Abstract: In this paper, we deal with a stabilization problem for a type of blending control system, which originated from studies of brain motor control. In our approach, the feedback controller has a module structure with softmax blending. The controller is composed of multiple modules, each of which consists of a state predictor and a controller, and the weights of blending are given by the softmax function of the prediction error from each module. We establish exponential stability of our system based on theory of slowly time-varying systems.

TuA01
A New Perspective in Biological Signal Processing and Motor Control I

Chair: Ghosh, Bijoy Washington Univ.
Co-Chair: Kimura, Hidenori Univ. of Tokyo
Organizer: Kimura, Hidenori Univ. of Tokyo
Organizer: Ghosh, Bijoy Washington Univ.

10:00
The Stability Analysis of Module Blending
Architecture in Brain Motor Control (I)................................. 1
Matsuura, You The Univ. of Tokyo
Kimura, Hidenori The Univ. of Tokyo

Abstract: In this paper, we deal with a stabilization problem for a type of blending control system, which originated from studies of brain motor control. In our approach, the feedback controller has a module structure with softmax blending. The controller is composed of multiple modules, each of which consists of a state predictor and a controller, and the weights of blending are given by the softmax function of the prediction error from each module. We establish exponential stability of our system based on theory of slowly time-varying systems.

10:20
Identification of Adaptation in Human Postural Control using GARCH Models (I) ........................................ 7
Johansson, Rolf Lund Univ.
Fransson, Per A. Lund Univ.
Magnusson, Måns Lund Univ.

Abstract: Human postural dynamics was investigated in twelve normal subjects by means of a force platform recording body sway induced by bipolar transmastoid galvanic stimulation of the vestibular nerve and labyrinth. We modeled the stabilizing forces actuated by the feet as resulting from complex muscular activity subject to feedback of body velocity and position. Time series analysis demonstrated that a transfer function from stimulus to sway-force response with specific parameters could be identified. In addition, adaptation to the vestibular stimulus was demonstrated to exist. Residual GARCH modeling (generalized autoregressive conditional heteroskedasticity) suggested a postural adaptation time constant in the range of 40–50 s. The results suggest means to evaluate adaptive behavior in postural control and in other physiological contexts.
Abstract: This note presents an extension of the absolute stability problem and of the Lagrange-Dirichlet theorem, when the nonlinearities entering the model are considered within the class of monotone operators (consequently including operators with piecewise-linear graphs that may represent physical effects like Coulomb friction, dead-zones, saturations, elasto-plasticity, and unilateral constraints).

10:20
Incremental Positivity Non-Preservation by Stability Multipliers ...... 33
Kulkarni, Vishwesh V.  Univ. of Southern California, Los Angeles
Safonov, Michael G.  Univ. of Southern California, Los Angeles

Abstract: It is proved that stability multipliers such as Zames-Falb multipliers, Popov multipliers and RL/RC multipliers, known to preserve positivity of monotone memoryless nonlinearities, do not, in general, preserve their incremental positivity. Our result implies that stability results based on these multipliers should be interpreted with caution since without incremental positivity, continuity of the closed loop system's input-output relation may not be assured.

10:40
When Does or Does Not Circle Criterion Help in Robust Control Synthesis for LTI Systems with Sector Type Nonlinearities? ...... 39
Kiyama, Tsyoshi  Tokyo Inst. of Tech.
Hara, Shinji  Tokyo Inst. of Tech.
Iwasaki, Tetsuya  Univ. of Virginia

Abstract: This paper proposes regional L2 performance analysis and synthesis methods for linear time-invariant systems with sector type nonlinearities using circle criterion. The methods can treat both nonzero initial state vectors of systems belong to a bounded set and disturbance inputs belong to a set of signals having bounded L2 norm. We show that a solvability of the synthesis problem can be checked by a linear matrix inequality (LMI) optimization problem if outputs of the nonlinear elements are measurable. Moreover, advantages of synthesis based on the circle criterion compared with a linear analysis are clarified especially in the case where the nonlinearities appear only in the control input parts.

11:00
Necessary and Sufficient Conditions for Robust Absolute Stability of Time-Varying Nonlinear Continuous-Time Systems ............... 45
Molchanov, Alexander  Inst. of Control Sciences
Liu, Derong  Univ. of Illinois, Chicago

Abstract: The present paper establishes results for the robust absolute stability of a class of nonlinear continuous-time systems with time-varying matrix uncertainties of polyhedral type and multiple time-varying sector nonlinearities. By using the variational method and the Lyapunov Second Method, criteria for robust absolute stability are obtained in different forms for the given class of systems. Specifically, the parametric classes of Lyapunov functions are determined which define the necessary and sufficient conditions of robust absolute stability. The piecewise linear Lyapunov functions of the infinity vector norm type are applied to derive an algebraic criterion for robust absolute stability in the form of solvability conditions of a set of matrix equations.
formulation of state estimation is introduced to ensure the regulation is a global one with respect to state variables. Adaptive control technique is used to deal with uncertainty in a recently introduced formulation of exosystems. In the proposed control design, a number of control coefficients are made adaptive so that the regulation is global with respect to unknown frequencies in the disturbances.

10:40
Output Regulation of Singular Nonlinear Systems by Output Feedback

Zhu, Jiandong  Shandong Univ.
Cheng, Zhaolin  Shandong Univ.

Abstract: A necessary and sufficient condition for the output regulation problem to be solvable by output feedback reduced-order normal controllers is derived, which can be constructed explicitly.

11:00
Causal Inversion of Nonminimum Phase Systems

Wang, Xuezhen  Iowa State Univ.
Chen, Degang  Iowa State Univ.

Abstract: Inversion of nonminimum phase systems is a challenging problem. The classical causal inverses proposed by Hirschorn result in unbounded solutions to the inverse problem where the zero dynamics are unstable. Stable inversion introduced by Chen and Paden obtains bounded but noncausal inverses for nonminimum phase systems. As a first step, this paper addresses bounded causal inversion of nonlinear nonminimum phase systems. It is shown that an optimal causal inversion problem is equivalent to a minimum energy control problem of the zero dynamics driven by a causal reference output profile. A causal inversion solution for nonlinear systems and an optimal causal inversion solution for linear systems are also proposed. Simulation results demonstrate the effectiveness of the new causal inversion approach in output tracking.

11:20
Global Output Regulation of Nonminimum Phase Nonlinear Systems

Onishi, Norio  Nara Inst. of Sci. & Tech.
Yamashita, Yuh  Nara Inst. of Sci. & Tech.
Nishitani, Hirokazu  Nara Inst. of Sci. & Tech.

Abstract: We address the problem of global output regulation for a single-input single-output nonlinear system that may not be minimum phase. Some invariant manifolds are introduced to transform the system into a form that is easier to handle. It is shown that a variable-gain feedback law can carry out the global output regulation of the system under some additional assumptions.

11:40
Backstepping Stabilization of Nonlinear Systems with a Nonminimum Phase Zero

Ding, Zhengtao  Ngee Ann Polytechnic

Abstract: This brief paper deals with stabilization of a class of nonlinear systems with a nonminimum-phase zero via backstepping. A state transform is introduced so that the system is minimum phase with respect to the transformed output that is not measurable. Backstepping design is applied to the transformed system based on an estimate of the transformed output to achieve the stabilization of the original system.
TuA05
Distributed Parameter Systems I
Chair: Demetriou, Michael A.  Worcester Polytechnic Inst.
Co-Chair: Van der Schaft, Arjan J.  Univ. of Twente

10:00
An Approximation Theory for Strongly Stabilizing
Solutions to the Operator LQ Riccati Equation .......................  123
Oostveen, Job C.  Univ. of Groningen
Curtain, Ruth F.  Univ. of Groningen
Ito, Kazufumi  North Carolina State Univ.

Abstract: The linear-quadratic (LQ) control problem is considered for a class of infinite-dimensional systems with bounded input and output operators, that are not exponentially stabilizable, but only strongly stabilizable. A sufficient condition for the existence of a minimizing control and of a stabilizing solution to the associated LQ Riccati equation is given. The main contribution of this paper is the convergence of the stabilizing solutions of a sequence of finite-dimensional Riccati equations to the strongly stabilizing solution of the infinite-dimensional Riccati equation. We will illustrate the approximation result with an example of LQ control for a model of propagation of sound waves in a one-dimensional wave-guide.

10:20
Examples of Regular Linear Systems Governed
by Partial Differential Equations ................................. 129
Byrnes, Christopher I.  Washington Univ., St. Louis
Gilliam, David S.  Texas Tech. Univ.
Shubov, Victor I.  Texas Tech. Univ.

Abstract: In this short paper we describe our recent results establishing that a broad class of distributed parameter systems described in terms of boundary controlled heat conduction problems on bounded domains in arbitrary dimensional Euclidean space are governed by regular linear systems.

10:40
Panel Discussion
Abstract: This paper presents a robust model-based technique for the detection and isolation of sensor faults in a chemical process. The diagnosis system is based on the robust estimation of process outputs. A dynamic non-linear model of the process under investigation is obtained by a procedure exploiting Takagi-Sugeno (T-S) multiple-model fuzzy identification. The combined identification and residual generation schemes have robustness properties with respect to modelling uncertainty, disturbance and measurement noise, providing good sensitivity properties for fault detection and fault isolation. The identified system consists of a fuzzy combination of T-S models to detect changing plant operating conditions. Residual analysis and geometrical tests are then sufficient for Fault Detection and Isolation (FDI), respectively. The procedure here presented is applied to the problem of detecting and isolating faults in a benchmark simulation of a tank reactor chemical process.

Abstract: The early detection of system malfunctions and faults as well as the isolation of their origin have become an important issue in advanced control system design and a great deal of research has been concentrated on this topic in the last two decades. Much attention has been paid to the design of robust Fault Detection and Isolation (FDI) systems. More recently, certain results concerning robustness of filters using H∞ optimization techniques have appeared both in the FDI scenario and estimation scenario. However, the design problem which accounts simultaneously disturbance robustness and fault detection performance, has been rarely considered within an H∞ setting. The reason is that the resulting joint optimization problem cannot be easily formulated in an H∞ setting, because capturing all performance objectives in a single cost function is not possible. In this paper, an iterative scheme is presented to design a filter which takes into account multiple FDI objectives. The aim is to detect additive faults promptly with minimal delays and false alarms, whilst satisfying robustness performance against external disturbances, normal variations of system parameters and unmodeled dynamics. The proposed procedure can be summarized as follows: First, a FDI filter is designed such that robustness and dynamic objectives are achieved. It is shown that, all specifications can be formulated into a Linear Matrix Inequalities (LMI) optimization problem. Second the generalized structured singular value is used to check robust fault sensitivity.

Abstract: This paper deals with the design of a nonlinear fault tolerant controller for the induction motor. We show how an indirect field oriented (IFO) controller can be modified in order to compensate the side-effects arising in presence of electrical and mechanical faults and, so doing, also to detect the occurrence of the fault. To this end we follow the nonlinear regulation theory, namely we design a nonlinear controller embedding an internal model of the numerical example is used to illustrate the efficiency of the proposed method.
fault which automatically activate in case spurious harmonic currents arise (namely in case of fault occurrence).

Abstract: We present a game-theoretic treatment of distributed power control in CDMA wireless systems. We make use of the conceptual framework of noncooperative game theory to obtain a distributed and market-based control mechanism. We address not only the power control problem, but also pricing and allocation of a single resource among several users. A cost function is introduced as the difference between pricing and utility functions, and the existence of a unique Nash equilibrium is established. Furthermore, two update algorithms, namely parallel update and random update, are shown to be globally stable under specific conditions. Convergence properties and robustness of each algorithm are also studied through extensive simulations.

Abstract: In this paper we develop results for analysis and synthesis of networked control systems. Specifically, we consider distributed control in a so-called linear parameter-varying setting. Operator theoretic tools for working with these systems are developed, and lead to sufficient convex conditions for analysis and synthesis with respect to the L2 induced norm.

Abstract: This paper discusses flow control in networks, in which sources control their rates based on feedback signals received from the network links, a feature present in current TCP protocols. We develop a congestion control system which is arbitrarily scalable, in the sense that its stability is maintained for arbitrary network topologies and arbitrary amounts of delay. Such a system can be implemented in a decentralized way with information currently available in networks plus a small amount of additional signaling.

Abstract: The problem of sequential vector quantization of a stationary Markov source is cast as an equivalent stochastic control problem with partial observations. This problem is analyzed using the techniques of dynamic programming, leading to a characterization of optimal encoding schemes.

Abstract: We adopt optimal preview control methodology to design a terrain following controller for cruise missile. In this methodology, both tracking errors and control increments are considered in a quadratic penalty function. An augmented error system that involves future command inputs is built. Thus, the preview control problem can be formulated as an optimal regulator problem. Integrating the general optimal servo system with preview feed-forward compensations that respectively feed forward future command inputs and future disturbances, produces an optimal preview servo system. In the terrain following system, the flight altitude of cruise missile is the command input and its future information can be known a priori. The wind is viewed as the disturbance in the system and is not previewable. Hence, we designed a terrain following controller with a basic state feedback, and a feed-forward compensation for future altitude information while regarding the wind as a constant signal. Simulation results show that the performance of the terrain following system with such an optimal preview controller is improved dramatically.

Abstract: In this paper, we offer a new design method for the flight control of a nonlinear non-minimum phase VTOL aircraft. The non-minimum phase property is caused by the small coupling between rolling moments and lateral acceleration, and a few researchers have derived control laws by neglecting the coupling. We show that the true model can be transformed equivalently into a model with zero coupling by changing the plant output from the center of mass to the Huygens center of oscillation. Then, we design a controller by applying a linear high gain approximation of backstepping to the model; we call this method a two-step linearization. Computer simulation shows that the control law robustly stabilizes the true model with good tracking for both small and large couplings. Experiments using a twin rotor helicopter model which has a similar dynamics also show equally good performance.
Abstract: This paper proposes a novel nonlinear approach for high performance flight control design. The dynamic linearization is accomplished via a kind of unknown input observer, called Extended State Observer. A non-smooth feedback law is employed to achieve the desirable dynamic performances. A Lyapunov function is constructed for the proposed method.

11:00
Reliable and Robust H-Infinity Flight Controller Design for Bank-Angle Tracking Maneuver of a Jet Transport Aircraft ..... 229
Yee, Jong Sang Nanyang Tech. Univ.
Wang, Jian Liang Nanyang Tech. Univ.
Sundararajan, N. Nanyang Tech. Univ.
Yang, Guang Hong Temasek Labs

Abstract: This paper studies the reliable and robust H-infinity (RRH-infinity) flight controller design, based on the iterative linear matrix inequality (ILMI) approach, for a bank-angle tracking maneuver of a jet transport aircraft. While meeting certain robustness properties, the RRH-infinity flight controller explicitly considers a reliability property which tolerates the loss of actuator effectiveness. The RRH-infinity flight controller also seeks to optimize the nominal performance of the resultant closed-loop system. Simulation results demonstrate good performance using the RRH-infinity flight controller scheme.

11:20
Hovering Flight Control of a Micromechanical Flying Insect ..... 235
Deng, Xinyan Univ. of California, Berkeley
Schenato, Luca Univ. of California, Berkeley
Sastry, Shankar Univ. of California, Berkeley

Abstract: This paper describes recent results on the design and simulation of a flight control strategy for the Micromechanical Flying Insect (MFI), a 10-25mm (wingtip-to-wingtip) device capable of sustained autonomous flight. Biologically inspired by the real insect's flight maneuver, the wing kinematics are parametrized by a small set of parameters which are sufficient to generate desired average torques to regulate its attitude. Position control was achieved through attitude control based on the linearized dynamics under small angle assumption near hovering. During its continuous flight, the controller schedules the desired wing kinematic parameters according to the inverse map based on the feedback error at the end of each wingbeat. The proposed controller was simulated with the Virtual Insect Flight Simulator, and the results show convergence of both position and orientation.

11:40
Automatic Landing Control using H-Infinity Control and Stable Inversion .......................................................... 241
Che, Jun Beijing Univ. of Aero. & Astro.
Chen, Degang Iowa State Univ.

Abstract: This paper presents a new method for developing robust tracking controllers for automatic landing systems. We first develop a linearized longitudinal model of the Boeing 747 commercial airplane together with models for the control actuators, wind gust, and wind shear. The H-infinity control provides robust stability against uncertainties caused by exogenous disturbances and signals noise. The stable inversion provides precision tracking. Both methods are integrated to satisfy both robust and exact tracking requirements for the automatic landing system. Based on the stable inversion technique, the desired altitude and airspeed trajectories are also designed. The numerical simulation results show that the proposed automatic landing system can exceed FAA (Federal Aviation Administration) requirements for Category III precision approach landing. Furthermore, the integrated system can achieve robust accurate tracking in the presence of measurement noises, wind gust, and wind shear with middle intensity. Compared with existing approaches, our method achieved higher precision with excellent robustness.

TuA09
H-Infinity Control Systems
Chair: Zhou, Kemin Louisiana State Univ.
Co-Chair: Sebe, Noboru Kyushu Inst. of Tech.

10:00
A New Upper Bound for the Real Structured Singular Value ... 247
Gungah, Satindra K. Imperial College
Malik, Usman Imperial College
Jaimoukh, Imad M. Imperial College
Hallkias, George D. City Univ.

Abstract: A new, easily computable, upper bound on the real structured singular value is derived under the assumption of a nonpeated largest singular value. The condition under which real structured singular value is (strictly) less than the largest singular value is used to embed the structured uncertainty set in a larger related set. This is then used to derive an upper bound strictly less than the largest singular value without the use of scaling matrices.

10:20
H-Infinity Strong Stabilization .............................................. 249
Campos-Delgado, Daniel Ulises Louisiana State Univ.
Zhou, Kemin Louisiana State Univ.

Abstract: This paper presents a technique for designing stable H_infinity controllers. Similar to some methods in the existing literature, the proposed method also uses the parameterization of all suboptimal H_infinity controllers so that the stable H_infinity design problem can be (conservatively) converted into another 2-block H_infinity problem. However, a weighting function is introduced in this method to alleviate the conservativeness of the previous formulations. It is further shown that the resulting highorder controller can be significantly reduced by a two-step reduction algorithm. Numerical examples are presented to demonstrate the effectiveness of the proposed method.

10:40
Synthesis of H-Infinity PID Controllers .................................. 255
Ho, Ming-Tzu Natl. Cheng Kung Univ.

Abstract: This paper considers the problem of synthesizing proportional-integral-derivative (PID) controllers for which the closed-loop system is internally stable and the H_infinity norm of a related transfer function is less than a prescribed level for a given single-input single-output plant. It is shown that the problem to be solved can be translated into simultaneous stabilization of the closed-loop characteristic polynomial and a family of complex polynomials. It calls for a generalization of the Hermite-Biehler Theorem applicable to complex polynomials. Then a linear programming characterization of all admissible H_infinity PID controllers for a given plant is obtained.

11:00
Fast Algorithms for Solving H-Infinity-Norm Minimization Problems .............................................................. 261
Varga, Andras German Aerospace Center
Parrilo, Pablo California Inst. of Tech.

Abstract: In this paper we propose an efficient computational approach to minimize the H-infinity-norm of a transfer-function matrix depending affinely on a set of free parameters. The minimization problem, formulated as a semi-infinite convex programming problem, is solved via a relaxation approach over a finite set of frequency values. In this way, a significant speedup is achieved by avoiding the solution of high order linear matrix inequalities (LMIs).
resulting by equivalently formulating the minimization problem as a high dimensional semidefinite programming problem. Numerical results illustrate the superiority of the proposed approach over LMIs based techniques in solving zero order H-infinity-norm approximation problems.

11:20
Poly-Quadratic Stability and H-Infinity Performance for Discrete Systems with Time Varying Uncertainties ............... 267
Daaofou, Jamal
Bernussou, Jacques

Abstract: In this paper, we consider discrete time systems with polytopic time varying uncertainty. We look for a class of Parameter Dependent Lyapunov Functions (PDLF) which are quadratic on the system state and depend in a polytopic way on the uncertain parameter. We propose a necessary and sufficient condition for the computation of such a Lyapunov function. This allows to check asymptotic stability of the system under study. Robust H infinity performance problem is presented as an application.

11:40
A Characterization of Solutions to the Inverse H-Infinity Optimal Control Problem ......................... 273
Sebe, Noboru

Abstract: This paper is concerned with the inverse H-infinity optimal control problem. The inverse H-infinity optimal control is to find plants whose H-infinity optimal controller is a given controller. This paper gives a characterization of solutions to the inverse H-infinity optimal control problem. For some plants on the ‘boundary’ of the set parametrized with respect to a given controller, the given controller is an H-infinity optimal controller and the optimal value is the prespecified value. In other word, such plants on the ‘boundary’ of the parametrization are of the same difficulty with respect to all the possible controllers. The characterization of such plants is given in this paper.
Abstract: This paper presents an algorithm for the stabilization of a multi-input/multi-output discrete time linear system via a limited capacity channel. The approach taken is a deterministic multi-rate state space approach which leads to a nonlinear dynamic feedback controller.

Necessity of a Sampled-Data Approximation Result ............... 310
Cantoni, Michael
Univ. of Melbourne

Abstract: A computationally tractable, sufficient condition was given in [1] for a periodic sampled-data (SD) controller to: (i) lie within a specified pointwise gap metric distance, closely related to the nu-gap metric, from a given LTI controller C; and (ii) stabilise any LTI plant that achieves a certain level of closed-loop performance with C. In this paper, it is shown that the condition is also necessary. As such, the result gives rise to an algorithm for computing the distance between an LTI controller and a given discretisation, and an optimal technique for SD approximation in the gap metric. An example is presented to demonstrate the use of these tools. Key Words: Sample-Data Control, Controller Discretisation, (nu-)Gap Metric, Feedback Systems

Positive-Realness Analysis of Sampled-Data Systems and Its Applications .................................................. 316
Hagiwara, Tomomichi
Kyoto Univ.
Mugiuda, Toru
Kyoto Univ.

Abstract: This paper is concerned with positive-realness of sampled-data systems. We first review a few slightly different notions of positive-realness of sampled-data systems, and clarify their mutual relationships. We then focus on so-called strong positive-realness among them, and introduce a useful measure called the positive-realness gap index. We show that this index can be computed quite efficiently with a bisection method, and provide state space formulas for its computation. The importance of this index lies in that it is quite useful for stability analysis of sampled-data systems. This will be demonstrated with the nonlinear stability analysis as well as the gain margin analysis, or a sort of stability radius analysis.

On Discrete-Time Models of Linear and a Class of Nonlinear Systems ..................................................... 322
Rabbath, Camille A.
Opal-RT Technologies
Lechevin, Nicolas
Opal-RT Technologies
Hori, Noriyuki
Univ. of Tsukuba

Abstract: This paper investigates the concept of discrete-time models of continuous-time systems. The framework proposed applies to linear, time-invariant systems as well as to triangular nonlinear systems. Numerical examples of nonlinear triangular systems illustrate the concepts involved. Discretization of the average model of a PWM-regulated rectifier is considered. Furthermore, the impact of the combinations of different hold functions with respect to accuracy and complexity is analyzed for the simulations of a nonlinear RLC circuit.

On Sampled-Data System Zeros ............................................. 328
Yame, Joseph J.
Univ. libre de Bruxelles

Abstract: The notion of zeros of sampled-data systems is introduced in the lifting framework so that from the continuous-time viewpoint the zeros have signal transmission blocking properties. A characterization of all such zeros is given in terms of the eigenvalues of a bounded operator on the state space.

Visual Servoing based on Intersample Disturbance Rejection by Multirate Sampling Control ....................... 334
Fujimoto, Hiroshi
Nagaoka Univ. of Tech.
Hori, Yoichi
Univ. of Tokyo

Abstract: In this paper, novel multirate sampling controllers are proposed for digital control systems, where the speed of the A/D converters is restricted to be slower than that of the D/A converters. The proposed feedback controller assures perfect disturbance rejection (PDR) at M intersample points in the steady state. The proposed method is extended to systems with time delay, and the compensation method is proposed based on the observer including time delay model. Next, the novel scheme of repetitive control is proposed based on the open-loop estimation and switching function, which enables the rejection of periodical disturbance without any sacrifice of the closed-loop characteristics. Finally, the proposed controllers are applied to visual servo system by introducing the workspace controller and nonlinear perspective transformation. The advantages of these approaches are demonstrated by simulations and experiments using a robot manipulator.

On Sampled-Data System Zeros ............................................. 328
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Visual Servoing based on Intersample Disturbance Rejection by Multirate Sampling Control ....................... 334
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Modeling of Hybrid Systems
Chair: Pappas, George J.
Univ. of Pennsylvania
Co-Chair: Davoren, J. M.
Australian Natl. Univ.

Continuity and Invariance in Hybrid Automata ...................... 340
Lygeros, John
Univ. of Cambridge
Johansson, Karl Henrik
Royal Inst. of Tech.
Simic, Slobodan N.
Univ. of California, Berkeley
Zhang, Jun
Univ. of California, Berkeley
Sastry, Shankar
Univ. of California, Berkeley

Abstract: Hybrid automata have been proposed as a language for modelling and analysing the interaction of digital and analogue dynamics in embedded computer systems. In this paper, hybrid automata are studied from a dynamical systems perspective. Extending earlier work on conditions for existence and uniqueness of executions of hybrid automata, we characterise a class of hybrid automata whose executions depend continuously on the initial state. The continuity conditions are subsequently used to derive an extension of LaSalle’s principle for studying the stability of invariant sets of states of hybrid automata.

On the Zeno Behavior of Linear Complementarity Systems .... 346
Çamlibel, M. Kanat
Univ. of Groningen
Schumacher, J. M.
Tilburg Univ.

Abstract: In this paper, the so-called Zeno phenomenon is addressed for linear complementarity systems which are interconnected by linear systems and complementarity conditions. We present some sufficient conditions for absence of Zeno behavior. It is also shown that the zero state, which is the most obvious candidate for being a Zeno state, cannot be a Zeno state in certain cases.
Concatenability of Behaviors in Hybrid System Interconnection

Abstract: Abstraction is a natural way to hierarchically decompose the analysis and design of hybrid systems. Given a hybrid control system and some desired properties, one extracts an abstracted system while preserving the properties of interest. Abstractions of purely discrete systems is a mature area, whereas abstractions of continuous systems is a recent activity. In this paper we present a framework for abstraction that applies to abstract control systems capturing discrete, continuous, and hybrid systems. Parallel composition is presented in a categorical framework and an algorithm is proposed to construct abstractions of hybrid control systems. Finally, we show that our abstractions of hybrid systems are compositional.

Abstract: This paper proves that an ARMA system is asymptotically stable if its transfer function has a minimum entropy tracking error. A set of sufficient conditions have been established to guarantee stability of the closed loop system. Discussions on the design of the controller can thus reduce the uncertainty of the closed loop system.

Abstract: Stochastic adaptive stabilization usually leads to the boundedness of the average of squared output of the stabilized system. An illustrative example is utilized to demonstrate the use of the control algorithm, and satisfactory results have been obtained.

Abstract: Hybrid dynamical systems are systems that contain both analog (continuous) and logical (discrete) components. Recently, these systems receive a lot of attention from both the computer science and the control community. As tractable methods to analyze general hybrid systems are not available, several authors have focused on special subclasses for which analysis and control design techniques are currently being developed. In this paper we show the equivalence (under some mild assumptions) between the following discrete-event and hybrid model classes: piecewise affine, mixed logical dynamical, (extended) linear complementarity and max-min-plus-scaling systems. The equivalence should be understood in the sense that the "input-state-output behaviour" generated by the model classes are equal. These results enable the transfer of knowledge from one class to another, they show that more applications belong to these classes and moreover, for the study of a particular hybrid system one can choose the modeling framework that is most suitable.

Abstract: A behavioral approach to analysis of hybrid system interconnections. The hybrid system interconnection is defined as a dynamical system consisting of past and future trajectories which are switched at a certain instant by an external switching mechanism. We define the concatenability of the behaviors of the past and future interconnections, and derive a necessary and sufficient condition for the behavioral concatenability based on the notion of a state map. If the past interconnection behavior is concatenable with the future one, every past trajectory can be continued by some future trajectory without causing any impulsive phenomena. Moreover, we show that the regular feedback structure of the future interconnection guarantees the concatenability for any past interconnections.

Abstract: This paper is concerned with a behavioral approach to analysis and design of hybrid systems. Given a hybrid control system and some desired properties, one extracts an abstracted system while preserving the properties of interest. Abstractions of purely discrete systems is a mature area, whereas abstractions of continuous systems is a recent activity. In this paper we present a framework for abstraction that applies to abstract control systems capturing discrete, continuous, and hybrid systems. Parallel composition is presented in a categorical framework and an algorithm is proposed to construct abstractions of hybrid control systems. Finally, we show that our abstractions of hybrid systems are compositional.

Abstract: On the Equivalence of Classes of Hybrid Dynamical Models... 364

Heemels, Maurice
Eindhoven Univ. of Tech.
De Schutter, Bart
Delft Univ. of Tech.
Bemporad, Alberto
Univ. di Siena

Abstract: Hybrid dynamical systems are systems that contain both analog (continuous) and logical (discrete) components. Recently, these systems receive a lot of attention from both the computer science and the control community. As tractable methods to analyze general hybrid systems are not available, several authors have focused on special subclasses for which analysis and control design techniques are currently being developed. In this paper we show the equivalence (under some mild assumptions) between the following discrete-event and hybrid model classes: piecewise affine, mixed logical dynamical, (extended) linear complementarity and max-min-plus-scaling systems. The equivalence should be understood in the sense that the "input-state-output behaviour" generated by the model classes are equal). These results enable the transfer of knowledge from one class to another, they show that more applications belong to these classes and moreover, for the study of a particular hybrid system one can choose the modeling framework that is most suitable.

Abstract: Stochastic adaptive stabilization usually leads to the boundedness of the average of squared output of the stabilized system. An illustrative example is utilized to demonstrate the use of the control algorithm, and satisfactory results have been obtained.

Abstract: This paper presents a new method to minimize the closed loop randomness for general dynamic stochastic systems using the entropy concept. The system is assumed to be subjected to any bounded random inputs. Using the recently developed linear B-spline model for the shape control of the system output probability density function, a control input is formulated which minimizes the output entropy of the closed loop system. Since the entropy is the measure of randomness for a given random variable, this controller can thus reduce the uncertainty of the closed loop system. A set of sufficient conditions have been established to guarantee the local minimum property of the obtained control input and the stability of the closed loop system. Discussions on the design of minimum entropy tracking error have also been made. An illustrative example is utilized to demonstrate the use of the control algorithm, and satisfactory results have been obtained.

Abstract: This paper is concerned with a behavioral approach to analysis of hybrid system interconnections. The hybrid system interconnection is defined as a dynamical system consisting of past and future trajectories which are switched at a certain instant by an external switching mechanism. We define the concatenability of the behaviors of the past and future interconnections, and derive a necessary and sufficient condition for the behavioral concatenability based on the notion of a state map. If the past interconnection behavior is concatenable with the future one, every past trajectory can be continued by some future trajectory without causing any impulsive phenomena. Moreover, we show that the regular feedback structure of the future interconnection guarantees the concatenability for any past interconnections.
lized stochastic system in its steady state is asymptotically stable in the conventional sense.

11:00
Panel Discussion

11:20
Logic-Based Switching for the Stabilization of Stochastic Systems in Presence of Unmodeled Dynamics ........................................... 393
Prandini, Maria
Campi, M. C.
Univ. di Brescia
Univ. di Brescia

Abstract: In this paper, we describe a supervisory control scheme for adaptively stabilizing an unknown discrete time linear system affected by a possibly unbounded noise. The scheme incorporates a switching logic mechanism, which, at adaptively selected event times, places in feedback with the system the controller designed for the model which is the best according to the least squares criterion. The event times are chosen so as to uniformly stabilize the estimated system. We show that, when the controller selection is based on a reduced order model of the system and the unmodeled dynamics is sufficiently small, the introduced switching scheme is successful in stabilizing the system. Moreover, in absence of unmodeled dynamics, we are also able to characterize the switching scheme performance in terms of a self-tuning result.

11:40
Stochastic Stability of Singularly Perturbed Nonlinear Systems ... 399
Tang, Cheng
 Başar, Tamer
Univ. of Illinois, Urbana-Champaign
Univ. of Illinois, Urbana-Champaign

Abstract: The stability of a nonlinear stochastic dynamic system with singular perturbations is considered. Based on the notion of stochastic input-to-state stability and using time scale decomposition, a result of the “total stability” type is obtained, i.e. if the fast subsystem and the slow subsystem are both input-to-state stable with respect to disturbances, then the property continues to hold for the full-order system as long as the singular perturbation parameter is sufficiently small and a stochastic small gain condition is satisfied. The result is general in that it holds for a broad class of disturbances, and resembles similar results for deterministic systems.

13:00
Neural Inputs for Smooth Pursuit Eye Movement (I) ............................... 405
Sugathadasa, Samanmala
Dayawansa, Wijesuriya P.
Martin, Clyde F.
Texas Tech. Univ.
Texas Tech. Univ.
Texas Tech. Univ.

Abstract: The goal of this paper is to verify that position and velocity of a spot of light incident on the retina of a turtle are encoded by the associated spatiotemporal dynamics of the cortical waves they generate. This conjecture is verified by synthesizing a biophysically realistic large scale model of the visual cortex using a software package called GENESIS. The cortical waves are recorded and analyzed using the principal components analysis and the position and velocity information from the visual space is mapped onto an abstract B-space, to be described, using the coefficients of the basis vectors. The likely values of the position/velocity are estimated using standard statistical detection methods.

13:40
Reinforcement Learning of Walking Behavior for a Four-Legged Robot (I) ............................................................... 411
Kimura, Hajime
Yamashita, Toru
Kobayashi, Shigenobu
Tokyo Inst. of Tech.
Tokyo Inst. of Tech.
Tokyo Inst. of Tech.

Abstract: Reinforcement learning is a promising method for robots to obtain and improve control rules from interaction with their environment. In this paper, we investigate a reinforcement learning of walking behavior for a four-legged robot. The robot has two servomotors per leg, so this problem has eight-dimensional continuous state/action space. We present an action selection scheme for actor-critic algorithms, in which the actor selects a continuous action from its bounded action space by using the normal distribution. The experimental results show the robot successfully learns to walk in practical learning steps.

14:00
A Computational Model of Cerebellum and Midbrain to Realize the Human Smooth Constrained Motion and Bimanual Cooperative Motion (I) ................................................. 417
Nakayama, Takayuki
Riken Bio-Mimetic Control Research Ctr.
Kimura, Hidenori
Univ. of Tokyo

Abstract: It is known that the intermediate part of cerebellum plays a key role in adjusting the motion of distal part of limbs to make the movement smooth. In this paper, a computational model for the intermediate part of cerebellum which ensures smooth contact motion with environment is developed. In this model, the cerebellum realizes a smooth contact motion by estimating the conditions of environment in the intermediate part of cerebellar hemisphere and tuning the desired motion via rubrospinal tract. The stability of contact motion is proven theoretically along the Lyapunov’s direct method and its feasibility is demonstrated through some computer simulations. A redundant description of contact force using mirror symmetrically positioned two viscoelastic springs is introduced in the synthesis of contact motion controller. It makes the synthesis of consistent controller for both single arm contact motion and bimanual cooperative motion possible.

14:20
Van der Pol Networks with Symmetry (I) ......................................... 423
Dayawansa, Wijesuriya P.
Martin, Clyde F.
Texas Tech. Univ.
Texas Tech. Univ.

14:40
Systematic Synthesis of Nano- and Micro-Electromechanical Systems .................................................................. 425
Lyshevski, Sergey Edward
Lyshevski, Marina Alexandra
Purdue Univ.
Purdue Univ.

Abstract: Nanoelectromechanical and microelectromechanical systems (NEMS and MEMS) are studied in this paper from synthesis and design perspectives. The systems are synthesized, and the system architecture is devised. These NEMS and MEMS must be analyzed, controlled, and optimized. The basic components of NEMS and MEMS are nano- or microscale transducers, radiating energy devices, signal processing and controlling ICs, input-output and networking devices, etc. The emphasis of this paper is focused on control of transducers, and the electromagnetic torque is developed if the transducer is properly regulated. To design control algorithms, the basic operating principles must be applied and studied. Novel electromagnetic transducers studied and mathematical models are developed. We research the relationships between biological and synthesized transducers through biomimicking. For example, molecular bionanomotors provide the bacterial locomotion, active transport, and delivery. The bacterial flagellar E.coli bionanomotor, which is 40 nm in diameter, is comprised of a complex assembly of more than ten different proteins. This bionanomotor rotates the helical flagella of the bacterium. The chemical energy
(protons or sodium) is converted into electrical, and then into me-
chancial energy. Other examples of molecular biomotors in-
clude RNA polymerase, myosin, kinesin, etc. The fuel that powers
these biomotors is high-energy phosphate compound adenosine
triphosphate (ATP). The devised radial and axial transducers are
controlled using the electromagnetic field. The controllers are de-
signed to optimize the performance. The current reported by the
authors is concentrated on devising and designing of innovative
man-made nano- and microscale actuators through biomimicking,
prototyping, and application of electromagnetic theory to research
and study actuation and sensing mechanisms based upon energy
conversion and transmission. To this end, we devise electromag-
netic nano- and microtransducers using fundamental electromag-
netic principles. Modeling, analysis, and simulations are performed
applying classical mechanics and nanoelectromechanics using charge
density. It is shown that the desired comprehensiveness and
accuracy are achieved. The major emphases are placed on
the nanoscale electromagnetic transducers, and the angular ve-
cility is regulated changing the external electromagnetic field.
It should be emphasized that the magnetic properties of the materi-
als used to build NEMS and MEMS must be studied. For example,
depending upon the thickness, composition, and deposition proc-
esses, the NiFe thin films exhibit different BH curves, magnetiza-
tion, permeability, and other properties. These effects and phe-
nomena must be considered, and the simple scaling down cannot
be viewed as the promising approach for NEMS. It is shown that
the nanoelectromechanical theory must be applied to devise feed-
back mechanisms and design control laws because the basic elec-
 tromagnetic (energy conversion) principles must be guaranteed.
The complexity of nanoscale integrated circuits and radiating en-
ergy devices used to control nanomachines does not allow one to
employ complete mathematical models. Therefore, while model-
ing, simulating, and analyzing transducers, the circuitry dynamics is
studied as uncertainties. Using robust control theory, control laws
are designed and verified.

TuM02
Dissipative Systems
Chair: Tadmor, Gilead
Co-Chair: Haddad, Wassim M.
13:00 On the Existence of a Continuous Storage
Function for Dissipative Systems ...................................... 431
Polushin, Ilya G. Marquez, Horacio J.
Univ. of Alberta Univ. of Alberta

Abstract: Conditions for nonlocal existence of a continuous stor-
age function for nonlinear dissipative system are presented. It is
shown that under the local w-uniform reachability assumption at
one point x the required supply function is continuous on the set
of points reachable from x. Conditions for the local w-uniform
reachability based on the local controllability properties of the
system are provided.

13:20 Numerical Computation of Anti-Stabilizing Storage
Functions for Nonlinear Systems with Power Gain .............. 436
Dower, Peter M. La Trobe Univ.

Abstract: In this paper, the problem of computing an analogue of
the standard energy dissipative (H-infinity) required supply for sys-
tems with power gain is considered. Unlike conventional nonlinear
H-infinity theory, this facilitates worst case stability analysis of sys-
tems with disturbances such as forced limit cycle systems. Key-
words: Numerical solutions, finite differences, limit cycles, H-infinity
optimization.

13:40 Stability and Dissipativity Theory for Nonnegative Dynamical
Systems: A Thermodynamic Framework for Biological and
Physiological Systems ...................................................... 442
Haddad, Wassim M. Georgia Inst. of Tech.
Chellaboina, Vijay Sekhar Univ. of Missouri, Columbia
August, Elias Georgia Inst. of Tech.

Abstract: Nonnegative dynamical system models are derived from
mass and energy balance considerations that involve dynamic
states whose values are nonnegative. These models are wide-
spread in biological, physiological, and ecological sciences and
play a key role in the understanding of these processes. In this pa-
per we develop several results on stability, dissipativity, and stabil-
ity of feedback interconnections of linear and nonlinear nonnega-
tive dynamical systems. Specifically, using linear Lyapunov func-
tions we develop necessary and sufficient conditions for
Lyapunov stability, semistability, and asymptotic stability for non-
negative systems. In addition, using linear storage functions and
linear supply rates we develop new notions of dissipativity theory
for nonnegative dynamical systems. Finally, these results are used
to develop general stability criteria for feedback interconnections
of nonnegative dynamical systems.

14:00 Phasor Models in Bilinear Dissipative Systems .................. 459
Tadmor, Gilead Northeastern Univ.

Abstract: Transients of leading harmonics of nearly periodic sys-
tems (e.g., electric machines), have been approximated by re-
duced order dynamic phasors. Both plausibility analytic arguments
and restrictions are explored in dissipative systems with quadratie
nonlinearities.

14:20 Derivation of an Energy Function Reflecting Damping
Effects in Multi-Machine Power Systems.......................... 461
Moon, Young-Hyun Yonsei Univ.
Kwon, Jong-ju Yonsei Univ.
Ryu, Heon-Su Yonsei Univ.
Choi, Byoung-Kon LG-EDS Systems, Inc.

Abstract: This paper presents a new energy function reflecting the
damping effect in multi-machine power systems. The Lyapunov
direct method provides precise and rigorous theoretical back-
grounds for stability analysis of nonlinear systems. Incorporating
damping effects into accurate estimates of the domain of attraction,
which is a minor but crucial point, has been attempted with long
history to yield partial success for single machine systems. In this
paper, the damping-reflected energy function presented in the pre-
vious work has been generalized for application to multi-machine
systems. The generalized energy function is tested for the WSCC
9-bus system to show the semi-negativeness of its time derivative.

14:40 Equivalent Mechanical Model of Power Systems
for Energy-Based System Analysis ................................. 466
Moon, Young-Hyun Yonsei Univ.
Ryu, Heon-Su Yonsei Univ.
Lee, Jong-Gi Yonsei Univ.
Kook, Hyun-Jong Yonsei Univ.

Abstract: This paper presents a new mechanical analogy of power
systems for energy-based system analysis based on an Equivalent
Mechanical Model (EMM). The EMM is developed on the basis of
mechanical analogy of power system by using spring connected
rod-inertia system. The proposed EMM introduces an imaginary
spring for the analogical correspondence to the transfer conduc-
tance of a transmission line with discussion of its energy storage
properties. The imaginary spring produces its forces acting on
the both ends perpendicular to its displacement vector. The rod-inertia
system is completely analyzed in order to show that it has just the
same dynamic equations as the power system. The proposed
EMM provides theoretical background for energy-based analysis of
Abstract: In this paper, a new formulation of constrained stabilizing receding horizon control is proposed. This formulation is based on the use of open loop steering path generators. The underlying open loop optimization problem is scalar in which the decision variable is the prediction horizon length. Stability is proved in a sampling control scheme.

14:40

Motion Planning of Rolling Surfaces ........................................ 502

Chelouah, Abdelkader  CNRS - Supelec
Chitour, Yacine  Univ. de Paris-Sud

Abstract: In this paper, we address the issues of controllability and motion planning for the control system Sr that results from the rolling without slipping nor spinning of a two dimensional Riemmanian manifold M1 onto another one M2. In the first part of the paper, we describe precisely the control system under consideration together with its Lie algebraic structure. This leads to a recovery of the result of Agrachev and Sachkov who provided a necessary and sufficient condition on the manifolds for complete controllability of Sr. In the main part of the paper, we present two procedures to tackle the motion planning problem when M1 is a plane and M2 a convex surface. The first approach is based on differential algebra. We show that Sr is a Liouvillian system and if M2 has a symmetry of revolution, we compute a maximal linearizing output. The second technic consists of the use of a continuation method to attack the motion planning problem. Eventhough Sr admits nontrivial abnormal exremals, we are still able to successfully apply the continuation method if M2 admits a stable periodic geodesic.

