framework used enables LTI stability, robustness, performance and delay analysis.

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MS24

Robust Quantum Potential Profile Design for Electron Transmission

Abstract not available at time of publication.

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MS24

Robust Design of Slow-Light Tapers in Periodic Waveguides

Abstract not available at time of publication.

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MS24

Robust Optimization in Electromagnetics

Abstract not available at time of publication.

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MS24

Non-Intuitive Design of Negative Refractive Index and Nano-Scale Electronic Devices

Optimal design is used to show that electromagnetic resonators with almost uniform field intensity and up to twice the energy density of conventional structures are possible by exploiting the properties of negative refractive index materials. Efficient computation and local optimization is achieved by solving the underlying PDE on an unbounded domain and the adjoint method to efficiently compute the gradient of the cost functional with respect to design parameters. The same method has also been applied to nano-scale electronic device design.

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MS25

Combinatorial Motion Planning of Multi-Vehicle Systems

In this talk, I will consider the problem of motion planning for vehicles with a constraint on the minimum turning radius. The motion planning problem is as follows: Given a set of n targets to visit, m vehicles that start at distinct lo-

cations (depots), choose at most $p \leq m$ vehicles and their corresponding tours so that (1) each target is visited by at least one vehicle and (2)the total distance travelled by the collection is a minimum among all possible choices of vehicles and their tours. By a tour, one must find not only the sequence of targets to be visited by the vehicle but also the angle at which it must be visited. I will present approximate algorithms based on a two step procedure: In the first step, the combinatorial problem is solved based on the Euclidean distances between the targets and the second step is to find the heading angles at the targets using a dynamic programming approach.

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MS25

Value Function Based Control of Sensing Operations

The problem of tasking sensing assets when little prior information is known is very challenging. In such situations, one must clearly keep in mind that the value of information is in its ability to help win the battle. In this paper, we present a game-theoretic approach to designing sensing plans in order to maximize success of the overall battleplan. Dynamic programming provides means of determining optimal sensing courses of action.

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MS25

Title Not Available at Time of Publication

Abstract not available at time of Publication.

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MS25

Real-Time Optimal Motion Planning for Unmanned Vehicles

Abstract not available at time of publication.

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MS26

The LaxFriedrichs Sweeping Method for Optimal Control Problems in Continuous and Hybrid Dynamics

Assuming that the Hamiltonian is strictly convex in the control variable, we derive a pair of HJ equations in continuous time through the dynamic programming formulation. The LaxFriedrichs sweeping (LFS) method is applied to solve the coupled PDEs by successive iteration of the optimal cost and control. The method also applies to optimal control problems in hybrid systems. We demonstrate the efficiency of the method through numerical examples in both continuous and hybrid dynamics.

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MS26

PDEs in Control Theory

We review the important PDEs that arise in nonlinear control theory and methods for solving them.

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MS26

Numerical Method for Hamilton-Jacobi-Bellman Equations in High Dimension

We present a novel method for solving the Hamilton-Jacobi-Bellman PDE arising in optimal control problems in high dimension. First the HJB PDE is solved locally using Albrecht's power series method. Then power series solutions of the HJB PDE outside the local neighborhood are patched together. For each power series solutions, we solve a Cauchy problem where the boundary conditions are the Cauchy data defined on a noncharacteristic surface of the PDE.

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MS26

A New Discontinuous Galerkin Method for Directly Solving Hamilton-Jacobi Equations

Different to Hu-Shu's paper in 1999, we propose a direct discontinuous Galerkin method to solve Hamilton-Jacobi equations. For the linear case, the method is equivalent to the discontinuous Galerkin method for conservation laws. Thus, stability and error analysis are valid. For both convex and nonconvex Hamiltonians, optimal (k+1)-th order of accuracy for smooth solutions are obtained with piecewise k-th polynomial approximations. The schemes are numerically tested on a variety of one and two dimensional problems. The method works well to capture sharp corners(discontinuous derivatives) and converges to the viscosity solution.

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MS27

Military Applications and Sensitivity Analysis of Coupling Game

Coupling game theory can formulate some non-ideal game cases and provide more reasonable control strategies. Traditional TU cooperative games, non-cooperative games, and two-person zero-sum games are special cases of coupling game. This paper describes military applications of coupling game theory in a Navy research project. Approaches to determine coupling factors in coupling games are discussed. Sensitivity functions of coupling factors are provided. Experiments confirm the benefits of applying coupling game theory to non-ideal complex military situations.

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MS27

Robust Cooperative Control in Multi-Player Pursuit Evasion Games with Communication Delays

The performance of the multiple players Pursuit-Evasion game is often highly dependent on the utilization of the communication network. However, it seems like that issues of intermittent communications and limited available information have not been adequately addressed. Innovative approaches are requested to deal with multiple players PE control issues arising from intermittent and asynchronous communications, where pursuer team members communication is limited. To extend our robust cooperative control in multiple agent PE game to environments with intermittent asynchronous communication, we proposed an Open-Loop Asynchronous Feedback Nash Optimal (OLAFNO) strategy in this talk. The advantages of OLFO are 1) OLFO is simple in concept. Open loop optimization assumes no further feedback beyond the initial identification and estimates of the system states and parameters; 2) OLFO is an adaptive controller using current estimates. We also describe a simulation to illustrate the performance of our proposed approach.

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MS27

Cooperative Control Solutions in Multi-Person Quadratic Decision Problems: Cost Cumulants and Finite-Horizon Paradigm

In the cooperative control regime using cost cumulants for the class of multi-person single-objective decision problems characterized by quadratic random costs and state-feedback information structures, individual decision makers share state information with their neighbors and then autonomously determine decision strategies to achieve the desired goal of the group which is a minimization of a finite linear combination of the first k cost cumulants of a finite-horizon integral quadratic cost associated with a linear stochastic system, when the decision makers measure the states. Since this problem formulation is parameterized by the number of cost cumulants, the scalar coefficients in the linear combination and the group of decision makers, it may be viewed both as a generalization of linear-quadratic Gaussian control, when the first cost cumulant is minimized by a single decision maker and of the problem class of linear-quadratic identical-goal stochastic games when the first cost cumulant is minimized by multiple decision makers. Using a more direct dynamic programming approach to the resultant cost-cumulant initial-cost problem, it is shown that the decision laws associated with multiple persons are linear and are found as the unique solutions of the set of coupled differential matrix Riccati equations, whose solvability guarantees the existence of the closed-loop feedback decision laws for the corresponding multi-person single-objective decision problem.

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MS27

Nash and Minimax, Cumulant, Stochastic Differential Games: Going Beyond the Mean

The mean value of a cost plays prominently into control and game theory. Recently cost cumulants have been used in both control and games. We will extend the use of cost cumulants in games to the third and fourth cumulants, for minimax and Nash games. A class of nonlinear systems with nonquadratic costs are examined. Equilibria for linear quadratic case will be found. This work was supported in part by Air Force grant number FA9550-07-1-0319.

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