TuM04

Automotive Applications

Chair: Kolmanovsky, Ilya V.  Ford Motor Co.
Co-Chair: Gao, Zhiqiang  Cleveland State Univ.

13:00

Adaptive Identification Schemes in Presence of Bounded Disturbances: An Automotive Case Study ............................... 508

Kolmanovsky, Ilya V.  Ford Research Lab.
Silverguina, Irina  Oakland Univ.

Abstract: This paper addresses an (on-line) parameter identification problem for a first order system affected by an unmeasured input with a priori known bounds. The study is motivated by an estimation problem arising in control of direct injection spark ignition (DISI) engines. Several adaptation approaches are investigated and applied to the DISI engine example.

13:20

Line Following Control of Two Wheeled Vehicle by Symbolic Controller ........................................ 514

Konaka, Eiji  Nagoya Univ.
Suzuki, Tatsuya  Nagoya Univ.
Okuma, Shigeru  Nagoya Univ.

Abstract: Hybrid Dynamical Systems (HDS), which contain both discrete logical symbol and continuous signal, are attracting great attention in the field of system control. In this paper, a new symbolic based control strategy for a line following control of a two wheeled vehicle is proposed. The vehicle is supposed to have a low-resolution sensor and actuator. The control requirement, however, is specified so as to keep the vehicle as close as possible to the center of the line. The controllability and observability issues are investigated, and a concrete control policy based on the continuous state estimation is proposed. Experiment result is shown to demonstrate the usefulness of our idea.

14:20

New Path-Generation based Receding Horizon Formulation for Constrained Stabilization of Nonlinear Systems ............... 496

Alamir, Mazen  LAG-CNRS UMR 5528

Abstract: In this paper, a new formulation of constrained stabilizing receding horizon control is proposed. This formulation is based on the use of open loop steering path generators. The underlying open loop optimization problem is scalar in which the decision variable is the prediction horizon length. Stability is proved in a sampling control scheme.

TuM03

Tracking Control

Chair: Maggiore, Manfredi  Univ. of Toronto
Co-Chair: Nesić, Dragan  Univ. of Melbourne

13:00

Global Tracking Control for a Class of Nonlinear Uncertain Systems .............................................. 473

Bartolini, Giorgio  Univ. of Cagliari
Pisano, Alessandro  Univ. of Cagliari
Usai, Eli  Univ. of Cagliari

Abstract: In this paper the exponential tracking problem for a class of single-input nonlinear uncertain systems expressed in canonical Brunovsky form, with non-affine dependence on the control, is addressed and solved by a second-order sliding-mode control methodology. The presence of unmodelled first-order actuators is considered in the design procedure, and the proposed controller provides for a global domain of attraction and counteracts the typical transient peaking of the state trajectory. Computer simulations confirm the feasibility of the proposed approach.

13:20

Tracking Trajectories of Feedforward Systems: Application to the Cart-Pendulum System ............................. 479

Mazenc, Frédéric  INRIA Lorraine
Bowong, Samuel  INRIA Lorraine

Abstract: The objective of the work is twofold. A first part is devoted to the problem of tracking trajectories of feedforward systems. A family of the time-varying state feedbacks which globally uniformly asymptotically and locally exponentially stabilize trajectories which are not necessarily periodic functions of the time is exhibited. Strict Lyapunov functions are constructed. In a second part, the problem of tracking a trajectory of the practical system called cart-pendulum system is solved.

14:00

A Model-Predictive Satisficing Approach to a Nonlinear Tracking Problem ............................................ 491

Curtis, J. Willard  Brigham Young Univ.
Beard, Randal W.  Brigham Young Univ.

Abstract: In this paper we use the recently introduced concept of satisficing decision theory in conjunction with a receding horizon optimization technique to achieve suitable tracking for a nonholonomic robot system. The satisficing approach creates a family of “universal formulas” parameterized by two functions. A model predictive scheme is employed to generate these two functions in a way that minimizes the quadratic cost at the next time step. By always choosing an element of the satisficing set, global stability is guaranteed.

power systems, which enables us to utilize well-known theories such as Lagrange’s equation.
13:40
An Application of Nonlinear PID Control to a Class of Truck ABS Problems .............................................. 516
Jiang, Fangjun  Ford Motor Co.
Gao, Zhiqiang  Cleveland State Univ.

Abstract: A new NPID (Nonlinear Proportional-Integral-Differential) control algorithm is applied to a class of truck ABS (Anti-lock Brake System) problems. The NPID algorithm combines the advantages of robust control and easy tuning. Simulation results at various situations using TruckSim show that NPID controller has shorter stopping distance and better velocity performance than the conventional PID controller and a loop-shaping controller.

14:00
Robust Observer-Based Monitoring of a Hydraulic Actuator in a Vehicle Power Transmission Control System ........................................... 522
Hahn, Jin-Oh  Seoul Natl. Univ.
Hur, Jae-Woong  Seoul Natl. Univ.
Cho, Young Man  Seoul Natl. Univ.
Lee, Kyo-II  Seoul Natl. Univ.

Abstract: The availability of pressure information of a hydraulic actuator makes it possible to improve the quality of vehicle power transmission via precise feedback control and to realize on-board fault diagnosis. However, the high cost of a pressure sensor has not allowed its widespread deployment despite such apparent advantages. This paper presents an observer-based algorithm to estimate the pressure output of a hydraulic actuator in a vehicle power transmission control system. The proposed algorithm builds on more readily available slip velocity and the models of a hydraulic actuator and a mechanical subsystem. The former is obtained empirically via system identification, while the latter is derived physically. The resulting robust observer is guaranteed to be stable against possible parametric variations and torque estimation errors. The hardware-in-the-loop studies demonstrate the viability of the proposed algorithm in the field of advanced vehicle power transmission control and fault diagnosis.

14:20
Smooth Engagement for Automotive Dry Clutch ........................................... 529
Garofalo, Franco  Univ. di Napoli
Gliemlo, Luigi  Univ. del Sannio
Iannelli, Luigi  Univ. di Napoli
Vasca, Francesco  Univ. di Napoli

Abstract: Two piecewise linear time-invariant models of the automotive driveline are presented and their hybrid structure due to the presence of the dry clutch is highlighted. Based on a second order model, a slip control technique for the dry clutch engagement process is proposed. The feedback controller is designed by using the crankshaft speed and the clutch disk speed as measured variables. The controller guarantees comfortable lock-up and avoids the engine stall by decoupling the control of engine speed and slip speed. The regulation of the slip acceleration at the lock-up is shown to reduce the undesired driveline oscillations. The critical standing start operating conditions are considered and numerical results show the good performance of the proposed controller.

14:40
Multi-Objective Control of Decoupled Vehicle Suspension Systems ........................................... 535
Wang, Jun  Univ. of Leeds
Wilson, David A.  Univ. of Leeds

Abstract: A multi-channel multi-objective synthesis framework, involving generalized L2 (GL2), H2, and generalized H2 (GH2) control with minimum damping-factor pole placement, is formulated and applied to a decoupled vehicle suspension system. It is demonstrated that improved vehicle ride comfort and decreased suspension travel are achieved while guaranteeing robust stability.

13:00
Output Feedback Control of Parabolic PDE Systems with Input Constraints ........................................... 541
El-Farra, Nael H.  Univ. of California, Los Angeles
Armaou, Antonios  Univ. of California, Los Angeles
Christofides, Panagiotis D.  Univ. of California, Los Angeles

Abstract: This paper presents a methodology for output feedback control of parabolic PDE systems with input constraints. Initially, Galerkin's method is used for the derivation of a finite-dimensional ODE system that captures the dominant dynamics of the PDE system. This ODE system is then used as the basis for the synthesis, via Lyapunov techniques, of stabilizing bounded output feedback control laws that use only measurements of the outputs and provide, at the same time, an explicit characterization of the set of admissible control actuator locations that can be used to guarantee closed-loop stability for a given initial condition. Precise conditions that guarantee stability of the constrained closed-loop parabolic PDE system are provided. The proposed output feedback design is shown to recover, asymptotically, the set of stabilizing actuator locations obtained under state feedback, as the separation between the fast and slow eigenvalues of the spatial differential operator increases.

13:20
Examples of Output Regulation for Distributed Parameter Systems with Infinite Dimensional Exosystem ........................................... 547
Byrnes, Christopher I.  Washington Univ., St. Louis
Gilliam, David S.  Texas Tech Univ.
Hood, Jeffrey B.  Texas Tech Univ.
Shubov, Victor I.  Texas Tech Univ.

Abstract: In this short paper we show, by way of an example, that the classical design methodology based on the geometric theory of output regulation can be applied to solve a problem of output regulation for plant consisting of a boundary controlled distributed parameter system with bounded input and output maps and a disturbance and signal to be tracked generated by an infinite dimensional exosystem. The exosystem is neutrally stable but with an infinite (unbounded) set of eigenmodes distributed along the imaginary axis. For this reason the standard methods of analysis do not apply.
PDEs that have a linear part with a finite number of unstable eigenvalues and a nonlinear part that satisfies a linear bound in the inner product. The controller is constructed by analyzing a control Lyapunov function based on the infinite-dimensional dynamics and applying a finite-dimensional linear quadratic regulator (LQR) controller. We first summarize the controller derivation for the full information case. It is found that a sufficient condition for the controller to stabilize the system is a simple finite-dimensional matrix inequality. We apply the stability analysis and control design procedure to construct a static output feedback controller and a decentralized controller for systems with collocated sensors and actuators. As an example, the control designs are applied to the stabilization of the Kuramoto-Sivashinsky equation.

Abstract: This paper proposes two methods for reconstructing sensor faults using a second-order sliding mode observer. For both methods, there are conditions which must be satisfied for successful fault reconstruction. The methods are demonstrated with a chemical process example.

14:20 Discontinuous Feedback Stabilization of Minimum Phase Semilinear Distributed Parameter Systems ............................................. 567
Orlov, Yuri  CICESE Research Center  
Dochain, Denis  CESAME, Univ. Catholique de Louvain

Abstract: Discontinuous control methods are developed for minimum phase semilinear infinite-dimensional systems driven in a Hilbert space. Control algorithms presented ensure asymptotic stability, global or local according as state feedback or output feedback is available. Useful robustness properties against external disturbances with the apriori known norm bounds are provided for the closed-loop system. The theory is applied to stabilization of chemical processes around prespecified steady-state temperature and concentration profiles corresponding to a desired coolant temperature.

TuM06 Fault Diagnosis I
Chair: Saif, Mehrdad  Simon Fraser Univ.  
Co-Chair: Parisini, Thomas  Politecnico di Milano

13:00 Robust and Nonlinear Fault Diagnosis using Sliding Mode Observers ............................................. 567
Xiong, Yi  Simon Fraser Univ.  
Saif, Mehrdad  Simon Fraser Univ.

Abstract: Sliding mode observers for robust fault diagnosis of linear and a class of nonlinear uncertain systems are presented. It is shown that as compared to unknown input fault diagnostic observers, sliding mode fault diagnostic observers can be designed under less restrictive conditions.

13:20 Robust Fault Detection in Uncertain Nonlinear Systems via a Second Order Sliding Mode Observer ....................... 573
Chen, Wen  Simon Fraser Univ.  
Saif, Mehrdad  Simon Fraser Univ.

Abstract: In this paper, a second order sliding mode observer-based robust fault detection in uncertain nonlinear systems is discussed. First of all, a second order sliding mode observer is presented. The reason why the second order sliding mode observer is used for fault detection is that the second-order sliding surface dynamics can sharply filter unwanted high frequencies due to unmodeled dynamics. The sliding condition is derived based on the sliding observer switching gain can be selected. The stability of the reduced sliding mode observer is then proved by assuming that the considered nonlinear system has a single output and two outputs, respectively. An example is employed to show that the proposed sliding mode observer can work very effectively.

13:40 Reconstruction of Sensor Faults using a Secondary Sliding Mode Observer ............................................. 579
Tan, Chee Pin  Univ. of Leicester  
Edwards, Christopher  Univ. of Leicester

Abstract: This paper proposes two methods for reconstructing sensor faults using sliding mode observers. In both methods, fictitious systems are introduced in which the original sensor fault appears as an actuator fault. The original sensor faults are then reconstructed using a secondary sliding mode observer. For both methods, there are conditions which must be satisfied for successful fault reconstruction. The methods are demonstrated with a chemical process example.

14:00 On an Algebraic and Differential Approach of Nonlinear Systems Diagnosis ............................................. 585
Diop, Sette  CNRS-Supélec  
Martinez-Guerra, R.  CINVESTAV-IPN

Abstract: In a previous communication [4] we proposed a new approach of systems diagnosis which consists of viewing the ability to detect, identify and estimate the fault variable as an observation problem of the latter variable with respect to the input and output online data. Once a fault component is recognized as “diagnosable”, i.e., observable, we then propose an estimation scheme which mainly rely on data numerical differentiation. In the present communication some of the main points of this approach are further discussed. First, the fact that “diagnosability” is the condition where, one would ideally need to virtually completely solve the fault detection, identification and estimation problem is exemplified. Next, we discuss the point that a system may be “diagnosable” without being observable. In that case we cannot simply use standard observers to design the so-called detection filters. Next, we provide further comments on a question that one may ask about the interrelation between practical differentiation schemes and the potential presence of uncertainties in the system dynamics. Finally we further illustrate the approach through two simple nonlinear examples.

14:20 Residual Generation for Uncertain Models ....................... 590
Janati Idrissi, Hicham  Cran-Inpl  
Adrot, Olivier  Cran-Inpl  
Ragot, José  Cran-Inpl

Abstract: The generation of redundancy equations using a parity space technique is a very effective method for fault detection and identification (FDI) in LTI models. However, for physical systems, the assumption of models with invariant parameters is too difficult to be accepted, it is then advisable to propose a method taking into account time parameter fluctuations. In this paper, a technique for parity vector generation in linear models affected by bounded uncertainties, is proposed. In order to eliminate unknown variables, the projection matrix depends on uncertainties. A systematic method for matrix projection computation is developed, leading to an exact expression of the parity vector. Since uncertainties are bounded, residues move in a bounded domain representing the normal operating of the studied system.

14:40 Fault Detection and Isolation for Descriptor Systems using Sliding Mode Observer ............................................. 596
Yeu, Tae Kyeong  Kumamoto Univ.  
Kawai, Shigeyasu  Kumamoto Univ.

Abstract: This paper considers the application of sliding mode observer to the problem of fault detection and isolation for descriptor system with input fault. Further, the reconstruction of the fault is studied through a residual signal as well as fault detection and isolation.
Abstract: Power control is considered as an efficient scheme to mitigate co-channel and multiple-access interference in cellular radio systems. Various approaches have been proposed in recent years to design power control algorithms. We focus on the feedback algorithms that are based on Signal to Interference plus Noise Ratios (SIR-based algorithms). We review SIR threshold approach and then discuss how power control design can be formulated as a decentralized regulation problem. We use a robust control framework to analyze global stability of a network on a single channel. We obtain a sufficient condition, which guarantees that the deviations of the power levels from their optimal values remain bounded, even when the channel gains change, as long as the network stays feasible.

13:00
On the H-Infinity Controller Design for Congestion Control in Communication Networks with a Capacity Predictor (I) .................................................. 598
Quet, Pierre-François
The Ohio-State Univ.
Ramakrishnan, Shanunathan
Rensselaer Polytechnic Inst.
Ozbay, Hitay
The Ohio-State Univ.
Kalyanaraman, Shikumar
Rensselaer Polytechnic Inst.

Abstract: In this paper we investigate the use of the outgoing link capacity information in the H-infinity controller design for rate based flow control in a communication network for the case of a single bottleneck node and a single source. In the previous works in this line of research it was assumed that the controller implemented at the bottleneck node has access to queue length information, and robust controllers were designed for queue management, under time varying time delay uncertainties. Here we assume that, besides the queue information, the controller has access to the outgoing link capacity. On top of the existing robust controller, we use an additional controller term, acting on the capacity information. We investigate optimal ways to design such additional controller term.

13:20
Equilibria for Multiclass Routing in Multi-Agent Networks (I) .................. 604
Altman, Eitan
INRIA
Kameda, Hisao
Univ. of Tsukuba

Abstract: We study optimal static routing problems in open multi-class networks with state-independent arrival and service rates. Our goal is to study the uniqueness of optimal routing under different scenarios. We consider first the overall optimal policy that is the routing policy whereby the overall mean cost of a job is minimized. We then consider an individually optimal policy whereby jobs are routed so that each job may feel that its own expected cost is minimized if it knows the mean cost for each path. This is related to the Wardrop equilibrium concept in a multi-class framework. We finally study the case of class optimization, in which each of several class of jobs tries to minimize the averaged cost per job within that class; this is related to the Nash equilibrium concept. For all three settings, we show that the routing decisions at optimum need not be unique, but that the utilizations in some large class of links are uniquely determined.

13:40
Global Stability of Feedback Power Control
Algorithms for Cellular Radio Networks (I) ............................................. 610
Shoarnejad, Kambiz
UCLA
Paganini, Fernando
UCLA
Pottie, Gregory J.
UCLA
Speyer, Jason L.
UCLA

Abstract: Power control is considered as an efficient scheme to mitigate co-channel and multiple-access interference in cellular radio systems. Various approaches have been proposed in recent years to design power control algorithms. We focus on the feedback algorithms that are based on Signal to Interference plus Noise Ratios (SIR-based algorithms). We review SIR threshold approach and then discuss how power control design can be formulated as a decentralized regulation problem. We use a robust control framework to analyze global stability of a network on a single channel. We obtain a sufficient condition, which guarantees that the deviations of the power levels from their optimal values remain bounded, even when the channel gains change, as long as the network stays feasible.
tion methodology using an example of an air military operation that involves two opposing forces.

13:20

A Hierarchical Approach to Probabilistic Pursuit-Evasion

Games with Unmanned Ground and Aerial Vehicles .......... 634

Kim, H. Jin
Univ. of California, Berkeley

Vidal, René
Univ. of California, Berkeley

Shim, David H.
Univ. of California, Berkeley

Shakernia, Omid
Univ. of California, Berkeley

Sastry, Shankar
Univ. of California, Berkeley

Abstract: We consider the problem of having a team of Unmanned Ground Vehicles (UGV) and Unmanned Aerial Vehicles (UAV) pursue a team of evaders while concurrently building a map in an unknown environment. We cast this problem in a probabilistic game-theoretic framework and consider two computationally feasible pursuit policies: greedy and global-max. We implement this scenario on a fleet of UGVs and UAVs by using a distributed hierarchical system architecture. Finally, we present both simulation and experimental results that evaluate the pursuit policies relating expected capture times to the speed and intelligence of the evaders and the sensing capabilities of the pursuers.

13:40

Initial Study of Autonomous Trajectory Generation for Unmanned Aerial Vehicles ................................................. 640

Prasanth, Ravi K.
Scientific Systems Co., Inc.

Bošković, Jovan D.
Scientific Systems Co., Inc.

Li, Sai-Ming
Scientific Systems Co., Inc.

Mehra, Raman K.
Scientific Systems Co., Inc.

Abstract: Many approaches to trajectory generation for nonlinear systems approximate the feasible set using polytopes. This approximation can be very poor even for simple differentially flat systems. For a large class of flat systems arising in aerospace applications, the feasible flat output set is defined in terms of rational approximations. We use this observation and a well-known approximation methodology using an example of an air military operation that involves two opposing forces.

14:20

Advanced Guidance Law Design based on the Information-Set Concept ......................................................... 652

Emelyanov, Dmitry
Inst. of Control Sciences

Rubinovich, Eugene
Inst. of Control Sciences

Miller, Boris M.
Inst. for Info. Trans. Problem

Abstract: This paper addresses a new approach to guidance algorithm design based on the concept of information sets (IS). As an example of guidance problem, a model of defense scenario against reentering ballistic missile is considered. In this scenario, a maneuverable decelerating target is to be destroyed by a hit-to-kill interceptor outfitted with an IR array seeker and lateral impulse thrusters. The key element of the proposed approach is a description of the “interceptor-target” state system by means of IS. The results of Monte Carlo tests of the developed algorithm are presented.

14:40

Nonlinear Energy-Based Control Method for Aircraft Dynamics .. 658

Akmeleliawati, Rini
Univ. of Melbourne

Marreiros, Iven
Univ. of Melbourne

Abstract: In this paper, we approach control of aircraft dynamics from an energy perspective. The method is based on the passivity-based control technique, and similar to Total Energy Control Systems (TECS). The aircraft dynamics are presented through the energy functions. By modifying these functions, stabilisation and tracking can be achieved. The method is illustrated on an automatic landing system problem for a twin-engine civil aircraft, developed by Group for Aeronautical Research and Technology in Europe (GARTEUR). To deal with the separation of the short-period and the phugoid dynamics, we use ideas from singular perturbation theory. Disturbance rejection and robustness analysis are performed via Monte Carlo simulations. The proposed control laws behave well even under extreme flight conditions.

TuM09

H-Infinity Control and Estimation

Chair: Sayed, Ali H. 
Univ. of California, Los Angeles
Co-Chair: Bentsman, Joseph 
Univ. of Illinois, Urbana-Champaign

13:00

Design of Robust Filters with Improved Robustness Margins via Parameter Scaling ................................................. 664

Terra, Marco Henrique
Univ. of São Paulo, São Carlos

Sayed, Ali H.
Univ. of California, Los Angeles

Abstract: The paper describes a procedure for improving the robustness margins of robust filters via parameter scaling. The scaling parameter is chosen as the square-root factor of the inverse of a positive-definite solution to certain matrix inequalities. This choice is motivated by the desire to generate an estimator dynamics with a stable closed-loop matrix whose maximum singular value is bounded by unity; a step that enhances the robustness of the filters.

13:20

Simultaneous Synthesis of Weights and Controllers in H-Infinity Loop-Shaping .................................................. 670

Lanzon, Alexander 
Georgia Inst. of Tech.

Abstract: In this paper, several steps of the standard H-infinity loop-shaping design procedure are combined into one optimization problem that maximizes the robust stability margin over the loop-shaping weights subject to constraints which ensure that the loop-shape and the singular values/condition numbers of the weights lie in pre-specified regions. Thus, loop-shaping weights, which can be required to have either a diagonal or a non-diagonal structure, and a robustly stabilizing controller are simultaneously synthesized by one algorithm in a systematic way. This approach greatly simplifies the often long and tedious process of designing “good” loop-shaping weights directly and allows the designer to quickly get an idea of what is attainable.
Abstract: The linear discrete-time polynomial optimal feedback control laws are typically obtained via simultaneous solution of two Diophantine equations. In the present work, a number-theory based technique is introduced that permits reduction of the polynomial controller synthesis procedures for the single-input-single-output (SISO) H2 and H-infinity regulation and tracking control problems with a classical feedback structure and plants with arbitrary stability properties to solving a single Diophantine equation. The technique proposed is also used to reduce the solution of the multi-input-multi-output (MIMO) generalized H-infinity control problem.

14:00
Reduced Order Solutions for the Singular H-Infinity Filtering Problem .......................... 682

Abstract: In this paper we consider the finite horizon filtering H-infinity problem for linear time varying systems. This problem has already been solved in the case when the direct feedthrough matrix F between the disturbance and the output vectors is full row rank. Here we consider the case when the problem is singular, i.e. the matrix F is not full row rank. We will show that in this case a reduced observer can be designed in order to meet the desired performance.

14:20
Design of Reduced Order Robust Controller Class for the Systems with Observation Disturbances based on Frequency Conditions .............................................. 684

Abstract: The considered problem consists in the design of controller for the systems when the state disturbances and disturbances in the observation be present. The class of the controllers is given. Theorems solving this problem are stated. A method of reduced-order controller design is presented. Application to mechanical system is given.

14:40
J-Spectral Factorization for General Rational Matrices with Application in Robust Estimation .............................................. 686

Abstract: J-spectral factorization for general discrete rational matrices is considered in this paper. We propose a simple approach based on the Kalman filtering in Krein space. The main idea is to construct a stochastic state space filtering model in Krein space such that the spectral matrix of the output is equal to the rational matrix to be factorized. The spectral factor is then easily derived by using the generalized Kalman filtering in Krein space, which is similar to the H2 spectral factorization. Our approach unifies the treatment of the H2 spectral factorization and the J-spectral factorization. The applications of the derived results in H-infinity and risk-sensitive estimation for both nonsingular and singular systems are demonstrated.
Abstract: The problem of bifurcation control is addressed in this paper. The analysis and feedback design are based on a matrix, whose entries are quadratic invariants of the system; we prove that the stability of equilibria and its control around transcritical and saddle-node bifurcations is solely based on the quadratic invariants, which can be easily found from the quadratic terms in the uncontrollable dynamics. Thus, the approach avoids the computation of nonlinear normal forms.

TuM11
Adaptive Control I
Chair: Goodwin, Graham C.  Univ. of Newcastle
Co-Chair: Pait, Felipe M.  Univ. de São Paulo

13:00
Robust Feasibility in Model Predictive Control: Necessary and Sufficient Conditions ........................................ 728
Kerrigan, Eric C.  Univ. of Cambridge
Maciejowski, Jan M.  Univ. of Cambridge

Abstract: A number of results are derived for analysing the robust feasibility of a given Model Predictive Control (MPC) scheme which ignores model mismatch and/or disturbances during control input computation. The main contribution of this paper is the development of computationally tractable tests for determining the robust feasibility of an MPC controller for linear or piecewise affine systems, where the constraints are given by the union of convex polyhedra and the disturbance acts additively on the state. Practical tests are also presented which allow one to give robust feasibility guarantees for all optimal and sub-optimal MPC control actions.

13:20
On the Design of Direct Adaptive Controllers ......................... 734
Pait, Felipe M.  Univ. de São Paulo

Abstract: Direct adaptive control without the familiar reference models is considered. A framework for design using quadratic cost functions is presented, and corresponding error equations are derived using ideas from linear-quadratic optimal control. Convexity of a suitably defined cost function is studied, indicating that parameter estimation can be accomplished using standard optimization techniques. Conditions for existence of a global minimum are presented, and shown to depend crucially on the time variation of the actual feedback control used in the loop. A good starting point is to take a feedback gain random in intervals, and feed data from these intervals into a standard minimization algorithm.

13:40
Analysis of a Self Tuning Iteration in the Presence of Noise Undermodelling ............................................. 739
Welsh, James S.  Univ. of Newcastle
Goodwin, Graham C.  Univ. of Newcastle

Abstract: Self tuning controllers are widespread throughout industry. These controllers use a variety of techniques and algorithms to determine a set of operating parameters for the control system. Recent research has emphasized the interaction between closed loop experimentation and the closed loop performance. However, an open question exists as to the sensitivity of the resulting control system to these experimental conditions. In this paper we examine the sensitivity with respect to the nature of the disturbance. To highlight the issues we examine the case when no external reference signal is applied and analyse stationary points, if they exist, of a simple self tuning algorithm.

TuM12
Hybrid Systems
Chair: Krogh, Bruce H.  Carnegie Mellon Univ.
Co-Chair: Bullo, Francesco  Univ. of Illinois, Urbana-Champaign

13:00
Modeling and Verification of Hybrid Systems with Clocked and Unclocked Events ..................................... 762
Silva, B. Izaias  Carnegie Mellon Univ.
Krogh, Bruce H.  Carnegie Mellon Univ.

Abstract: We define sampled-data hybrid automata (SDHA), to model systems with clocked and unclocked events. Although clocked events can be modeled in standard hybrid automata by introducing additional continuous state variables, we show in this paper how the SDHA formalism provides a basis for more efficient computational methods for verification. Towards this end, we define a transition system semantics for the SDHA and present a method for computing approximate quotient transition systems using a modification of existing tools for computing reachable sets for hybrid systems. The definitions and the elements of a model checking procedure for SDHA are illustrated with an example.
Abstract: We propose a notion of passivity for hybrid systems. Our work is motivated by problems in haptics and teleoperation where several computer controlled mechanical systems are connected through a communication channel. To account for time delays and to better react to user actions it is desirable to design controllers that can switch between different operating modes. Each of the interacting systems can be therefore naturally modeled as a hybrid system. A traditional passivity definition requires that a storage function exists that is common to all operating modes. We show that stability of the system can be guaranteed even if different storage function is found for each of the modes, provided appropriate conditions are satisfied when the system switches.

Abstract: This paper presents a framework for modeling faults in Sensor-Rich Hybrid Systems. A traditional passivity definition requires that a storage function exists that is common to all operating modes. We show that stability of the system can be guaranteed even if different storage function is found for each of the modes, provided appropriate conditions are satisfied when the system switches.

Abstract: This paper studies decentralized control of uncertain systems. The class of systems considered are stochastic strict-feedback systems which interact through their outputs, and performance is measured with respect to a risk sensitive cost criterion. The unknown nonlinear interconnection terms are assumed to be bounded by some known functions of the outputs of the subsystems, multiplied by some unknown parameters. The controllers designed for each subsystem have access only to the information available on the respective subsystem, and they achieve an arbitrarily small value for the risk-sensitive cost for the overall system. Under this completely decentralized control scheme, all closed-loop signals remain bounded in probability.
Abstract: The idea of minimal cost variance (MCV) control, which is a part of stochastic control based upon constrained cost means and minimized cost variances, may be viewed as a generalization of linear quadratic Gaussian (LQG) and of risk-sensitive control strategies, the former when a cost mean is constrained to be minimum and the latter when the risk-sensitive cost function is considered as a denumerable linear combination of cost cumulants. This paper finds the solutions of the infinite time horizon MCV control problem, a pair of coupled Riccati equations arises. This paper considers the existence and uniqueness of a positive semidefinite solution pair for the steady-state version of these equations, where one entry of the pair corresponds to cost mean, while the other entry of the pair corresponds to cost variance. From this result it is established that the MCV feedback controller stabilizes the closed loop system under special conditions. Furthermore, the algorithm to find the solutions of the coupled algebraic Riccati equations is presented with an example. The MCV control method is illustrated by applying it to simulations of satellite attitude control.

Abstract: We study a linear discrete-time partially observed system by applying it to simulations of satellite attitude control.

Abstract: Numerical examples around the Braess-like paradox such as the original Braess paradox, this behavior occurs only in the case of finely many users and not in the case of infinite number of users in the models examined. This study examines a number of numerical examples around the Braess-like paradox such as above. The numerical examples suggest that the Braess-like paradox is stronger, i.e., the performance degradation of all users in the Brass-like paradox is larger when the system has a higher degree of symmetry and, in particular, is strongest in the completely symmetrical system whereby the parameter values describing each user are identical, which is against our previous intuition.
from dynamic feedback has inspired many mathematical models of this process. In the present work, the ability of four models from the literature to produce reliable oscillations in the face of stochastic disturbances is explored. The results show that there is a trade off of resistance to some disturbances for increased sensitivity to others, which allows an analogy to the Bode Sensitivity Integral to be made.

17:30
System Identification Applied to Spatial and Temporal Propagation of Atrial Activity during Atrial Fibrillation (I) .......... 855
Santos, Susana  Lund Inst. of Tech.
Carlson, Jonas  Lund Univ.
Hertervig, Eva  Lund Univ.
Olsson, Bertil  Lund Univ.
Johansson, Rolf  Lund Inst. of Tech.

Abstract: The purpose of this paper is to apply correlation analysis and system identification methods to study spatial and temporal propagation of atrial activation along coronary sinus (situated in the posterior left part of the heart, in the groove between left atrium and left ventricle) during paroxysmal atrial fibrillation (PAF) using data recorded catheter from 7 different patients. Furthermore, interatrial mechanisms of impulse conduction can be derived due to the position of coronary sinus. This study demonstrated consistency in electrical activity propagation during atrial fibrillation (AF) along coronary sinus in five patients out of six included. Nevertheless, results on direction and speed of propagation depended on the patient. For reference purposes, the method was tried out during sinus rhythm (SR) obtaining the expected high consistency in propagation direction and speed.

17:50
Closed-Loop Control of Analgesia in Humans (I) ............... 861
Gentili, Andrea  ETHZ
Morari, Manfred  ETHZ
Bieniok, Christian  Univ. Hospital Bern
Wymann, Rolf  Univ. Hospital Bern
Schneider, Thomas W.  Univ. Hospital Bern

Abstract: We designed a feedback controller for the automatic delivery of analgesics drugs during surgery. The manipulated variable in the control system is the infusion rate of the opiate alfentanil, administered intravenously through a Computer Controlled Infusion Pump (CCIP). The controller regulates two outputs: the patient’s Mean Arterial Pressure (MAP) and the drug concentrations in the plasma. Maintaining MAP within acceptable physiological ranges minimizes the patient’s stress response to surgical stimulation. Tracking plasma concentrations offers the possibility of titrating analgesic drugs to alternative, qualitative signs of inadequate analgesia. Since analgesic drug concentrations can not be measured on-line, a pharmacokinetic model is used to predict the second output of the control system. An explicit Model Predictive Controller was designed and implemented in our real-time platform. Artifact tolerant control schemes were introduced to prevent the system from harmful behaviour in the presence of MAP artifacts. The closed-loop controller was tested during surgical procedures in humans. The results are presented and discussed.

18:10
An Investigation of Multivariable Models for Human Response to Anesthesia (I) ....................... 867
Lin, Hui-Hung  Univ. of Illinois, Urbana-Champaign
Beck, Carolyn L.  Univ. of Illinois, Urbana-Champaign
Nedumgottil, Joseph  Univ. of Illinois, Urbana-Champaign
Bloom, Marc  New York Univ.

Abstract: The use of linear multi-input multi-output models for describing the relations between input anesthetic agents and surgical stimuli to the patient endpoint variables of heart rate, mean arterial pressure, and EEG signals are investigated. Comparisons are made to pharmacokinetic-pharmacodynamic compartment models.

18:30
Stability and Reachability Analysis of a Hybrid Model of Luminescence in the Marine Bacterium Vibrio Fischeri .......... 869
Belta, Calin  Univ. of Pennsylvania
Schug, Jonathan  Univ. of Pennsylvania
Dang, Thao  Univ. of Pennsylvania
Kumar, Vijay  Univ. of Pennsylvania
Pappas, George J.  Univ. of Pennsylvania
Rubin, Harvey  Univ. of Pennsylvania
Dunlap, Paul  Univ. of Michigan

Abstract: This paper addresses the mathematical modeling and analysis of the quorum sensing system found in unicellular bacteria that exhibit bioluminescence. The luminescence is governed by the expression of genes in the cell, which in turn is controlled by the density of cells in a population. The paper illustrates the application of standard tools in control theory and some recent tools in hybrid systems to the quorum sensing system, and demonstrates that bioluminescence can be modeled and understood as the output of a switched dynamical system.
controller that input-to-state stabilizes an approximate discrete-time model of a nonlinear continuous-time plant with disturbances would also input-to-state stabilize (in an appropriate sense) the exact discrete-time plant model.

17:30
Power Formulations of Input to State Stability Notions .............. 893
Angeli, David
Univ. di Firenze
Nesić, Dragan
Univ. of Melbourne

Abstract: Several new characterizations of input-to-state stability and integral input-to-state stability are presented. The new characterizations involve estimates that are given in terms of powers of input signals and/or states.

17:50
Almost Global Stability of Phase Locked Loops ...................... 899
Rantzer, Anders
Lund Inst. of Tech.

Abstract: Many control systems have a global dynamical behavior that in addition to a desired stable equilibrium has one or more unstable equilibria or other exceptional trajectories. Typical examples of such systems are pendulums or so called phase locked loops. The objective of this paper is to compare two different methods for analysis of the global behavior in such systems. The first method is LaSalle's invariant set theorem. The second method is the criterion for almost global stability recently introduced by the author. Both methods can be used to prove that for almost all initial states the trajectory tends toward the stable equilibrium. However, the robustness properties of the two criteria turn out to be different.

18:10
Bounded-Input Bounded-Output Stability of a Class of Lasers ... 901
Shahruz, Shahram M.

Abstract: In this note, a large class of lasers represented by planar nonlinear ordinary differential equations, known as the rate equations, are considered. It is shown that the outputs of the lasers are bounded when bounded inputs (currents) are applied to them.

TuP03
Sliding Mode Control
Chair: Yu, Xinghuo
Central Queensland Univ.
Co-Chair: Misawa, Eduardo
Oklahoma State Univ.

16:30
Sliding Mode Control of a Single-Phase AC/DC/AC Converter .... 903
Blanco, Yann
LAIL-UPRESA CNRS
Gouaisbaut, Frédéric
LAIL-UPRESA CNRS
Perruquetti, Wilfrid
LAIL-UPRESA CNRS
Borne, Pierre
LAIL-UPRESA CNRS

Abstract: This paper presents a new method to design a sliding mode controller for a wide class of perturbed nonlinear systems. The system is first transformed into the regular form. The non-matching part of dynamics of the system are then written under a polytopic formulation. At this stage, linear/nonlinear sliding surfaces are used to provide the asymptotic stability of the origin. The proposed approach relies on an appropriate prediction error. It is shown that, in practice, successful performance of the basic sliding controller requires adequate filtering of the measured signal. A particular Kalman-filter, independent of the plant itself, is shown to yield very satisfactory experimental results obtained on a 1 d.o.f. helicopter-like mechanism.

18:10
Experimental Results on Smooth Sliding Control of Uncertain Systems .............................................. 928
Peixoto, Alessandro Jacud
Federal Univ. of Rio de Janeiro
Lizarraide, Fernando
Federal Univ. of Rio de Janeiro
Hsu, Liu
Federal Univ. of Rio de Janeiro

Abstract: This paper addresses the design, implementation and experimental evaluation of a sliding control scheme for uncertain systems which is free of chattering and results in smooth control signals. The proposed approach relies on an appropriate prediction error. It is shown that, in practice, successful performance of the basic sliding controller requires adequate filtering of the measured signal. A particular Kalman-filter, independent of the plant itself, is shown to yield very satisfactory experimental results obtained on a 1 d.o.f. helicopter-like mechanism.
Abstract: In this paper, dynamic sliding surface design is presented to avoid the chattering effects, which are always associated with practical implementations of variable structure control. We propose the use of compensator dynamics in sliding mode through a class of switching surfaces which has the interpretation of linear operators. This approach originally proposed by Young and Ozguner (1993) as dynamic sliding surface design is shown to be related to design of high order sliding mode controllers.

**TuP04**

**Marine Applications**

Chair: Gravdahl, Jan Tommy  
Co-Chair: Egeland, Olav  
Norwegian Univ. of Sci. & Tech.

16:30  
**Way-Point Tracking Control of Ships**  
Pettersen, Kristin Y.  
Lefeber, Erjen  
Norwegian Univ. of Sci. & Tech.  
Eindhoven Univ. of Tech.

Abstract: The paper considers way-point tracking control of ships using yaw torque control. A full state feedback control law is developed using a cascaded approach, and proved to globally asymptotically stabilize the heading and the cross-track error of the ship. Simulation results are presented.

**TuP05**

**Delay Systems**

Chair: Gu, Keqin  
Southern Illinois Univ., Edwardsville  
Co-Chair: Pepe, Pierdomenico  
Univ. of L’Aquila

17:10  
**Active Depth Control of Towed Cables in 2D**  
Türkylmaz, Yılmaz  
Egeland, Olav  
Norwegian Univ. of Sci. & Tech.

Abstract: A two-dimensional dynamic model for active depth control of a towed cable is presented. This is accomplished by incorporating the dynamics of a foil into the cable dynamics. The foil is attached at the cable-end which is towed at a commanded speed. A linear passive control law is applied to the foil-cable system. Solutions are numerically approximated and results of simulations for different depth-keeping tasks are presented.

**17:30**  
**The Hough Transform for Long Chirp Detection**  
Sun, Yan  
Willett, Peter  
Univ. of Connecticut

Abstract: The online detection of a very long and weak chirp signal is studied. The signal has an extremely slowly-decreasing frequency and is corrupted by white Gaussian noise, and also possibly by powerful tones. Four methods (the Hough transform, multiple frequency tracker, Page’s test and EM algorithm) are explored. It is found that the Hough transform (HT) detector appears to be most suitable given constraints on computational load and detectability. It is compared with the GLRT, which is assumed to be optimal as possible. Applying a suitable threshold for the HT can increase the speed dramatically while preserving the performance. We have found that for the HT detector both dithering (taking varied frequency shifts for FFTs) and increasing the FFT length can reduce the minimum detectable frequency slope with nearly no additional computation.

17:50  
**Combined Trajectory Tracking and Path Following: An Application to the Coordinated Control of Autonomous Marine Craft**  
Encarnação, Pedro  
Pascoal, Antonio  

Abstract: The paper presents a solution to the problem of combined trajectory tracking and path following system design for autonomous marine craft. This problem is motivated by the practical need to develop control systems for marine craft that can yield good trajectory tracking performance while keeping some of the desired properties normally associated with path following. The solution described builds on and extends previous work by Hindman and Hauser on so-called maneuver modified trajectory tracking. An application is made to the problem of designing a control system for the coordinated operation of an autonomous surface craft (ASC) and an autonomous underwater vehicle (AUV). Simulations with nonlinear models of an underactuated marine craft and a fully actuated underwater vehicle illustrate the performance of the control system derived.

18:10  
**Dynamic Gravity I/O Coupling and Control of Under-Actuated Systems**  
Galindo, Rene  
Enriquez, Carlos  
Univ. of Nuevo Leon

Abstract: A control strategy for Euler-Lagrange (E-L) Under-Actuated (U-A) MIMO Linear Systems is proposed. For Dynamic Gravity I/O Decoupling (DGD) Systems a coupling transformation is presented. Asymptotic stability is guaranteed and the regulation control problem is solved. Simulation results are given.

**TuP06**

**Internally Stable Realization of Finite-Dimensional Approximation of a Delay for Gain Scheduling**  
Suyama, Koichi  
Tokyo Univ. of Mercantile Marine
cellation in realizing directly the approximation error, this paper presents a method for obtaining its internally stable realization using finite Laplace transforms.

17:10
Refined Discretized Lyapunov Functional Method for Systems with Multiple Delays
Gu, Keqin
Southern Illinois Univ., Edwardsville

Abstract: The previously proposed discretized Lyapunov functional method for systems with multiple delays is refined. The main ideas used are variable elimination and integral inequality. The resulting new stability criterion is simpler. Numerical examples indicate that the new method is much less conservative for a given discretization mesh. In most applications, it appears that a most coarse discretization mesh compatible with the delays is sufficient.

17:30
H-infinity Control for Preview and Delayed Strategies
Kojima, Akira
Tokyo Metro. Inst. of Tech.
Ishijima, Shintaro
Tokyo Metro. Inst. of Tech.

Abstract: Explicit formulas on full-information H-infinity control problem are obtained for a broader class of systems, which covers H-infinity preview control and H-infinity control of delay systems. The solvability is characterized by finite-dimensional operation and the control law is analytically given based on the solution to matrix Riccati equation. It is also shown that the formulas provide analytic representation of LQ control law for multiple input delay systems.

17:50
Some Results on Adaptive Tracking for a Class of Nonlinear Time-Delay Systems
Pepe, Pierdomenico
Univ. degli Studi dell’Aquila

Abstract: In this paper the tracking control problem is addressed for a class of nonlinear delay systems with some unknown parameters. Such a problem is solved in the case that the nonlinear delay system has some geometrical properties, that is full delay relative degree and no unstable internal dynamics when the output and its derivatives are taken bounded by the control law, such a particular minimum phase nonlinear delay systems class. It is supposed moreover that the unknown parameters do not affect the output and its derivatives until n-1, where n is the dimension of the state euclidean vector. As usual, the control law here found depends on the state variables in present and past times, and on the control law itself in past times too. Standard Lyapunov methodology is here used to find out the adaptive control law and the dynamics of estimated parameters. It is proved that when the found control law is applied to the system, the tracking error asymptotically goes to zero. The case of unknown delay is considered too. An upper bound for the error in delay knowledge is found which can be tolerated when controlling the system by recent methodologies based on standard nonlinear analysis. Simulation results are here shown for a prey-predator Lotka Volterra system.

18:10
An LMI Approach to Robust Stability of Linear Delayed Systems
Ni, Mao-Lin
Nanyang Tech. Univ.
Er, Meng Joo
Nanyang Tech. Univ.
Chu, Yun-Chung
Nanyang Tech. Univ.

Abstract: In this paper, a new stability condition is proposed for linear systems with time-varying perturbations and time-delays. By using the linear matrix inequality (LMI) technique, we give a method for determining the stability bound. Compared with existing results, this approach is less conservative.

16:30
Inversion based Fault Detection and Isolation
Szigel, Ferenc
Univ. of Los Andes, Merida
Vera, Carmen E.
Cent. Univ. of Venezuela, Caracas
Bokor, Jozsef
Hungarian Academy of Sci.
Edelmayer, Andras
Hungarian Academy of Sci.

Abstract: In this paper the design of detection filters for fault detection and isolation in linear systems by means of dynamic inversion is addressed. This approach is based on the left inverse and arrives at detector architectures whose outputs are the fault signals while the inputs are the measured system inputs and outputs and possible their time derivatives. This will make not only the detection and isolation but also the estimation of the fault signals possible.

16:50
H-Infinity Optimization of Luenberger State Observers and its Application to Fault Detection Filter Design
Ibaraki, Soichi
Kyoto Univ.
Suryanarayanan, Shashikanth
Univ. of California, Berkeley
Tomizuka, Masayoshi
Univ. of California, Berkeley

Abstract: This paper considers H-infinity optimization of Luenberger state observers. The conventional formulation of H-infinity-optimal state observers does not allow the augmentation of dynamic performance weightings in the optimization objective, since it makes the problem a nonconvex optimization problem. We propose an algorithm to locally solve an H-infinity optimization problem of Luenberger state observers by transforming the problem into an H-infinity optimization problem of a static output feedback controller. The proposed approach offers an intuitive and efficient way to explicitly design the estimation error dynamics of the observer in the frequency domain. As an application example, the proposed approach is applied to the tuning of fault detection filters for lateral control of automated passenger vehicles. Numerical simulations are conducted to show the effectiveness of the proposed tuning method.

17:10
Multi-Fault Detection of Systems with Bounded Uncertainties
Janati Idrissi, Hicham
CRAN-INPL
Adrot, Olivier
CRAN-INPL
Ragot, José
CRAN-INPL

Abstract: Fault detection in linear static models with uncertain parameters is studied in this paper. Using a parity space technique, a method based on the bounding approach is proposed. Several types of structured faults may affect a physical system and in this context, two cases are distinguished: -the structured fault is a priori identified as a region in the parameter space, by considering the physical knowledge on the studied system. The corresponding procedure is called supervised. -the second case corresponds to a fault which has an unknown structure. The corresponding procedure is called unsupervised fault. In this article, a strategy consists first in characterizing various fault structures and then in establishing a fault detection and identification (FDI) procedure by using interval analysis.

17:30
A Frequency Domain Approach for Fault Detection
Fong, Kin F.
Natl. Univ. of Singapore
Loh, Al P.
Natl. Univ. of Singapore

Abstract: This paper considers the use of online frequency response estimates for change detection, which serves as a preliminary for fault detection and diagnosis. In general, a finite time frequency response estimator will always show some deviations from its nominal response even when a change has not occurred. The question we address is when does a fault detector decide if a
change has occurred based on these estimates. The approach taken is based on statistical decision theory. When deviations from the nominal frequency response are detected, the detector decides with good statistical accuracy, whether a change has indeed occurred. The design is based on the Neymann-Pearson criterion, which allows for the specification of a constant false alarm rate. The performance of the detector and some practical considerations are discussed. Simulations are used to illustrate the performance and properties of the detector.

17:50
Controller Failure Time Analysis for
H-Infinity Control Systems ........................................... 1029
Zhai, Guisheng  Wakayama Univ.
Chen, Xinkai  Kinki Univ.
Takai, Shigemasa  Wakayama Univ.
Yasuda, Kazunori  Wakayama Univ.

Abstract: In this paper, we consider a controller failure time analysis problem for linear time-invariant H-infinity control systems. By using a piecewise Lyapunov function, we show that if the unavailability rate of the designed controller is smaller than a specified constant and the average time interval between controller failures (ATBCF) is large, then the system achieves a reasonable weighted H-infinity disturbance attenuation level, and the weighted H-infinity disturbance attenuation approaches normal H-infinity disturbance attenuation if the ATBCF is sufficiently large.

TuP07
Control and Networks I
Chair: Kabamba, Pierre.  Univ. of Michigan
Co-Chair: Caines, Peter E.  McGill Univ.

16:30
On a Class of Singular Stochastic Control Problems Arising
in Communications and their Viscosity Solutions ................... 1031
Caines, Peter E.  McGill Univ.
Malhamé, Roland P.  École Polytech. de Montréal

Abstract: This paper considers a class of optimization problems arising from wireless communication systems. We show the existence and uniqueness of the optimal control laws, and the associated Hamilton-Jacobi-Bellman (HJB) equations are investigated. It turns out that the value function is a unique viscosity solution of the HJB equation in a certain function class. The optimization problem with state constraints is also considered.

16:50
Stochastic Power Control for Wireless Systems:
Classical and Viscosity Solutions ..................................... 1037
Huang, Minyi  McGill Univ.
Charalambous, Charalambos D.  Univ. of Ottawa
Malhamé, Roland P.  École Polytech. de Montréal

Abstract: This paper considers power control for log-normal fading channels. A rate based power set point control model and an associated performance measure are introduced. Within this framework, a stochastic optimal power control law exists and the associated value function satisfies a degenerate HJB equation in a viscosity solution sense. The HJB equation is approximated by a uniformly parabolic second order equation which has a classical solution and a suboptimal control is derived. The suboptimal control is more realistic for practical implementation.

17:10
Feedforward Control of Data Rate in Wireless Networks ...... 1043
Kabamba, Pierre T.  Univ. of Michigan
Meerkov, Semyon M.  Univ. of Michigan
Stark, Wayne E.  Univ. of Michigan
Tang, Choon Y.  Univ. of Michigan

Abstract: This paper develops a feedforward approach to data rate control in wireless networks. The development is based on designing an optimal, but non-causal, controller and its subsequent “causalification”, which results in a practical, implementable controller, driven by an estimate of the bit error probability. It is shown that this controller leads to a minimum of 5%-85% increase in average throughput without additional power utilization, as compared with fixed data rate operation.

17:30
Stochastic Power Control for Short-Term Flat Fading
Wireless Networks: Almost Sure QoS Measures .................... 1049
Charalambous, Charalambos D.  Univ. of Ottawa
Denic, Stoian Z.  Univ. of Ottawa
Djouadi, Seddik M.  Univ. of Arkansas
Menemenlis, Nickie  McGill Univ.

Abstract: The power control of wireless networks is formulated using a stochastic optimal control framework, in which the evolution of the channel is described by stochastic differential equations. Under this scenario, average and probabilistic Quality of Service (QoS) measures are introduced to evaluate the performance of any control strategy, while a solution of the stochastic optimal power control is obtained through pathwise optimization. The pathwise optimization can be solved using linear programming techniques. Several optimization problems are identified.

17:50
Partially Observed Stochastic Shortest Path Problem –
Application to Sequential Paging in Cellular Networks .......... 1053
Singh, Sumeetpal  Univ. of Melbourne
Krishnamurthy, Vikram  Univ. of Melbourne

Abstract: Polling a roaming mobile user in a cellular network to determine its location is called paging and it requires the use of limited wireless resources. In this paper, we formulate the paging problem as an optimal sequential search problem for a Markovian target and show that the resulting problem is an instance of a Partially Observed Stochastic Shortest Path (POSSP) problem. Using the theory of POSSP problems, we propose optimal and suboptimal paging algorithms with performance bounds. We then propose a scalable sequential paging architecture for polling multiple mobile stations simultaneously using a finite number of paging resources.

TuP08
Cooperative and Formation Control
Chair: Polycarpou, Marios M.  Univ. of Cincinnati
Co-Chair: Kapila, Vikram  Polytechnic Univ.

16:30
Semi-Globally Stable Formation Flight
Control Design in Three Dimensions ................................. 1059
Božković, Jovan D.  Scientific Systems Co., Inc.
Li, Sai-Ming  Scientific Systems Co., Inc.
Mehra, Raman K.  Scientific Systems Co., Inc.

Abstract: In this paper we develop a semi-globally stable nonlinear formation flight control algorithm for a leader-follower configuration in three dimensions. The objective is to maintain the relative distances between the vehicles close to their desired values. It is shown that the conditions under which the control law is well-defined depends on the choice of the reference frame and control inputs. These conditions in the case when the design is carried out in the body frame of the follower are more restrictive than those encountered in the case of the body frame of the leader. The control algorithm is based on a
new error formulation in the inertial frame. A detailed analysis and
control design procedure are presented.

16:50
On Controlling Aircraft Formations ........................................... 1065
Fierro, Rafael  Oklahoma State Univ.
Belta, Calin  Univ. of Pennsylvania
Desai, Jaydev P.  Drexel Univ.
Kumar, Vijay  Univ. of Pennsylvania

Abstract: We describe a framework for controlling a group of un-
manned aerial vehicles (UAVs) flying in close formation. We first
present a nonlinear dynamical model which includes the induced
rolling moment by the lead aircraft on the wing of the following air-
craft. Then, we outline two methods for trajectory generation of the
leading aircraft, based on interpolation techniques on the Euclid-
ean group, SE(3). Two formation controllers that allow each aircraft
to maintain its position and orientation with respect to neighboring
UAVs are derived using input-output feedback linearization. Nu-
merical simulations illustrate the application of these ideas and
demonstrate the validity of the proposed framework.

17:10
Optimal Collision Avoidance and Formation
Switching on Riemannian Manifolds ....................................... 1071
Hu, Jianghai  Univ. of California, Berkeley
Sastry, Shankar  Univ. of California, Berkeley

Abstract: In this paper the problems of optimal collision avoidance
and optimal formation switching for multiple agents moving on a
Riemannian manifold are studied. It is assumed that the underlying
manifold admits a group of isometries, with respect to which the
Lagrangian function is invariant. Reduction method is used to de-
rive optimality conditions for the solutions. Some examples are
presented.

17:30
Stability Analysis of One-Dimensional
Asynchronous Mobile Swarms .............................................. 1077
Liu, Yang  Ohio State Univ.
Passino, Kevin M.  Ohio State Univ.
Polycarpou, Marios M.  Univ. of Cincinnati

Abstract: Coordinated dynamical swarm behavior occurs when cer-
tain types of animals forage for food or try to avoid predators.
Analogous behaviors can occur in engineering systems (e.g., in
groups of autonomous mobile robots or air vehicles). In this paper,
we characterize swarm “cohesiveness” as a stability property and
provide conditions under which an asynchronous mobile swarm
following (pushed by) an “edge-leader” can maintain cohesion dur-
ing movements even in the presence of sensing delays and asyn-
chronism. Such stability analysis is fundamental to understanding
the coordination mechanisms for groups of autonomous vehicles or
robots where inter-member communication channels are less than
perfect.

17:50
Fuel Optimal Maneuvers for Multiple Spacecraft Formation
Reconfiguration using Multi-Agent Optimization ........................ 1083
Yang, Guang  Polytechnic Univ.
Yang, Qingsong  Case Western Reserve Univ.
Kapila, Vikram  Polytechnic Univ.
Palmer, Dan  John Carroll Univ.
Vaidyanathan, Ravi  Orbital Research, Inc.

Abstract: In this paper, generation of fuel optimal maneuvers for
spacecraft formation reconfiguration is modeled and analyzed as a
multi-agent optimal control problem. Multi-agent optimal control is
quite different from the traditional optimal control for single agent.
Specifically, in addition to fuel optimization for a single agent, multi-
agent optimal control necessitates consideration of task assign-
ment among agents for terminal targets in the optimization proc-
ess. In this paper, we develop an efficient hybrid optimization algo-

18:10
Adaptive Learning Control for Spacecraft Formation Flying ... 1089
Wong, Hong  Polytechnic Univ.
Pan, Haizhou  Polytechnic Univ.
de Queiroz, Marcio S.  Louisiana State Univ.
Kapila, Vikram  Polytechnic Univ.

Abstract: This paper considers the problem of spacecraft formation
flying in the presence of periodic disturbances. In particular, the
nonlinear position dynamics of a follower spacecraft relative to a
leader spacecraft are utilized to develop a learning controller which
accounts for the periodic disturbances entering the system model.
Using a Lyapunov-based approach, a full state feedback control
law, a parameter update algorithm, and a disturbance estimate rule
are designed which facilitate the tracking of given reference trajec-
tories in the presence of unknown spacecraft masses. Illustrative
simulations are included to demonstrate the efficacy of the pro-
posed controller.

18:30
Analysis of Formation Flying Control
of a Pair of Nano-Satellites ................................................. 1095
Veres, Sándor M.  Univ. of Southampton
Gabriel, Steve B.  Univ. of Southampton
Rogers, Eric  Univ. of Southampton
Mayne, David Q  Imperial College

Abstract: This paper gives an analysis and provides implementable
solutions for constrained control problems of stabilization and ma-
neuver control of two nano-satelites. The methodology provides
solutions under various constraints of propulsion and differential
drag control: magnitude constraints, disturbances and measure-
ment errors are taken into account. The methods are illustrated in
simulation of a realistic nano-satellite pair.
analyze the worst-case gain from disturbances to errors of a system subjected to 2 real, scalar uncertainties. The 2 scalar uncertainties are typically normalized so that they have absolute value less than or equal to one. In the parameter space, this constrains the uncertainties to lie in the unit cube. The contribution of this paper is that we also assume that the 2 scalar parameters are correlated. This correlation is represented by an additional offset rectangle constraint in the parameter space. The motivation for this problem is to use our knowledge of parameter correlation to remove some of the conservativeness in the standard performance analysis.

17:10
Duality in Robust Control: Uncertainty vs. Controller .......... 1113
Ghulchak, Andrey
Lund Inst of Tech.

Abstract: To find a controller that provides the maximal stability margin to an LTI system under rank-one perturbations is a quasi-convex problem. In this paper, the dual quasi-convex problem is obtained, using the convex duality arguments in the Hardy space H-infinity. It is shown that the dual problem can be viewed as a minimization of a "length" of uncertainties that destabilize the system. Several examples establishing a connection with such classical results as the corona theorem and the Adamyan-Arov-Krein theorem are considered.

17:30
A Robust Solver using a Continuation Method for Nevanlinna-Pick Interpolation with Degree Constraint .......... 1119
Nagamune, Ryozo
Royal Inst of Tech.

Abstract: This paper is concerned with computational aspects in solving the Nevanlinna-Pick interpolation problem with degree constraint tackled by Byrnes, Georgiou and Lindquist. The previous solver for obtaining a positive real interpolant with a bounded degree sometimes reveals numerical difficulties caused by the inaccuracy of spectral factorization and the ill-conditioning of a system of linear equations. The solver is modified so that it does not have these drawbacks. The modified approach is based on a continuation method with predictor-corrector steps. The proposed solver turns out to be quite efficient and numerically robust.

17:50
f. Controller Design with Frequency Domain Constraints:
Finite Dimensional Approximation of Dual Problems .......... 1125
Ohta, Yoshito
Osaka Univ.

Abstract: This paper studies the ell_1 controller design with frequency domain constraints using the duality theorem. For this class of problems it was shown in the literature that the standard finite dimensional approximation of the dual problem in the space of finite support sequences may not converge to the optimal value. In this paper, a condition assuring no duality gap is studied, and a way to approximate the dual problem with arbitrary tolerance by finitely many variables is proposed.

18:10
Robust Time Optimization for Linear Systems: Finite Uncertainty Set Case ............................................. 1131
Boltianski, Vladimir
CIMAT Poznyak, Alexander
CINVESTAV-IPN

Abstract: A linear optimization problem with unknown parameters from a given finite set is tackled. A compact, convex terminal body M is assumed to be given. The problem is to find the robust time-optimal control transferring a given initial point to M for all unknown parameters in a shortest time. The Maximum Principle for this minimax problem is formulated. It gives a necessary and sufficient condition of robust optimality. Under natural conditions, the existence and uniqueness of robust optimal controls are proven when the resource set is a convex polytope. Several illustrating examples, including a bang-bang robust optimal control, considered in details.
the considered plants are: a robotic arm with flexible joint, a synchronous generator connected to an infinite bus, and a flexible transmission system.

17:50
PD Control of Robot with Velocity Estimation and Uncertainties Compensation .......................... 1162
Yu, Wen CINVESTAV-IPN
Li, Xiaou CINVESTAV-IPN

Abstract: In this paper the normal PD control of the two-link robot is modified in following two ways: (1) A high-gain observer is applied to estimate the joint velocities; (2) The RBF neural networks are used to compensate the gravity and friction. The new PD control may overcome the two drawbacks of the normal PD control. The main contributions of this paper are: a new proof of high-gain observer gives a direct relation between observer gain and observer error. Based on Lyapunov-like analysis, we prove the stability of the closed-loop system if the weights of RBF have certain learning rules and the observer is faster enough.

18:10
An Experimental Comparison between Several Pneumatic Position Control Methods ............................................ 1168
Chillari, Sebastiano Univ. degli Studi di Catania
Guccione, Salvatore Univ. degli Studi di Catania
Muscato, Giovanni Univ. degli Studi di Catania

Abstract: In this paper an experimental comparison is made between six different techniques to control the position of a pneumatic actuator. Six different reference signals have been tested on each control technique. The methods considered are: A) PID, B) Fuzzy, C) PID with pressure feedback, D) Fuzzy with pressure feedback, E) Sliding mode and F) Neuro-Fuzzy control. In the last method, proposed by the authors, the differential pressure sensor has been replaced by a neural network-based estimator. Details of each control method and the results obtained are given and finally a global comparison is made with several critical considerations.

18:30
Model Inversion for a Particular Class of Nonlinear Non-Minimum Phase Systems: An Application to the Two-Link Flexible Manipulator .......................... 1174
Benesman, Mouhacine IRCCyN
Le Vey, Georges IRCCyN

Abstract: The problem addressed here concerns the output trajectory tracking for a particular (but not restrictive) class of nonlinear non-minimum phase systems, namely, systems described by Lagrange equations of motion. It is well known that, in the non-minimum phase case, the direct application of classical input-output inversion procedure fails, due to the unacceptable nature of internal dynamics. Thus the main contribution of this work concerns the inversion of those internal dynamics. Inversion yielding a bounded state permits then to achieve exact output tracking (or at least asymptotic tracking), without control saturation. The inversion scheme deals equally with systems having either hyperbolic or non-hyperbolic equilibrium points of zero dynamic. This is a direct consequence of a different formulation of the stable inversion problem. The nonlinear internal dynamics are inverted, without any non-causal computation and are fully based on nonlinear terms, without local dynamic linearization. The performance of this approach is demonstrated through its application to the tip trajectory tracking for a two-link flexible robot manipulator. We have chosen initial non-hyperbolic, zero dynamics equilibrium point, to prove the efficiency of this inversion method, when dealing with this special case, which is a well known obstruction to applying available stable techniques.
Abstract: Explicit solutions to constrained linear MPC problems can be obtained by solving multi-parametric quadratic programs (mp-QP) where the parameters are the components of the state vector. We study the properties of the polyhedral partition of the state-space induced by the multiparametric piecewise linear solution and propose a new mp-QP solver. Compared to existing algorithms, our approach adopts a different exploration strategy for subdividing the parameter space, avoiding unnecessary partitioning and QP problem solving, with a significant improvement of efficiency.

On Some Aspects of Discrete Equivalents of Differential Linear Repetitive Processes

Abstract: Differential linear repetitive processes are a distinct subclass of 2D continuous-discrete linear systems which pose problems which cannot (except in a few very restrictive special cases) be solved by direct application of standard, termed 1D here, systems theory and hence by direct use of a large number of the currently available tools for computer aided analysis/design. One such area is the construction of discrete approximations to their dynamics. In this paper we investigate some problems which arise during the discretization of differential linear repetitive processes and develop solutions to them.

Robust Discrete-Time Iterative Learning

Abstract: This paper is concerned with the initial shift problem of iterative learning control for a class of nonlinear discrete-time systems with well-defined relative degree. The information from several previous operation cycles is used and the learning algorithm is shown robust with respect to initial shifts. In the presence of an initial shift, the converged output trajectory is assessed as the iteration number increases. Initial rectifying action is an alternative approach to address the initial shift problem and is proved to ensure complete tracking with a transitional trajectory.

Abstract: A decentralized hybrid intersection control method can improve the performance of traffic networks. A simulation example is given in this paper, in which a finite state machine contains five states to represent different traffic conditions. A decentralized hybrid intersection control is concluded as a decentralized hybrid intersection control method can improve the performance of traffic networks.
18:10
Decidable and Semi-Decidable Controller Synthesis for Classes of Hybrid Systems .......................... 1243
Vidal, René  Univ. of California, Berkeley
Schaffert, Shawn  Univ. of California, Berkeley
Shakernia, Omid  Univ. of California, Berkeley
Lygeros, John  Univ. of California, Berkeley
Sastry, Shankar  Univ. of California, Berkeley

Abstract: In this paper, we study classes of discrete-time hybrid systems for which the classical algorithm for computing the maximal controlled invariant set and the least restrictive controller is computable and guaranteed to terminate in a finite number of iterations. We show how the algorithm can be encoded using quantifier elimination, which leads to a semi-decidability result for definable hybrid systems. For discrete time linear systems with linear constraints that are either controllable or nilpotent and have bounded disturbances, we show that the controlled invariant algorithm terminates in a number of iterations which is at most the dimension of the state space. Both in the hybrid and in the linear case, our results are much more general than the corresponding ones for continuous time systems. Finally we show that for linear systems with ellipsoidal constraints, an approximated solution can be obtained using robust convex programming. We provide an example showing that our algorithm gives better estimations than other ellipsoidal methods and is more efficient than the exact method for linear constraints.

TuP13
Stochastic Systems III
Chair: Pan, Zigang  Univ. of Cincinnati
Co-Chair: Grimble, Michael  Univ. of Strathclyde

16:30
Discrete-Time Indefinite LQ Control with State and Control Dependent Noises ............................. 1249
Rami, Mustapha Ait  Chinese Univ. of Hong Kong
Chen, Xi  Chinese Univ. of Hong Kong
Zhou, Xun Yu  Chinese Univ. of Hong Kong

Abstract: This paper deals with the discrete-time stochastic LQ problem involving state and control dependent noises, whereas the weighting matrices in the cost function are allowed to be indefinite. We show that the well-posedness and the attainability of the LQ problem are equivalent. Furthermore, the set of all optimal controls is identified in terms of the solution to a generalized difference Riccati equation.

16:50
Optimal Policies for Some n-Dimensional Singular Stochastic Control Problems .......................... 1251
Kruk, Lukasz  Maria Curie-Skłodowska Univ.

Abstract: We consider a singular stochastic control problem with a radially symmetric running cost. We show that the value function is smooth, the non-action region is a ball and the problem has an explicit solution in terms of power series. Also, for a singular ergodic control problem with the class of admissible processes constrained to Brownian motions reflected normally at the boundary of some open, connected Caccioppoli set, we show existence, regularity and basic properties of optimal domains using a geometric measure-theoretic approach.

17:10
On Maximal Solution of Infinite Dimensional Perturbed Riccati Differential Equations Arising in Stochastic Control ................................. 1257
Baczynski, Jack  Natl. Lab for Sci. Computing
Fragoso, Marcelo D.  Natl. Lab for Sci. Computing

Abstract: Finding the maximal solution for a certain class of infinite dimensional perturbed Riccati algebraic equations is the main concern of this paper. In addition, we provide a sufficient and necessary condition for stochastic stability. Also, we obtain necessary conditions which unveil some structural properties. Besides the interest in its own right, this class of equations turns out to be essential, for instance, when dealing with linear systems with infinite countable Markov jump parameters or infinite dimensional linear time-invariant systems with state-dependent noise.

17:30
Indefinite Stochastic Linear Quadratic Control and Generalized Differential Riccati Equation .................. 1263
Rami, Mustapha Ait  Chinese Univ. of Hong Kong
Moore, John B.  Australian Natl. Univ.
Zhou, Xun Yu  Chinese Univ. of Hong Kong

Abstract: We consider a stochastic linear–quadratic (LQ) problem with possible indefinite cost weighting matrices for the state and the control. An outstanding open problem is to identify an appropriate Riccati-type equation whose solvability is (if equivalent) to the solvability of this possibly indefinite LQ problem. In this paper we introduce a new type of differential Riccati equation, called the generalized (differential) Riccati equation, which in turn provides a complete solution to the indefinite LQ problem. Moreover, all the optimal feedback/open-loop controls can be identified via the solution to this Riccati equation.

17:50
Output Feedback Control Design for Strict-Feedback Stochastic Nonlinear Systems under a Risk-Sensitive Cost ......................... 1269
Liu, Yungang  Chinese Acad. of Science
Pan, Zigang  Univ. of Cincinnati
Shi, Songjiao  Shanghai Jiao Tong Univ.

Abstract: In this paper, we study the problem of output-feedback control design for a class of strict feedback stochastic nonlinear systems. Under a infinite-horizon risk-sensitive cost criterion, the controller designed can guarantee an arbitrary small long-term average cost for arbitrary risk-sensitivity parameter and achieve boundedness in probability for the closed-loop system, using the integrator backstepping methodology. Furthermore, the controller preserves the equilibrium at the origin of the nonlinear system.

18:10
Stabilization of Partially Bilinear Composite Stochastic Systems by Linear Feedback Laws .......................... 1275
Florchinger, Patrick  Univ. Metz

Abstract: This paper deals with the stabilizability in mean square for partially bilinear composite stochastic systems by means of linear feedback laws. Sufficient conditions under which there exists a linear feedback law such that the equilibrium state of the closed-loop system deduced from a partially bilinear composite stochastic system is exponentially stable in mean square are given.

18:30
Discrete-Time Stochastic Minimax Control of Partially Observable Systems .............................. 1277
Charalambous, Charalambos D.  Univ. of Ottawa

Abstract: This paper presents a sample path optimization technique, as an alternative to the ensemble average in formulating and solving stochastic minimax dynamic games. The stochastic games are nonlinear, discrete-time, and partially observable. The controlled state and observation processes are subject to non-Gaussian inputs and square-summable disturbances.
Abstract: In this paper we study a simple high–gain type adaptive control scheme for surge stabilization in compression systems. We consider a typical configuration in which the throttle valve at the plenum exit is the actuator, while the measured output is given by the total pressure at the compressor inlet. The system does not satisfy standard minimum–phase assumptions, nevertheless the proposed scheme turns out to be convergent to the desired equilibrium point. We finally validate the proposed controller by numerical simulation, using both a simplified model of the controlled system and a fifth order model, the latter being more realistic to describe some non–dominant fast dynamics often present in real compression systems.

Abstract: A novel approach to active surge control is presented. A centrifugal compressor driven by an electrical motor is studied, and the drive itself is used for surge control, thus eliminating the need for additional actuators. It is shown that by using the rotational speed of the motor as control, previous unstable operating points to the left of the surge line can be made globally exponentially stable. It is also shown that using the torque of the drive as control, previous unstable operating points can be made globally exponentially stable.

Abstract: We analyze the effect of functional feedback in an extremum seeking loop. Our study is motivated by a formation flight problem where the trailing aircraft experiences an outward rolling moment as the vortex effects of the leading aircraft come into play. Viewed as the extremized functional, this rolling moment feeds itself back to the lateral dynamics of the aircraft. In the initial half of the paper we impose restrictions on the curvature of the extremized functional and examine the effect under the assumption of a dynamic time-scale separation between the tracking loops of the linear dynamical system and the extremum seeking loop; in the later half we remove both these assumptions and instead impose assumed functional forms on the extremized functional.
Abstract: A global decentralized adaptive output-feedback dynamic compensator is proposed for stabilization and tracking of a class of large-scale systems that are globally diffeomorphic into systems which are interconnections of subsystems in generalized output-feedback canonical form. This form includes as special cases the standard output-feedback canonical form and various other forms considered previously in the literature. Output-dependent nonlinearities are allowed to enter both additively and multiplicatively. The system is allowed to contain unknown parameters multiplying output-dependent nonlinearities, and, also, unknown nonlinearities satisfying certain bounds. Under the assumption that a constant matrix can be found to achieve a certain property, it is shown that reduced-order observers and backstepping controllers can be designed to achieve practical stabilization of the tracking error in each subsystem. Sufficient conditions under which asymptotic tracking and stabilizing control law is designed by parametrically shaping the averaged potential. Practical features of the control law are discussed, and performance of the controlled system is shown to be robust with respect to a class of disturbances.
to have a lower triangular structure. We propose a step-by-step design, based on splitting the system into one-dimensional interconnected systems; assuming that for each one-dimensional system there exists a smooth time-varying measurement feedback stabilizing controller which achieves some stability properties, we give conditions under which the interconnection of the closed-loop one-dimensional systems maintains the same stability properties. We apply these results to nonholonomic systems with uncertainties in lower triangular form.

08:40
Observer-Based Control of Piecewise-Affine Systems .......... 1366
Rodrigues, Luiz Stanford Univ.
How, Jonathan P. Massachusetts Inst. of Tech.

Abstract: Previous work by the authors presented a new synthesis method for both state and output feedback controller design for piecewise-affine systems. The control strategy was shown to perform effectively in several exam- ples. However, its theoretical properties were only investigated for a very specific case based on two implicit assumptions: (i) the absence of sliding modes at the hyperplane boundaries between regions with different affine dynamics; and (ii) the fact that both the plant and the controller started in the same region and always switched regions at the same time. The current paper addresses the problems that can arise when these assumptions are violated, and it presents, for the first time, a rigorous and general analysis of the stability of the closed-loop system when the assumptions are removed.

09:00
Controller-Observer Scheme for a Class of Nonlinear Singly Perturbed Systems ......................... 1372
De Leon-Morales, Jesus Univ. Autó. de Nuevo León
Castro-Linares, Rafael CINVESTAV-IPN
Alvarez-Gallegos, Ja. CINVESTAV-IPN
Mendivil-Avila, Juan M. Univ. Autó. de Nuevo León

Abstract: This paper is concerned with the design of a controller-observer scheme for the exponential stabilization of a class of singularly perturbed nonlinear systems based on sliding-modes techniques and nonlinear observers. Under the assumption that only the fast state is available for measurement, an observer design is presented in order to estimate the slow variables. Furthermore, a stability analysis of the closed-loop system is also made to provide sufficient conditions for the exponential stability of the full order closed-loop system when the slow state is estimated by means of the observer. The proposed scheme is applied to the model of a permanent magnet stepper motor in order to illustrate the methodology.

09:20
Global Asymptotic Stability of Bounded Output Feedback Tracking Control for Robot Manipulators ............. 1378
Santibañez, Victor Inst. Tech. de la Laguna
Kelly, Rafael CICESE

Abstract: This note shows that global asymptotic stability of the closed-loop system formed by an output feedback tracking bounded controller (previously reported in the literature) for robot manipulators in presence of sufficiently large viscous friction, can be achieved provided that a feedforward compensation term of the viscous friction is added to the controller.

09:40
Generalized Nonlinear Output-Feedback Canonical Form: Global Output Tracking ........................... 1380
Krishnamurthy, Prashanth Polytechnic Univ.
Khorrami, Farshad Polytechnic Univ.
Jiang, Zhong-Ping Polytechnic Univ.

Abstract: A global robust output feedback dynamic compensator is proposed for stabilization and tracking of a class of systems that are globally diffeomorphic into systems which are in generalized output-feedback canonical form. This form includes as special cases the standard output-feedback canonical form and various other forms considered previously in the literature. Output-dependent nonlinearities are allowed to enter both additively and multiplicatively. The system is allowed to contain uncertain nonlinearities satisfying certain bounds. Under the assumption that a constant matrix can be found to achieve a certain property, it is shown that a reduced-order observer and a backstepping controller can be designed to achieve practical stabilization of the tracking error. Sufficient conditions under which asymptotic tracking and stabilization can be achieved are also obtained. For the special case of linear systems, the designed dynamic controller reduces to the standard reduced-order observer and linear controller. This is the first global output-feedback tracking results for this class of systems.

Grand Cypress Ballroom A

WeA04
Variable Structure Control of Mechanical Systems
Chair: Usai, Elio Univ. degli Studi di Cagliari
Co-Chair: Pan, Yaodong The Ohio State Univ.
Organizer: Usai, Elio Univ. degli Studi di Cagliari
Organizer: Pan, Yaodong The Ohio State Univ.

08:00
Position Control of an Inertia-Spring DC-Motor System without Mechanical Sensors: Experimental Results (I) .......... 1386
Hernández, Víctor M. Univ. Autónoma de Querétaro Sira-Ramírez, Hebertt J. CINVESTAV-IPN

Abstract: In this article, two Generalized Proportional-Integral (GPI) feedback control schemes are proposed for the stabilization of the angular position of a DC-motor actuated rotation inertia load, fixed to a wall by means of a rotation spring. The feedback schemes, which are not based on asymptotic observers nor calculations based on samplings, use only electrical variables measurements.

08:20
Lazy VS-Control Strategy for Passive Walking (I) .............. 1392
Suzuki, Satoshi Tokyo Denki Univ.
Furuta, Katsuhisa Tokyo Denki Univ.
Pan, Yaodong Ohio State Univ.
Hatakeyama, Shoshihiro Tokyo Denki Univ.

Abstract: New control strategy called 'lazy control' is proposed. This concept has its origin in Sliding-Sector Variable Structure Systems (SS-VSS). In SS-VSS system, the state is carried by specified variable-structure input(VS-input) law to a stable region which is called a 'sliding sector', and after reaching into the sector the system is stabilized with zero-input. Here we apply this scheme to active control of passive walking. Passive walking motion emerges autonomously on slight incline slope, and don't need external power except a potential energy. The limit cycle is stable locally, but the stable region is narrow. It will be shown that lazy control enhances the stability by minimum attention to the system. I.e., the walker can walk by itself as long as the own stability is valid without external input, and is helped to recover the stable motion only when the walker might not be able to walk by itself. The effectiveness is demonstrated by simulation.

08:40
Hybrid Second Order Sliding Mode Control of Constrained Manipulators with Frictional Contact (I) ............. 1398
Bartolini, Giorgio Univ. of Cagliari
Punta, Elisabetta Univ. of Genova

Abstract: This paper deals with the hybrid position/force control of constrained manipulators subjected to uncertainties and disturbances of various nature, including Coulomb friction. The proposed solution is based on sliding-mode control theory, which has been shown to be highly effective in counteracting uncertainties and disturbances for some classes of uncertain nonlinear systems. Specific drawbacks presented by the classical sliding mode techniques are the chattering phenomenon and the algebraic coupling between constraint forces and possibly discontinuous control signals. Both these problems are addressed in the paper by exploiting the
robustness properties of second-order sliding-mode control algorithms. A specific algorithm of this kind, recently developed by the authors, is proven to be effective also when the dynamic equation of the system includes discontinuous disturbances.

09:00  
Control of a Large Flexible Space Structure: A Hybrid Sliding Mode Approach (I) ........................................... 1404
Ferrara, Antonella  Univ. of Pavia
Magnani, Lorenza  Univ. of Pavia
Scattolini, Riccardo  Univ. of Pavia

Abstract: A hybrid sliding mode control strategy for large flexible structure is presented in this paper. It relies on a system state decomposition into regions, and on a suitable event-driven switching among the corresponding control laws in order to guarantee the asymptotic stability of the origin of the system state space and to reduce energy consumption. Experimental results are illustrated.

09:20  
Robust Control of Container Cranes: Theory and Experimental Validation (I) ................................................. 1409
Bartolini, Giorgio  Univ. of Cagliari
Pisano, Alessandro  Univ. of Cagliari
Usai, Elio  Univ. of Cagliari

Abstract: Fast and swing-free transfer of a suspended load is not easy to obtain in the presence of model uncertainties (e.g. unknown load mass) and disturbances. In this paper we exploit the positive features that characterize the second-order sliding mode approach to design a simple control system which, unless other approaches, guarantees the suppression of the load swing during transport and a precise final positioning, by relying on a weak amount of informations about the crane and load parameters. The trolley position, the rope length and the swing angle are the only measured quantities, and the controller uses for feedback also the estimates of the trolley and rope velocities provided by real-time sliding-mode differentiators. The features of the observer-controller scheme, and the relevant implementation issues, are discussed and some results from experiments carried out on a laboratory-sized overhead crane model are provided.

09:40  
Existence Conditions and Applications of Shifting Sliding Mode Control ..................................................... 1415
Zhou, Jun  Kyoto Univ.
Hagiwara, Tomomichi  Kyoto Univ.

Abstract: By introducing shifting factors into sliding surfaces, shifting sliding mode control (SSMC) is defined. Sufficient existence conditions of SSMC are proved. Based on SSMC, output tracking, in which perfect tracking is achieved in a finite time under matched and bounded unmatched uncertainties, and optimal LQ regulation under matched uncertainties are considered. SSMC makes it possible for the design of control law (to induce sliding motion) and that of system performances to be completed separately. This gives designers one more freedom in improving system performances in sliding mode control setting.

08:00  
Analytical Stability Bound for a Class of Delayed Fractional-Order Dynamic Systems ..................................... 1421
Chen, YangQuan  Utah State Univ.
Moore, Kevin L.  Utah State Univ.

Abstract: A class of delayed linear time-invariant (LTI) fractional-order dynamic systems is considered. The analytical stability bound is obtained by using the Lambert function. Two examples are presented to illustrate the analytical results.

08:20  
Nonconservative LMI Criteria for Delay-Independent Stability of Delay Systems, based on Quadratic Lyapunov-Krasovskii Functionals ...................................... 1427
Bliman, Pierre-Alexandre  INRIA

Abstract: In this note, one studies the delay-independent stability of delay systems of retarded or neutral type. It is shown that the strong delay-independent stability is equivalent to the feasibility of certain linear matrix inequality, that is to the existence of certain quadratic Lyapunov-Krasovskii functional, independent of (nonnegative) value of the delay. This constitutes the analogue of some well-known properties of finite-dimensional systems. This result gives a method for computation of some nontrivial structured singular values. It is applied to study delay-independent stability of systems with polytopic uncertainties.

08:40  
Time-Delay Compensation in Unstable Plants using Delayed State Feedback .......................................... 1433
Michiels, Wim  Katholieke Univ. Leuven
Roose, Dirk  Katholieke Univ. Leuven

Abstract: In this paper we propose modifications of the classical Smith Predictor which are applicable to a class of unstable systems. These predictors are observer based. The observation error is controlled with delayed state feedback, whereby parameters are calculated using a recently developed numerical method for the stabilization of linear time-delay systems. We consider the class of stabilizable systems in the two-dimensional case and make a comparison with related methods in the literature.

09:00  
LMI Approach to Spectral Stabilizability of Linear Delay Systems and Stabilizability of Linear Systems with Complex Parameter ............................................. 1438
Bliman, Pierre-Alexandre  INRIA

Abstract: The present paper is focused on the issue of pointwise [Kamen et al., 1984], or (strong) delay-independent [Niculescu et al., 1996], stabilization of linear delay systems with commensurate delays. A criterion using LMI formulation is proposed, which is sufficient to have this property. Necessity is conjectured.

09:20  
An LMI-Based Disturbance Reduction Control for Systems with Multiple State and Input Delays ....................... 1444
Tshiofwe, Isaac M.  Univ. of Arkansas
Alotaibi, Mosleh  Univ. of Arkansas
Amirzazdi, Javid  Univ. of Arkansas
Yaz, Edwin  Marquette Univ.

Abstract: A disturbance reduction control technique is proposed for systems with multiple state and input time delays to minimize the adverse effects of unmeasurable deterministic disturbances of known waveforms but unknown magnitudes and arrival times. This scheme is based on reconstructing the disturbance state through a multiple time-delay observer, which is designed using a linear matrix inequality approach and using part of the control signal to actively minimize the Euclidean norm of the disturbance vector estimate.

09:40  
H-Infinity Controller Design for Discrete-Time Linear Systems with Time-Varying Delays .............................. 1446
Kim, Ki Tae  Kyungpook Natl. Univ.
Cho, Sang Hyun  Kyungpook Natl. Univ.
Kim, Joon Ki  Kyungpook Natl. Univ.
Park, Hong Bae  Kyungpook Natl. Univ.

Abstract: This paper deals with the H_infinity controller design problems for discrete-time linear systems with time-varying delays
in state. The existence condition and the design method of the H_{\infty} state feedback controller are given. In this paper, the H_{\infty} control law is assumed to be a memoryless state feedback, and the upper-bound of time-varying delay is used. Through some changes of variables, Schur complement, and S-procedure, the obtained condition can be rewritten as an LMI (linear matrix inequalities) form in terms of all variables.

Abstract: This paper presents an integrated methodology for detecting, isolating, and accommodating faults in a class of nonlinear dynamical systems. A fault diagnosis module is used for fault detection and isolation. Based on the fault information obtained during the fault diagnosis procedure, a fault-tolerant control module is designed to compensate the effects of faults. In the presence of a fault, a nominal controller guarantees the boundedness of all the system signals until the fault is detected. Then the controller is reconfigured after fault detection and after fault isolation, respectively, to improve the control performance using the fault information generated by the diagnosis module. Under certain assumptions, the stability of the close-loop system is rigorously investigated.

Abstract: When an actuator fails and jams, it not only reduces the control authority but also presents a persistent disturbance to the system. In this paper we propose a regulator design to address the actuator failure. A set of regulator controllers are designed for all possible actuator failures and a switching mechanism determines which controller to step in to address the specific actuator failure. As a consequence, coverage of failures through redundancy management can be severely limited. The paper proposes to formulate the fault tolerant control problem as an optimization problem that maximizes coverage of failures through redundancy management. Coverage modeling is attempted in a way that captures its dependence on the control performance and on the diagnostic resolution. Under the proposed redundancy management policy, it is shown that an enhanced overall system reliability can be achieved with a control law of a superior robustness, with an estimator of a higher resolution, and with a control performance requirement of a lesser stringency.

Abstract: This paper reports Part II of a two part effort that is intended to delineate the relationship between reliability and fault tolerant control in a quantitative manner. Reliability properties peculiar to fault-tolerant control systems are emphasized, such as the presence of analytic redundancy in high proportion, the dependence of failures on control performance, and high risks associated with decisions in redundancy management due to multiple sources of uncertainties and sometimes large processing requirements. As a consequence, coverage of failures through redundancy management can be severely limited. The paper proposes to formulate the fault tolerant control problem as an optimization problem that maximizes coverage of failures through redundancy management. Coverage modeling is attempted in a way that captures its dependence on the control performance and on the diagnostic resolution. Under the proposed redundancy management policy, it is shown that an enhanced overall system reliability can be achieved with a control law of a superior robustness, with an estimator of a higher resolution, and with a control performance requirement of a lesser stringency.

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09:00
Reliability of Fault-Tolerant Control Systems: Part II .......................... 1466
Wu, Neng Eva  Binghamton Univ.

Abstract: This paper reports Part II of a two part effort that is intended to delineate the relationship between reliability and fault tolerant control in a quantitative manner. Reliability properties peculiar to fault-tolerant control systems are emphasized, such as the presence of analytic redundancy in high proportion, the dependence of failures on control performance, and high risks associated with decisions in redundancy management due to multiple sources of uncertainties and sometimes large processing requirements. As a consequence, coverage of failures through redundancy management can be severely limited. The paper proposes to formulate the fault tolerant control problem as an optimization problem that maximizes coverage of failures through redundancy management. Coverage modeling is attempted in a way that captures its dependence on the control performance and on the diagnostic resolution. Under the proposed redundancy management policy, it is shown that an enhanced overall system reliability can be achieved with a control law of a superior robustness, with an estimator of a higher resolution, and with a control performance requirement of a lesser stringency.

09:20
Robust Control of a Class of Nonlinear Uncertain Systems Fault Tolerance against Sensor Failures and Subsequent Self Recovery ............................................. 1472
Qu, Zhihua  Univ. of Central Florida
Ihlefeld, Curtis M.  Univ. of Central Florida
Yufang, Jin  Univ. of Central Florida
Saengdeejeing, Apiwat  Univ. of Central Florida

Abstract: In this paper, the problem of devising a fault-tolerant robust control for a class of nonlinear uncertain systems is investigated. Possible failures of the sensors measuring the state variables are considered, and robust measures are developed to identify the stability-vulnerable failures. Based on evaluation of the robust measures, a fault-tolerant robust control will switch itself among several robust control strategies designed under normal operation and under specific faulty conditions. It is shown that, under mild conditions, the proposed scheme guarantees not only the desired performance under normal operations but also robust stability and best achievable performance when there is a sensor failure of any kind.

09:40
On Matching Conditions for Adaptive State Tracking
Control of Systems with Actuator Failures ................................. 1479
Chen, Shuhao  Univ. of Virginia
Tao, Gang  Univ. of Virginia
Joshi, Suresh M.  NASA Langley Research Center

Abstract: New necessary and sufficient conditions are derived for state tracking with state feedback for linear time-invariant systems with actuator failures. The actuator failures are characterized by unknown input signals stuck at some unknown fixed values at unknown time instants. It is shown that the number of non-failed actuators is crucial in determining the actuation range which specifies the compensation design conditions. Such conditions are required for both a nominal design using system knowledge and an adaptive design without system knowledge. An adaptive actuator failure compensation control scheme based on relaxed system actuation conditions is developed for systems with unknown parameters and unknown actuator failure values, times and patterns. Simulation results are presented to verify the desired system performance with failure compensation.
Abstract: Autonomous vehicle systems have been the topic of much research due to their ability to perform dangerous, repetitive and automated tasks in remote or hazardous environments. The potential for multi-vehicle systems cooperating together to accomplish given tasks is starting to draw together researchers from several fields, including robotics, control systems, and computer science. Multiple vehicles can be more effective than a single one, for example in information gathering tasks. By spreading out over the terrain to be searched, a cluster of autonomous helicopters, for example, can locate a target quite rapidly, or a group of coordinated autonomous underwater vehicles can search a coastal area for mines. In other cases, the coordinated operation of multiple vehicles can provide new capabilities. This is the case, for example, of the PATH strategy of platooning several vehicles as they travel along the highway, which may yield up to a four-fold increase in transportation capacity while enhancing safety. Another example is the Mobile Offshore Base, where semi-submersible modules are aligned to form a military base and runway at sea. The unprecedented length of the at-sea runway (up to a mile long) warrants the use of several modules. In each of these cases, there is a need for inter-vehicle communications so that each vehicle can know the status of the operation, the position of its counterparts, and whether the specific mission goals have changed. Thus the control and communication problems become inextricably tied. However, few results are available to analyze performance and stability of a closed loop system where some of the loops are closed by communicated variables. Using the above examples as a motivation, this paper examines emerging results in networked multi-vehicle systems. Recent work has taken many different approaches, such as hybrid systems, distributed control, differential games, control architectures, and artificial intelligence. The focus of this paper is on the control systems perspective. We attempt to present some current issues common to networked multi-vehicle systems, and to show how they have been solved to date in the perspective of the case studies.

Abstract: In this paper, we propose a hierarchical control architecture for an enhanced variant of Cooperative Adaptive Cruise Control (CACC), which would include some Cooperative Forward Collision Warning (CFCW) functionality. Simply put, a CACC system is a more sophisticated variant of cruise control. By a control architecture we mean a specific way of organizing the motion control and navigation functions performed by the cars. It is convenient to organize the functions into hierarchical layers. This way, a complex design problem is partitioned into a number of more manageable sub-problems that are addressed in separate layers. This paper discusses vehicle control requirements and maps them onto a layered control architecture. The formalization of the hierarchy is accomplished in terms of the specific functions accomplished by each layer and of the interfaces between layers. The implementation of the layers is discussed and illustrative examples are provided.
Abstract: The proposed control law is efficient in the presence of some unknown disturbances. The analytical and simulation results show that the proposed control law is less than the given value, within which the warhead of the missile will intercept the target by keeping the relative vertical separation rates between the target and missile, the proposed RHG is shown to intercept the target by keeping the relative vertical separation, the missile acceleration, and the terminal miss distance.

Abstract: In this paper, we examine the model reduction problem for the two structural systems namely stage 1R and stage 2A of the International Space Station (ISS). Several model reduction algorithms are applied and the results are compared.

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Abstract: In this paper, we propose a force and attitude control law of an asteroid sample return robot to obtain an enough constraint force for taking samples from the surface of the asteroid during contact. In a phenomenon of the impact between the robot and the asteroid, there is a complementary relation between the robot acceleration and the constraint force on the contact point. To pay attention to the complementarity, we derive a condition to constrain the robot on the surface of the asteroid based on Complementarity System (CS). We design a control law which achieves the desired force and attitude with keeping the contact, and verify the effectiveness of the proposed control law by simulations.

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Robust Stability of Polynomials with Nonlinear Dependent Coefficient Perturbations .................................. 1551
Liu, Wan Quan Curtin Univ. of Tech.
An, Senjian Melbourne Univ.

Abstract: This paper deals with the robust stability analysis of polynomials with nonlinear uncertainty structure. For a special class of polynomial family with nonlinear dependent coefficient perturbations, some new extreme point results are obtained.

09:00
Robustness Analysis via Tchebyshev Representations ......... 1557
Keel, Lee H. Tennessee State Univ.
Bhattatcharyya, Shankar P. Texas A&M Univ.

Abstract: In this paper we develop some new techniques for the computation of stability margins under parameter variations, for discrete time systems. This is based on representing the unit circle image of a real polynomial in terms of Tchebyshev polynomials. The Tchebyshev representation leads to simple formulas for stability margin computation. We specifically develop a method of verifying the Schur stability of a line segment and also compute the parametric stability margin of a parameter vector, centered around a nominal value. Potential applications of the Tchebyshev representation are discussed.

09:20
On the Synthesis of Restricted Complexity Controllers for Uncertain Plants with Ellipsoidal Perturbations ...................... 1562
Bianchini, Gianni Univ. di Siena
Falugi, Paola Univ. di Firenze
Tesi, Alberto Univ. di Firenze
Vicino, Antonio Univ. di Siena

Abstract: In this paper the problem of restricted complexity stability margin maximization (RCSMM) for SISO plants affected by rank one real perturbations is considered. This problem amounts to maximizing the $L_2$ parametric stability margin over an assigned class of restricted complexity controllers, described by rational transfer functions of fixed order with coefficients depending affinely on some free parameters. It is shown that the RCSMM problem, which in general admits local maxima, can be approached by means of convex optimization techniques. Specifically, an optimization procedure, which requires at each step the computation of a rational function via polynomial factorization and the solution of an LMI feasibility problem with respect to the free controller parameters, is devised.

09:40
Robust Pole Clustering in Bilinear Transformation Regions ... 1568
Ou, Jih Hwa Natl. Sun Yat-Sen Univ.
Lee, Li Natl. Sun Yat-Sen Univ.

Abstract: In this paper the definition of a family of regions in the complex plane, called the bilinear transformation region, is given. Based on it, the problem of robust pole clustering within these regions is investigated. By some LFT treatments, it is shown that the answer to the problem can be obtained by the mixed nu computation.

08:40
Feedback Control of Thin Film Growth in an HPCVD Reactor via Reduced Order Models (I) .......................... 1577
Banks, H. Thomas North Carolina State Univ.
Kepler, G. M. North Carolina State Univ.
Tran, H. T. North Carolina State Univ.

Abstract: This paper describes the development of a reduced order model-based feedback control methodology for the regulation of the growth of thin films in a high-pressure chemical vapor deposition (HPCVD) reactor. This is achieved in the context of gas dynamics coupled with a nonlinear reduced order model of the surface reactions involved in the source vapor decomposition and film growth on the substrate. Also modeled is the real-time observation technique used to obtain a partial measurement of the deposition process. The control problems are optimal tracking problems of the film thickness that employ state-dependent Riccati gains with nonlinear observations and the resulting state dependent Riccati equations for the compensator gains.

08:40
Experimentally Validated Multivariable $\mu$ Feedback Controller Design for a High-Precision Wafer Stage Stage .................. 1583
van de Wal, Marc Philips Centre for Ind. Tech.
van Baars, Gregor Philips Centre for Ind. Tech.
Sperling, Frank Philips Centre for Ind. Tech.
Bosgra, Okko Delft Univ. of Tech.

Abstract: Conventional PID-like SISO controllers are still common in industrial servo systems, but the ever increasing performance requirements call for advanced MIMO control. This paper presents a $\mu$ feedback controller design for high-precision wafer stage motion. Weighting filters are proposed to straightforwardly and effectively impose performance and uncertainty specifications. The performance has been experimentally verified and compared with conventional multiloop SISO control.

09:00
Notions of Controllability for Quantum Mechanical Systems .. 1589
Albertini, Francesca Univ. di Padova
D'Alessandro, Domenico Iowa State Univ.

Abstract: In this paper, we define three different notions of controllability for quantum mechanical systems involving the possibility of driving the evolution operator as well as the state of the system. By using general results on transitivity of transformation groups on spheres we establish the connections among these different notions of controllability. Motivated by the physical model of multilevel quantum systems, we also study the relation between the controllability in arbitrary small time of a system varying on a compact transformation Lie group and the corresponding system on the associated homogeneous space. As an application, we prove for the system of two interacting spin 1/2 particles the negative result that not every state transfer can be obtained in arbitrary time.
article: A direct robust adaptive control framework for nonlinear uncertain systems with constant linearly parameterized uncertainty and nonlinear state-dependent uncertainty is developed. The proposed framework is Lyapunov-based and guarantees partial asymptotic robust stability of the closed-loop system; that is, asymptotic robust stability with respect to part of the closed-loop system states associated with the plant. Finally, a numerical example is provided to demonstrate the efficacy of the proposed approach.

09:00
Simple Robust Adaptive Control for Structured Uncertainty Plants with Unknown Dead-Zone ................................ 1621
Deng, Mingcong  Exeter Univ.
Yu, Hongnian  Exeter Univ.
Iwai, Zenta  Kumamoto Univ.

Abstract: This paper presents a new simple robust adaptive control method for an unknown plant with an unknown input dead-zone. The design scheme of a robust parallel compensator is proposed, and an adaptive robust controller is also given. The simulation results are presented to demonstrate the proposed method.

09:20
Robust Adaptive Control of a Class of Nonlinear Systems with Unknown Dead-Zone ........................................ 1627
Wang, Xing-Song  Southeast Univ.
Su, Chun-Yi  Concordia Univ.
Hong, Henry  Concordia Univ.

Abstract: This paper deals with the adaptive control of a class of continuous-time nonlinear dynamic systems preceded by an unknown dead-zone. By using a new description of a dead-zone and by exploring the properties of this dead-zone model intuitively and mathematically, a robust adaptive control scheme is developed without constructing the dead-zone inverse. The new adaptive control law ensures global stability of the adaptive system and achieves desired tracking precision. Simulations performed on a typical nonlinear system illustrate and clarify the validity of this approach.

09:40
An Estimation based Robust Adaptive Control of Nonlinear Systems with a General Set of Uncertainty ..................... 1633
Ahn, Choon-Ki  Korea Univ.
Kim, Beom-Soo  Korea Univ.
Lim, Myo-Taeg  Korea Univ.

Abstract: In this paper, a novel estimation technique based robust adaptive control scheme is presented for a class of uncertain nonlinear systems with a general set of uncertainty. Firstly, we introduce a more extended semi-strict feedback form which generalizes the systems studied in recent years. Secondly, a novel estimation technique is proposed to estimate the states of unmodeled dynamics under very mild conditions. With the introduction of powerful functions, estimation error can be tuned to a desired small region around the origin via the estimator parameters. Thirdly, with gamma function, a modification of adaptive backstepping for dynamic uncertainties is presented to drive the output to an arbitrarily small region around the origin by appropriate choice of the design parameters. With our proposed schemes, we can remove or relax the assumptions of the existing results.
Abstract: Impulse differential inclusions provide a framework for modelling hybrid phenomena. In the context of impulse differential inclusions, verification for safety specifications and safe controller synthesis can be formulated as viability and invariance questions for appropriate sets of states. In this paper, a characterisation of viability and invariance kernels (i.e. the largest subsets of a given set that are viable or invariant) is presented. In the process, a method for computing these sets using standard viability and invariance tools is developed.

08:20
On Hybrid Systems and Closed-Loop MPC Systems ............... 1645
Bemporad, Alberto
Univ. di Siena
Heemels, Maurice
Eindhoven Univ. of Tech.
De Schutter, Bart
Delft Univ. of Tech.

Abstract: The following five classes of hybrid systems were recently proved to be equivalent: linear complementarity (LC) systems, extended linear complementarity (ELC) systems, mixed logical dynamical (MLD) systems, piecewise affine (PWA) systems, and max-min-plus-scaling (MMPS) systems. Some of the equivalences were obtained under additional assumptions, such as boundedness of system variables. In this paper, for linear or hybrid plants in closed-loop with a model predictive control (MPC) controller based on a linear model and fulfilling linear constraints on input and state variables, we provide a simple and direct proof that the closed-loop system (cl-MPC) is a subclass of any of the former five classes of hybrid systems. This result opens the use of tools developed for hybrid systems (such as stability, robust stability, and safety analysis tools) to study closed-loop properties of MPC.

08:40
Feedback can Reduce the Specification Complexity of Motor Programs .............................................. 1651
Egerstedt, Magnus
Georgia Inst. of Tech.
Brockett, Roger
Harvard Univ.

Abstract: In this paper we show that when it is possible to use feedback in the specification of “motor programs”, the length of the descriptions of the instruction sequences for carrying out a given task can be reduced by a factor that reflects the richness of the available feedback signals. The model on which this work is based is that of a finite automaton, modified in such a way that instruction processing is akin to the way in which difference or differential equations “process” piecewise constant inputs.

09:00
A Construction Procedure using Characteristics for Viscosity Solutions of the Hamilton-Jacobi Equation ............... 1657
Bayen, Alexandre M.
Stanford Univ.
Tomlin, Claire J.
Stanford Univ.

Abstract: This paper provides a procedure to generate continuously differentiable or continuous, piecewise continuously differentiable solutions of a one-dimensional Hamilton-Jacobi equation with nonsmooth Hamiltonian, based on the method of characteristics. The continuously differentiable solutions constructed are classical solutions. We prove on examples the piecewise continuously differentiable constructed solutions to be the viscosity solutions, with help of a minimax-viscosity equivalence. We show how shock waves and voids are generated by initial conditions. We show with two-dimensional examples how this technique might be applied to differential games.
Abstract: In this article we consider a dynamic M-ary detection problem when Markov chains are observed through a Wiener process. These systems are fully specified by a candidate set of parameters, whose elements are: a rate matrix for the Markov chain and a parameter for the observation model. Further, we suppose these parameter sets can switch according to the state of an unobserved Markov chain and thereby produce an observation process generated by time varying (jump stochastic) parameter sets. Given such an observation process and a specified collection of models, we estimate the probabilities of each model parameter set explaining the observation. By defining a new augmented state process, then applying the method of reference probability, we compute matrix-valued dynamics whose solutions estimate joint probabilities for all combinations of candidate model parameter sets, and values taken by the indirectly observed state process. These matrix-valued dynamics satisfy a stochastic integral equation with a Wiener process integrator. Using the gauge transformation techniques introduced by J M Clark and a pointwise matrix product, we compute robust matrix-valued dynamics for the joint probabilities on the augmented state space. In these new dynamics the observation Wiener process appears as a parameter in the fundamental matrix of a linear ordinary differential equation, rather than an integrator in a stochastic integral equation. Finally, by exploiting a duality between causal and anticausal robust detector dynamics, we develop an algorithm to compute smoothed mode probability estimates without stochastic integrations.

Abstract: We present management of diabetes mellitus as a constrained control problem, with very sparse sampling, where no information on dynamics are available. This problem has been approached through modelling of the system as a Markov Decision Process, and through direct derivation of control rules. Considering the complexity of the system constraints imposed by lack of information, we argue that non-model based control is the best and simplest method for this problem.

Abstract: Some Properties of the Nonlinear Filter: Markovity and Ergodicity

Budhiraja, A. Univ. of North Carolina

Abstract: In this paper we first prove, under quite general conditions, that the nonlinear filter and the pair: (signal,filter) are Feller-Markov processes. The state space of the signal is allowed to be non locally compact and the only condition on the observation function, h, is that it be continuous. Our proofs in contrast to those of Kunita(1971,1991), Stettner(1989) do not depend upon the uniqueness of the solutions to the filtering equations. Indeed, in the generality we consider, the uniqueness of the solutions may not hold. We then obtain conditions for existence and uniqueness of invariant measures for the nonlinear filter and the pair process. These results extend those of Kunita and Stettner, which hold for locally compact state space and bounded h, to our general framework. Finally we show that the recent results of Ocone and Pardoux (1996) on asymptotic stability of the nonlinear filter, which use the Kunita-Stettner setup, hold for the general situation considered in this paper.

Abstract: This paper studies a stochastic linear quadratic (LQ) problem when Markov chains are observed through a Wiener process. These systems are fully specified by a candidate set of parameters, whose elements are: a rate matrix for the Markov chain and a parameter for the observation model. Further, we suppose these parameter sets can switch according to the state of an unobserved Markov chain and thereby produce an observation process generated by time varying (jump stochastic) parameter sets. Given such an observation process and a specified collection of models, we estimate the probabilities of each model parameter set explaining the observation. By defining a new augmented state process, then applying the method of reference probability, we compute matrix-valued dynamics whose solutions estimate joint probabilities for all combinations of candidate model parameter sets, and values taken by the indirectly observed state process. These matrix-valued dynamics satisfy a stochastic integral equation with a Wiener process integrator. Using the gauge transformation techniques introduced by J M Clark and a pointwise matrix product, we compute robust matrix-valued dynamics for the joint probabilities on the augmented state space. In these new dynamics the observation Wiener process appears as a parameter in the fundamental matrix of a linear ordinary differential equation, rather than an integrator in a stochastic integral equation. Finally, by exploiting a duality between causal and anticausal robust detector dynamics, we develop an algorithm to compute smoothed mode probability estimates without stochastic integrations.

Abstract: Decomposition and Aggregation of Large-Dimensional Markov Chains in Discrete Time

Zhang, Qing Univ. of Georgia
Jiang, Fei Wuhan Univ.

Abstract: This paper studies a stochastic linear quadratic (LQ) problem in the infinite time horizon with Markovian jumps in parameter values. In contrast to the deterministic case, the cost weighting matrices of the state and control are allowed to be indefinite here. When the generator matrix of the jump process -- which is assumed to be a Markov chain -- is known and time-invariant, the well-posedness of the indefinite stochastic LQ problem is shown to be equivalent to the solvability of a system of coupled generalized algebraic Riccati equations (CGAREs) that involves equality and inequality constraints. To analyze the CGAREs, linear matrix inequalities (LMIs) are utilized, and the equivalence between the feasibility of the LMIs and the solvability of the CGAREs is established. Finally, an LMI-based algorithm is devised to solve the CGAREs via a semidefinite programming, and numerical results are presented to illustrate the proposed algorithm.
Stability of Extremum Seeking Control for a Class of Discrete-Time Systems ........................................ 1717
Choi, Joon-Young Pohang Univ. of Sci. & Tech.
Krstić, Miroslav Univ. of California, San Diego
Arany, Kartik B. Univ. of California, San Diego
Lee, Jin S. Pohang Univ. of Sci. & Tech.

Abstract: We present an extremum seeking control algorithm for discrete-time systems applied to a class of plants that are represented as a series combination of a linear input dynamics, a static nonlinearity with an extremum, and a linear output dynamics. By using the two-time scale averaging theory, we derive a mild sufficient condition under which the plant output exponentially converges to an O(\(\alpha^2\)) neighborhood of the extremum value, where \(\alpha\) is the magnitude of modulation signal. The sufficient condition is related to positive realness of linear parts of the plant but only at the modulation frequency. The algorithm is illustrated with a brief simulation study.

11:00 Disturbance Rejection with Saturating Actuators for Discrete-Time Linear Systems ........................................ 1723
Hu, Tinghua Univ. of Virginia
Lin, Zongli Natl. Univ. of Singapore
Chen, Ben M. Univ. of Virginia

Abstract: Several analysis and design problems related to disturbance rejection with saturating actuators are studied for linear discrete-time systems. Conditions are derived for set invariance in the presence of persistent disturbance. Based on these conditions, optimization approaches are proposed for maximizing/minimizing invariant ellipsoid and for disturbance rejection with guaranteed stability requirements.

11:20 On Stabilization of Discrete Time Nonlinear Systems with Time Delay ........................................ 1729
Aggoune, Woihida CRP Public Henri Tudor
Sallet, Gauthier INRIA-Lorraine

Abstract: In this contribution, the problem of stabilization of a class of discrete time nonlinear systems with time delay is addressed. We investigate the Lyapunov approach to deduce general conditions for stabilizing the closed loop system and derive stabilizing state feedback control laws.

11:40 Control of Nonlinear Driftless Dynamics: Continuous Solutions from Discrete Time Design ............................ 1731
Di Giambberardino, Paolo Univ. di Rome

Abstract: The problem of giving an explicit closed form for the integration of a particular class of time varying dynamics and its relationship with the integration under constant inputs is addressed. As a consequence, the possibility of the computation of a continuous control law starting from a piecewise continuous control designed on the basis of the sampled equivalent dynamics is shown. Simulations results validate the results and the proposed solutions.

12:00 Backstepping on the Euler Approximate Model for Stabilization of Sampled-Data Nonlinear Systems .............. 1737
Nesić, Dragan Univ. of Melbourne
Teel, Andrew R. Univ. of California, Santa Barbara

Abstract: Two integrator backstepping designs are presented for digitally controlled continuous-time plants in special form. The controller designs are based on the Euler approximate discrete-time model of the plant and the obtained control algorithms are novel. The two control laws yield, respectively, semiglobal-practical stabilization and global asymptotic stabilization of the Euler model. Both designs achieve semiglobal-practical stabilization (in the sampling period that is regarded as a design parameter) of the closed loop sampled-data system. A simulation example illustrates that the obtained controllers may be superior to backstepping controllers based on the continuous-time plant model that are implemented digitally.

10:40 Preliminary Analysis of a Nonlinear Control Scheme Related to Feedback Linearization ............................... 1743
Rojas, Osvaldo J. The Univ. of Newcastle
Goodwin, Graham C. The Univ. of Newcastle

Abstract: Generalized Feedback Linearization (GFL) is a control strategy aimed at extending input-output Feedback Linearization to certain non-stable invertible nonlinear systems. GFL maintains the distinctive simplicity of Feedback Linearization whilst overcoming the well known stable invertibility restriction of feedback linearizable systems. Preliminary results on the stability of the GFL strategy are presented. In particular, we show that the scheme is locally stabilizing for a broad class of nonlinear systems. Also, for the specific class of nonlinear systems of Lur’e type, we give sufficient conditions for the GFL scheme to be globally stabilizing.

10:40 Nonlinear PI Control of Uncertain Systems: An Alternative to Parameter Adaptation .................................. 1749
Ortega, Romeo LSS-SUPELEC
Astolfi, Alessandro Politecnico di Milano/Imperial College

Abstract: A novel approach to stabilization and trajectory tracking for nonlinear systems with unknown parameters and uncertain disturbances is developed. We take a drastic departure from the classical adaptive control theory and we consider a parameterized feedback law and an identifier, which tries to minimize a tracking (or prediction) error. Instead, we propose a simple nonlinear PI structure that generates a stable error equation with a perturbation function that exhibits at least one root. This root is made an attractive equilibrium by suitably adjusting the nonlinear PI gains. We consider the two basic problems of: i) matched uncertainties, when the uncertain terms are in the image of the input matrix, and ii) unknown control directions, when the control signal is multiplied by a gain of unknown sign.

11:00 Constrained Output Regulation of Discrete-Time Linear Plants ......................................................... 1755
Shi, Guoyong Washington State Univ.
Saberi, Ali Washington State Univ.
Stoorvogel, Anton A. Eindhoven Univ. of Tech.
Sannuti, Peddapullaiah Rutgers Univ.

Abstract: Output regulation of discrete-time linear systems with state and/or input constraints on magnitude is considered. The structural properties of linear plants are identified under which the so called constrained semiglobal and global output regulation problems are solvable. As in the case of continuous-time systems, an important aspect of our development is a taxonomy of constraints to show a clear relationship between the type of constraints and the output regulation results. Solvability conditions are developed for semiglobal and global output regulation problems. Appropriate regulators are constructed.

11:20 Practical Stabilization of Driftless Homogeneous Systems based on the use of Transverse Periodic Functions ............. 1761
Morin, Pascal INRIA
Samson, Claude INRIA

Abstract: We address the problem of practical stabilization of driftless nonlinear control systems with homogeneous vector fields. A
general feedback design approach, based on the concept of transverse functions recently introduced by the authors, is presented. This approach allows to achieve global stabilization of any neighborhood of the origin, possibly in the presence of additive --- known or measured --- perturbations acting on the system.

11:40
Time-Varying Stabilizing Feedback
Control for Nonlinear Systems with Drift ......................... 1767
Michalska, Hannah McGill Univ.
Torres-Torriti, Miguel McGill Univ.

Abstract: A novel method is presented for the construction of time varying stabilizing feedback control for nonlinear systems with drift. The proposed feedback law is a composition of a periodic time-varying control, and an asymptotically stabilizing feedback "correction" term. The periodic control is obtained through a solution of an open loop control problem on the associated Lie group which is posed as a trajectory interception problem in the Philip Hall coordinates of flows.

12:00
Selecting the Level of Actuator Saturation for Small Performance Degradation of Linear Designs ..................... 1769
Eun, Yongsoon Univ. of Michigan
Gökcek, Cevat Visteon Corp.
Kabamba, Pierre T. Univ. of Michigan
Meerkov, Semyon M. Univ. of Michigan

Abstract: This paper addresses the problem of selecting an actuator so that the performance degradation due to its saturation is sufficiently small. The following scenario is considered. The plant is assumed to be linear and the problem of colored noise disturbance rejection is addressed. The controller is designed using a linear technique (for instance, PID, LQG, etc). This controller is to be implemented with a saturating actuator. How large should the level of saturation be so that the performance will not degrade too much? We provide an answer to this question (in terms of the Nyquist plot of the loop gain) for any desired level of degradation. In addition, the following rule-of-thumb is established: To guarantee less than 10% of performance degradation, the level of actuator saturation should be at least twice larger than the standard deviation of the signal at the controller output in linear design.

WeM03
Nonlinear Mechanical Systems
Chair: Menini, Laura Univ. di Roma ‘Tor Vergata’
Co-Chair: Reyhanoglu, Mahmut Embry Riddle Aeronautical Univ.

10:20
Control of High Order Nonholonomic Systems by Backstepping ........................................... 1775
Nam, Taek-Kun Tokyo Inst. of Tech.
Jongusuk, Jurachart Tokyo Inst. of Tech.
Mita, Tsutomu Tokyo Inst. of Tech.

Abstract: In this paper, we propose feedback controller for stabilization of nonholonomic systems in high order chained form by integrator backstepping method. The proposed controller yields asymptotic convergence of the states to the origin. The control strategy is applied to posture control of an underactuated manipulator in order to verify effectiveness of the control algorithm.

10:40
Transforming Nonholonomic Control Systems into the Canonical Contact Form .................................... 1781
Respondek, Witold INSA de Rouen

Abstract: We give a new geometric characterization of nonholonomic control systems that are feedback equivalent to the canonical contact system. This characterization uses only one involutive distribution in which all information about the geometry of the problem and its regularity is encoded. It also allows us to compute canonical coordinates and feedback transformation that bring the system to the canonical contact form. We illustrate our result by applying it to the nonholonomic two-car system.

11:00
Panel Discussion

11:20
Use of Non-Smooth Impacts for the Control of (Otherwise) Uncontrollable Linear Mechanical Systems ...................... 1787
Menini, Laura Univ. Roma Tor Vergata
Tonombe, Antonio Univ. Roma Tor Vergata

Abstract: In this paper, a class of under actuated linear mechanical systems subject to non-smooth impacts is considered, which would be uncontrollable if the impacts were absent. It is shown that just the non-smooth impacts can be used in order to solve for the overall system a dead-beat regulation problem, which otherwise would be impossible to be solved in absence of impacts due to the uncontrollability of the unconstrained (impulse free) mechanical system.

11:40
Linear Symmetry of Nonlinear Systems ......................... 1789
Cheng, Daizhan Chinese Academy of Sci.
Yang, Guowu Chinese Academy of Sci.

Abstract: This paper tackles the symmetries of control systems. Main attention has been focused on the linear symmetry of affine nonlinear systems. That is, the symmetry under the action of a sub-group of general linear group GL(n,R). The structure of the groups of symmetry and their Lie algebras is investigated. Using left semi-tensor product[6], a complete classification of symmetric plane systems is presented. Finally, a set of linear algebraic equations are presented, whose solutions provide the largest Lie algebra. Its connected Lie group is the largest one, with which the system is symmetric.

12:00
How many Symmetries does Admit a Nonlinear Single-Input Control System around an Equilibrium? ............... 1795
Respondek, Witold INSA de Rouen
Tall, Issa Amadou INSA de Rouen

Abstract: We describe all symmetries of a single-input nonlinear control system, that is not feedback linearizable and whose first order approximation is controllable, around an equilibrium point. For a system such that a feedback transformation, bringing it to the canonical form, is analytic we prove that the set of all local symmetries of the system is exhausted by exactly two 1-parameter families of symmetries, if the system is odd, and by exactly one 1-parameter family otherwise. We also prove that the form of the set of symmetries is completely described by the canonical form of the system: possessing a nonstationary symmetry, a 1-parameter family of symmetries, or being odd corresponds, respectively, to the fact that the drift vector field of the canonical form is periodic, does not depend on the first variable, or is odd. If the feedback transformation bringing the system to its canonical form is formal, we show an analogous result for an infinitesimal symmetry: its existence is equivalent to the fact that the drift vector field of the formal canonical form does not depend on the first variable. We illustrate our results by studying symmetries of the variable length pendulum.
10:20

Estimation of Xenon Concentration and Reactivity in Nuclear Reactors using Sliding Mode Observers (I) .......................... 1801

Abstract: The inherent dynamic behavior of thermal reactors is governed by external reactivity input and xenon poisoning and other power induced reactivity effects. Accurate xenon concentration and external reactivity knowledge are important in reactor control. In this paper, sliding mode observers are developed based on Chemick's model [2,4,5] and Point Reactor Kinetics model [3] to estimate the xenon concentration and reactivity in a nuclear reactor. The simulation results are also shown. Keywords: Sliding Modes, Observers and Nuclear Reactor

10:40

Chattering Analysis in Sliding Mode Systems with Inertial Sensors (I) .................................................. 1807

Fridman, Leonid M.  Oshnauha Inst. of Tech.

Abstract: The singularly perturbed relay control systems with second order sliding modes (SP2SM) are considered for modeling of sliding mode control systems with inertial sensors. It is shown the asymptotically stable slow motions integral manifold of smooth singularly perturbed system, describing the motion of original SP2SM in the second order sliding domain, is the asymptotically stable slow motions integral manifold of original SP2SM. For sliding mode control systems with inertial sensors sufficient conditions for the exponential decreasing of the amplitude of chattering and unlimited growth of frequency are found. Formula for asymptotic representation of “ideal” switching surface oscillations is suggested for sliding mode systems with inertial sensors.

11:00

Analog-to-Digital Converters: Sliding Mode Observer as a Pulse Modulator (I) .................................................. 1813

Shkolnikov, Ilya A.  Univ. of Alabama, Huntsville
Shtessel, Yuri B.  Univ. of Alabama, Huntsville
Plekhanov, Sergey V.  Univ. of Alabama, Huntsville

Abstract: Sliding mode observers (SMO) and principles of digital delta and sigma modulation in implementations of feedback processing systems under the discrete-time control with a zero-order hold are analyzed. An equivalency is established between the structures of delta and sigma-modulators on one hand and the sliding mode observers configured as a “signal estimator” and a “disturbance estimator”. The perceived similarity is utilized in combining the properties of a control system and a communication system in one on an example of a proportional-derivative-controller with delta-sigma-modulation. A common problem of excessive chattering in SMO or the “hunting” of the estimate about the signal in delta-modulator is addressed. Another setback, which is the slope overload problem, is addressed using the adaptive gain and a SMO with higher order sliding modes. In addition, a new type of pulse modulator, the second differential pulse code modulator, is proposed.
Abstract: In this paper, bounds on approximating time-delay systems are proposed. Bounds on the infinity norm of the weighted error are obtained when the approximating function is a general rational function, all-pass function, Padé and Laguerre approximations. An example is presented in illustration.

10:40
Global Asymptotic Stabilization for Chains of Integrators with a Delay in the Input

Mondié, Sabine
CINVESTAV-IPN
Niculescu, Silviu-Iulian
Univ. de Tech. de Compiègne

Abstract: The stabilization of chains of integrators with delayed control has been a challenging case study for researchers in the field of delayed systems due to the robustness problems with respect to the delay values. Some natural questions that arise are: is it possible to construct feedbacks bounded in norm which globally uniformly asymptotically stabilize chains of integrators with delay in the input? How robust is the closed loop in terms of delays? The study of this problem is motivated by the fact that, first, it is appealing from a practical point of view to have at our disposal bounded feedbacks and, second, computational or propagation delays in the input are frequently encountered in practice. Since the forwarding approach yields bounded feedbacks for feedforward systems and in particular for chains of integrators when no delay is present, it is natural to investigate whether this technique can be extended to the case where there is a delay in the input. This is the purpose of the present paper. More precisely, we address the problem of stabilizing a chain of integrators of arbitrary length with a delay in the input of arbitrary size using feedbacks arbitrarily small in norm. The strategy of proof consists in showing first that we can globally uniformly asymptotically stabilize chains of integrators with the help of a nested saturation control law when the time delay is sufficiently small. Next, the result is established for arbitrarily large delays through a simple homogeneous transformation.

11:00
Deadbeat Disturbance Response of Integral Processes with Dead-Time

Zhong, Qing-Chang
Technion-Israel Inst. of Tech.
Li, Han Xiong
City Univ. of Hong Kong

Abstract: Deadbeat disturbance response of the integral processes with dead-time is obtained with two adjustable delay elements intentionally used in the controller. They are tuning parameters rather than fixed ones. The shorter one is optimally determined to minimize the robustness indicator and the longer one, i.e., the deadbeat time itself, is determined with compromise of robustness. An example is given to show the effectiveness, in which the stability of the controller is analyzed with dual-locus diagram.

11:20
Stability Analysis of a Modified Smith Predictor for Integrative Plants with Dead-Time Uncertainties and Saturations

Pagano, Daniel J.
Univ. Fed. de Santa Catarina
Norney-Rico, Julio E.
Univ. Fed. de Santa Catarina
Franco, Ana L. D.
Univ. Fed. de Santa Catarina

Abstract: This paper proposes a methodology for the analysis of the stability in a 2 DOF dead-time compensator when controlling integrative processes. The study considers the effects of the dead-time uncertainties and the actuator saturation on the closed-loop stability. The obtained results allows to define a robust tuning rule for the controller. Some simulation results illustrate the proposed methodology.

11:40
Fault Tolerant Control II

Chair: Demetriou, Michael A.  Worcester Polytechnic Inst.
Co-Chair: Staroswiecki, Marcel  Univ. des Sci. et Tech. Lille

10:20
Reconfigurable Control System Design for Fault Diagnosis and Accommodation

Ho, Liang-Wei
Oklahoma State Univ.
Yen, Gary G.
Oklahoma State Univ.

Abstract: The growing demand in system reliability and survivability under failures has urged ever-increasing research effort on the development of fault diagnosis and accommodation. In this research work, the on-line fault tolerant control problem for dynamic systems under unanticipated failures is investigated from a realistic point of view without any specific assumption on type of system dynamical structure or failure scenarios. The necessary and sufficient conditions for system on-line stability under catastrophic failures have been derived using the discrete-time Lyapunov stability theory. Based upon the existing control theory and the modern intelligent techniques, an on-line fault accommodation control strategy is proposed to deal with the desired trajectory-tracking problems for systems suffering from various unknown and unanticipated catastrophic component failures. Theoretical analysis indicates that the control problem of interest can be solved on-line without a complete realization of the unknown failure dynamics provided an on-line estimator that satisfies certain conditions. Through the on-line estimator, effective control signals to accommodate the dynamic failures can be computed using only the partially available information of the faults. Several on-line simulation studies have been presented to demonstrate the effectiveness of the proposed strategy. To investigate the feasibility of using the developed technique for
unanticipated fault accommodation in real hardware under the real-time environment, an on-line fault tolerant control test bed has been constructed to validate the proposed technology. Both on-line simulations and the real-time experiment show encouraging results and promising futures of on-line real-time fault tolerant control based solely upon insufficient information of the system dynamics and the failure modes.

10:40
Adaptive Reorganization of Switched Systems with Faulty Actuators ............................................. 1879
Demetriou, Michael A.  Worcester Polytechnic Inst.

Abstract: The objective of this note is to introduce an intelligent controller reorganization for systems with actuator failures (outages). An adaptive detection observer is utilized to monitor the system for possible actuator outages and a control logic is incorporated to switch (reorganize) the control policy the instance an actuator failure is detected in order to improve performance. The system under consideration is assumed to be square and the requisite control and stability arguments for failure detection and accommodation are similar to those for switched systems and which employ LMI’s for controller design.

11:00
Utilization of LMI Methods for Fault Tolerant Control of a Flexible Cable with Faulty Actuators ......................... 1885
Demetriou, Michael A.  Worcester Polytechnic Inst.

Abstract: The objective here is to introduce a fault tolerant controller in a system describing cable dynamics with actuator outages (float type failures). The system under study employs a finite number of actuators and it is assumed that the nature of failures renders the actuators completely inoperative at some unknown time instances. The issue of placing a finite number of actuators along the span of the cable with respect to a fault-tolerant measure is first discussed. By using the control distribution matrix for all possible combinations of healthy/faulty actuators and expressing the resulting dynamics as a differential inclusion and then using already established results from convex optimization, a common stabilizing feedback for all possible healthy/faulty actuator combinations is found by solving an appropriate LMI problem that renders the system quadratically stabilizable. The proposed fault-tolerant scheme for actuator outages is simulated for a flexible cable and whose results demonstrate its performance enhancement over the case of a non-fault-tolerant controller.

11:20
An Efficient Algorithm for the Design of Fault Tolerant Multi-Sensor System ......................................... 1891
Attouche, Slimane INRETS-ESTAS
Hayat, Said INRETS-ESTAS
Staroswiecki, Marcel CNRS UPRESA

Abstract: The paper presents a new algorithm for design of fault tolerant multi-sensor systems. The design is essentially based on some Observability properties, which are the Observability indexes and the Pseudo-Observability indexes [1]. These properties are used in [2][3] to define Minimal Sensor Sets (MSS) and Pseudo-Minimal Sensor Sets (PMSS). The paper contribution is the introduction of a definition of an equivalence relation between PMSS, which allows to build Sensor Sub-sets Classes (SSC). The design method is illustrated by an application example, which is the automated truck platooning.

11:40
A Stability Guaranteed Active Fault-Tolerant Control System against Actuator Failures .............................. 1893
Maki, Midori  Univ. of Electro-Communications
Jiang, Jin  Univ. of Western Ontario
Hagino, Kojiro  Univ. of Electro-Communications

Abstract: In this paper a new strategy has been proposed for fault-tolerant control system (FTCS) design using multiple controllers. The design of such multiple controllers is shown to be unique in the sense that the resulting control system does neither have the problem of conservativeness of conventional passive fault-tolerant control (FTC) nor the risk of instability associated with active FTCS in case of an incorrect fault detection and isolation (FDI) decision. In other words, the stability of the closed-loop system is always ensured regardless the FDI decisions. The correct FDI decision will further lead to optimal performance of the system. The paper presents an interesting way to deal with the conflicting requirements among stability, redundancy, and graceful degradation in performance for fault-tolerant control systems. Detailed design procedure has been presented with consideration of possible parameter uncertainties.

12:00
Non-Concurrent Error Detection and Correction in Discrete-Time LTI Dynamic Systems .............................. 1899
Hadjicostis, Christoforos N.  Univ. of Illinois, Urbana-Champaign

Abstract: In this paper we develop fault-tolerant constructions for discrete-time (DT) linear time-invariant (LTI) dynamic systems that are build out of appropriately interconnected delay, adder and gain elements. More specifically, we extend previously developed techniques, in which error detection and correction was based on concurrent parity checks at the end of each time step, by developing schemes that depend on non-concurrent (e.g., periodic) parity checks. Our approach relies on carefully choosing the redundant dynamics of the fault-tolerant implementation in a way that allows parity checks to capture the evolution of errors in the system and determine the initial value of each error, the time at which it took place and the state variable it originally affected. The resulting (non-concurrent) error detection and identification approach significantly reduces the overhead in terms of error detection, identification and correction operations, thereby relaxing the stringent requirements on the checking mechanism.
Abstract: The problem of congestion control in networks with multi-rate multiclass traffic along with unicast sessions has been addressed in this paper. We present a decentralized algorithm which enables the different rate-adaptive receivers in different multicast sessions to adjust their rates to satisfy some fairness criterion. We propose a one-bit ECN marking strategy to be used at the nodes. The congestion control mechanism does not require any per-flow state information for unicast flows at the nodes. Per receiver state information may be required for each multicast flow. The congestion control mechanism takes into account the diverse user requirements when different receivers within a multicast session have different utility functions, but does not assume the network to have any knowledge about the receiver utility functions and also converges under certain reasonable assumptions.

11:00
Stochastic Fluid Models for Control and Optimization of Systems with Quality of Service Requirements (I) .......................... 1917
Cassandras, Christos G.  Boston Univ.
Sun, Gang  Boston Univ.
Panayiotou, Christos G.  Boston Univ.

Abstract: We use Stochastic Fluid Models (SFM) for control and optimization of communication networks in which detailed discrete event models become impractical. By analyzing an SFM for a threshold-based admission control problem on a single node, we derive gradient estimators which can subsequently be used on the actual system. It is shown that these gradient estimators are unbiased and independent of all traffic and service processes involved, including the traffic and service rates. Moreover, they enable us to develop simple optimization schemes that recover the optimal thresholds of the actual discrete event model.

11:20
On Fluid Queueing System with Strict Priority (I) ................... 1923
Liu, Yong  Univ. of Massachusetts, Amherst
Gong, Weibo  Univ. of Massachusetts, Amherst

Abstract: In telecommunication systems, different applications have different quality of service requirements. We consider a fluid queueing system with two priority classes. High priority traffic has strict priority access to service to meet its stringent quality of service requirements. We analyze steady state queueing behavior of the system. Analytical results are derived for different fluid traffic models. They can be used to infer the quality of service received by each class and provide an analytical tool for traffic engineering of network with differentiated services.

11:40
Adaptive Error Control for Mobile Networks: On-Line Optimization based on a Single Sample Path (I) ..................... 1929
He, Ming  Hong Kong Univ. of Sci. & Tech.
Cao, Xi-Ren  Hong Kong Univ. of Sci. & Tech.

Abstract: Link layer error control is one of the important technologies in mobile systems. In this paper, adaptive error control investigated using a modified Markov Decision Process (MDP) model is discussed. An adaptive error control strategy, where the MAC frame length adapts to the varying channel condition, was developed. The proposed algorithm, implemented on-line, achieves better average link layer throughput in a dynamic data channel. The simulation example provided shows that the algorithm can improve the throughput of the wireless data channel by 23%.

12:00
Protocols for Media Access Control and Power Control in Wireless Networks (I) .............................................. 1935
Kawadia, Vikas  Univ. of Illinois, Urbana-Champaign
Narayanaswamy, Swetha  Univ. of Illinois, Urbana-Champaign
Rozovsky, Robert  Univ. of Illinois, Urbana-Champaign
Sreenivas, Ramavarapu S  Univ. of Illinois, Urbana-Champaign
Kumar, P R  Univ. of Illinois, Urbana-Champaign

Abstract: We present two protocols for ad hoc wireless networks, one for the media access control problem, and the other for the power control problem. For the media access control problem we present a protocol called SEEDEX which does not explicitly make reservations for packets, a la the IEEE 802.11 protocol, yet allows scheduling to minimize conflicts. The idea is to use known finite state machines at nodes which are driven by pseudo-random number generators. The seeds of these pseudo-random number generators are exchanged between nodes in a two hop neighborhood. A further refinement is a hybrid version, which employs SEEDEX only on the RTS-CTS handshake of the IEEE 802.11 protocol. This algorithm provides improved throughput-delay and delay jitter performance in an ns simulation. For the power control problem we first provide a framework for conceptualizing the problem. This leads us to propose a network layer approach to power control which consists of finding the least common network wide power level at which all nodes are connected. This can be shown to maximize the throughput traffic carrying capacity of the network. We then propose a feedback algorithm COMPOW which tunes to this minimum power level adaptively. We also propose a software architecture for integrating this into the OSI protocol stack. The new idea is to introduce a parallel analog of the hierarchical OSI layers into the network layer which still allows modularity, and usability with any routing table driven routing algorithm. We also describe our implementation, which takes advantage of the port demultiplexing service provided by the transport layer.
Optimal Allocation of Heterogeneous Resources: A Control-Theoretic Approach ........................................ 1953
Wang, Yanfeng Boston Univ.
Perkins, James R. Boston Univ.
Vakili, Pirooz Boston Univ.
Khurana, Anil Boston Univ.

Abstract: This paper considers problems motivated by the need for effective dynamic allocation of limited heterogeneous resources in new product development (NPD) projects. The interchangeability of resources and simultaneous resource sharing are defining characteristics of NPD processes. A continuous flow model is introduced that incorporates these features. For problems without activity precedence constraints, a linear program is presented which yields the minimum completion time for all activities. A dynamic, rule-based algorithm is shown to be optimal for two resources processing a multiple-activity arrival stream. For problems with precedence constraints, some special cases are solved, and structural properties of the class of optimal controls for the general problem are discussed.

A Dynamic-Programming-Styled Algorithm for Time-Optimal Multi-Agent Task Assignment .......................... 1959
Yang, Guang Polytechnic Univ.
Kapila, Vikram Polytechnic Univ.

Abstract: Cooperative control of multiple agents is an area of intense current research activity. Many practical applications of multi-agent control frequently necessitate assignment of tasks among agents such that the overall mission goals are accomplished in a minimal amount of time. In this paper, we use a dynamic programming formulation to address a class of time-optimal multi-agent task assignment problems. Based on the recurrence relation obtained from the celebrated principle of optimality, we develop an algorithm with a distributed computational architecture for the global time-optimal task assignment. In addition, we propose a communication protocol to facilitate distributed decision making among agents. Illustrative studies are included to demonstrate the efficacy of the proposed time-optimal multi-agent task assignment algorithm.

Dependent Policy for Order Quantity Problems with Time-Varying Demands ................................................. 1965
Tang, Jiafu Northeastern Univ.
Fung, Richard City Univ. of Hong Kong
Yung, Kai-Leung The Hong Kong Polytechnic Univ.
Wang, Dingwei Northeastern Univ.

Abstract: The time-varying demands in a period considered in most of the heuristics in literatures is generally assumed to be less than the basic EOQ in a planning period, and hence the decisions of total replenishment quantity, not the economic order quantity in each planning period, are concerned. This paper focuses on a dependent policy-based heuristic for order quantity problems with time-varying demand. The independent policy, abnormal independent policy and various dependent policies are discussed and compared.

An Effective Short-Term Scheduling Model for Multiproduct Batch Plants with Parallel Lines ................................ 1971
Changling, Chen Shanghai Jiao Tong Univ.
Changling, Liu Shanghai Jiao Tong Univ.
Decheng, Yuan Shenyang Inst. of Chemical Tech.
Huihe, Shao Shanghai Jiao Tong Univ.

Abstract: This paper presents a new MILP model for the batch plants with parallel lines based on the continuous time domain representation and the notation of time slot. When the model is built, the allocation of batches of products and units to time slots is formulated as two sets of binary variables respectively. This model has less binary variables than any other model based on the idea of time slot, and can accommodate sequence-dependent setup times. The computational examples show that the optimal scheduling can be obtained by solving MILP model in a reasonable short time, especially when the scheduling problem involving product with several batches is considered.

Robustness and Interval Systems
Chair: Orlando, Giuseppe Univ. di Ancona
Co-Chair: Barmish, B. Ross Case Western Reserve Univ.

10:40
Robust Stabilization of Interval Plant Family using H-Infinity Optimization Technique ................................. 1975
Xie, Dahua Beijing Inst. of Tech.
Li, Kan Beijing Inst. of Tech.
Wu, Qinghe Beijing Inst. of Tech.

Abstract: The robust stabilization problem (RSP) of interval plant family is considered. By representing the nominal plant with the normalized coprime factorization description, the RSP of interval plant family is converted to a particular H_infinity control problem. An analytical formula for calculating the parametric stability radius delta_max of the closed-loop system consisting of the interval plant family and the H_infinity controller is given. Using delta_max, the stability margin epsilon_(rm IP) of the closed-loop system, described in terms of the H_infinity-norm of the uncertain factors in the NCF description, is calculated. Numerical example shows that epsilon_(rm IP) is larger than the stability margin of the general unstructured uncertainties case.

11:00
An Output Feedback Switching Controller for the Stabilization of Uncertain Interval Plants ......................... 1980
Corradini, Maria L. Univ. di Lecce
Orlando, Giuseppe Univ. di Ancona

Abstract: The robust stabilization problem for a family of linear uncertain interval plants is considered. The solution presented is based on switching control, and is constituted by a deterministic time-varying compensator (assuming a finite number of possible different configurations) and by a supervisor. Moreover, the entire switching procedure is made using only information of the output variable. An appealing feature of the proposed algorithm is that the phase of ‘scanning’ among the different configurations can be shortened with respect to existing algorithms, thus reducing the transient phase during which the system output may diverge because of destabilizing controllers applied. Part of the switching control scheme is based on Variable Structure Control. The convergence of the switching algorithm has been theoretically proved.

11:20
Double Edge Family: Extreme Point Results .......................... 1986
Trejo, Hugo Romero CINVESTAV-IPN
Kharitonov, Vladimir L. CINVESTAV-IPN

Abstract: In this paper the robust stability of a special polynomial family is studied. Such families appear in stability analysis of uncertain uniform systems.

Abstract: In this paper, the problem of robust absolute stability for discrete-time interval Lurie systems containing an arbitrary number of monotonic sector-bounded memoryless time-invariant nonlinearities is studied via analysis of interval matrix, and an algebraic sufficient condition with interval matrix inequality form is obtained for the discrete-time interval Lurie systems.

Avoiding Possible Instability in Robust Simulation of Stable Parametric Uncertain Time-Invariant Systems ............. 1993 Cugueró, Pep Univ. Politec. de Catalunya
Puig, Vicenç Univ. Politec. de Catalunya
Saludes, Jordi Univ. Politec. de Catalunya
Escobet, Teresa Univ. Politec. de Catalunya

Abstract: When the problem of robustly simulating a time-invariant uncertain system is faced, a one step simulation is often chosen due to its lower complexity. However, this approach does not take into account the time invariant nature of the system. This typically results into very conservative simulations, moreover, in dramatic cases can result into unstable simulations for even stable systems. In this paper one such case is presented to illustrate the problem with a solution getting a compromise between complexity of the simulation and fidelity to the time invariant nature of the system.


Abstract: Feedback is ubiquitous and is a basic concept in the area of control, where it is used primarily for reducing internal or external uncertainties, or both. In this paper we will study the capability of feedback in dealing with both internal and external uncertainties for a class of p-th order nonlinear autoregressive control systems. The size of the uncertainty is described by the Lipschitz constant (say L) of the uncertain nonlinear function in consideration. It is shown that if p and L satisfy a certain relationship, then there exists no globally stabilizing feedback for the corresponding class of uncertain systems, and thus finding a quantitative limit to the capability of the feedback mechanism in dealing with structural uncertainties.


Abstract: This paper presents an alternative approach to solve robust performance problems for linear parameter-varying (LPV) control systems. In contrast to previous methods, which are focused on deterministic algorithms, this paper is based on a probabilistic setting. The proposed randomized algorithm provides a sequence of candidate solutions converging with probability one to a feasible solution in a finite number of steps. The main advantages of this method over the previous literature are as follows: (i) The randomized algorithm gives a direct method for general LPV plants with state space matrices depending on scheduling parameters in a nonlinear manner. That is, the probabilistic setting does not require any approximation, such as a linear fractional transformation (LFT), of the state space matrices or a gridding on the set of scheduling parameters. (ii) The proposed algorithm is sequential and, at each iteration, it does not require heavy computational effort such as solving simultaneously a large number of linear matrix inequalities.

Feedback is ubiquitous and is a basic concept in the area of control, where it is used primarily for reducing internal or external uncertainties, or both. In this paper we will study the capability of feedback in dealing with both internal and external uncertainties for a class of p-th order nonlinear autoregressive control systems. The size of the uncertainty is described by the Lipschitz constant (say L) of the uncertain nonlinear function in consideration. It is shown that if p and L satisfy a certain relationship, then there exists no globally stabilizing feedback for the corresponding class of uncertain systems, and thus finding a quantitative limit to the capability of the feedback mechanism in dealing with structural uncertainties.
Design conditions on systems suitable for actuator failure compensation are briefly discussed. Results are presented for a scalar system and generalizations are made for a three-dimensional case. The a-priori information on the unknown plant dynamics, which can be transformed into parametric strict-feedback form with zero dynamics, is investigated. Direct adaptive compensation control schemes are developed to ensure that the adaptation process terminates to a parameterized nonlinear controller that stabilizes the system despite the uncertainties in actuator failures as well as in system parameters. Two main cases are studied for adaptive actuator failure compensation: systems with stable zero dynamics and systems with extra controls for stabilization. Design conditions on systems suitable for actuator failure compensation are clarified.

Abstract: Actuator failure compensation for the nonlinear systems which can be transformed into parametric strict-feedback form with zero dynamics is investigated. Direct adaptive compensation control schemes are developed to ensure asymptotic output tracking and stabilize the system despite the uncertainties in actuator failures as well as in system parameters. Two main cases are studied for adaptive actuator failure compensation: systems with stable zero dynamics, and systems with extra controls for stabilization. Design conditions on systems suitable for actuator failure compensation are clarified.

10:40 Panel Discussion

11:00 Stable Auto-Tuning of the Adaptation Gain for Continuous-Time Nonlinear Systems

Abstract: In direct adaptive control, the adaptation mechanism attempts to adjust a parameterized nonlinear controller to approximate an ideal controller. In the indirect case, however, we approximate parts of the plant dynamics that are used by a feedback controller to cancel the system nonlinearities. In both cases, “approximators” such as linear mappings, polynomials, fuzzy systems, or neural networks can be used as either the parameterized nonlinear controller or identifier model. In this paper, we present an algorithm to tune the adaptation gain for a gradient-based hybrid update law used for a class of nonlinear continuous-time systems in both direct and indirect cases. In our proposed algorithm, the adaptation gain is obtained by minimizing the instantaneous control energy.

11:20 A Non-Singular Performance Comparison between Two Robust Adaptive Control Designs

Abstract: We consider standard robust adaptive control designs based on the dead-zone and projection modifications, and compare their performance w.r.t. worst case transient cost functional penalizing the L-infinity norm of the state, control and control derivative. If a bound on the L-infinity norm of the disturbance is known, it is shown that the dead-zone controller outperforms the projection controller when the a-priori information on the unknown system parameter is sufficiently conservative. For simplicity the results are presented for a scalar system and generalizations are briefly discussed.
Abstract: In multi-modal control paradigm, a set of controllers of satisfactory performance have already been designed and must be used. Each controller may be designed for a different set of outputs in order to meet the given performance objectives and system constraints. When such a collection of control modes is available, an important problem is to be able to accomplish a variety of high level tasks by appropriately switching between the low-level control modes. In this paper, we propose a framework for determining the sequence of control modes that will satisfy reachability tasks. Our framework exploits the structure of output tracking controllers in order to extract a finite graph where the mode switching problem can be efficiently solved, and then implement it using the continuous controllers. Our approach is illustrated on a robot manipulator example, where we determine the mode switching logic that achieves the given reachability task.

Hierarchies of Stabilizability Preserving Linear Systems .......... 2081
Pappas, George J.                Univ. of Pennsylvania
Lafferriere, Gerardo             Portland State Univ.

Abstract: Hierarchical decompositions of control systems are important for reducing the analysis and design of large scale systems. Such decompositions depend on the notion of abstraction: Given a large scale system and a desired property, one tries to extract an abstracted model with equivalent properties, while ignoring details that are irrelevant. Checking the property on the abstraction should be equivalent to checking the property on the original system. In this paper, we focus on large scale linear systems and the property of stabilizability. This results in a hierarchy of linear abstractions that are equivalent from a stabilizability point of view. This is important as high level controller designs are guaranteed to have lower level implementations.

Structural Stability of Filippov Automata .......................... 2087
Broucke, Mireille               Univ. of Toronto
Pugh, Charles                  Univ. of California, Berkeley
Simic, Slobodan N.             Univ. of California, Berkeley

Abstract: We introduce Filippov automata which are based on Filippov's theory of dynamical systems governed by piecewise smooth vector fields. We develop some of the global and generic aspects of the dynamics of Filippov automata. In particular we establish generic structural stability theorem for two dimensional Filippov automata, which is a natural generalization of Mauricio Peixoto's classic result.

Static Output Feedback Control for Switched Systems .......... 2093
Daafouz, Jamal                  CRAN-INPL-ENSEM
Riedinger, Pierre              CRAN-INPL-ENSEM
Iung, Claude                   CRAN-INPL-ENSEM

Abstract: In this paper we investigate the design of a static output feedback control for switching discrete time systems. Looking at the problem of stability analysis, we give two conditions allowing to check the existence of a particular class of Lyapunov functions. Although one can recover the first condition as a particular case from the second one, it is proved that the two conditions are equivalent for stability analysis. Then we show that when one is faced with a static output feedback control problem, the second condition leads to a sufficient solution to build a stabilizing static output feedback controller which is less conservative than the solution based on the first condition.

Switching Control in Multi-Mode Markov Decision Processes ...................... 2095
Ren, Zhiyuan                    Carnegie Mellon Univ.
Krogh, Bruce H.                Carnegie Mellon Univ.

Abstract: This paper presents a switching control strategy for multi-mode Markov decision processes (MDPs). The system to be controlled is modeled as a finite-state controlled Markov chain with a mode that evolves stochastically. Although the system state is observable, the mode is only partially observable in the sense that we know the system mode only when it is in a given set of observable modes. Given a set of controllers for the system, we consider the problem of determining a switching rule that selects the controller to be applied each time the system mode is observable. The objective is to minimize a long-term average cost from the system while satisfying bounds on the long-term average of other given performance measures. We assume the multi-mode model parameters are unknown a priori, so an adaptive switching rule is required. Algorithms are presented for computing approximations to the optimal switching rule based on estimating the model parameters on line. The approach is illustrated for an example of dynamic power management of hard disk drives in computer systems.

Nash Equilibria in Partial-Information Games on Markov Chains .................. 2102
Hespanha, João P.              Univ. of Southern California
Prandini, Maria                Univ. of Brescia

Abstract: We consider a two-player partial-information game on a Markov chain, where each player attempts to minimize its own cost over a finite time horizon. We show that this game has always a Nash equilibrium in stochastic behavioral policies. The technique used to prove this result is constructive but has severe limitations because it involves solving an extremely large bi-matrix game. To alleviate this problem, we derive a dynamic-programming-like condition that is necessary and sufficient for a pair of policies to be a Nash equilibrium. This condition automatically gives Nash equilibria when a pair of “cost-to-go” functions can be found that satisfy certain inequalities.

Controlled Markov Chains with Risk-Sensitive Average Cost Criterion: The Non-Irreducible Case .. 2108
Brau-Rojas, Agustin              Univ. de Sonora
Fernández-Gaucherand, Emmanuel  Univ. of Cincinnati

Abstract: We study discrete controlled Markov chains with finite state and action spaces. The performance of control policies is measured by a risk-sensitive average cost, the exponential average cost (EAC), which models risk-sensitivity by means of an exponential (dis)utility function (so that a constant risk-sensitivity coefficient is assumed). The main result is the characterization of the EAC corresponding to an arbitrary stationary deterministic policy in terms of the spectral radii of suitable irreducible matrices. This result generalizes a well known theorem of Howard and Matheson that deals with the particular case in which the transition probability matrix induced by the policy is primitive. The following results are obtained using the above mentioned characterization. It is shown that, when a stationary deterministic policy determines only one class of recurrent states, the corresponding EAC converges to the risk-null average cost as the risk-sensitivity coefficient goes to zero. However, it is also shown that for large risk-sensitivity, fundamental differences arise between both models. In particular, the limiting values of the EAC as $\gamma \to 0$, the risk sensitivity coefficient, goes to infinity are determined. Further insight and illustration of the behavior of the EAC are provided by means of simple exam-
A proof of the existence of solutions to the associated optimality equation, under a simultaneous Doeblin condition and for small enough risk-sensitivity coefficient, is given. Our proof relies on the Perron-Frobenius theory of non-negative matrices. An example that shows the impact of risk-sensitivity on recently obtained (weak) conditions by Hernandez-Hernandez for the existence of solutions to an optimality inequality is constructed. The example illustrates how the result by Hernandez-Hernandez is significantly weakened when large risk-sensitivity is considered.

Abstract: We study discrete-time Markov Decision Processes with denumerable state space and bounded costs per stage. It is assumed that the decision maker exhibits a constant sensitivity to risk, and that the performance of a control policy is measured by a (long-run) risk-sensitive average cost criterion. Besides standard continuity-compactness conditions, the basic structural constraint on the decision model is that the transition law satisfies a Simultaneous Doeblin condition. Within this framework, the main objective is to study the existence of bounded solutions to the risk-sensitive average cost optimality equation. Our main result guarantees a bounded solution to the optimality equation only if the risk-sensitivity coefficient is small enough and, via a detailed example, it can be shown that such a conclusion cannot be extended to arbitrary values of the risk sensitivity coefficient. Our results are in opposition to previous claims in the literature, but agree with recent results obtained via a direct probabilistic analysis. A key analysis tool developed in the paper is the definition of an appropriate operator with contractive properties, analogous to the dynamic programming operator in Bellman's equation, and a family of (value) functions with a discounted stochastic games interpretation. NOTE: a full version of this paper can be obtained from the authors.

Abstract: This paper deals with the fitting of Hidden Markov Models to data generated by ergodic stochastic processes. More specifically we consider the problem of fitting a family of partially observed finite state Markov chain parameters (or Hidden Markov Models, HMM's) with continuous output to an ergodic process, with continuous values, which is not necessarily a member of the family. In this context we derive the main asymptotic results: almost sure consistency, asymptotic normality and rate of convergence of the MLE of HMM (consistency). Under proper conditions asymptotic normality has been studied mainly for model classes of independent models which do not contain the process generating the observations. A proof of the existence of solutions to the associated optimality equation, under a simultaneous Doeblin condition and for small enough risk-sensitivity coefficient, is given. Our proof relies on the Perron-Frobenius theory of non-negative matrices. An example that shows the impact of risk-sensitivity on recently obtained (weak) conditions by Hernandez-Hernandez for the existence of solutions to an optimality inequality is constructed. The example illustrates how the result by Hernandez-Hernandez is significantly weakened when large risk-sensitivity is considered.

Abstract: This paper proposes a nonlinear filtering algorithm for unknown dynamics and high-complexity observations. We show that the algorithm yields bounded error under redundant observations and small bounded disturbances. The algorithm is a generalization of what we have used to achieve the first reported real-time estimation of submicron patterned wafer geometries during a plasma etching process with spectral reflectometry.

Abstract: This paper presents an effective method of nonlinear systems identification. The method is based on nonparametric Hermite series approach. The method avoids heuristic searches. These searches may be quite time consuming, and lead only to approximate model structures, whose errors may be responsible of bad propagation of prediction errors, especially for the multi-step ahead prediction. Moreover, the method proposed in this paper assumes only that the noise is bounded, in contrast with statistical approaches, which rely on assumptions such as stationarity, ergodicity, uncorrelation, type of distribution, etc. The validity of these assumptions may be difficult to be reliably tested in many applications, where series of short length are available, and is certainly lost in presence of approximate modeling. The effectiveness of the method is tested on simulated data and real word data (Wolf Sunspot Numbers series), comparing the obtained prediction performances with those obtained by methods based on neural networks and on statistical models.

Abstract: In this paper a nonlinear prediction method based on a Set Membership approach is proposed. Such method does not need any assumption about the functional form of the model used for prediction, but uses only some information on its regularity. At the contrary, most of the existing prediction methods need the choice of a model structure and this choice is usually the result of heuristic searches. These searches may be quite time consuming, and lead only to approximate model structures, whose errors may be responsible of bad propagation of prediction errors, especially for the multi-step ahead prediction. Moreover, the method proposed in this paper assumes only that the noise is bounded, in contrast with statistical approaches, which rely on assumptions such as stationarity, ergodicity, uncorrelation, type of distribution, etc. The validity of these assumptions may be difficult to be reliably tested in many applications, where series of short length are available, and is certainly lost in presence of approximate modeling. The effectiveness of the method is tested on simulated data and real word data (Wolf Sunspot Numbers series), comparing the obtained prediction performances with those obtained by methods based on neural networks and on statistical models.

Abstract: The fundamental problem of nonlinear filtering theory is how to solve robust DMZ equation in real time and in memoryless manner. This paper describes a new real time algorithm which reduces the nonlinear filtering problem to off-line computations. Our algorithm gives convergent solutions in both pointwise sense and $L^2$ in case that the drift term and observation dynamic term have linear growths.
merstein and Wiener systems. Simulation experiments were performed and results displayed. Also, the convergence and general performance of the proposed algorithm were discussed.

15:40
Reduced Order Unbiased Filtering for a Class of Uncertain Bilinear Systems ......................... 2145
Souley Ali, H.  Univ. Henri Poincaré
Zasadzinski, Michel  Univ. Henri Poincaré
Darauoch, Mohamed  Univ. Henri Poincaré
Rafaralahy, Hugues  Univ. Henri Poincaré

Abstract: This paper presents a simple solution to the H-infinity unbiased functional reduced order filtering problem via LMI methods for bilinear systems. We extend the result to the robust filtering for bilinear systems subject to structured norm-bounded time-varying uncertainties. After giving conditions for the existence of the unbiased filter in the nominal case, we show that the filter design is reduced to a small gain problem in the nominal case and to a static output feedback one when the nominal bilinear system is affected by the uncertainties.

16:00
Identification of Extended Bilinear State Space Models .......... 2151
Schrempf, Andreas  Johannes Kepler Univ., Linz
del Re, L.  Johannes Kepler Univ., Linz

Abstract: In this paper an identification algorithm for a special model class which captures essential characteristics of many nonlinear systems is presented. Conditions are given under which this nonlinear model can be identified by use of efficient linear tools. Subspace identification is used here to determine the linear part of the model and an initial estimate for the nonlinear one. The estimate of the nonlinear part is computed by a final numerical optimization step. A simulation study illustrates the applicability of the proposed method.

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WeP02
Lyapunov based Designs
Chair: Fuji, Takao  Osaka Univ.
Co-Chair: Balas, Mark  Univ. of Colorado

14:20
Extended-Space Control Design with Parameter-Dependent Lyapunov Functions ......................... 2157
Shimomura, Takashi  Osaka Univ.
Takahashi, Masahiro  Osaka Univ.
Fuji, Takao  Osaka Univ.

Abstract: This paper addresses a new framework of control design, in which controllers are designed in extended spaces rather than those where design problems are originally given. Inverse use of the elimination lemma can explore this framework and allows us to use parameter-dependent Lyapunov functions. For continuous-time systems, multiojective control, robust control against polytopic uncertainties, and gain-scheduled control for linear parameter-varying systems are considered. An illustrated example is included.

14:40
Ultimate Boundedness Sets for Discrete-Time Linear Systems with Deadzone Feedback Controls ............... 2163
Milani, Basilio E. A.  Univ. de Campinas - FEEC
Coelho, Alessandra Dutra  Escola de Engenharia Mauá

Abstract: This paper is concerned with positively invariant convex polyhedral uniform ultimate boundedness sets for linear discrete-time systems with stabilizing deadzone feedback control laws. The objective is delimitation and region of attraction estimation of a possible limit cycle around origin of open-loop unstable systems. Limit cycle delimitation is performed via algebraic characterization of polyhedral positively invariant sets and construction of a positively invariant convex compact polyhedral estimate of the minimal positively invariant set containing an arbitrarily small neighborhood of origin. This convex positively invariant set contains a limit cycle if it does not contain any stable equilibrium point. The region of attraction estimation is performed via algebraic characterization of piecewise-affine Lyapunov functions and construction of a piecewise-affine Lyapunov function assuring uniform ultimate boundedness in the above mentioned convex positively invariant polyhedral set.

15:00
Quadratic Stabilizability of Discrete-Time Switched Systems via State and Output Feedback ................. 2165
Zhai, Guisheng  Wakayama Univ.

Abstract: We study quadratic stabilizability via state and output feedback for switched systems composed of several discrete-time linear time-invariant subsystems, under the assumption that all subsystem matrices are unstable. We derive a sufficient condition expressed as a matrix inequality under which the switched system is quadratically stabilizable via state-based switching strategy, and we show the sufficient condition is also necessary if the number of subsystems is two. When a robust detectability condition is satisfied in addition to the sufficient condition, we construct a quadratically stabilizing switching strategy based on the measurement output.
Abstract: A common quadratic Lyapunov function (CQLF) guarantees asymptotic stability of a set of systems. Complete characterizations of the set of systems with such a property are unsuccessful except second-order systems. Thus for both continuous-time and discrete-time cases, several subsets of linear systems which have a CQLF are known. Some results indicate that there is a parallelism between continuous-time case and discrete-time case. In this paper, we show a new subclass for continuous-time systems which have a CQLF by using a property of $M$-matrices. This is an extended subclass of the known result. We also show the discrete-time counterpart of the above new subclass. Next, it is shown that the whole class of continuous-time linear systems having a CQLF is connected directly with its discrete-time one by using a bilinear transformation. For some known subclasses of systems having a CQLF, the transformation gives a one-to-one correspondence between continuous-time and discrete-time cases. We further show relationships among obtained results and known results.

Abstract: In this paper, the problem of nonsmooth bifurcation control is addressed. The design technique is based on the so-called fractional power control, i.e., nonsmooth feedback laws with terms of fractional powers. A new special bonder-collision bifurcation, namely the trumpet bifurcation, is introduced by the nonsmooth fractional power control, i.e., nonsmooth feedback laws with terms of fractional powers. A new special bonder-collision bifurcation, namely the trumpet bifurcation, is introduced by the nonsmooth feedback laws with terms of fractional powers. A new special bonder-collision bifurcation, namely the trumpet bifurcation, is introduced by the nonsmooth feedback laws with terms of fractional powers.

Abstract: In this brief paper we revisit an existing chaos control scheme by using simple frequency domain analysis criteria. In particular, we highlight some interesting links with other proposed chaos control techniques, and envisage the possibility to apply well-known sufficient stability criteria such as circle criterion and generalizations thereof to evaluate its performance. Duffing equation is chosen as a simple test bench for the proposed analysis.

Abstract: Delayed feedback control (DFC) is a useful method of stabilizing unstable fixed points of chaotic systems with impact. If, on the other hand, the flow of information has to be limited, for instance because of the use of a limited capacity transmission channel, then some specific considerations are in order. The aim of this paper is to obtain a detailed analysis line systems with quantized feedback in the simple scalar case. In the scalar case a rather complete analysis is possible through a nice geometric characterization of asymptotically stable closed loop maps. Moreover a lower bound on the number of quantization levels is obtained in this case, showing that the logarithmic connection between the number of quantization levels and the rate of convergence is quite intrinsic in this approach.

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Abstract: In this paper we describe a general model for permanent magnet synchronous motors suitable for control and estimation. Various models are introduced as well, producing various models suitable for different control and estimation tasks. Several applications that illustrate uses of different models are also presented.

Abstract: The control section of power electronics equipment interacts with power section through Pulse Width Modulator (PWM) on the output and through A/D converter(s) on the input side. The most important presently used sampling and PWM methods are presented in the paper. Influence of different sampling and PWM methods on quality of control and on the power losses is analyzed.

Abstract: The paper presents an analytical and experimental evaluation of observer-based methods for estimating the position and speed for switched reluctance motor (SRM) drives. Two observers, the sliding mode observer (SMO) and the standard state observer (SSO), are both found to provide good position and speed estimates. The resolution and reliability of the position estimation scheme are analyzed in detail. Error analysis is carried out under various operating conditions using estimated position and speed in the controller. The results demonstrate the applicability of observer-based sensorless controller for SRM drives.

Abstract: Many processes present delay in their input or output signals. We use relative sensitivity functions to quantify the conditioning of individual machine parameters and rotor speed to input data. The sensitivity functions allow us to identify ill conditioned parameters in the estimation problem. To deal with ill conditioning, we use a parameter subset selection method where only a subset of parameters is estimated from the available data while the other parameters are fixed to a priori values. The resulting speed and parameter estimation algorithms are more robust because we are including in the estimation approach information to stabilize the estimates and make them less sensitive to perturbations in the measured data. Experimental results are presented which illustrate the potential of the proposed methodology to deal with ill conditioning in parameter estimation problems in energy processing systems.

Abstract: The control of a mathematical model of the power circuit of a three-phase Voltage Source Converter (VSC) was developed in the synchronous reference frame. The mathematical model was then used to design an algorithm to estimate position of line voltage essential for operation of regenerative three-phase PWM controlled VSC. The PI current regulator in D axis of VSC current control was modified to obtain angle error signal. The angle error signal drives the observer (similar in structure to PLL) which provides position or angle of line voltages. To achieve fast and reliable lock with utility system with minimal duration of transients, initial line voltage position was estimated first. The initial line voltage position estimation was done by measuring amount of current change when zero state voltage vectors were applied at the output of inverter for defined time intervals.
tainty, delay uncertainty and external disturbances is shown. An illustrative academic example is presented. The fact that the introduction of a resetting allows the use of the Smith predictor in order to control unstable systems is also discussed.

14:40
Coprime Parametrization of 2DOF Controllers to Obtain Sub-Ideal Disturbance Response for Processes with Dead-Time ........................................... 2253
Mirkin, Leonid
Zhong, Qing-Chang
Imperial College

Abstract: This paper presents the parametrization of all stabilizing two-degree-of-freedom (2DOF) controllers for (possibly unstable) processes with dead-time. The parametrization is based on the derived state-space formulae for the double coprime factorization of dead-time systems. Furthermore, the (sub-)ideal disturbance response is studied. The proposed method is applied to integral processes with dead-time to obtain sub-ideal disturbance response.

15:00
A Non-Conventional Robust PI-Controller for the Smith Predictor ........................................... 2259
Marquez, Richard
Flies, Michel
Mounier, Hugues
LSS, CNRS-Supelec-Paris XI
CMLA, ENS de Cachan
Univ. Paris XI

Abstract: A novel PI-controller is proposed as a primary controller in conjunction with the Smith Predictor. Our approach, which results in a zero steady-state error to step disturbances when controlling a pure integrator with delay, can be extended to unstable systems.

15:20
Disturbance Observer-Based Control for Processes with an Integrator and Long Dead-Time ........................................... 2261
Zhong, Qing-Chang
Normey-Rico, Julio E.
Technion-Israel Inst. of Tech.
Univ. Federal de Santa Catarina

Abstract: This paper reveals the disturbance observer-based control scheme, a version of 2DOF internal model control, for processes with an integrator and long dead-time. The controller can be designed to reject ramp disturbance as well as step disturbances, even arbitrary disturbances. If the model is available, then only two parameters are left to be tuned. One is the time constant of the setpoint response and the other is the time constant of the disturbance response which is tuned to compromise disturbance response with robustness. It has simple, clear, easy-to-design, easy-to-implement structure and good performance. The proposed solution is compared to the best results recently published with some simulation examples.

15:40
A Unified Approach to Design Dead-Time Compensators for Stable and Integrative Processes with Dead-Time ........... 2267
Normey-Rico, Julio E.
Camacho, Eduardo F.
Univ. Federal de Santa Catarina
Univ. de Seville

Abstract: This paper proposes a unified 2DOF robust dead-time compensator, for both stable and integrative plants. Using the performance and robustness as closed loop specifications simple and effective tuning rules are derived for the proposed controller. A comparative analysis with some structures of dead-time compensators that have been recently proposed in literature is presented. The analysis is made using the two most typical models of processes with delay that are found in the process industry. The comparison analysis shows that for the cases studied the proposed controller gives better or at least the same performance as the others. It is also shown that the tuning of this structure is simple because the tuning parameters have the usual physical meaning. Some simulation results illustrate the performance of the controller.

16:00
Stabilization of Second-Order Systems by a Relay Controller with Time Delay ........................................... 2273
Shustin, Eugenii
Tel Aviv Univ.

Abstract: We consider a stabilization problem of unstable scalar systems of the second order, and, under certain restrictions to the parameters of the systems considered, we design a discontinuous negative feedback with time delay (in the form of a relay with a variable magnitude) which provides an exponential decay of oscillations.

WeP06
Identification Methods for Fault Detection
Chair: Parisini, Thomas
Co-Chair: Speyer, Jason L.
Univ. of California, Los Angeles

14:20
Fault Detection: A Subspace Identification Approach ........ 2275
Lowera, Marco
Parisini, Thomas
Verhaegen, Michel
Politecnico di Milano
Univ. of Twente

Abstract: Some results on the analysis of the fault detection problem in a subspace identification framework are presented and two approaches are proposed, exploiting an existing perturbation analysis of subspace methods.

14:40
Fault Reconstruction from Sensor and Actuator Failures .... 2277
Chen, Robert H.
Speyer, Jason L.
Univ. of California, Los Angeles
Univ. of California, Los Angeles

Abstract: Many fault detection filters have been developed to detect and identify sensor and actuator faults by using analytical redundancy. In this paper, an approach for reconstructing sensor and actuator faults from the residual generated by the fault detection filter is proposed. The transfer matrix from the faults to the residual is derived in terms of the eigenvalues of the fault detection filter and the invariant zeros of the faults. For each fault, the fault reconstruction process is derived by applying a projector to the transfer matrix and taking inverse. In order to have a well-conditioned fault reconstruction process, the invariant zeros of the faults have to be in the left-half plane. Furthermore, for reconstructing a sensor fault, the system has to be detectable with respect to the other sensors.
is proportional. In the case of delay-free marking, we show the system's equilibrium point to be asymptotically stable for all proportional gains. In the more realistic case of delayed feedback, we establish local asymptotic stability and quantify a region of attraction.

15:00
Bounded Control of Multiple-Delay Systems with Applications to ATM Networks ................................. 2315
Tarbouriech, Sophie  
LAAS-CNRS
Abdallah, Chaouki T.  
Univ. of Tennessee
Ariola, Marco  
Univ. degli Studi di Napoli Federico II

Abstract: Congestion control in the Available Bit Rate (ABR) class of Asynchronous Transfer Mode (ATM) networks poses interesting challenges due to the presence of multiple-delays, magnitude and rate constraints on the inputs and additive disturbances. We consider a fixed-structure controller for an ATM/ABR network, and solve a robust tracking control problem in which the target is a threshold on the queue level.

15:20
Joint Optimization of Communication Rates and Linear Systems ......................................................... 2321
Xiao, Lin  
Stanford Univ.
Johansson, Mikael  
Stanford Univ.
Hindi, Haithman  
Stanford Univ.
Boyd, Stephen  
Stanford Univ.
Goldsmith, Andrea  
Stanford Univ.

Abstract: We consider a linear system, such as a controller or estimator, in which several signals are transmitted over communication channels with bit rate limitations. We model the effect of bit rate limited wireless channels by conventional uniform quantization, and use a standard white-noise model for quantization errors. We focus on finding the allocation of communication resources such as transmission powers, bandwidths, or time-slot fractions, that yields optimal system performance. We show that if the linear system is fixed, the problem of allocating communication resources is often convex. We discuss optimization algorithms that exploit the problem structure, and present efficient heuristics for obtaining integer-valued solutions. The problem of jointly allocating communication resources and designing the linear system is in general not convex, but can be solved heuristically in a way that exploits the problem structure and appears to work well in practice.

15:40
Optimal Control of Networked Systems via Asynchronous Communication Channels with Irregular Delays .......... 2327
Matveev, Alexey S.  
St. Petersburg Univ.
Savkin, Andrey V.  
Univ. of New South Wales

Abstract: The paper is directed towards development of a new chapter of control theory that deals with networked systems in which control and communication issues are combined together, and all the delays and limitations of the communication channels between sensors, actuators, and controllers are taken into account. We consider a situation where a single decision-maker both receives the sensor data and controls many linear discrete-time partially observed subsystems perturbed by white noises via randomly delayed communication channels with finite capacities. Neither these delays nor their statistics are known in advance, but each message transmitted is equipped with a "time stamp" indicating the time of the transfer beginning. Under certain assumptions, a finite horizon linear-quadratic optimal control problem is solved.

16:00
Change Detection in the Dynamics with Recursive Subspace Identification ........................................... 2297
Oku, Hiroshi  
Univ. of Twente
Nijssen, Gerard  
Univ. of Twente
Verhaegen, Michel  
Univ. of Twente
Verduilt, Vincent  
Univ. of Twente

Abstract: In this paper, we propose a tracking mechanism to follow time-variations in the dynamics of a linear system with a recursive identification of the PI-MOESP scheme. The proposed mechanism consists of change detection scheme followed by a re-initialization of the recursive calculations. The change detection is based on the least-squares interpretation of the calculation in the subspace scheme and detects whether the estimates of the recursive solution without exponential forgetting lies in the confidence interval of the estimates obtained with a second finite-window length solution to the least-squares problem. When a change has been detected, the estimate by the recursive implementation is re-initialized via the solution of a constrained least-squares problem. One numerical example is presented to illustrate that our change detection and re-initialization scheme can detect incipient changes in the system dynamics without detecting changes in input dynamics.

16:40
Nonlinear Stability Analysis for a Class of TCP/AQM Networks ......................................................... 2309
Hollot, Christopher V.  
Univ. of Massachusetts
Chaït, Yossi  
Univ. of Massachusetts

Abstract: Recent work has shown the benefit of using proportional feedback in TCP/AQM networks. By proportional feedback we mean the marking probability is proportional to the instantaneous queue length. Our earlier work relied on linearization of nonlinear fluid-flow models of TCP. In this work we address these nonlinearities directly and establish some stability results when the marking
Abstract: The prescription of sets of trajectories for a finite determin- 
istic automaton A is formulated via the notion of specifications 
denoted, both individually and collectively, by SPEC. Necessary 
and sufficient conditions for the existence of sets of trajectories sat-
sifying a given SPEC are provided. The formulation and specifica-
tion of structures for interacting automata are developed within the 
Multi-Agent (MA) product framework and the associated MA prod-
uct of specifications (MSPEC) is introduced.

14:40
Optimal Control of Discrete Event
Systems under Partial Observation .............................. 2335
Marchand, Herve  
IRISA/INRIA Rennes
Boivineau, Oliver  
Electricité de France
Lafortune, Stéphane  
Univ. of Michigan

Abstract: We are interested in a new class of optimal control prob-
lems for Discrete Event Systems (DES). We adopt the classical 
formalism of supervisory control theory and model the system as a 
finite state machine (FSM). Our control problem is characterized by 
the presence of uncontrollable as well as unobservable events, the 
notion of occurrence and control costs for events and a worst-case 
objective function. We first derive an observer for the partially un-
observable FSM, which allows us to construct an approximation of 
the unobservable trajectory costs. We define the performance 
measure on this observer rather than on the original FSM itself. 
Further, we use the algorithm of [Sengupta & Lafortune, Siam Con-
trol and Optimisation, 36(2), 1998] to synthesize an optimal sub-
machine of the observer. This submachine leads to the desired su-
ervisor for the system.

15:00
Writing Maximum Gap Constraints for Part Routing in 
Manufacturing Systems Modelled as Petri Nets .............. 2341
Giglio, Davide  
Univ. di Genova
Minciardi, Riccardo  
Univ. di Genova

Abstract: This paper considers the problem of part routing within a 
manufacturing system, represented as a timed Petri net. On the 
basis of such a model, it is possible to write the constraints affect-
ing the system behaviour. A scheme is proposed in which token 
assignment (i.e., part routing) decisions must fulfill maximum gap 
constraints, which limit the set of allowed routing decision se-
quences.

15:20
Stochastic Production Systems: Production and 
Maintenance Scheduling with Finite Buffers .................. 2343
Westman, John J.  
Univ. of California, Los Angeles
Boukas, El-Kebir  
Ecole Polytech. de Montréal
Hanson, Floyd B.  
Univ. of Illinois, Chicago

Abstract: Consider the production of a single consumable product 
that is fabricated in a process of k stages that is subject to an un-
certain environment. There are a number of workstations on each 
stage that have different operating parameters. The workstations 
are subject to the discrete events of repair, failure, and preventive 
maintenance that generate a jump in the state of the system. Be-
tween each stage of the manufacturing process is a finite buffer 
that holds pieces before they can be processed by the next stage. 
If a buffer is full, then the preceding stage cannot produce pieces 
since there will be no place for them to go. This formulation of a

WeP08
Manufacturing Systems
Chair: Minciardi, Riccardo  
Univ. of Genova
Co-Chair: Marchand, Herve  
IRISA/INRIA Rennes

14:20
On Vector Trajectory Specifications for 
Multi-Agent Product Systems ................................. 2333
Romanovskiy, Iakov  
McGill Univ.
Caines, Peter E.  
McGill Univ.

Abstract: The prescription of sets of trajectories for a finite determi-
nistic automaton A is formulated via the notion of specifications 
denoted, both individually and collectively, by SPEC. Necessary 
and sufficient conditions for the existence of sets of trajectories sat-
sifying a given SPEC are provided. The formulation and specifica-
ton of structures for interacting automata are developed within the 
Multi-Agent (MA) product framework and the associated MA prod-
uct of specifications (MSPEC) is introduced.

14:40
Optimal Control of Discrete Event
Systems under Partial Observation .............................. 2335
Marchand, Herve  
IRISA/INRIA Rennes
Boivineau, Oliver  
Electricité de France
Lafortune, Stéphane  
Univ. of Michigan

Abstract: We are interested in a new class of optimal control prob-
lems for Discrete Event Systems (DES). We adopt the classical 
formalism of supervisory control theory and model the system as a 
finite state machine (FSM). Our control problem is characterized by 
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observable FSM, which allows us to construct an approximation of 
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measure on this observer rather than on the original FSM itself. 
Further, we use the algorithm of [Sengupta & Lafortune, Siam Con-
trol and Optimisation, 36(2), 1998] to synthesize an optimal sub-
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ervisor for the system.

15:00
Writing Maximum Gap Constraints for Part Routing in 
Manufacturing Systems Modelled as Petri Nets .............. 2341
Giglio, Davide  
Univ. di Genova
Minciardi, Riccardo  
Univ. di Genova

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manufacturing system, represented as a timed Petri net. On the 
basis of such a model, it is possible to write the constraints affect-
ing the system behaviour. A scheme is proposed in which token 
assignment (i.e., part routing) decisions must fulfill maximum gap 
constraints, which limit the set of allowed routing decision se-
quences.

15:20
Stochastic Production Systems: Production and 
Maintenance Scheduling with Finite Buffers .................. 2343
Westman, John J.  
Univ. of California, Los Angeles
Boukas, El-Kebir  
Ecole Polytech. de Montréal
Hanson, Floyd B.  
Univ. of Illinois, Chicago

Abstract: Consider the production of a single consumable product 
that is fabricated in a process of k stages that is subject to an un-
certain environment. There are a number of workstations on each 
stage that have different operating parameters. The workstations 
are subject to the discrete events of repair, failure, and preventive 
maintenance that generate a jump in the state of the system. Be-
tween each stage of the manufacturing process is a finite buffer 
that holds pieces before they can be processed by the next stage. 
If a buffer is full, then the preceding stage cannot produce pieces 
since there will be no place for them to go. This formulation of a

WeP09
Linear Parameter Varying Systems
Chair: Kaminer, Isaac  
Naval Post-Graduate School
Co-Chair: Casavola, Alessandro  
Univ. Della Calabria

14:20
Linear Parametrically varying Systems with Brief Instabilities: 
An Application to Integrated Vision/IMU Navigation ........... 2361
Hespahna, João P.  
Univ. of Southern California
Yakimenko, Oleg  
Naval Postgraduate School
Kaminer, Isaac  
Naval Postgraduate School
Pascoal, Antonio  
Inst. Superior Técnico

Abstract: This paper studies linear parametrically varying systems 
(LPVs) with brief instabilities. LPVs are ubiquitous because they 
provide an elegant, albeit conservative framework for the study of 
nonlinear sys-tems. This is done by analyzing a related family of 
linear time-invariant systems parameterized by a parameter p that 
lives in some compact set. In the conventional set-up of LPV the-
ory, it is usually required that the system matrices in the family of 
parameterized linear systems be stable for all values of p. How-
ever, there are interesting prob-lems for which this requirement 
does not hold true, that is, the linear system matrices are unstable 
for some values of the parameter p, instability occurring for brief 
instants of time only. This paper intro-duces the concept of LPVs
with brief instabilities and derives tools for stability and performance analysis of these systems, where per-formance is evaluated in terms of L2 induced norms. The main results show that stability and performance can be assessed by examining the feasibility of parameterized sets of Linear Matrix Inequalities (LMIs). An application to the problem of designing a nonlinear vision/inertial navigation filter for an aircraft approaching an aircraft carrier is included. The results developed provide the proper framework to deal with out-of-frame events that arise when the vision system loses its target temporarily. Field tests with a prototype unmanned air vehicle illustrate the performance of the filter and illustrate the scope of applications of the new theory developed.

**14:40**

**A Scheduling MinMax Predictive Control Algorithm for LPV Systems Subject to Bounded Rate Parameters**

Casavola, Alessandro  
Univ. degli Studi della Calabria

Famularo, Domenico  
ISI-CNR

Franzè, Giuseppe  
Univ. degli Studi della Calabria

**Abstract:** A novel optimal receding horizon control strategy for input saturated LTV discrete-time systems with polytopic model uncertainties when the actual realization of the uncertain parameter is known and when bounded rate uncertain parameter variations are present, is proposed. The approach is based on, the updating at each step, in a binary tree fashion, of the closed convex hulls of all k-steps state trajectories originating from x at time 0 under a quadratically scheduling stabilizing state feedback. The solution is computed by solving an upper-bound on the “worst-case” infinite horizon quadratic cost under the constraint of steering the future state evolutions emanating from the current state into a feasible and positive invariant set, whose “size” depends on the rate variation of the uncertain parameter. Feasibility and closed loop stability of this strategy are here proved.

**15:00**

**Parameter-Dependent Control with γ-Performance for Affine LPV Systems**

Bara, G. Iulia  
CRAN-INPL

Daafouz, Jamal  
CRAN-INPL

**Abstract:** In this paper, we address the problem of robust parameter-dependent control synthesis for linear parameter varying (LPV) systems. We propose here a full-state feedback controller whose gain is parameter-dependent. Our synthesis method is based on parameter-dependent Lyapunov functions and gives sufficient conditions for the controller design which are expressed as a more flexible LMI feasibility conditions.

**15:20**

**Control of Nonstationary LPV Systems**

Farhood, Mazen  
Univ. of Illinois, Urbana-Champaign

Dullerud, Geir E.  
Univ. of Illinois, Urbana-Champaign

**Abstract:** This paper considers control of nonstationary linear parameter-varying systems, and is motivated by interest in the control of nonlinear systems along prespecified trajectories. In the paper, synthesis conditions are derived for such systems using an operator theoretic framework with the L2 induced norm as the performance measure. These conditions are given in terms of structured operator inequalities. In general, evaluating the validity of these conditions is an infinite dimensional convex optimization problem; however, if the initial system is eventually periodic, they reduce to a finite dimensional semi-definite programming problem, and are thus readily verified.

**15:40**

**Gain Scheduling via Affine Linear Parameter-Varying Systems and H-Infinity Synthesis**

Bruzelius, Fredrik  
Chalmers Univ. of Tech.

Breitholtz, Claes  
Chalmers Univ. of Tech.

**Abstract:** In this paper an alternative method for Gain Scheduling is considered, based on so called affine Linear Parameter Varying systems (LPV) and an H-infinity-like method. It is showed that the necessary constraints for existence of such a controller can be reduced. This decreases the computational burden, in the process of finding a controller. The method is illustrated by application to a 3-state Moore-Greitzer compressor model. The nonlinear model is rewritten as a so called quasi-LPV system which the control synthesis is based on, and the derived controller is simulated with the nonlinear model.

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**16:00**

**Weighted Incremental Norm: A New Approach to Gain Scheduling**

Fromion, Vincent  
INRA

Scorletti, Gerard  
ISMRA-LAP

**Abstract:** The weighted incremental norm approach was originally introduced as a natural framework for extending well-known H-infinity linear control concepts into the nonlinear context. In this paper, we investigate the numerous links between this new approach and the classical gain-scheduling technique: more precisely, we show that the control objectives of the gain-scheduled controller design can be expressed as the weighted incremental norm minimization of a nonlinear operator. The result is twofold: it first provides a rigorous mathematical formulation of the gain-scheduling problem. Furthermore, existing gain-scheduling techniques can be interpreted as approximate solutions to the weighted incremental norm minimization of a nonlinear operator.

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**Grand Cypress Ballroom I**

**WeP10**

**Robotics**

Chair: Ghosh, Bijoy  
Washington Univ.

Co-Chair: Tang, Yu  
Natl. Univ. of Mexico

**14:20**

**Dynamic Vision and Inertial Sensors**

Rehbinder, Henrik  
Royal Inst. of Tech.

Ghosh, Bijoy  
Washington Univ.

**Abstract:** In this paper, estimation of rigid body orientation is studied. The measurements are angular velocities from a rate gyro and the perspective projections of lines, obtained from a computer vision system. The problem is formulated as an implicit output problem for a system evolving on the special orthogonal group and it is shown that it is possible to decouple the rotation estimation problem from the position estimation. Observability is studied for different line configurations and an observer for the rotation is proposed. It is shown that under some natural conditions on the translation, the observer is locally exponentially stable. The observer does not use any local parameterization of the special orthogonal group but instead evolves on the group of rotation matrices.

**14:40**

**Robust Fuzzy Control of Mechanical Systems**

Tang, Yu  
Natl. Univ. of Mexico

Vélez-Díaz, Daniel  
Natl. Univ. of Mexico

**Abstract:** This paper considers the problem of controlling a mechanical system described by Euler-Lagrange equations to follow a desired trajectory in the presence of uncertainties. A fuzzy logic system (FLS) is used to approximate the unknown dynamics of the system. Based on the a priori information, the premise part of the FLS as well as a nominal weight matrix are designed first and are fixed. A compensation signal to the weight matrix error is designed based on Lyapunov analysis (Corless and Leitmann, 1981). To further reduce the tracking error due to the function reconstruction error, a second compensation signal is also synthesized. By running two estimators on-line for weight matrix error bound and function reconstruction error bound the implementation of the proposed controller needs no a priori information on these bounds. Exponential tracking to a desired trajectory upto a uniformly ultimately bounded error is achieved with the proposed control. The effectiveness of this control is demonstrated through simulations. The
simulations also show that by incorporating a priori information about the system, the fuzzy logic control can result good tracking behavior using a few fuzzy IF-THEN rules.

15:00
Dynamic Output Feedback Passification
with Application to an Elastic Joint Robot
Son, Young I. Seoul Natl. Univ.
Shim, Myungho Univ. of California, Santa Barbara
Seo, Jin H. Seoul Natl. Univ.

Abstract: Output feedback passification problem is studied when the given system is not minimum-phase or does not have relative degree one. Using a parallel connection with an additional dynamics, the authors provide a dynamic output feedback control law which renders the composite system passive. For linear time-invariant systems, a necessary and sufficient condition for designing an input-dimensional additional system is presented. Motivated by the dynamic passification scheme, a point-to-point control law for an elastic joint robot is presented when only the position measurements are available. This provides an alternative way of replacing the role of the velocity measurements for the proportional-derivative (PD) feedback law. The performance of the proposed control law is illustrated in the simulation studies of a manipulator with three revolute elastic joints.

15:20
Manipulator Motion Control in Operational Space using Joint Velocity Inner Loops
Kelly, Rafael CICESE
Moreno, Javier CICESE
Pérez, Fémin CICESE

Abstract: An operational space motion control scheme based on velocity feedback inner loops is considered in this paper. This scheme uses kinematic control for providing joint velocity and acceleration commands to an inner joint velocity control loop system. We present an outline of the stability analysis and some experimental results on a two degrees-of-freedom direct-drive arm.

15:40
Visual Feedback Control of Nonlinear Robotics Systems via Stabilizing Receding Horizon Control Approach
Kawai, Hiroyuki Kanazawa Univ.
Fujita, Masayuki Kanazawa Univ.

Abstract: This paper investigates a robot motion control with visual information via the nonlinear receding horizon control approach. Firstly, the model of the relative rigid body motion and the nonlinear observer are considered in order to derive the visual feedback system. Secondly, the stabilizing feedback control law for the closed-loop system is discussed as a preparation for our main result. Finally, we propose the stabilizing receding horizon control scheme for the 3-D visual feedback control problem by using an appropriate control Lyapunov function as the end point penalty. The proposed scheme employs the cost function as a Lyapunov function for establishing stability.

16:00
Discontinuous Feedback Control of a 3 Link Planar PPR Underactuated Manipulator
Mahindrakar, Arun D. Indian Inst. of Tech.
Banavar, Ravi N. Indian Inst. of Tech.
Reyhanoglu, Mahmut Embry-Riddle Aeronautical Univ.

Abstract: In this paper we consider the synthesis of a point-to-point control law for a three degrees of freedom planar PPR underactuated manipulator moving in a horizontal plane. We apply the results of Mahmut and co-workers (2000) where a discontinuous feedback controller construction for a special class of underactuated systems is presented. By using a coordinate transformation provided by Imura and co-workers (1996) we transform the system into chained form which makes it suitable for the application of the discontinuous control law. Simulation results are presented that demonstrate the effectiveness of the controller.

14:20
Adaptive Visual Tracking for Motions on Smooth Surfaces
Hsu, Liu COPPE/Federal Univ. of Rio de Janeiro
Zachi, Alessandro R. L. COPPE/Federal Univ. of Rio de Janeiro
Lizarralde, Fernando Federal Univ. of Rio de Janeiro

Abstract: A robot visual servoing system using an uncalibrated fixed camera is considered. An adaptive controller is proposed for visually tracking a predefined trajectory on some unknown smooth surface. Adaptation is designed to compensate the camera uncertainties and the lack of knowledge about the surface. The key idea is to extend the use of a recently proposed hierarchy of control method to solve the adaptive control problem which now consists of a non-linear visual servoing system. Experimental results illustrate the robustness and viability of the proposed scheme.

14:40
Chatter Suppression with Adaptive Control in Turning Metal via Application of Piezoactuator
Pan, Jingchuan Concordia Univ.
Su, Chun-Yi Concordia Univ.

Abstract: Self-excited vibration, so called chatter, is known to cause detrimental effects on the machined surface finish and to decrease the machining efficiency. In this paper, in order for chatter suppression, a piezoactuator is introduced for the regulation of the machine tool displacement. In order for the ultra-precision control in turning via piezoactuator, a model with hysteretic nonlinearity accounting for the dynamics of turning process, cutting tool and piezoactuator is presented. With this model, a robust adaptive controller for the metal cutting system of ultra-precision is proposed and the simulation results shows that the proposed adaptive controller significantly eliminates the chatter phenomena.

15:00
Multivariable Adaptive Controller Design for a Class of Non-Affine Models Arising in Flight Control
Bošković, Jovan D. Scientific Systems Co., Inc.
Chan, Lingi Scientific Systems Co., Inc.
Mehra, Raman K. Scientific Systems Co., Inc.

Abstract: In this paper we extend our previous results on adaptive tracking control design for single-input non-affine dynamic models to the multivariable case. The proposed procedure was first developed for the case of known parameters, and then extended to the adaptive control design in the case of uncertain parameters. It is shown that the key design aspect is the definition of the estimate of the derivative of system’s state, which results in a convenient error model from which the adaptive laws can be written by inspection. The proposed approach is tested using a 3DOF simulation of a typical fighter aircraft, and is shown to result in substantially improved response of the system.

15:20
An Adaptive Scheme for Compensation of Loss of Effectiveness of Flight Control Effectors
Bošković, Jovan D. Scientific Systems Co., Inc.
Mehra, Raman K. Scientific Systems Co., Inc.

Abstract: In this paper we present two stable adaptive tracking control algorithms for compensation of loss of effectiveness of control effectors in flight control applications. The overall approach is based on suitable failure parametrization, control law and adaptive algorithm design, and Lyapunov analysis of the properties of the overall system. The proposed adaptive algorithms are based on parameter-adaptive and variable-structure control approaches. It is shown that, in both cases, the overall system is stable and the tracking error converges to zero asymptotically. The properties of
the proposed algorithms are illustrated through simulations of the F/A-18C/D aircraft in the presence of multiple control effector failures. The proposed algorithms appear to be promising tools for effective on-line compensation of multiple flight critical failures.

15:40
Reduced-Order Adaptive Controllers for MHD Flows using Proper Orthogonal Decomposition
Ravindran, S. S.  Univ. of Alabama, Huntsville

Abstract: We present a reduced-order adaptive controller design for MHD flows. Frequently, reduced-order models are derived from low-order bases computed by applying proper orthogonal decomposition (POD) on an a priori ensemble of data of cw model. This reduced-order model is then used to derive a reduced-order controller. The approach discussed here differ from these approaches. It uses an adaptive procedure that improves the reduced-order model by successively updating the ensemble of data. The idea is illustrated on a control problem in unsteady magneto-hydrodynamic (MHD) flows. Numerical implementations and results are provided illustrating feasibility.

16:00
Premise-Part Adaptation Laws for Adaptive Fuzzy Control and its Application to Vehicle Speed Control
Lee, Gi D.  Pohang Univ. of Sci. & Tech.
Kim, Sang W.  Pohang Univ. of Sci. & Tech.
Park, Tae J.  Research Inst. of Ind. Sci. & Tech.

Abstract: In the adaptive fuzzy control, approximation accuracy of the designed fuzzy system plays a key role in the overall system performance. Up to now, linear parameterization method has been used to derive suitable adaptive laws, even in the adaptation of premise-part membership functions. However, the premise-part adaptation schemes with linear parameterization have some fundamental limitation due to the inadequacy of gradient algorithm for general nonlinearly parameterized functions. In this paper, a new adaptive fuzzy control method with adaptation both of the premise-part and consequence-part membership functions is presented. The proposed adaptive fuzzy control scheme does not suffer from the problems appearing in conventional premise-part adaptation by using a nongradient strategy. The global stability as well as performance enhancement is given via simulations and application results to vehicle speed control.

WeP12
Switched Systems II
Chair: Antsaklis, Panos J.  Univ. of Notre Dame
Co-Chair: Yedavalli, Rama K.  Ohio State Univ.

14:20
Advanced Performance Analysis and Robust Controller Synthesis for Time-CONTROLLED Switched Systems with Uncertain Switchings
Masubuchi, Izumi  Hiroshima Univ.
Tsutsui, Makoto  Hiroshima Univ.

Abstract: Design of control systems with discrete switches of their continuous dynamics has been receiving much attention recently with their increasing importance in control engineering. In this paper, a robust controller synthesis approach is proposed for time-controlled switched systems with providing advanced stability and L₂-gain performance analysis. Piecewise differentiable storage functions are utilized to derive linear matrix inequalities (LMIs) for performance analysis and controller synthesis. In particular, unstable subsystems are admitted to switched systems and robust controller synthesis methods are shown with uncertainties in continuous dynamics and time lag between the switches of the plant and the controller.

14:40
Supervisory Control of Railway Networks with Petri Nets
Giua, Alessandro  Univ. of Cagliari
Seatzu, Carla  Univ. of Cagliari

Abstract: The paper deals with the optimal control of switched piece-wise linear autonomous systems, where the objective is that of minimizing a quadratic performance index over an infinite time horizon. We assume that the switching sequence and the corresponding jump matrices sequence is known, while the unknown switching times are the optimization parameters. The optimal control for this class of systems, assuming a switching sequence of finite length, takes the form of a homogeneous state feedback, i.e., it is possible to identify a homogeneous region of the state space such that an optimal switch should occur if and only if the present state belongs to this region; we show how such a region can be computed with a numerical procedure. As the number of allowed switches goes to infinity, we study the stability of the system and discuss some preliminary results related to the convergence of the state feedback law.

15:00
An Approach for Solving General Switched Linear Quadratic Optimal Control Problems
Xu, Xuping  Univ. of Notre Dame
Antsaklis, Panos J.  Univ. of Notre Dame

Abstract: This paper successfully addresses an important class of hybrid optimal control problems of practical significance. It provides a viable general approach to hybrid optimal control based on nonlinear optimization and it shows that when this approach is applied to linear quadratic problems it leads to computationally attractive algorithms. Unlike conventional optimal control problems, optimal control problems for switched systems require the solutions of not only optimal continuous inputs but also optimal switching sequences. Many practical problems only involve optimization where the number of switchings and the sequence of active subsystems are given. This is stage 1 of the two stage optimization method proposed by the authors in previous papers. In order to solve stage 1 problems using efficient nonlinear optimization techniques, the derivatives of the optimal cost with respect to the switching instants need to be known. In this paper, we focus on and solve a special class of optimal control problems, namely, general switched linear quadratic problems. The approach first transcribes a stage 1 problem into an equivalent problem parameterized by the switching instants and then obtains the derivative values based on the solution of an initial value ordinary differential equation formed by the general Riccati equation and its differentiations. Examples illustrate the results.

15:20
Robustness of Transitions in Switched Hybrid Systems
Jönsson, Ulf T.  Royal Inst. of Tech.

Abstract: A robustness problem for transitions in switched hybrid systems is considered in this paper. The specific problem is to estimate the size of the image set when a subset of an affine manifold is mapped by an uncertain system to another affine manifold. It is assumed that the system dynamics is linear and that the uncertainty and the disturbances are characterized by integral quadratic constraints. The estimates can be obtained by solving a special affinely parameterized linear quadratic optimal control problem.

15:40
Ultimate Boundedness Control of Linear Switched Systems using Controlled Dwell Time Approach
Yedavalli, Rama K.  Ohio State Univ.
Sparks, Andrew  AFRL/VACA

Abstract: Motivated by the Satellite Formation Keeping Control Problem, this paper addresses the aspect of control design for the ultimate boundedness of linear switched systems consisting of both controlled (and thus stable) and uncontrolled (possibly unstable) subsystems. First, explicit formulae for the bounds on total ac-
Stochastic Estimation and Filtering

Chair: Charalambous, Charalambos D. 
Co-Chair: Davison, Edward J.

14:40 Signed Adaptive Filtering Algorithms with Iterate Averaging .... 2508
Yin, George 
Krishnamurthy, Vikram
Wayne State Univ. 
Univ. of Melbourne

Abstract: This paper develops two-stage sign algorithms for adaptive filtering. The proposed algorithms are based on constructions of a sequence of estimates using large step sizes followed by iterate averaging. It is proved that the averaged sign-error algorithm converges to the minimizer with probability one. Then the asymptotic normality of a suitably scaled sequence of the estimation error is established. The asymptotic covariance is explicitly calculated and shown to be the smallest possible. Hence the asymptotic efficiency or asymptotic optimality is obtained.

15:00 Optimal Linear Filtering for Stochastic Non-Gaussian Descriptor Systems ......................... 2514
Germani, Alfredo 
Manes, Costanzo 
Palombo, Pasquale
Univ. degli Studi dell’Aquila 
Univ. degli Studi dell’Aquila 
IASI-CNR

Abstract: Stochastic linear discrete-time singular systems, also named descriptor systems, have been widely investigated in recent years and important results on optimal filtering according to the maximum likelihood (ML) criterion have been achieved in the Gaussian framework. The ML approach can not be easily extended to non-Gaussian systems. In this paper the estimation problem for non-Gaussian descriptor systems is studied following the minimum error variance criterion and the optimal linear filter is developed by constructing the best estimator among a suitable class of linear output transformations. It is shown that when applied in the Gaussian case, the proposed filter gives back the ML filter. Simulations support theoretical results.

15:20 Stochastic Nonlinear Minimax Filtering in Continuous-Time ... 2520
Charalambous, Charalambos D. 
Djouadi, Seddik M.
Univ. of Ottawa 
Univ. of Arkansas

Abstract: This paper discusses nonlinear stochastic minimax games in which the minimizing player is the state estimate while the maximizing players are square-integrable stochastic disturbances. A pathwise optimization method is considered, and an information state is introduced as in (c) satcharalambous999, which is governed by a second-order Hamilton-Jacobi-Bellman (HJB) equation. The HJB equation is subsequently employed to characterize the dissipation properties of the estimator error with respect to the stochastic disturbances, and to introduce a certainty equivalence estimator.

15:40 Parameter Estimation of Stochastic Linear Systems Subject to Colored Noise ....................... 2526
Zheng, Wei Xing 
Univ. Of Western Sydney

Abstract: In this paper a generalized version of bias-eliminated least-squares (BELS) method is developed for the purpose of unbiased estimation of the system transfer function, without parametric modelling of the process disturbance acting on the system. Three weighting matrices are introduced to construct a new composite signal in terms of the delayed system inputs and the delayed system outputs. Identification of the corresponding new model provides an estimate of the colored-noise-induced bias, which is then removed from the LS parameter estimate. It is shown that several existing BELS based methods are a special case of the developed method if the three weighting matrices are properly selected. The interplay between the developed method and the instrumental variables methods is also studied.

16:00 Efficient Estimation of Autocorrelation Functions of Random Data with Time Series Models .................. 2532
Broersen, P. M.T. 
de Waele, S. 
Delft Univ. of Tech. 
Delft Univ. of Tech.

Abstract: Sample covariances, estimated as mean-lagged-products of random data, are poor and inaccurate fundaments for the non-parametric spectral estimation with tapered and windowed peridograms. However, the autocovariance can be estimated efficiently with a parametric method as a transformation of an estimated time series model, if model type and model order are known a priori. After the computation of hundreds of candidate models of different order and type, a statistical criterion select one single time series model. The accuracy of this identification from many candidates is sufficient to approach the performance that can be obtained with parametric estimation if the type and the order of the time series model would be known a priori. Hence, the accuracy (mean square error) of parametric covariance estimates is typically the same or better than what can be achieved by non-parametric mean-lagged-product estimates.
Abstract: We are interested in the identification of an unknown time-varying additive component of a controlled nonlinear autoregressive stochastic model, a problem of interest in the modeling and control of uncertain systems, such as those met in biotechnological processes. A kernel-based nonparametric estimator is proposed whose almost sure convergence is studied by means of a Lyapunov stabilizability assumption and laws of large numbers for martingales. We then adapt the general result to several classes of deterministic or random functional model uncertainties.
ThA02
Control of Mechanical Systems I
Chair: Demetriou, Michael A. Worcester Polytechnic Inst.
Co-Chair: Tornambe, Antonio Univ. di Roma Tre

10:00 Wave-Based Analysis and Wave Control of Damped Mass-Spring Systems ........................................... 2574
Ojima, Hirotaka Nagoya Univ.
Nagase, Kenji Nagoya Univ.
Hayakawa, Yoshikazu Nagoya Univ.

Abstract: This paper concerns with active vibration control of non-uniform damped mass-spring systems by the wave control. Especially, this study considers clarifying a class of a damped mass-spring system that can be analyzed by the wave-based analysis. Because the wave properties are determined by the propagation constants, three conditions for the propagation constants are considered. Necessary and sufficient condition for the physical parameters to hold the three conditions is obtained. Moreover, for this class of damped mass-spring systems, properties of the propagation constants and the characteristic impedances, which achieve the impedance matching, are studied. Numerical examples are shown to prove efficiency of the impedance matching controller.

10:20 Modification of the Youla-Kucera Parameterization for Linear Mechanical Systems Subject to Non-Smooth Impacts ............ 2580
Menini, Laura Univ. of Roma Tor Vergata
Tornambe, Antonio Univ. of Roma Tor Vergata

Abstract: In this paper, a class of n-degrees of freedom mechanical systems subject to non-smooth impacts is considered, for which only the generalized position coordinates are assumed to be available for feedback. The systems considered are fully actuated and are nonlinear, although, in absence of the inequality constraint determining the admissible region, their dynamics would be linear. For such systems, a family of compensators is proposed, by suitably modifying the Youla-Kucera parameterization of all stabilizing linear compensators that could be derived for the mechanical system under consideration in absence of the inequality constraint: such a modification renders nonlinear also the proposed controllers. Under mild assumptions, all the compensators belonging to the proposed family guarantee the exponential stability of the origin (which is a configuration belonging to the border of the admissible region), and the BIBS (Bounded-Input Bounded-State) stability for the closed-loop system. The results presented in the paper can be proven by means of Liapunov techniques.

10:40 A Study of Hybrid Control based on H-Infinity Synthesis Technique of Active Noise Control ..................... 2586
Xiaoming, Dai Shanghai Jiao Tong Univ.
Tao, Yang Shanghai Jiao Tong Univ.
Huile, Shao Shanghai Jiao Tong Univ.

Abstract: This paper studies the hybrid control based on H-infinity synthesis of active noise cancellation for ducts. A method of construction of the augmented matrix in hybrid ANC system based on state space is presented. At first the transfer functions of primary path, secondary path and feedback path of the particular acoustic structure are measured and then normalized to create state space model for augmented matrix construction. The acoustic feedback problem, which plagues the feedforward control strategies, can be automatically incorporated into the design process. It is shown by computer simulation with white noise source that the method presented in this paper is effective to reduce noise within the range below cut-off frequency with the H-infinity controller.

11:00 Acoustical Room Transfer Functions without using Green’s Functions ............................................. 2588
Pota, Hemanshu R. Univ. College, Univ. of New South Wales

Abstract: Acoustical room transfer functions are obtained in this paper for rooms with soft boundaries, i.e., taking wall damping into account. The transfer functions derived in this paper are well-known but all the known derivations make use of Green’s functions. In this paper a derivation, starting from fundamentals, is given which doesn’t use Green’s functions. This makes the derivation straightforward and can be understood easily by researchers without acoustics background. This has obvious use for control engineers who are drawn in large numbers to the active noise control research. It is shown that under certain conditions the room transfer functions are a weighted sum of damped second order transfer functions.

11:20 Frequency Domain and Dynamic Game Methods for Actuator/Sensor Selection in Systems with Sector Nonlinearities .......... 2590
Demetriou, Michael A. Worcester Polytechnic Inst.
Charalambous, Charalambos D. Univ. of Ottawa

Abstract: The purpose of this note is to provide a method for placing actuators and sensors in systems with nonlinear dynamics wherein the choices for actuator and sensor locations are such that the resulting system is rendered dissipative. The proposed method casts the problem of actuator and sensor selection as a convex optimization problem and which ensures that the resulting transfer function of the linear component becomes strictly positive real. Hence for an actuator and/or sensor whose dynamics have sector bounded nonlinearities, an application of Popov’s/circle criterion with a simple static feedback would ensure absolute stability. Furthermore, the nonlinear extension is formulated using dynamic game theory under partial state information.

11:40 On Selecting Sensor and Actuator Locations for ANC in Ducts .................................................... 2593
Toochinda, Varodom Univ. of Massachusetts, Amherst
Holiot, Christopher V. Univ. of Massachusetts, Amherst
Chait, Yossi Univ. of Massachusetts, Amherst

Abstract: In this paper we investigate the effects of microphone and speaker locations on the performance of active noise control in ducts. We study a so-called “symmetric” configuration in which the colocated performance microphone/control speaker and the colocated measurement microphone/disturbance source pairs are located equidistance from the duct center. By applying an “alignment angle” analysis to a duct model, we show this configuration to be prone to plant-disturbance misalignment. As a result, amplification at the measurement microphone and reduced stability margins occur. Stability robustness to modeling uncertainty is improved if the measurement microphone/disturbance source are de-colocated.
tions, including the possibility of driving the state or the evolution operator of the system, are equivalent. We also give a necessary and sufficient condition for controllability in terms of the properties of the above described graph. We provide extensions to the case of possibly equal gyromagnetic ratios.

10:20
Non-Reachable Target States for Pure-State Controllable
and Non-Controllable Quantum Systems
Schirmer, Sonia G. The Open Univ.
Solomon, Allan I. The Open Univ.

Abstract: We consider the problem of identifying non-reachable target states for N-level quantum systems that are not completely controllable.

10:40
A High Order Sufficient Condition for Local Controllability
Hirschorn, Ron M. Queen’s Univ.
Lewis, Andrew D. Queen’s Univ.

Abstract: We obtain sufficient conditions for local controllability of families of vector fields which involve Lie Brackets of arbitrarily high order.

11:00
Set-Valued Differentials and a Nonsmooth Version of Chow’s Theorem
Rampazzo, Franco Univ. degli Studi di Padova
Sussmann, Héctor J. Rutgers Univ.

Abstract: We prove a nonsmooth analogue of the usual second-order Chow Theorem, for vector fields that are only Lipschitz. This requires that we define a notion of Lie bracket for Lipschitz vector fields, as a set-valued map with compact convex nonempty values, and use an appropriate theory of generalized differentials to construct variations in the direction of these brackets.

11:20
On Nonlinear Controllability and Series Expansions
for Lagrangian Systems with Dissipative Forces
Cortés, Jorge Consejo Superior de Investigaciones Científicas
Martínez, Sonia Consejo Superior de Investigaciones Científicas
Bullo, Francesco Univ. of Illinois, Urbana-Champaign

Abstract: This note presents series expansions and nonlinear controllability results for Lagrangian systems subject to dissipative forces. The treatment relies on the assumption of dissipative forces of linear isotropic nature. The approach is based on the affine connection formalism for Lagrangian control systems, and on the homogeneity property of all relevant vector fields.

11:40
Nonlinear Hilbert Adjoints of Fliess Operators
Gray, W. Steven Old Dominion Univ.

Abstract: Given a causal analytic nonlinear input-output system represented as a Chen-Fliess functional series, this paper investigates how to apply an existing notion of a nonlinear Hilbert adjoint operator to explicitly compute a corresponding adjoint operator. The method is demonstrated for the bilinear case.
stable regulator are compared with a regulator based on the nominal system parameters.

11:00
Robust Control and Stability Analysis of Linearized System with Parameter Variation: Application to Induction Motors ....... 2645
Caudet, Sebastien ESIP-LAII
Rambaut, Laurent ESIP-LAII
Bachelier, Olivier ESIP-LAII
Mehdi, D. ESIP-LAII

Abstract: This paper discusses the synthesis and the analysis techniques applied to a nonlinear system subjected to parameter variations for which an exact feedback linearization is performed. The obtained linear system is described by a linear and a nonlinear dependant parameter parts. An H2/Hinfinity robust output feedback controller is designed on the linear part. The effect of the nonlinear part is attenuated by means of a reference model. A stability analysis method using parameter-dependant Lyapunov function is used to check the stability in the presence of the nonlinearity which has been ignored in the synthesis step. The synthesis and the analysis results are then applied to an induction motor.

11:20
Speed Regulation of Induction Motors: A Sliding Mode Observer-Differentiator based Control Scheme ............ 2651
Aurora, Claudio Univ. of Pavia
Ferrara, Antonella Univ. of Pavia
Levant, Arie Tel-Aviv Univ.

Abstract: A current-based output feedback sliding mode control for induction motors is presented in this paper. It guarantees asymptotic tracking of prespecified speed and square of the rotor flux magnitude references, in spite of the presence of an uncertain, even time-varying, load torque, and of an unknown constant value of the rotor resistance. The control algorithm is based on a sliding mode differentiator which provides a noiseless speed signal time derivative. The problem of chattering, typical of sliding mode controllers, is overcome since the derivative of the stator currents are used as discontinuous forcing actions, while the actual control signals are continuous, thus limiting the mechanical stress.

11:40
Position Control of an Inertia-Spring-DC Motor System without Mechanical Sensors: Experimental Results ............... *
Hernandez, Victor M. Univ. Autonoma de Queretaro
Sira-Ramirez, Hebertt J. CINVESTAV-IPN

Abstract: This paper reports a new experimental system to test the observability and controllability tests for this extended framework.

10:00
Experimental Results in Optimal Linear Anti-Windup Compensation .................................................. 2657
Grimm, Gene Univ. of California, Santa Barbara
Hatfield, Jay Univ. of California, Santa Barbara
Postlethwaite, Ian Univ. of Leicester
Teel, Andrew R. Univ. of California, Santa Barbara
Turner, Matthew C. Univ. of Leicester
Zaccarian, Luca Univ. of Rome

Abstract: In this paper, the optimal anti-windup synthesis proposed in (Grimm et al., ACC 2001) is demonstrated on an experimental mechanical system. A windup-prone controller is first shown to induce severe performance degradation when saturation is hit. According to a linearized model of the mechanical system, static anti-windup compensation is infeasible, hence dynamic anti-windup of order equal to that of the plant is shown to induce performance recovery both in simulation with the linearized and nonlinear model, and in the experimental runs on the physical system.

10:20
A New Stability Criterion on Space Coefficients ...................... 2663
Elizondo-González, César Univ. Autó. de Nuevo León

Abstract: In this paper is presented a new table to determine the number of roots of a real polynomial in the right half of the complex plane. The new table is based in Sturm theorem and Routh theorem. The new table presents some advantages: It is fast and also the robust stability of Linear Time Invariant systems with parametric uncertainty is possible to determine in necessary and sufficient conditions by means of “Sign Decomposition” previously published by the author.

10:40
Parametric Eigenstructure Assignment via Output Feedback based on Singular Value Decompositions ............. 2665
Duan, Guang-Ren Queen’s Univ. of Belfast
Mezić, Igor Harvard Univ.

Abstract: This paper investigates eigenstructure assignment in multivariable linear systems via output feedback. Three problems are proposed and are related to a type of generalized Sylvester matrix equations. By proposing a general complete parametric solution to this type of generalized Sylvester matrix equations based on singular value decompositions, a general complete parametric approach is then presented for the proposed eigenstructure assignment problems. General parametric expressions for both the closed-loop eigenvector matrices and the output feedback gain are established in terms of certain parameter vectors. These parameter vectors provide the design degrees of freedom and can be utilized to achieve some desired specifications. Bases on the proposed results and the Matlab Optimization Toolbox, a Matlab file is created, which finds for the problem of eigenstructure assignment via output feedback a solution that gives minimum closed-loop eigenvalue sensitivities.

Abstract: This paper investigates eigenstructure assignment in multivariable linear systems via output feedback. Three problems are proposed and are related to a type of generalized Sylvester matrix equations. By proposing a general complete parametric solution to this type of generalized Sylvester matrix equations based on singular value decompositions, a general complete parametric approach is then presented for the proposed eigenstructure assignment problems. General parametric expressions for both the closed-loop eigenvector matrices and the output feedback gain are established in terms of certain parameter vectors. These parameter vectors provide the design degrees of freedom and can be utilized to achieve some desired specifications. Bases on the proposed results and the Matlab Optimization Toolbox, a Matlab file is created, which finds for the problem of eigenstructure assignment via output feedback a solution that gives minimum closed-loop eigenvalue sensitivities.

11:00
Observability and Controllability in Systems with Moving Averages ............................................. 2671
Valente, André Harvard Univ.
Mezić, Igor Harvard Univ.

Abstract: We extend the standard state space linear control systems framework to allow for the inclusion of moving averages in both the input and output signals. We develop observability and controllability tests for this extended framework.

11:20
Robust Stabilization of a Class of Switched Linear Systems .... 2674
Zhang, Xiaoli Northeastern Univ.
Zhao, Jun Northeastern Univ.

Abstract: Robust stabilization of a class of switched systems whose nominal subsystems have a common Lyapunov function is considered. The uncertainties do not satisfy the so-called matching condition. A state feedback controller and an output feedback controller are designed respectively. Under certain class of switching laws, the states of the closed-loop systems asymptotically converge to the equilibrium point.

11:40
The Controllability of Linear Systems Over F(z) ................. 2676
Lu, Kai-Sheng Wuhan Univ. of Tech.

Abstract: In this paper, the controllability of the linear systems over the field of rational functions with real coefficients in q independently variable parameters is studied. Some conditions are derived.
Robust Design from Data: Direct and Model based Approaches

Abstract: Unfalsified control theory facilitates the representation of adaptive processes of control law discovery from evolving information flows and noisy data. In this paper, the theory of unfalsified adaptive control is examined from the behavioral perspective of Willems. An abstract, but parsimonious, min-max optimization problem formulation is developed that describes and unifies direct adaptive control, learning theory and system identification problems in a common behavioral setting based on the concept of controller/model unfalsification. Thus, adaptive control is seen to be firmly and directly linked to, and to conceptually unified with, the growing body of knowledge on behavioral approaches to model validation and unfalsified system identification. The results elucidate and underscore the fertile conceptual links that exist between adaptive control theory and the rich theory of system identification.

10:20
Robust Control from Data via Uncertainty
Model Sets Identification (I) .............................................. 2686

Malan, Stefano
Politecnico di Torino
Milanese, Mario
Politecnico di Torino
Regruto, Diego
Politecnico di Torino
Taragna, Michele
Politecnico di Torino

Abstract: In this paper, an integrated robust identification and control design procedure is proposed. It is supposed that the plant to be controlled is linear, time invariant, stable, possibly infinite dimensional and that input-output noisy measurements are available, together with some general information on the plant and on the noise characteristics. The emphasis is placed on the design of controllers guaranteeing robust stability and robust performances, and on the trade off between controller complexity and achievable robust performances. First, an uncertainty model is identified, consisting of a parametric model and a tight frequency bound on the magnitude of the modelling error, accounting for the dynamics not modelled by the parametric model. Second, an Internal Model Control, guaranteeing robust closed loop stability and best approximating the “perfect control” ideal target, is designed using H-infinity optimization techniques. This control structure is chosen because, if needed, it can be designed to be robust also in presence of input saturation. Then, the robust performances of the designed controller are computed, allowing to determine the level of model complexity needed to guarantee desired closed loop performances. A numerical example illustrates the effectiveness of the proposed design procedure.

10:40
Uncertain LTI-Models for Linear Control
Design of Non-Linear Systems (I) .................................. 2692

Glad, S. Torkel
Linköping Univ.
Helmersson, Anders
Linköping Univ.
Ljung, Lennart
Linköping Univ.

Abstract: Much attention in robust identification and control has been focused on linear low order models approximating high order linear systems. We consider the more realistic situation with a linear model approximating a non-linear system. We describe how a linear time invariant (LTI) model with unstructured uncertainty, i.e. a “band” of Nyquist curves, can be developed using a non-linear model error model. Applying standard linear robust control design to this uncertain LTI model will lead to a (non-linear) closed loop system with performance robustness guarantees (in terms of gain from disturbance to output) well in line with the objectives of the linear design. Clearly the design can be successful only if the linear model is a reasonably good approximation of the system. A particular aspect of the design process is to define a workable definition of “practical stability” for robust control design, with possibly non-linear model errors. We use affine power norms for that purpose.

11:00
On Worst-Case Approximation of Feasible System Sets via Orthonormal Basis Functions (I) ............................. 2695

Casini, Marco
Univ. di Siena
Garulli, Andrea
Univ. di Siena
Vicino, Antonio
Univ. di Siena

Abstract: This paper deals with the approximation of sets of linear time-invariant systems via orthonormal basis functions. This problem is relevant to conditional set membership identification, where a set of feasible systems is available from observed data, and a reduced-complexity model must be estimated, within a linearly parameterized model class. The basis of the model class is a collection of impulse responses of linear filters (e.g. Laguerre functions), whose poles must be chosen properly. The objective of the paper is to select the basis function pole according to a worst-case optimality criterion taking into account the uncertainty system set. This leads to complicated min-max optimization problems. Suboptimal conditional identification algorithms are introduced and tight bounds are provided on the associated identification errors.

11:20
Identification for Control: L_2 and L-Infinity Methods (I) .......... 2701

Hjalmarsson, Håkan
The Royal Inst. of Tech.
Lindqvist, Kristian
The Royal Inst. of Tech.

Abstract: Identification of restricted complexity models for linear time-invariant systems is considered. A method, with ties to model reduction and the extended instrumental variable method, which uses a cost function based on cross-correlations between the prediction error and some auxiliary variable such as the input is presented. In open loop and under linear feedback, this method is able to asymptotically approximate the underlying system in L_2 or L-infinity norm without an explicit noise model under noisy conditions. Arbitrary frequency weighting, also depending on the true frequency function, can be used. The method is applied to identification of models suited for control design. It is shown that some model free methods can be fit into this framework. It is also pointed out that closed loop stability is not taken into account in the bias tuning due to the fact that L-norms are used.

11:40
Unfalsified Adaptive Control of Bilinear Systems (I) ............ 2707

Kosut, Robert L.
SC Solutions, Inc.

Abstract: A variety of dynamical systems are bilinear in state and control. Examples include kinematic steering, surface morphology and growth of thin films, and quantum control of atomic and molecular motion. In this note we focus on systems of the latter two types under adaptive run-to-run control. A brief description is given as to how the unfalsified control concept can be used to adapt the control from run-to-run to meet a performance goal described by a closed-loop gain constraint.
Abstract: In this paper a novel neural network (NN) backstepping controller is modified for application to an industrial motor drive system. A control system structure and NN tuning algorithms are presented that are shown to guarantee stability and performance of the closed-loop system. The NN backstepping controller is implemented on an actual motor drive system using a two-PC control system developed at UTA. The implementation results show that the NN backstepping controller is highly effective in controlling the industrial motor drive system. It is also shown that the NN controller gives better results on actual systems than a standard backstepping controller developed assuming full knowledge of the dynamics. Moreover, the NN controller does not require the linear-in-the-parameters assumption or the computation of regression matrices required by standard backstepping.

Abstract: A componentwise estimate of exponential convergence is obtained for a class of neural networks with multiple delays by using a method based on a comparison principle of delay differential systems. The method is simple and straightforward in analysis, without resorting to any Lyapunov functionals. The result shows explicitly the effect of time delays on exponential decay rate of the networks and is of practical significance for designing fast and stable neural networks. Some existing results for Hopfield model and DCNN models via Lyapunov functional method are found to be special cases of the present result.

Abstract: The flatness control in a cold rolling mill is an important subject because of the need for improvement in cold-rolled strip quality. It, however, is a difficult problem for a conventional approach to achieve since the cold rolling process is a highly nonlinear system in which many uncertain parameters are involved. The fuzzy controller for the flatness controller is designed by the heuristic approach that is based on the operator’s experience and knowledge gained in the experiments. The feature of a neural network’s learning and adapting ability is used for inverse modeling of the static model, and the error-decomposition network is developed as the inverse static model.

Abstract: As a nonlinear system, a recurrent neural network generally has an incremental gain different from its induced norm. While most of the previous research efforts were focused on the latter, this paper presents a method to compute an effective upper bound of the former for a class of discrete-time recurrent neural networks, which is not only applied to systems with arbitrary inputs but also extended to systems with small-norm inputs. The upper bound is computed by simple optimizations subject to Linear Matrix Inequalities.

Abstract: This paper provides a structural condition on the nominal symmetric interconnection matrix of a neural network, which implies the existence of stable limit cycles generated via Hopf bifurcations, even for arbitrarily small perturbations of the interconnections.

Abstract: In this paper we propose sufficient conditions for the existence of reduced-order H-infinity output feedback controllers for discrete-time nonlinear systems. State space formulas for such reduced-order H-infinity controllers are derived in terms of the solutions to two Hamilton-Jacobi inequalities.
Abstract: In this paper, the problem of reducing limit cycle behaviour in nonlinear systems with disturbances is expressed as an optimal control problem. This optimal control problem is a generalization of the standard state feedback nonlinear dissipative control problem. One of the features of this formulation is the ability to trade off asymptotic stability requirements and disturbance attenuation. Controllers which solve this optimal control problem are computed using a variable grid finite difference method.

Keywords: Optimal control, dissipative systems, state feedback, limit cycle reduction, disturbance attenuation, numerical solutions, finite differences, H-infinity control.

11:00
Optimization of Quadratic Performance
Indexes for Nonlinear Control Systems ......................... 2758
Kazantzis, Nikolaos  Worcester Polytechnic Inst.
Kravaris, Costas  Univ. of Patras
Wright, Raymond A.  The Dow Chemical Co.

Abstract: The proposed approach aims at the development of a systematic method to optimally choose the controller tunable parameters in a nonlinear control system, where in addition to the traditional set of closed-loop performance specifications (stability, fast and smooth set-point tracking, disturbance rejection, etc.), optimality is also requested with respect to a physically meaningful quadratic performance index. In particular, the value of the performance index can be calculated exactly by solving Zubov’s partial differential equation (PDE). It can be shown that Zubov’s PDE admits a unique and locally analytic solution that is endowed with the properties of a Lyapunov function for the closed-loop system. Moreover, the analyticity property of the solution of Zubov’s PDE enables the development of a series solution method that can be easily implemented with the aid of a symbolic software package such as MAPLE. It can be shown, that the evaluation of the above Lyapunov function at the initial conditions leads to a direct calculation of the value of the performance index which now explicitly depends on the controller parameters. Therefore, the employment of static optimization techniques can provide the optimal values of the finite-set of controller parameters. Finally, it should be pointed out, that for the optimally calculated controller parameter values, an explicit estimate of this size of the closed-loop stability region can be provided by using results from Zubov’s stability theory.

11:20
Duality and Dynamics in Hamilton-Jacobi
Theory for Fully Convex Problems of Control .................. 2763
Rockafellar, R. Tyrrell  Univ. of Washington
Wolenski, Peter R.  Louisiana State Univ.

Abstract: This paper describes some recent results in Hamilton-Jacobi theory that hold under strong convexity assumptions on the data. Generalizations of linear-quadratic control models satisfy such assumptions, for example. The results include a global method of characteristics and a strong duality theory.

11:40
Envelope Representations in Hamilton-Jacobi
Theory for Fully Convex Problems of Control .................. 2768
Rockafellar, R. Tyrrell  Univ. of Washington
Wolenski, Peter R.  Louisiana State Univ.

Abstract: This paper is a sequel to the one in this same session which surveys recent results on the role of convexity in Hamilton-Jacobi theory. We describe here how value functions in optimal control can be represented as upper and lower envelopes involving so-called kernel functions. Particularly noteworthy is a lower envelope formula given in terms of the dualizing kernel, which is a value function in its own right with many surprising and attractive properties.
feedback control strategies for nonlinear systems subject to unknown disturbances. The result is a point-wise “input-to-state satisfying” set of control options from which a continuous feedback strategy can be selected. We show that every input-to-state satisfying control also defines a universal formula in the sense defined by Sontag.

11:20
Dynamic Surface Control Design for a Class of Nonlinear Systems .......................... 2797
Song, Bongsob  Univ. of California, Berkeley
Howell, Adam  Univ. of California, Berkeley
Hedrick, Karl J.  Univ. of California, Berkeley

Abstract: In this paper, a new method for analyzing the controller gains and filter time constants of Dynamic Surface Control (DSC) is presented. First, DSC provides linear closed loop error dynamics with bounded perturbation terms for a class of nonlinear systems. This can be used to assign the desired eigenvalues to the system matrix of the error dynamics for the nominal stability. Then a procedure for testing the stability and performance of the fixed controller in the face of uncertainties is presented. Finally, a feasible quadratic Lyapunov function for a regulation problem and an ellipsoidal approximation of tracking error bounds are obtained via convex optimization.

A Second-Order Smooth Sliding Mode Control ....................... 2803
Shkolnikov, Ilya A.  Univ. of Alabama, Huntsville
Shtessel, Yuri B.  Univ. of Alabama, Huntsville
Brown, Mark D.J.  US Army Space & Missile Defense Command

Abstract: Presented is a method of continuous sliding mode control design to provide for the second-order sliding mode on the selected sliding surface. The control law is a nonlinear dynamic feedback that in absence of unknown disturbances provides for finite-time convergence of the second-order reaching phase dynamics. The application of the second-order disturbance observer in a combination with the proposed continuous control law gives the second-order sliding accuracy in presence of unknown disturbances and the discrete-time control update. The piecewise constant control feedback is “smooth” in the sense that its derivative numerically taken at sampling rate does not contain high frequency components.

10:20
A Virtual Laboratory Experience based on a Double Tank Apparatus (I) .......................... 2815
Irawan, Remy  Univ. of Melbourne
Ooi, Melvyn  Univ. of Melbourne
Yeung, Gabriel  Univ. of Melbourne
Weyer, Erik  Univ. of Melbourne
Nesić, Dragan  Univ. of Melbourne
Mareels, Iven  Univ. of Melbourne

Abstract: How can a virtual laboratory experience achieve the typical educational outcomes expected from a normal in situ laboratory experience? This paper deals with this question in the context of a double tank apparatus experimental set up. For this laboratory experiment a world wide web interface was developed to assist students in assimilating control engineering concepts at the University of Melbourne.

10:40
A Web-Based Laboratory on Control of a Two-Degree-of-Freedom Helicopter (I) .................... 2821
Zhang, Jing  Natl. Univ. of Singapore
Chen, Jianping  Natl. Univ. of Singapore
Chen, Ben M.  Natl. Univ. of Singapore
Ge, Shuzhi S.  Natl. Univ. of Singapore

Abstract: In this paper, we discuss the design and implementation of a series of linear or nonlinear control strategies for a two-degree-of-freedom (2DOF) helicopter through a web-based laboratory. The physical structure of the 2DOF helicopter makes it ideal platform for implementing and evaluating control strategies such as proportional-integral-derivative control (PID), fuzzy control and general state space feedback control. Thus, it is appropriate for all levels of university education and research. The web-based laboratory on helicopter is currently being utilized in teaching both undergraduate and postgraduate courses in the Department of Electrical and Computer Engineering, National University of Singapore. The system is particularly beneficial to part-time students, who are unable to access to the University laboratory facilities during normal operating hours. The web-based laboratory on helicopter, together some other laboratories implemented earlier, can be accessed at the web site http://vlab.ee.nus.edu.sg/vlab.

11:00
Development of an Access-by-the-Internet Control Laboratory (I) .................................. 2827
Fisher, James  Univ. of Virginia
Hoye, W. Scott  Univ. of Virginia
Koehler, John  Univ. of Virginia
Lian, Ray  Univ. of Virginia
Lin, Zongli  Univ. of Virginia

Abstract: The paper reports on the on-going development of a control laboratory that can be accessed remotely through the Internet. This laboratory currently consists of a few sets of signal generator/oscilloscope experiments, five Feedback 33-002 Analogue Fundamentals Trainers, and five Feedback 33-003 Digital Servo Fundamentals Trainers. The key tasks involved in the development of this laboratory include the interface between the physical instruments for experiment with computers that are connected to the Internet, creation of virtual instrument panels on the remote computers from which the experiment is run, and the streaming to the remote computers of the real time video that captures what is actually happening in the physical laboratory.

Grand Cypress Ballroom I

ThA10
Web-Based Laboratories for Control Engineering Education
Chair: Chen, Ben M.  Natl. Univ. of Singapore
Co-Chair: Huang, Jie  Chinese Univ. of Hong Kong
Organizer: Chen, Ben M.  Natl. Univ. of Singapore
Organizer: Huang, Jie  Chinese Univ. of Hong Kong

10:00
Development of the Internet based Control Experiment (I) .... 2809
Yeung, Kin  The Chinese Univ. of Hong Kong
Huang, Jie  The Chinese Univ. of Hong Kong

Abstract: This paper presents the development of a remote-access control experiment laboratory, which allows users to perform control experiments through the Internet. A DC motor control experiment is used as an example to illustrate our design. Open loop, PID and State Space controllers are provided for users to conduct this experiment. The experiment can be accessed from http://acciserv.acae.cuhk.edu.hk/.

11:20
An Internet based Laboratory for Control Education (I) ........ 2833
Corradini, Maria L.  Univ. di Lecce
Ippoliti, Gianluca  Univ. di Ancona
Leo, Tommaso  Univ. di Ancona
Longhi, Sauro  Univ. di Ancona

Abstract: The paper presents the experiences on the development of remote laboratories at the Universities of Ancona and Lecce,
aimed at supporting institutional education. The remote laboratories provide a remote access to a number of ‘virtual rooms’ (containing physical processes) by a commercial Web browser. Different processes are connected to the remote laboratories: a fan and plate process, a robot manipulator, a tank process and a toy helicopter. Students can use the laboratory for process identification and control, and experimental data files can be downloaded for further local processing. Software and hardware solutions used in the design of the remote laboratories are presented. The integration of the traditional classroom lectures with the experimental training is also discussed.

11:40
Virtual Control Systems Laboratory .............................. 2839
Navaratna, Channa  Texas Tech. Univ.
Dayawansa, Wijesuriya P.  Texas Tech. Univ.
Martin, Clyde F.  Texas Tech. Univ.

Abstract: Control system simulation on the world wide web is a research area where few studies have been done. Possibilities for simulation and animation control systems on the Internet are immense. With the flexibility afforded by the Java language to execute routines written on a server in a client machine in a platform independent manner it is possible to create a vast virtual control systems laboratory. This paper describes the work during initial phases of such a project.

ThA11
Descriptor Systems: Stability
Chair: Fridman, E. M.  Tel-Aviv Univ.
Co-Chair: De Schutter, Bart  Delft Univ. of Tech.

10:00
A Lyapunov Approach to Analysis of
Discrete Singular Systems .......................... 2844
Zhang, Qingling  Northeastern Univ.
Liu, Wan Quan  Curtin Univ. of Tech.
Hill, David J.  Univ. of Sydney

Abstract: In this paper, a new type generalized Lyapunov equation for discrete singular systems is proposed. Then it is applied to study problems such as pole clustering, controllability and observability for discrete singular systems. First, some necessary and sufficient conditions for pole clustering are derived via the solution of this new type Lyapunov equation. Further, the relationship between the solution of the Lyapunov equation and structure properties of discrete singular systems will be investigated based on these results. Finally, a type of generalized Riccati equation is proposed and its solution is used to design state feedback law for discrete singular systems such that all the finite poles of the closed-loop systems are clustered into a specified disk.

10:20
A Lyapunov-Based Approach to Stability
of Descriptor Systems with Delay .................. 2850
Fridman, E. M.  Tel Aviv Univ.

Abstract: The Lyapunov second method is developed for linear coupled system of delay differential and functional equations. By conventional approaches such equations may be reduced to the neutral systems and the known results for the latter may be exploited. In the present paper we introduce a new approach by constructing Lyapunov-Krasovskii functional that corresponds directly to the descriptor form of the system. Moreover, by representing a neutral system in the descriptor form we obtain new stability criteria for neutral systems which lead to less conservative than the existing results. Sufficient conditions for delay-dependent stability are given in terms of linear matrix inequalities. Illustrative examples show the effectiveness of the method.

10:40
Input Estimation for Uncertain Linear Singular
Systems and Robust Stabilization ..................... 2856
Shuqian, Zhu  Shandong Univ.
Liying, Sun  Shandong Univ.
Zhaolin, Cheng  Shandong Univ.

Abstract: In this paper, the problem of state and input estimation for uncertain linear singular systems with unknown inputs is concerned. The necessary and sufficient conditions for the existence of the observer and the simple method to design the observer are given. The robust stability of the closed-loop obtained by dynamic output feedback is also discussed.

11:00
Generalized Lyapunov Theorems for
Rectangular Descriptor Systems ...................... 2858
Ishihara, João Yoshiyuki  Univ. of São Paulo
Terra, Marco Henrique  Univ. of São Paulo

Abstract: In this paper we extend the stability analysis with generalized Lyapunov equations to general descriptor systems. With mild conditions, the existence of solutions of these equations are necessary and sufficient for column regularity and stability.

11:40
On the Lyapunov Theorem for Descriptor Systems .......... 2860
Ishihara, João Yoshiyuki  Univ. of São Paulo
Terra, Marco Henrique  Univ. of São Paulo

Abstract: In this paper we make some comments on a well known generalized Lyapunov theorem. We show that this theorem is not always valid. Some cases where the Lyapunov equation of this theorem can be used are clarified and we also present a corrected version of this theorem with a generalized Lyapunov equation similar to the original one.

11:40
Passivity Approach to Feedback Connection
Stability for Discrete-Time Descriptor Systems .......... 2865
Chen, Jian Liung  Natl. Sun Yat-Sen Univ.
Lee, Li  Natl. Sun Yat-Sen Univ.

Abstract: In this paper, the LMI-based passivity approach to studying both input-output and internal stability problems for feedback connections of discrete-time linear descriptor systems with passive nonlinearities is developed. We have shown that a set of LMIs, which, under a mild condition, is equivalent to the strictly positive realness of the linear descriptor systems, is strong enough to guarantee both the finite gain l2-stability and the asymptotic hyperstability of the feedback connection.
model for each tool. The concluding section suggests directions for future research and tool development based on the needs of industry for tools to perform verification and validation of designs for embedded control systems.

10:20
**Taxys = Estelar + Kronos A Tool for Verifying**

**Real-Time Properties of Embedded Systems (I) .................. 2875**

Berth, Valerie  
Closse, Etienne  
Poize, Michel  
Pulou, Jacques  
Sifakis, J.  
Venier, Patrick  
Weil, D.  
Yovine, Sergio  

Abstract: The goal of TAXYS is to provide a framework for developing real-time embedded code and verifying its correct behavior with respect to quantitative timing requirements. To achieve so, TAXYS connects France Telecom's Estelar compiler Saxo-RT with VERIMAG’s model-checker Kronos. TAXYS has been successfully applied on real industrial telecommunication systems, such as a GSM radio link from Alcatel and a phone prototype from France Telecom.

10:40
**UPPAAL - Present and Future (I) .............................. 2881**

Behrmann, Gerd  
Larsen, Kim G.  
Möller, Olve  
David, Alexandre  
Pettersson, Paul  
Yi, Wang  

Abstract: Uppaal is a tool for modelling, simulation and verification of real-time systems, developed jointly by BRICS at Aalborg University and the Department of Computer Systems at Uppsala University. The tool is appropriate for systems that can be modelled as a collection of non-deterministic processes with finite control structure and real-valued clocks, communicating through channels or shared variables. Typical application areas include real-time controllers and communication protocols in particular, those where timing aspects are critical. In this paper, we review the status of the currently distributed version of the tool as well as facilities to be found in upcoming releases.

11:00
**Some Lessons from the HyTech Experience (I) .......... 2887**

Henzinger, Thomas A.  
Preußig, Jörg  
Wong-Toi, Howard  

Abstract: We provide an overview of the current status of the tool HyTech, and reflect on some of the lessons learned from our experiences with the tool. HyTech is a symbolic model checker for mixed discrete-continuous systems that are modeled as automata with piecewise-constant polyhedral differential inclusions. The use of a formal input language and automated procedures for state-space traversal lays the foundation for formally verifying properties of hybrid dynamical systems. We describe some recent experiences analyzing three hybrid systems. We point out the successes and limitations of the tool. The analysis procedure has been extended in a number of ways to address some of the tool's shortcomings. We evaluate these extensions, and conclude with some desiderata for verification tools for hybrid systems.

11:20
**d/dt: A Verification Tool for Hybrid Systems (I) .............. 2893**

Asarin, Eugene  
Dang, Thao  
Maler, Oded  

Abstract: In this paper we describe the tool d/dt which provides automatic verification of safety properties of hybrid systems with linear continuous dynamics with uncertain bounded input. The verification procedure is based on a technique for over-approximating reachable sets by orthogonal polyhedra. In addition to verification, using reachability analysis, the tool allows to synthesize switching controllers for safety specifications.

11:40
**Discrete-Time Hybrid System Modeling and Verification (I) ... 2899**

Torrisi, Fabio Danilo  
Bemporad, Alberto  

Abstract: For hybrid systems described by interconnections of linear dynamical systems and logic devices, we recently proposed Mixed Logical Dynamical (MLD) systems and the language HYSDEL (Hybrid System Description Language) as a modeling tool. For MLD models, we developed a reachability analysis algorithm which combines forward reach set computation and feasibility analysis of trajectories by linear and mixed-integer linear programming. In this paper the versatility of the overall analysis tool is illustrated on the verification of an automotive cruise control system for a car with robotized manual gear shift.
Abstract: The paper addresses the H₂ estimation problem for linear discrete systems with current and delayed measurements. By re-organizing the measurements and introducing a re-organized innovation sequence, a unified solution to the H₂ filtering, prediction and fixed-lag smoothing is derived based on an innovation analysis method together with projection in Hilbert space. Our solution does not require system augmentation and the estimator is given in terms of a Riccati difference equation of the same order as that of the system state. The proposed results will find important applications in sensor and data fusion. Furthermore, it will be shown in a companion paper that our solution to the H₂ estimation forms the basis of solving the more complicated problem of H-infinity fixed-lag smoothing without resorting to system augmentation.

14:40
Quadratic Observability Normal Form ................................... 2942
Boutat-Baddas, Latifa ECE-ENSEA
Boutat, Driss LVR-ENSIB/Univ. d’Orléans
Barbot, Jean Pierre ECS-ENSEA
Taufeigne, Roger ECS-ENSEA

Abstract: This paper deals with quadratic observability normal form for nonlinear single output system. A linearly observable case is first investigated and after one dimensional linearly unobservable case is studied. More particularly, the effect of the so-called resonant terms on the observer design is pointed out. Throughout the paper, some academic examples as well as bio reactor example highlight our purpose.

14:20
Further Results on Nonlinear Receding Horizon Observers ... 2948
Alamir, Mazen LAG-CNRS UMR 5528
Calvillo, Luis LAG-CNRS UMR 5528

Abstract: In this paper, further results are proposed that concern the design and the convergence of receding horizon nonlinear observers. The key feature is the definition of observability-radius in relation with a pre-specified compact set of initial configurations. This enables a semi-global convergence result to be derived that turns to be a global convergence result when appropriate regularity assumptions are made. A simple example is proposed to illustrate the basic features of the paper.
Abstract: GPS and Inertial Navigation Systems (INS) have complementary properties, and they are therefore well suited for integration. The integrated solution offers better long term accuracy than a stand-alone INS, and better integrity, availability and continuity than a stand-alone GPS receiver, making it suitable for demanding applications. The integration filter is nonlinear both in state and measurements, and the extended Kalman-filter has been used with good results, but it has not been proven globally stable, and it is also computationally intensive, especially within a direct integration architecture. In this work a nonlinear observer suitable for direct integration, due to no covariance update equations, is presented. Global exponential stability of the origin of the combined attitude and velocity error systems is proven.

15:20
Global Observer Design for a Class of Homogeneous Systems .............................................. 2962
Hong, Yiguang Chinese Academy of Sci.
Qin, Huashu Chinese Academy of Sci.
Chen, Pengnian China Inst. of Metrology

Abstract: In this paper, the observer design problem of a class of homogeneous systems is addressed. With mild conditions like homogeneous detectability and based on Lyapunov functions, global asymptotic observers are constructed for these single-output homogeneous systems. These continuous observers may be nonsmooth when their linear approximation systems have undetectable modes.

13:40
Virtual Leaders, Artificial Potentials and Coordinated Control of Groups .................................... 2968
Leonard, Naomi Ehrich Princeton Univ.
Fiorelli, Edward Princeton Univ.

Abstract: We present a framework for coordinated and distributed control of multiple autonomous vehicles using artificial potentials and virtual leaders. Artificial potentials define interaction control forces between neighboring vehicles and are designed to enforce a desired inter-vehicle spacing. A virtual leader is a moving reference point that influences vehicles in its neighborhood by means of additional artificial potentials. Virtual leaders can be used to manipulate group geometry and direct the motion of the group. The approach provides a construction for a Lyapunov function to prove closed-loop stability using the system kinetic energy and the artificial potential energy. Dissipative control terms are included to achieve asymptotic stability. The framework allows for a homogeneous group with no ordering of vehicles; this adds robustness of the group to a single vehicle failure.

14:00
Gyroscopic Classical and Quantum
Oscillators Interacting with Heat Baths .................................... 2974
Bloch, Anthony M. Univ. of Michigan
Hagner, Patrick Univ. of Michigan
Rojo, Alberto G. Univ. of Michigan
Weinstein, Michael Bell Laboratories

Abstract: We analyze the stability of a gyroscopic oscillator interacting with a finite- and infinite-dimensional heat bath in both the classical and quantum cases. We consider a finite gyroscopic oscillator model of a particle in a magnetic field and examine the stability before and after coupling to a heat bath. It is shown that if the oscillator is gyroscopically stable, coupling to a sufficiently massive heat bath induces instability. The meaning of these ideas

heat bath induces instability. The meaning of these ideas in the quantum context is discussed. The model extends the exact diagonalization analysis of an oscillator and field of Ford, Lewis, and O’Connell to the gyroscopic setting.

14:20
Modelling of Nonlinear Systems from Input-Output
Data for State Space Realization ............................................. 2980
Foley, Dawn C. Univ. of Illinois, Urbana-Champaign
Sadegh, Nader Georgia Inst. of Tech.

Abstract: In this paper, we examine data driven modelling procedures for creating a discrete-time input-output map that can be transformed into an observable state space form. We first present previous results of a model form that guarantees the existence of an observable state space realization, as well as the state equations that can be implemented using that form. We then examine the feasibility of NARMA models, feedforward neural networks, and nodal link perceptron networks with local basis functions in creating the model. Simulation results are shown for these model types, as well as a linear model for comparison.

15:00
A Nonlinear Observer for GPS and INS Integration ............... 2956
Vik, Bjemar Norwegian Univ. of Sci. & Tech.
Fossen, Thor I. Norwegian Univ. of Sci. & Tech.

Abstract: In this paper we present a procedure to generate nonparametric bounds on the model errors of a measured frequency estimation of the unmodelled nonlinear effects. In a second step the nonlinear system is represented by a linear model for comparison. The model extends the exact
characteristics. The whole process is embedded in a simple and time efficient experimental procedure.

ThM03
Interconnected Nonlinear Systems
Chair: Hedrick, Karl J.  Univ. of California, Berkeley
Co-Chair: Astolfi, Alessandro  Imperial College

13:40
A Remark on the Stability of Interconnected Nonlinear Systems
Rapaport, Alan  INRA-LASB
Astolfi, Alessandro  Politecnico di Milano/Imperial College

Abstract: We use a notion of generalized L2-gain for nonlinear systems, where the gain is considered as a function of the state instead of a (global) constant, to characterize stability properties of interconnected systems. The obtained results generalize the well-known small-gain theorem.

14:00
Mesh Stability of Look-Ahead Interconnected Systems
Pant, Aniruddha  Univ. of California, Berkeley
Seiler, Peter  Univ. of California, Berkeley
Hedrick, Karl J.  Univ. of California, Berkeley

Abstract: In this paper we define a notion of mesh stability for a class of interconnected nonlinear systems. Intuitively mesh stability is the property of damping disturbance propagation. We derive a set of sufficient conditions to assure mesh stability of “look-ahead” interconnected systems. Mesh stability is shown to be robust with respect to structural and singular perturbations. The theory is applied to an example in vehicle following.

14:20
Decentralized Regulation of a Class of Nonlinear Systems
Gazi, Veyssel  Ohio State Univ.
Passino, Kevin M.  Ohio State Univ.

Abstract: In this article we investigate the decentralized output regulation problem of nonlinear systems. It is shown that the results of decentralized output regulation of linear systems can be easily adapted to nonlinear systems within the Isidori-Byrnes framework. The resulting decentralized controller consists of local controllers, each of which is a parallel connection of a stabilizer and a (partial) internal model. We present only local results.

14:40
Effective Signal Selection in Decentralized Control Design of Nonlinear Interconnected Systems
Fan, Lingling  West Virginia Univ.
Feliachi, Ali  West Virginia Univ.

Abstract: The paper deals with decentralized control of nonlinear interconnected systems. The objective is to control some specific modes, i.e., critical modes over a wide range of operating conditions. This paper presents an index to identify which control signal is most effective, and a second index to assess the effect of the control signal on other modes. The application of these indices allows determining which signal will control some specific modes without disturbing remaining modes. The methodologies are applied to a power system case study to demonstrate the proposed methodologies.

15:00
Trading the Stability of Finite Zeros for Global Stabilization of Nonlinear Cascade Systems
Sepulchre, Rodolphe  Univ. de Liege
Arcak, Murat  Rensselaer Polytechnic Institute
Teel, Andrew R.  Univ. of California, Santa Barbara

Abstract: This paper analyzes the stabilizability properties of nonlinear cascades in which a nonminimum phase linear system is interconnected through its output to a stable nonlinear system. It is shown that the instability of the zeros of the linear system can be traded with the stability of the nonlinear system up to a limit fixed by the growth properties of the cascade interconnection term. Below this limit, global stabilization is achieved by smooth static state feedback. Beyond this limit, various examples illustrate that controllability of the cascade may be lost, making it impossible to achieve large regions of attractions.

15:20
Controllability and Trajectory Tracking for Classes of Cascade-Form Second Order Nonholonomic Systems
Morgansen, Kristi A.  California Inst. of Tech.

Abstract: In this work we discuss classes of nonlinear systems with drift that can be reduced to the cascade of a linear system and a drift-free nonholonomic system. Building on previous work with amplitude-modulated sinusoids for trajectory tracking in drift-free systems, we present algorithms for configuration trajectory tracking in these dynamic settings. Results are demonstrated in simulation for representative examples.
tive mechanism can be introduced to the proposed feedback controllers for improving the robustness on the parametric uncertainty.

14:40

*Eigenvalue Sensitivities for Design of Power System Damping Controllers* ........................................ 3051

Rouco, Luis  Univ. Pontificia Comillas
Pagola, F. Luis  Univ. Pontificia Comillas

Abstract: This paper presents a comprehensive review of methods to compute eigenvalue sensitivities in large linear dynamic systems.

15:00

*Discretization Scheme for a Synchronous Generator* ............ 3056

Sanchez-Orta, Anand E.  Univ. Autó. de Nuevo León
Guerra-Torres, Cesar  Univ. Autó. de Nuevo León
De Leon-Morales, Jesus  Univ. Autó. de Nuevo León

Abstract: In this paper, we present a control-observer scheme for discrete-time nonlinear system. A controller and an observer are proposed for a class of discrete-time nonlinear systems. The results obtained are applied to synchronous generator in order to illustrate the proposed scheme.

15:20

*Energy-Based Approach to Power Transfer System Analysis* .... 3062

Moon, Young-Hyun  Yonsei Univ.
Lee, Jong-Gi  Yonsei Univ.
Kim, Seo-Joo  Korea Electrotech. Research Inst.
Hong, Hyo-Shik  Korea Natl. Railroad College

Abstract: This paper presents a new theoretical approach to energy-based power system analysis for multibus power transmission systems. On the basis of mechanical analogy, an exact energy integral expression is derived for lossy multi-bus systems through rigorous energy analysis. A simple rigid rod model of mechanical power transfer system is introduced to address the physical meanings of potential energy terms associated with transfer conductances as well as transfer susceptances. Finally, energy-based analysis has been proposed to show that the energy function has all information of the power system characteristics.

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**ThM05**

**Linear Systems II**

Chair: Vinnicombe, Glenn  Univ. of Cambridge
Co-Chair: Djaferis, Theodore E.  Univ. of Massachusetts, Amherst

13:40

*Additive, Multiplicative and Inverse Multiplicative Robust Stability: Connections with the ν-Gap Metric* ............ 3069

Anderson, Brian D. O.  Australian Natl. Univ.
Brinsmead, Thomas S.  Australian Natl. Univ.

Abstract: Existing Robust Stability Results based on the Nu-gap metric can be extended by the introduction of various weighting functions. By appropriately specialising these weighting functions it is possible to recover earlier robust stability results based on additive, multiplicative and inverse multiplicative uncertainty models. In this way it is demonstrated that some of these classical robustness conditions are a special case of the extended Nu-gap Robust Stability tests.

14:00

*Achievable Performance and Sensitivity Integral Constraints in Preview Control* ........................................ 3075

Midleton, Rick  Univ. of Newcastle
Chen, Jie  Univ. of California, Riverside
Freudenberg, James S.  Univ. of Michigan

Abstract: Preview Control refers to a tracking control scheme whereby a reference trajectory, and a finite ‘preview’ of future values of the reference trajectory are used in the controller. Such controllers have been explored in the context of linear and nonlinear inverse tracking controllers, where particularly for non stably invertible plants, preview of the reference trajectory gives significant performance advantages. Without the presence of preview, it has been known that lack of a stable inverse imposes inherent limitations on the achievable performance of a feedback control loop. In this paper, we explore the extension of these performance limitations to the preview control case. In particular, we consider the infimal achievable H-infinity performance, and Poisson sensitivity integral results for the finite preview case.

14:20

*Extended Argument Principle and Integral Design Constraints Part II: New Integral Relations* .......................... 3081

Chen, Gang  Univ. of California, Riverside
Chen, Jie  Univ. of California, Riverside
Qiu, Li  Hong Kong Univ. of Sci. & Tech.

Abstract: This paper studies performance limitation and design tradeoff issues in the analysis and design of linear time-invariant, single-input single-output feedback control systems. We develop a number of integral constraints, which extend the classical Bode/Poisson sensitivity and complementary sensitivity integrals. The new integral relations lead to new insights into the study of fundamental limitation and design tradeoff issues, and together with the classical results, enable a more refined and more informative performance analysis.

14:40

*Best Tracking and Regulation Performance under Control Effort Constraint* ............................................. 3087

Chen, Jie  Univ. of California, Riverside
Hara, Shinji  Tokyo Inst. of Tech.
Chen, Gang  Univ. of California, Riverside

Abstract: This paper studies optimal tracking and regulation control problems, in which objective functions of tracking error and regulated response, defined by integral square measures, are to be minimized jointly with the control effort, where the latter is measured by the plant input energy. The problems are solved explicitly by deriving analytical expressions for the best achievable performance. Besides the plant nonminimum phase zeros, time delays, and unstable poles, the results reveal and quantify how the lightly damped poles, the anti-resonant zeros, and the bandwidth of the plant may all affect the performance. These effects are nonexistent when the control effort is not taken into account.

15:00

*Optimal Symmetric H2 Controllers for Systems with Collocated Sensors and Actuators* ................................. 3093

Yang, Guang-Hong  Natl. Univ. of Singapore
Qiu, Li  Hong Kong Univ. of Sci. & Tech.

Abstract: This paper addresses the problem of designing the optimal symmetric H2 controller for a plant with collocated sensors and actuators but with possibly asymmetric disturbance injection and performance specification. For such a control problem, the generalized plant has a symmetric block representing the transfer matrix from the control input to the measured output. A complete solution to the optimal H2 control problem with the symmetric structural constraint is given in terms of the optimal solution to a standard H2 model matching problem without the constraint.

15:20

*On Closed-Loop Identification: Error Distributions in the ν-Gap Metric* ................................................. 3099

Vinnicombe, Glenn  Univ. of Cambridge

Abstract: If a model of a system is to be identified with the aim of using it to synthesize a feedback controller for that system using the H-infinity loop-shaping method then it is necessary to ensure that the appropriately weighted nu-gap distance between the true system and the identified model is small in order to ensure any level of guaranteed performance of the synthesized controller with the true plant. This
much is a direct result of the fact that the nu-gap metric is the smallest measure for which a particular robust performance inequality holds. This paper is a result of the observation that direct identification in closed-loop, using Prediction Error Methods, with reference inputs which are chosen to excite the plant input and output equally tends to provide “good” models (in terms of small nu-gap). We shall show, by an analysis of asymptotic parameter and frequency response covariances, why this is so (it is because the expected identification errors are uniformly distributed across frequency). In practice it is impossible to ensure such uniform excitation without knowledge of the plant. For a more practical reference injection scheme, based on a normalized coprime factorization of the controller, the expected identification errors in the nu-gap are inversely proportional to the H-infinity loop-shaping cost function, on a frequency by frequency basis. Thus, the identified model is likely to be good at frequencies where the existing controller is poor and vice-versa. These results suggest a scheme for iterative identification for control, based on successive prediction error identification and a control design step which trades off the H-infinity loop-shaping cost function of the next controller and the model against the the nu-gap distance between the next and the current controller. We analyse some properties of this scheme.

ThM06
System Identifiability Analysis and Constructive Algebra
Chair: Hanzon, Bernard Vrije Univ., Amsterdam
Co-Chair: Peeters, Raf M. Univ. Maastricht
Organizer: Hanzon, Bernard Vrije Univ., Amsterdam
Organizer: Jibetean, Dorina Cent. Voor Wiskunde En Informatica

13:40
On the State Isomorphism Approach to Identifiability of Homogeneous Systems (I) .......................... 3104
Hanzon, Bernard Vrije Univ., Amsterdam
Peeters, Raf M. Univ. Maastricht

Abstract: Two new theorems are presented concerning a class of homogeneous systems. The first result shows that the state isomorphism for a pair of indistinguishable systems is, under certain conditions, homogeneous of degree one. The second result shows that, under certain conditions, this state isomorphism is linear in case the observability rank condition holds at the origin of both systems and for each system the observability rank condition and the controllability rank condition hold in an open set bordering on the origin.

14:00
Identifiability of System: An Algorithm based on the Equivalence Approach (II) ................................. 3106
Denis-Vidal, Lilianne Univ. of Sci. & Tech. Lille
Joly-Blanchard, Ghislaine Univ. of Tech. Compiègne
Noiret, Céline Univ. of Sci. & Tech. Lille

Abstract: In this paper the identifiability of nonlinear uncontrolled dynamical systems is analysed by using the system equivalence based on the straightening out theorem. Previously we have stated a characterization of the identifiability by considering this approach. The so-obtained identifiability necessary condition leads to the solution of partial differential equations. On the other hand, the identifiability sufficient condition may need an extra elimination. First, our contribution consists in elaborating the corresponding algorithm and in justifying it by some algebraic differential notions. Then its implementation is presented in a symbolic computation language.

14:20
A New Differential Algebra Algorithm to Test Identifiability of Nonlinear Systems with Given Initial Conditions (I) ............. 3108
Saccomani, Maria Pia Univ. di Padova
Audoly, Stefania Univ. di Cagliari
Bellu, Giuseppina Univ. di Cagliari
D’Angiò, Leontina Univ. di Cagliari

Abstract: A priori global identifiability is a fundamental prerequisite for model identification. It concerns uniqueness of the parametric struc-
propagation to get guaranteed answers. When the data have already been collected, the notion of structural identifiability may not be the most pertinent concept. This paper shows how interval analysis and interval constraint propagation can again be used to bypass the identifiability study and estimate even parameters that are not identifiable uniquely.

Grand Cypress Ballroom F

ThM07
Neural Control
Chair: Lewis, Frank L. Univ. of Texas, Arlington
Co-Chair: Calise, Anthony J. Georgia Inst. of Tech.

13:40
Multimodel Neural Networks Identification and Failure Detection of Nonlinear Systems .................. 3128
Selmic, Rastiko R Signalogic, Inc.
Lewis, Frank L. Univ. of Texas, Arlington

Abstract: Multimodel identification and failure detection using neural networks (NN) is presented. It is an extension and application of nonlinear system identification using radial basis function NN. The state estimation error is proven to converge to zero asymptotically. Parameters of the identifier converge to the ideal parameters provided that persistency of excitation condition is fulfilled. Multiple model identification structure is analyzed, and its application to the multimodel failure detection. Two simulation examples for NN identifiers are given. Simulation for intelligent multimodel failure detection using multi-neural networks identifiers is presented.

14:00
An SPR Approach for Adaptive Output Feedback Control with Neural Networks ......................... 3134
Calise, Anthony J. Georgia Inst. of Tech.
Hovakimyan, Naira Georgia Inst. of Tech.
Idan, Moshe Fac. of Aerospace Eng., Technion

Abstract: A direct adaptive output feedback control design procedure is developed for highly uncertain nonlinear systems, that does not rely on state estimation. The approach is also applicable to systems of unknown, but bounded dimension. This includes systems with both parametric uncertainties and unmodelled dynamics. This result is achieved by extending the universal function approximation property of linearly parameterized neural networks to model unknown system dynamics from input/output data. The network weight adaptation rule is derived from Lyapunov stability analysis, that guarantees boundedness of the NN weights and the system tracking errors. Numerical simulations of an output feedback controlled Van der Pol oscillator, coupled with a linear oscillator, are used to illustrate the practical potential of the theoretical results.

14:20
Adaptive Critic Neural Network-Based Object Grasping Control using a Three-Finger Gripper .......... 3140
Galan, Gustavo The Univ. of Missouri at Rolla
Jagan Nathan, Sarangapani The Univ. of Missouri at Rolla

Abstract: Robotic grippers that are capable of manipulating objects such as plant trays, fruits, vegetables and so on are required in the MARS’ greenhouse operation. Grasping and manipulation of objects have been a challenging task for robots. It is important that the manipulator performs these tasks accurately and faster without damaging the object. The complex grasping task can be defined as object contact control and manipulation subtasks. In this paper, object contact task is defined for the fingers in terms of following a trajectory accurately. On the other hand, the grasping task is defined in terms of maintaining a predefined applied force by the fingers so that the object is properly secured. A sophisticated controller is required for the grasping task since the process of grasping an object without a priori knowledge of the object’s size, texture, and softness is rather difficult task. The proposed scheme consists of a feedforward action generating neural network (NN) that compensates for the nonlinear gripper and contact dynamics. The learning of this NN is performed on-line based on a critical signal so that a three-finger gripper track a predefined desired trajectory, which is specified in terms of a desired position and velocity for object contact control while it applies a desired force on the object for grasping. Novel NN weight tuning updates are derived for the action generating NN and a Lyapunov-based stability analysis is presented. Simulation results are shown for a three-finger gripper grasping an object.

14:40
Adaptive NN Control for a Class of Strict-Feedback Discrete-Time Nonlinear Systems via Backstepping .......... 3146
Ge, Shuzhi S. Natl. Univ. of Singapore
Li, Guang Y. Natl. Univ. of Singapore
Lee, Tong H. Natl. Univ. of Singapore

Abstract: In this paper, the state feedback controller is studied for a class of strict-feedback discrete-time nonlinear systems in the presence of bounded disturbances. A Lyapunov-based full state feedback neural network control structure is presented via backstepping, which solves the noncausal problem in the discrete-time backstepping design procedure. The closed-loop system is proven to be semi-globally uniformly ultimately bounded (SGUUB). An arbitrarily small tracking error can be achieved if the size of the neural network is chosen large enough, and the control performance of the closed-loop system is guaranteed by suitably choosing the design parameters.

15:00
Neuro-Fuzzy-Based Direct Adaptive Controller Design for a Class of Uncertain Multivariable Nonlinear Systems .... 3152
Lin, Wei-Song National Taiwan Univ.
Chen, Chun-Sheng National Taiwan Univ.

Abstract: This paper develops an approach for designing a direct adaptive MIMO fuzzy logic controller to overcome the interaction among the subsystems and facilitate robust properties. The proposed adaptive fuzzy controller requires no knowledge of the controlled nonlinear system. By employing fuzzy descriptions to the input applied to one subsystem affecting the other subsystem and using the Lyapunov stability theory, the overall adaptation scheme has been proved to be able to guarantee the tracking error residual set being uniform ultimate bounded. The bounds of the fuzzy modeling error are estimated adaptively using an estimation algorithm and the global asymptotic stability of the algorithm is established via H-Infinite tracking performance index. Simulation results of a two-dimensional inverted pendulum confirm that the effect of both the fuzzy approximation error and external disturbance on the tracking error can be attenuated efficiently by the proposed method.

15:20
Design Method of Adaptive Nonlinear H-Infinity Control Systems via Neural Network Approximators ............... 3158
Miyasato, Yoshihiko The Inst. of Statistical Math
Abstract: This article addresses the optimal output transition problem for linear systems with elastic dynamics. A technique to achieve optimal output transition with zero residual vibrations in the output is developed by (a)—using the standard optimal state transition approach to obtain the control law during the output transition and then (b)—integrating this with the inversion-based approach to find inputs that maintain perfect output tracking before the initiation of output transition and after the completion of output transition by using pre- and post-actuation. An example system is studied and simulation results are presented to illustrate the performance improvement over approaches to point-to-point output transition which do not use pre- and post-actuation.

14:00
Convergence of Pseudospectral Discretizations of Optimal Control Problems
Ross, I. Michael
Naval Postgraduate School
Fahroo, Fariba
Naval Postgraduate School

Abstract: A generic nonlinear optimal control problem with a Bolza cost functional is discretized by a Legendre pseudospectral method. According to the co-variant mapping theorem, the Karush-Kuhn-Tucker multipliers of the discrete problem map linearly to the spectrally discretized covectors of the Bolza problem. Using this result, it is shown that the nonlinear programming problem converges to the continuous Bolza problem at a spectral rate assuming regularity of appropriate functions.

14:20
Panel Discussion

14:40
Using Surrogates to Reduce Time Expenditure for Optimization in Systems and Control
Pietrobom, Hilton Cleber
ITA
Kienitz, Karl Heinz
ITA

Abstract: Many engineering applications of standard optimization methods result in heavy computational loads because involved objective function calculations are costly. Therefore traditional optimization techniques often may become computationally unattractive or even unacceptable. An alternative to unacceptably high computational loads in optimization may be the use of objective function approximations whose calculation (and optimization) is less expensive. Such approximations are often called "surrogates", which result from simplification in functions themselves and/or in the underlying system models. From a systems and control perspective this contribution discusses three types of surrogate functions and surrogate usage schedules (or schemes). The reduction in the number of "full" objective function calculations is sought. In such manner, using surrogate functions, constrained optimizer convergence is obtained with considerable reduction in computation time needed to determine a problem solution. Numerical examples are presented which show that the proposed tools may be used to efficiently reduce computation time without sacrificing convergence.

15:00
Finite Time Optimal Control for the Bilinear Systems by using the Successive Approximation Method
Kim, Beom-Soo
Korea Univ.
Lim, Myo-Taeg
Korea Univ.

Abstract: In this paper we develop a new finite time optimal control algorithm for the bilinear systems by using the successive approximation method. Hofer and Aganovic have been proposed iterative schemes to solve the optimal control problem for these systems. On the contrary to the results of Aganovic where the optimal solution has been obtained in terms of a sequence of the differential Lyapunov equations based on the results of Hofer, we propose a new method based on the the successive approximation method and the control law is represented by an explicit state feedback form. An example is presented to illustrate the results, and the proof of convergence is provided.

15:20
Optimal Synthesis of Control Systems
Balashevich, Natalya V.
Nat. Academy of Sci.
Kirillova, Faina M.
Nat. Academy of Sci.
Gabasov, Ralf
Belarus State Univ.

Abstract: A new approach to the synthesis problem of optimal feedback controls is proposed. An algorithm of operating optimal controllers able to calculate values of optimal feedbacks during each particular control process in real time is described. Under incomplete and inexact information, a problem of optimal observation is introduced. An algorithm of operating an optimal estimator constructing estimates of available information for the optimal output controller is described.
ties. Numerical examples are presented to show that the proposed results are less conservative than the existing results.

14:40
Robust Decentralized Reliable Control for a Class of Uncertain Interconnected Delayed Systems ........................................ 3218
Yanxin, Zhang  Northeastern Univ.
Zhang, Si-Ying  Northeastern Univ.

15:00
Robust H-Infinity Control for Uncertain Time Delay Stochastic Systems Containing Saturating Nonlinear Actuators ............... 3214
Xie, Li  Shanghai Jiaotong Univ.
Xiong, Gang  Tampere Univ. of Tech.
He, Xing  Shanghai Jiaotong Univ.
Nyberg, Timo  Tampere Univ. of Tech.
Zhang, Weidong  Shanghai Jiaotong Univ.
Xu, Xiaoming  Shanghai Jiaotong Univ.

Abstract: The robust H-infinity control problem for uncertain stochastic time-delay systems containing saturating nonlinear actuators is considered. The uncertainties are assumed to satisfy specific match condition. The time delays exist in state as well as control input. A sufficient condition for which the stochastic system is robust stable in probability for all admissible uncertainties and all time delays is derived. The delay-independent memoryless robust H-infinity controllers are constructed to stabilize the given system in terms of a group of linear matrix inequalities.

15:20
Synthesis of Guaranteed Dissipation Controller for Uncertain Time-Delay Systems ............................................. 3216
Liu, Fei  Zhejiang Univ.
Su, Hongye  Zhejiang Univ.
Chu, Jian  Zhejiang Univ.

Abstract: This paper addresses robust passive control synthesis problem in which the system contains structure uncertainties and time-delay. Both the state feedback and dynamic output feedback controllers are directly constructed by using linear matrix inequality techniques. In addition, by introducing the dissipation of system, a kind of robust feedback controllers named maximum guaranteed dissipation controller is then proposed, which aims to maximize the upper bound of the dissipation with respect to all admissible uncertainties.

Grand Cypress Ballroom I

ThM10
Control Education
Chair: Yurkovich, Stephen  The Ohio State Univ.
Co-Chair: Watkins, John M.  US Naval Academy

13:40
Learning Lab for Understanding Control Theory of Signals and Linear Systems ............................................ 3218
Coelho, Antonio A. R.  Univ. of Santa Catarina
Almeida, Otacilio M.  Univ. of Santa Catarina
Sumar, Rodrigo R.  Univ. of Santa Catarina
Santos, Jose E. S.  Univ. of Santa Catarina

Abstract: This paper describes the laboratory course contents of Signals and Linear Systems, the first practical activity in the control disciplines of the Automation and Control Engineering Undergraduate Program of the Systems and Automation Department at the Federal University of Santa Catarina/Brazil. The simulation laboratory provides students with important concepts regarding the analysis of discrete and continuous dynamic systems. Scientific programs such as Matlab/Simulink and VisSim have been utilized on experimental control stations to aid simulation activities in modeling, transient analysis, control, steady-state behavior and frequency response tasks. A short routine is presented for each experiment to be carried out in lab classes and reports. Lab experiments have yielded good results for the past five years.

14:00
A Streamlined Approach for Teaching Root Locus Compensator Design ......................................................... 3224
O’Brien, Jr., Richard T.  US Naval Academy
Watkins, John M.  US Naval Academy

Abstract: In this paper, classical root locus compensator design methods are streamlined with the objective of simplifying the computational procedures. The proposed methods place less emphasis on compensator synthesis and allow for more emphasis on compensator selection. The design procedures for four standard compensators are developed from a design procedure for the PD compensator: A numerical example is included.

14:20
Teaching Time-Varying Stability Theory using Autonomous Partial Stability Theory ........................................... 3230
Chellaboina, VijaySekhar  Univ. of Missouri, Columbia
Haddad, Wassim M.  Georgia Inst. of Tech.

Abstract: In this paper we present partial stability results; that is, stability with respect to part of the system’s state, for nonlinear dynamical systems. Using these results we provide a rigorous unification between partial stability theory for autonomous systems and stability theory for nonlinear time-varying systems. This unification allows for time-varying stability theory to be presented as a special case of autonomous partial stability theory in a first course on nonlinear systems.

14:40
A Webcast Virtual Laboratory on a Frequency Modulation Experiment ......................................................... 3236
Ko, Chi C.  Natl. Univ. of Singapore
Chen, Ben M.  Natl. Univ. of Singapore
Chan, Kian P.  Natl. Univ. of Singapore
Cheng, Chang D.  Natl. Univ. of Singapore
Zeng, Guo W.  Natl. Univ. of Singapore
Zhang, Jing  Natl. Univ. of Singapore

Abstract: A number of Internet remote experimentation has been successfully developed for teaching and research purposes in the National University of Singapore (NUS). As only one user can assume control of the apparatus in any physical or remote experiment, the access to these experiments has hitherto been only been limited to single users at a time. Without any increase in the hardware experimental apparatus needed, this paper presents a new webcast based approach for remote experimentation that allows several observing users to view an existing remote experimental session while it is being conducted by a main user. Multicast, the state of the art technology, is being adopted to implement the webcasting capability for remote experimentation purposes with some degree of reliability provided. In multicast, only one copy of the same data is sent to a group address, reaching all the observing users in a particular remote laboratory session. Thus, the system can be accessed by as many users as possible without overloading network and server resources. This is particularly useful as the number of users that may want to observe the experiment cannot be predicted in advance. The webcast virtual laboratory can be accessed at the web site http://vlab.ee.nus.edu.sg/vlab1/freqmod/index.html.

15:00
The Automatic Control Telelab: A Remote Control Engineering Laboratory ......................................................... 3242
Casini, Marco  Univ. of Siena
Prattichizzo, Domenico  Univ. of Siena
Vicino, Antonio  Univ. of Siena

Abstract: This paper describes the realization of a remote laboratory of automatic control developed at the University of Siena. The Automatic Control Telelab (ACT) allows the on-line interaction between remote users and a set of remote physical processes through the Internet. The key feature of this project is the user-defined controller facility. The remote user can design his/her own controller through the well---known Simulink environment. The overall architecture of the Automatic Control Telelaboratory has been designed with the goal of
simplifying the upgrading procedure and the procedures to add new experiments. The Automatic Control Telelab can be found at http://www.dii.unisi.it/~control/act/index.html.

15:20
A Matlab/GUI Case-Study Environment for Nonlinear Control Learning ........................................... 3248
Alamir, Mazen Lab. d’Auto de Gembloux
Khennouf, Hayate Domaine Univ.

Abstract: In this work a Matlab based environment is proposed to illustrate the concept of zero dynamics appearing in nonlinear control design. This is done through the study of the stability of a (torque/flux) oriented control of an AC-motor. The proposed tool is realized using the Matlab-GUI facility.

ThM11
Model-Order Reduction of Nonlinear Systems
Chair: Scherpen, Jacquelien M.A. Delft Univ. of Tech.
Co-Chair: Verriest, Erik I. Georgia Inst. of Tech.

13:40
Nonlinear Balanced Realizations ........................................... 3250
Verriest, Erik I. Georgia Inst. of Tech.
Gray, W. Steven Old Dominion Univ.

Abstract: In this paper a balanced realization for a smooth nonlinear system is defined. The approach is distinct from other notions of nonlinear balancing that appear in the literature and may be more computationally attractive since it avoids the need to compute the state transition matrix.

14:00
Model Reduction for Nonlinear Systems based on the Differential Eigenstructure of Hankel Operators .......... 3252
Fujimoto, Kenji Kyoto Univ.
Scherpen, Jacquelien M.A. Delft Univ. of Tech.

Abstract: This paper offers a new input-normal output-diagonal realization and model reduction procedure for nonlinear systems based on the differential eigenstructure of Hankel operators. Firstly, we refer to the preliminary results on input-normal realizations with original singular value functions and the differential eigenstructure of Hankel operators with axis singular value functions. Secondly, the relationship between the two different characterizations of singular value functions is clarified and, consequently, the new input-normal realization is characterized. Thirdly, we perform the model reduction based on the obtained realization. Furthermore numerical examples demonstrate the effectiveness of the proposed method.

14:20
Quadratic-in-the-State Representation of Nonlinear Systems via Immersion ........................................... 3258
Ohtsuka, Toshiyuki Osaka Univ.

Abstract: This paper considers quadratic-in-the-state representations, which consist of state equations that are at most quadratic with respect to the states, as representations for a broad class of nonlinear systems. A necessary and sufficient condition is shown for existence of a quadratic-in-the-state representation that has the identical input-output relation with a given nonlinear system. That condition is so moderate that many types of nonlinear systems can be represented with a state equation that is at most quadratic with respect to the states. The quadratic-in-the-state representation is expected to be useful as a general model structure in identification of nonlinear systems.

15:00
An Interpolation Method for the Control of \( \epsilon \)-Varying Singularly Perturbed Systems ....................... 3267
Fayaz, Akram M. CNAM/ENSAM

Abstract: This paper deals with the control of singularly perturbed systems when the singular perturbation parameter, \( \epsilon \), varies smoothly between a “very small” and a “large” value. This variation makes the dynamics of system to evolve between singularly perturbed behavior and a “regular” behavior, or between two different singularly perturbed behaviors, i.e. the fast dynamics becoming slow and the slow ones becoming fast. It is clear that in such situations, nor singular perturbations approach, neither “regular methods” alone are efficient globally. To deal with this problem, we propose a control law which essentially combines techniques of singular perturbations and stable scheduling-interpolation methods to build a globally stable and efficient controllers. Based on the variations of epsilon, first several local stable controllers are designed using singular perturbations approaches or “regular methods” and, then, they are interpolated in a way that guarantees global stability. Keywords: Singular perturbations, Scheduling, Interpolation, Control

15:20
Constant Disturbance Suppression for Nonlinear Systems Design using Singular Perturbation Theory ............. 3272
Su, Steven W. Australian Natl. Univ.
Anderson, Brian D. O. Australian Natl. Univ.
Brinsmead, Thomas S. Australian Natl. Univ.

Abstract: A relatively practical method of suppressing the effect of constant disturbances on nonlinear systems is presented. By adding an integrator to a stabilising controller, it is possible to achieve both constant disturbance rejection and zero tracking error. Sufficient conditions for the rejection of a constant input disturbance are given. We give both local and global conditions such that the inclusion of an integrator in the closed loop maintains closed loop stability. The analysis is based on singular perturbation theory. Furthermore, we extend these methods to deal with Multiple-input Multiple-output nonlinear systems. Finally, we implement our method in the control of a simulated helicopter model. The simulation results show that this method achieves satisfactory performance.

ThM12
Synchronous Programming: A Formal Approach for Specifying and Implementing Automatic Control Software
Chair: Girault, Alain INRIA Rhone-Alpes
Co-Chair: Benveniste, Albert INRIA-INRIA
Organizer: Girault, Alain INRIA Rhone-Alpes
Organizer: Benveniste, Albert INRIA-INRIA

13:40
From Control System Design to Embedded Code: The Synchronous Data-Flow Approach (I) .................................. 3278
CaspI, Paul VERIMAG-CNRS
Raymond, Pascal VERIMAG-CNRS

Abstract: This paper presents the synchronous data-flow approach for designing and implementing safety critical control systems and discusses the choices that have been made when designing it. It also discusses the reasons why this approach is still well-adapted to the challenges faced by designers nowadays.
Abstract: Dynamical systems working have been recognized as essential in the area of computer science, under the name of reactive systems by David Harel. Synchronous languages have been proposed as a paradigm to deal with reactive systems and develop tools for them. In this paper we introduce synchronous programming paradigm via the notion of multicontext dynamical systems and illustrate it via the Signal language. We give an outline of controller synthesis in Signal, and system/architecture design.

14:20
Synchronous Programming of Automatic Control Applications using ORCCAD and ESTEREL (I) .......................... 3290
Simon, Daniel INRIA
Girault, Alain INRIA

Abstract: Automatic control systems are typical examples of hybrid systems where continuous time aspects, related to control laws, must be carefully merged with discrete-time aspects related to control switches and exception handling. These two aspects interact in real-time to ensure the nominal behavior of the system and allow for safe and graceful degradation. In a mixed synchronous/asynchronous approach, ranging from user requirements to run-time code, Orccad provides formalized control structures, the coordination of which is specified using the Esterel synchronous language. Orccad is actually a set of CAD tools, that have been designed and integrated to help the users through programming, formal verification, - expressiveness -- enough to incorporate both data and control flow information, and - be close to a well-known pro-
Abstract: A scale and time recursive algorithm which computes the wavelet frame inverse of a signal is proposed. Boundary effects occur when the estimation delay is short. When it is long enough, the estimate becomes delay invariant and it is computed by the algorithm a trous.

14:40
Relay Feedback and Wavelet based Estimation of Plant Model Parameters ................................. 3326
Majhi, Somanath  Indian Inst. of Tech. Guwahati
Sahambi, Jyotindra S.  Indian Inst. of Tech. Guwahati
Atherton, Derek P.  Univ. of Sussex

Abstract: The paper presents a relay feedback and wavelet based method for the estimation of completely unknown processes for autotune purposes. From a single symmetrical relay feedback analysis a set of general expressions are presented for on-line process identification. Using these expressions the exact parameters of open loop stable and unstable first order plus time delay (FOPDT) and second order plus time delay (SOPDT) transfer function models may be obtained from simple measurements made on the limit cycle. However, noise in limit cycle output results in inaccurate estimate of the process model parameters. This paper proposes an effective mother wavelet for tracking the critical points of a noisy output signal. Further, using the wavelets based noise reduction it has been shown how accurate measurements can be made on the noisy limit cycle signal. Simulation studies illustrate the value of the proposed identification method.
Abstract: In this paper state observers for control systems with nonlinear outputs are studied. For such systems, the observability does not only depend on the initial conditions, but also on the exciting control used. In this paper some sufficient conditions are given for the convergence of an observer.

17:40
Existence of Unknown Input Observers and Feedback Passivity for Linear Systems ...................... 3366
Moreno, Jaime
UNAM

Abstract: The existence conditions of unknown input observers (UIO) for LTI systems are well known and several methods for its design have been proposed in the literature. These systems are able to estimate perfectly the state of the system despite of completely unknown input perturbations, i.e. they are robust to arbitrary disturbances, and play a key role in areas such as fault detection and isolation, decentralized control, and robust observers. Passivity is an important system property and has a central position in control theory. Recently the possibility of rendering a system passive by feedback (Feedback Passivity) has been thoroughly studied and necessary and sufficient conditions for this have been obtained. In this paper it is shown that if a LTI system has an UIO, then it can be rendered strictly dissipative (or passive plus a squared down output) by either output injection or state feedback, if stabilizability is assumed in the last case. Furthermore, these properties are equivalent to a strong detectability property and to the possibility of obtaining an stable inverse of the system, by using only one derivative of the output. This allows an interesting and surprising characterization of the existence of UIO in system terms and sheds also light into further properties of output injection or feedback passivizable systems. Lyapunov-like characterizations of these properties can also be given.

18:00
On the Design of Approximate State Estimators for Nonlinear Systems ................................. 3372
Alessandri, Angelo
IAN-CNR
Sanguinetti, Marcello
Univ. of Genova

Abstract: State estimation for continuous-time, nonlinear dynamic systems with Lipschitz nonlinearities is considered. A class of estimators composed of a prediction term and an innovation term is defined, where the innovation function belongs to a suitable smoothness class and has to be determined in such a way as to minimize an estimation cost, represented by the L_infinity norm of the estimation error. Since the admissible innovation functions belong to an infinite-dimensional functional space, the minimization of such a cost represents a functional optimization problem, difficult to solve in a general setting. Approximating the innovation function by a family of parametrized nonlinear approximators allows one to reduce the original functional optimization problem to a sequence of nonlinear programming problems.

16:00
Dissipation and Controlled Euler-Poincaré Systems ............. 3378
Woolsey, Craig A.
Virginia Tech.
Bloch, Anthony M.
Univ. of Michigan
Leonard, Naomi Ehrich
Princeton Univ.
Marsden, Jerrold E.
California Inst. of Tech.

Abstract: The method of controlled Lagrangians is a technique for stabilizing underactuated mechanical systems which involves modifying a system’s energy and dynamic structure through feedback. These modifications can obscure the effect of physical dissipation in the closed-loop. For example, generic damping can destabilize an equilibrium which is closed-loop stable for a conservative system model. In this paper, we consider the effect of damping on Euler-Poincare (special reduced Lagrangian) systems which have been stabilized about an equilibrium using the method of controlled Lagrangians. We describe a choice of feedback dissipation which asymptotically stabilizes a sub-class of controlled Euler-Poincare systems subject to physical damping. As an example, we consider intermediate axis rotation of a damped rigid body with a single internal rotor.

16:20
Noninteracting Control with Stability for Nonlinear m-Inputs m-Outputs Hamiltonian Systems ............... 3384
Astolfi, Alessandro
Imperial College/Politecnico di Milano
Menini, Laura
Univ. di Roma Tor Vergata

Abstract: The problem of noninteracting control with stability for a class of simple under-actuated Hamiltonian systems is considered. This paper extends previous results, which were limited to systems having two (scalar) inputs and two (scalar) outputs. The proposed result allows to decide the problem solvability on the data of the problem without explicitly computing the distribution Delta_mix.

16:40
Dynamic Output Feedback for a Class of Hamiltonian Systems .................................................. 3386
De Leon-Morales, Jesus
DIE-UANL
Espinosa-Pérez, Gerardo
DEPFI-UNAM
Macias-Gardosio, Ivan
DIE-UANL

Abstract: In this paper, we propose a controller design for a class of nonlinear systems using Passive and Hamiltonian design techniques. The result is applied to a synchronous generator in order to synthesize an excitation control which permits to stabilise the generator at its equilibrium position. The main characteristic of this proposition is that neither the equilibrium point of the system must be known nor the state of the generator must be available for measurement.

17:00
17:20
Abstract: The global adaptive observer is presented for illustration. It has been inspired by the technique of high systems. The proposed method is constructive and guarantees nonlinearity programming problems.

17:20
Global Adaptive Observer for a Class of Nonlinear Systems .... 3360
Zhang, Qinghua
IRISA-INRIA
Xu, Aiping
IRISA-INRIA

Abstract: The problem considered in this paper is the joint estimation of state and some parameters for a class of truly nonlinear systems. The proposed method is constructive and guarantees global convergence. It has been inspired by the technique of high gain observer and by a recent result on linear adaptive observer. A numerical example is presented for illustration.

17:00
State Observers of Linear Control Systems with Nonlinear Outputs ............................................. 3358
Ersson, Torvald
Royal Inst. of Tech.
Hu, Xiaoming
Royal Inst. of Tech.

Abstract: In this paper state observers for control systems with nonlinear outputs are studied. For such systems, the observability does not only depend on the initial conditions, but also on the exciting control used. In this paper some sufficient conditions are given for the convergence of an observer.
Abstract: Given a control system and a desired property, an abstracted system is a reduced system that preserves the property of interest while ignoring modeling detail. In previous work, we considered abstractions of linear and nonlinear analytic control systems while preserving reachability properties. In this paper we consider the abstraction problem for Hamiltonian control systems, that is, we preserve the Hamiltonian structure during the abstraction process. We show how the mechanical structure of Hamiltonian control systems can be exploited to simplify the abstraction computations and we provide conditions under which the local accessibility properties of the abstracted Hamiltonian system are equivalent to the local accessibility properties of the original Hamiltonian control system.

17:40
On Feedback Linearization of Underactuated Nonlinear Spacecraft Dynamics
Fang, Bo Iowa State Univ.
Kelkar, Atul G. Iowa State Univ.

Abstract: The feedback linearization problem of an underactuated spacecraft is considered in this paper. The spacecraft model considered is fully nonlinear with six degrees of freedom: three translational and three rotational. It is assumed that the control system has only four control inputs, i.e., the two degrees of freedom are unactuated. It is shown that the dynamical model of the spacecraft with trajectory-attitude parameter coupling having only one propulsion control can be linearized by a dynamic compensator. The linearization algorithm is also given.

18:00
The Berry-Hannay Phase of the Equal-Sided Spring-Jointed Four-Bar Mechanism
Andersson, Sean Univ. of Maryland
Krishnaprasad, P. S. Univ. of Maryland

Abstract: In this work we apply the moving systems approach developed by Marsden, Montgomery, and Ratiu to a free-floating, equal-sided, spring-jointed, four-bar mechanism that is being slowly rotated about its central axis and derive a formula for the induced geometric phase.

Poinciana AB
ThP03
Nonlinear System Analysis
Chair: Lawrence, Douglas Ohio Univ.
Co-Chair: Iglesias, Pablo A. Johns Hopkins Univ.

16:00
Pseudolinearization on Controlled Invariant Submanifolds
Lawrence, Douglas Ohio Univ.

Abstract: We extend the original notion of pseudolinearization on equilibrium submanifolds to general controlled invariant submanifolds for nonlinear systems. This extension is motivated by nonlinear tracking and regulation problems in which the control objective is to stabilize any nominal trajectory in the submanifold. A pseudolinearizing transformation renders linearizations about nominal trajectories in the submanifold trajectory-independent so that local stabilization to the submanifold can be achieved using linear time-invariant control laws. Necessary and sufficient conditions for pseudolinearization via static state feedback and coordinate change are derived which are weaker than those for exact feedback linearization. The study of a class of linear parameter-varying (LPV) systems provides valuable insight into the nonlinear problem.
Abstract: The Triaxial Attitude Control Testbed has been developed as part of a research program on spacecraft multibody rotational dynamics and control. In this paper, equations of motion are derived and presented in various forms. Actuation mechanisms are incorporated into the models; these include moment actuators that are fixed to the triaxial base body, as well as reaction wheel actuators and proof mass actuators that are fixed to the triaxial base body. The models also allow incorporation of unactuated auxiliary bodies that are constrained to move relative to the triaxial base body. The models expose the dynamic coupling between the rotational motion of the triaxial base body, the relative or shape motion of the triaxial base body. The models also allow incorporation of unactuated auxiliary bodies that are constrained to move relative to the triaxial base body. The models expose the dynamic coupling between the rotational motion of the triaxial base body, the relative or shape motion of the auxiliary degrees of freedom, and dynamics associated with actuation mechanisms.

16:20
Energy Management and Attitude Control Strategies using Flywheels ........................................ 3435
Costic, Bret T.  Clemson Univ.
de Queiroz, Marcio S.  Louisiana State Univ.
Dawson, Darren M.  Clemson Univ.
Fang, Yongchun  Clemson Univ.

Abstract: This paper is devoted to the use of multiple flywheels that integrate the energy storage and attitude control functions in space vehicles. This concept, which we refer to as an Integrated Energy Management and Attitude Control (IEMAC) system, reduces the space vehicle bus mass, volume, cost, and maintenance requirements while maintaining or improving the space vehicle performance. To this end, we present two nonlinear IEMAC strategies (model-based and adaptive) that simultaneously track a desired attitude trajectory and desired energy/power profile. Both strategies ensure asymptotic tracking while the adaptive controller compensates for uncertain spacecraft inertia.

16:40
Attitude Control of a Satellite around the Space Station ................... *
Zhang, Honghua  Chinese Academy of Space Tech.

Abstract: A nonlinear control scheme for attitude control of a spacecraft is combined with a nonlinear gyro bias observer for the case of constant gyro bias. A persistency of excitation analysis shows the observer bias estimate converges to the true bias values exponentially fast. The resulting coupled, closed loop dynamics are proven by a Lyapunov analysis to be globally stable, with asymptotically perfect tracking. The analysis is extended to consider the effects of noise in addition to the gyro bias. A simulation of the proposed observer-controller design is given for a rigid spacecraft tracking a specified, time-varying attitude sequence to illustrate the theoretical claims.
Abstract: We consider adaptive stabilization for a class of time-varying second-order systems. Interpreting the system states as position and velocity, the system is assumed to have unknown, non-parametric, bounded time-varying damping and stiffness coefficients. The coefficient bounds need not be known to implement the adaptive controller. Lyapunov methods are used to prove global convergence of the system state. For illustration, the controller is used to stabilize an example system.

Abstract: In this paper, we address H2 optimal control problem in a behavioral framework. First, we introduce a modified image representation in order to denote an exogenous disturbance. Next, we consider an interconnection between a plant described by such an image representations and a control law. We provide an explicit necessary and sufficient condition for this interconnected system to be H2 optimal. This condition is used to obtain parameterizations and concrete algorithms of H2 optimal control laws for behavioral systems. At last, we give an illustrative example do show the validity of our result.

Abstract: In this paper we study control by interconnection of linear differential systems. We give necessary and sufficient conditions for regular implementability of a given linear differential system. We formulate the problems of stabilization and pole placement as problems of finding suitable, regularly implementable sub-behaviors of the manifest plant behavior. The problem formulations and their resolutions are completely representation free, and specified in terms of the system dynamics only. Control is viewed as regular interconnection. A controller is a system that constrains the plant behavior through a distinguished set of variables, namely, the control variables. The issue of implementation of a controller in the feedback configuration and its relation to regularity of interconnection is addressed. Freedom of disturbances in a plant and regular interconnection with a controller also turn out to be inter-related.
decided by the dynamics of the corresponding Kalman filter, much like for the H-2 smoothing. Yet it is also shown that there exists a remarkable difference between the H-2 and H-inf cases; whereas in the former case the performance improves monotonically with h, in the latter case the achievable ‘gamma’ typically ‘saturates’ after some finite smoothing lag and any further increase of h has no effect on the achievable H-inf performance.

18:00 Subspace Identification for Nonlinear Systems that are Linear in Unmeasured States ................................. 3518
Lacy, Seth L.  Univ. of Michigan
Bernstein, Dennis S.  Univ. of Michigan

Abstract: In this paper we apply subspace methods to the identification of a class of multi-input multi-output discrete-time nonlinear time-varying systems. Specifically, we study the identification of systems that are nonlinear in measured data and linear in unmeasured states. We present numerical simulations to demonstrate the efficacy of the method.

ThP07 Neural Control: Theory and Application
Chair: Sanchez, Edgar N.  CINVESTAV
Co-Chair: Ge, Shuzhi Sam  Natl. Univ. of Singapore
Organizer: Sanchez, Edgar N.  CINVESTAV
Organizer: Ge, Shuzhi Sam  Natl. Univ. of Singapore

16:00 Neural Network based Adaptive Dynamic Surface Control for Nonlinear Systems in Strict-Feedback Form (I) ............... 3524
Wang, Dan  Chinese Univ. of Hong Kong
Huang, Jie  Chinese Univ. of Hong Kong

Abstract: The dynamic surface control technique developed recently by Swaroop et al has greatly simplified the backstepping design for the control of nonlinear systems in strict-feedback form by overcoming the problem of “explosion of complexity”. It was later extended to adaptive backstepping design for nonlinear systems with linearly parameterized uncertainty. In this paper, by incorporating this design technique into a neural network based adaptive control design framework, we have developed a backstepping based control design for a class of nonlinear systems in strict-feedback form with arbitrary uncertainty. Our development is able to eliminate the problem of “explosion of complexity” inherent in the existing method. In addition, a stability analysis result is given which shows that our control law can guarantee the uniform ultimate boundedness of the closed-loop system, and make the tracking error arbitrarily small.

16:20 Adaptive Neural Control of a Class of MIMO Nonlinear Systems (I) ........................................... 3530
Ge, Shuzhi S.  Natl. Univ. of Singapore
Wang, Cong  Natl. Univ. of Singapore

Abstract: In this paper, an adaptive neural control scheme is proposed for a class of uncertain MIMO nonlinear systems in block-triangular form. By exploiting the special structural property of the MIMO system, the developed scheme avoids the controller singularity problem completely without calculating the inverse of the estimated “decoupling matrix”. Moreover, the stability of the whole closed-loop system is concluded in a nested iterative manner. The proposed scheme offers a systematic design procedure for the control of a class of uncertain MIMO nonlinear systems.

17:00 Stable Optimal Neural Net Controller Design for a Class of Discrete-Time Systems (I) ......................... *
Tyukin, Ivan  Ford Motor Co.
Prokhorov, Danil  Ford Motor Co.

17:20 Can We Cope with the Curse of Dimensionality in Optimal Control by using Neural Approximators? (I) .......... 3540
Zoppoli, Riccardo  Univ. di Genova
Sanguineti, Marcello  Univ. di Genova
Parisini, Thomas  Politecnico di Milano

Abstract: An approximation procedure termed “extended Ritz method” is presented for the solution of functional optimization problems. The properties of powerful nonlinear approximators, such as neural networks, are exploited to face highly nonlinear optimization problems in high-dimensional settings, with the possibility of avoiding the so-called “curse of dimensionality.” As an example, a nonlinear control problem involving several tens of state variables is faced.

17:40 Robust High-Gain DNN Observer for Nonlinear Stochastic Continuous Time Systems (I) .......................... 3546
Murano, Daishi A.  CINVESTAV-IPN
Poznyak, Alexander  CINVESTAV-IPN
Ljung, Lennart  Linköping Univ.

Abstract: A class of nonlinear stochastic processes, satisfying a “Lipschitz-type strip condition” and supplied by a linear output equation, is considered. Robust asymptotic (high-gain) state estimation for nonlinear stochastic processes via differential neural networks is discussed. A new type learning law for the weight dynamics is suggested. By a stochastic Lyapunov-like analysis (with Itô formula implementation), the stability conditions for the state estimation error as well as for the neural network weights are established. The upper bound for this error is derived. The numerical example, dealing with “module”-type nonlinearities, illustrates the effectiveness of the suggested approach.

ThP08 Optimization
Chair: Beck, Carolyn L.  Univ. of Illinois, Urbana-Champaign
Co-Chair: Kabamba, Pierre T.  Univ. of Michigan

16:00 Conjugate Points for Calculus of Variations with Inequality State Constraints ................................. 3552
Kawasaki, Hideo  Kyushu Univ.
Zeidan, Vera  Michigan State Univ.

Abstract: In this paper, variational problems with equality and inequality state constraints are considered. The theory of conjugate points for these problems is developed, and necessary conditions for
weak local optimality are derived in terms of this concept and the Legenndre condition. For the case of inequality constraints, the envelope-like effect is taken into consideration in the accessory problem.

16:20
A Conjugate Point Theory for Nonlinear Programming Problems ........................................... 3558
Kawasaki, Hidefumi  Kyushu Univ.

Abstract: The conjugate point is an important global concept in the calculus of variations and optimal control. In these extremal problems, the variable is not a vector in $\mathbb{R}^n$ but a function. So a simple and natural question arises. Is it possible to establish a conjugate points theory for a nonlinear programming problem, $\min f(x)$ on $x \in \mathbb{R}^n$? This paper positively answers this question. We introduce the Jacobi equation and conjugate points for the nonlinear programming problem, and we describe necessary and sufficient optimality conditions in terms of conjugate points.

16:40
On State Constraint Representations and Mesh-Dependent Gradient Projection Convergence Rates for Optimal Control Problems ........................................... 3564
Dunn, Joseph C.  North Carolina State Univ.

Abstract: This note briefly summarizes the main results in a SIAM article with the same title. In the SIAM paper, two distinct nonlinear programming formulations are investigated for ODE optimal control problems with pointwise state and control constraints. The first formulation treats the differential equations of state as an equality constraint in the conventional manner. The second formulation employs a different equality constraint entailing the integrated state transition map. Related convergence rate estimates are developed for augmented gradient projection methods and discrete-time approximations to a large representative class of ODE control problems. In the first formulation, the rate estimates are mesh-dependent, and the predicted number of inner loop gradient projection iterations needed to achieve a fixed small deviation from the optimal value of the augmented Lagrangian is inversely proportional to the square of the mesh width. In the second formulation, the convergence rates and predicted iteration counts are mesh-invariant. The computational costs-per-iteration in the two formulations are comparable.

17:00
The Minimum Principle for Deterministic Impulsive Control Systems ........................................... 3569
Chudoung, Jerawan  Univ. of Illinois, Urbana-Champaign
Beck, Carolyn L.  Univ. of Illinois, Urbana-Champaign

Abstract: We prove the Minimum Principle for an optimal impulsive control problem. This result is a generalization of the well-known Pontryagin Minimum Principle, and yields a necessary condition for an optimal impulsive control strategy that minimizes an associated cost. Furthermore, we establish an explicit connection between the value function arising from the Dynamic Programming Principle approach and the costate arising from the Minimum Principle approach for the impulsive optimal control problem.

17:20
Filter Design under Magnitude Constraints is a Finite Dimensional Convex Optimization Problem ........................................... 3575
Rossignol, Laure  LAP ISMRA
Scorletti, Gerard  LAP ISMRA
Fromion, Vincent  LASB INRA

Abstract: We consider the design of filters satisfying upper and lower bounds on the frequency response magnitude. The paper contribution is to prove that such a problem is equivalent to a finite dimensional convex optimization program involving Linear Matrix Inequality constraints. Note that this filter design problem is usually reduced to a semi infinite dimensional Linear Programming optimization problem under the additional assumption that the filter poles are fixed (for instance, FIR design). Furthermore, the semi infinite dimensional optimization is practically solved, using a gridding approach on the frequency. In addition to be finite dimensional, our formulation allows to set or not the filter poles. In fact, weighting function design in the standard H-infinity approach to control is our motivating application. Unavailable systematic design method precludes a wider use of the H-infinity approach.

17:40
Optimal Paths for Avoiding a Radiating Source ........................................... 3581
Pachter, Lior S.  Univ. of California, Berkeley
Pachter, Meir  AFIT/ENG

Abstract: We consider the problem of navigating between points in the plane so as to minimize the exposure to a radiating source. Specifically, given two points $z_1, z_2$ in the complex plane, we solve the problem of finding the path $C(t)$ such that $C(0)=z_1, C(1)=z_2$ and the integral of the inverse distance raised to some power is minimized over the path. The parameter $k$ corresponding to the power in the integral specializes to a number of interesting cases: in particular $k=2$ pertains to the passive sensor avoidance problem and $k=4$ entails the active radar avoidance problem. The avoidance paths which minimize exposure may have infinite arc-length. To overcome this problem we introduce a weighted exposure and path length optimization problem whose solution requires a variational approach. The optimal trajectory results we obtain are surprisingly intuitive in the cases of interest.

ThP09
Linear Matrix Inequalities
Chair: Ohara, Atsumi  Osaka Univ.
Co-Chair: Gurfil, Pini  Princeton Univ.

16:00
LMI-Based Techniques for Solving Quadratic Distance Problems........................................... 3587
Chesi, Graziano  Univ. di Siena
Garulli, Andrea  Univ. di Siena
Tesi, Alberto  Univ. di Firenze
Vicino, Antonio  Univ. di Siena

Abstract: The computation of the minimum distance from a point to a surface in a finite dimensional space is a key issue in several system analysis and control problems. This paper presents a general framework in which some classes of minimum distance problems are tackled via LMI techniques. Exploiting a suitable representation of homogeneous forms, a lower bound to the solution of a canonical quadratic distance problem is obtained by solving a one-parameter family of LMI optimization problems. Several properties of the proposed technique are discussed. In particular, tightness of the lower bound is investigated, providing both a simple algorithmic procedure for a posteriori optimality testing and a structural condition on the related homogeneous form that ensures optimality a priori. Extensive numerical simulations are reported showing promising performances of the proposed method.

16:20
On Solvability and Numerical Solutions of Parameter-Dependent Differential Matrix Inequality ........................................... 3593
Ohara, Atsumi  Osaka Univ.
Sasaki, Yasuaki  Osaka Univ.

Abstract: This note considers solvability condition and a numerical algorithm for parameter-dependent differential affine matrix inequality. When the coefficient and solution matrices are assumed to be in a trigonometric polynomial form of the fixed order, the necessary and sufficient solvability condition is given in terms of linear matrix inequalities. The result is based on a simple idea to make use of positive real lemma to preserve positivity on an interval. Multi-dimensional parameter cases are also discussed.
Abstract: In this paper, we consider a novel approach to the initial condition response (ICR) analysis of non-linear time-varying systems of the Lur’e type. To quantify the transient behavior resulting from initial conditions, an ICR measure is defined. It is shown that an appropriate upper bound for the ICR measure can be calculated based upon the condition number of a positive definite matrix, associated with a quadratic Lyapunov function. Due to the particular structure of the Lur’e systems, bounding the ICR measure is transformed into a minimization problem, constrained by either two simultaneous Lyapunov matrix inequalities or a single algebraic Riccati inequality.

17:00 Handling Visual Servoing Schemes through Rational Systems and LMIs .......................................... 3601
Bellet, Delphine LAAS-CNRS
Danses, Patrick LAAS-CNRS

Abstract: This paper proposes a general framework for the analysis and the synthesis of multicroteria visual-based servocontrol schemes. The approach allows to consider position-based or feature-based controllers which can be static, dynamic or gain-scheduled. The visual servoing problem is stated under a state-space representation which is further turned into a rational system and then embedded in a Structured Norm-bounded Linear Differential Inclusion. Many visual servoing requirements may be dealt with, e.g. global stability, avoidance of actuators' saturation, 3D and image constraints. They often lead to Linear Matrix Inequalities.

17:20 A Parameter Optimization Approach to Solving Quasi-LMI Problems ............................................ 3607
Zheng, Feng Natl. Univ. of Singapore
Wang, Qing-Guo Natl. Univ. of Singapore
Lee, Tong H. Natl. Univ. of Singapore

Abstract: Many canonical and modern control problems can be recast into the problem of solving a group of matrix inequalities. Some of them are in the form of linear matrix inequalities (LMIs), which can be solved very efficiently by the powerful LMI toolbox in Matlab, but some others are in the form of quasi LMIs (QLMIs). By quasi, we mean that unknown parameters are involved in the matrix inequalities and these inequalities are LMIs only when the unknown parameters are fixed. Thus how to “guess” the unknown parameters is the key to solve the whole problem. In this note, we present an optimal estimate for the unknown parameters. We will illustrate our method by completely solving the problems of overshoot bound control and reachable set analysis for uncertain systems. Numerical examples are provided to show the effectiveness of the proposed method.

17:40 An LMI Approach to Robust Fault Detection Filter Design for Discrete-Time Systems with Model Uncertainty ........... 3613
Zhong, Maifying Donghua Univ.
Ding, Steven X. Lausitz Univ. of Applied Sci.
Tang, Bingyong Donghua Univ.
Zhang, Ping Lausitz Univ. of Applied Sci.
Jeanisch, Torsten Lausitz Univ. of Applied Sci.

Abstract: This contribution deals with the design of fault detection filter for discrete-time systems with both model uncertainty and disturbances. We propose an approach to the solution, which consists of two steps: a) selection of a stable weighting function matrix, optimized in the sense of the maximum sensitivity from the faults to residual signal; b) formulation of the design of fault detection filters as a model-matching problem and solving the optimization problem using the LMI technique. The achieved results are illustrated by a numerical example.

18:00 On the Observability Properties of a Class of 2D Discrete Linear Systems ........................................... 3625
Dymkov, Michael Natl. Academy of Sci. of Belarus
Gaishun, I. Natl. Academy of Sci. of Belarus
Rogers, Eric Univ. of Southampton
Galkowski, Krzysztof Univ. of Zielona Góra
Owens, David H. Univ. of Sheffield

Abstract: Repetitive processes are a distinct class of 2D systems of both theoretical and applications interest. They arise, for example, in the modeling of industrial processes such as long-wall coal cutting and are the essential starting point for the study of classes of linear iterative learning control schemes. The development of a ‘mature’ systems theory for these processes is the subject of this paper. In particular, a Volterra operator setting is used to produce the first significant results on an observability theory for the subclass of so-called discrete linear repetitive processes which are of particular interest in a number of areas, e.g. the modeling and analysis of a wide class of linear iterative learning control schemes.

18:40 Feedback Control Systems as users of a Shared Network: Communication Sequences that Guarantee Stability ........... 3631
Hristu-Varsakelis, Dimitris Univ. of Maryland

Abstract: We investigate the stability of a collection of systems which are governed by linear dynamics and operate under limited communication. We view each system and its feedback controller as users on an idealized shared network which grants access only to a few system- controller pairs at any one time. A communication sequence, which plays the role of a network admission policy, specifies the amount of time available for each system to complete its feedback loop. Using Lyapunov theory, we have a sufficient condition for the existence of a stabilizing communication sequence and show how one can be constructed in a way that minimizes network usage. Our solution depends on the parameters of the underlying system(s) and on the number of controller-plant connections that can be maintained simultaneously. We include simulation results illustrating the main ideas.
The Hankel singular values provide an upper bound for an appropriate norm of balanced truncation for instance, since the sum of the neglected singular values is dominated by the Hankel singular values of the system. This issue is of considerable interest in model reduction, by means of balanced truncation. The resulting model order is determined by testing the stability of the edges of the polytope. An example has been given to demonstrate the applicability of our new approach.

Abstract: In this paper, we develop computational techniques with enhanced accuracy for two frequency-weighted model reduction approaches, namely, balanced truncation, and singular perturbation approximation. New stability-enforcing choices of the frequency-weighted grammians can guarantee the stability of reduced models for two-sided frequency weights. Several numerical examples show the effectiveness of the new approximation techniques.

17:00 On Model Reduction in the $\nu$-Gap Metric ......................... 3665 Cantoni, Michael Univ. of Melbourne

Abstract: The problem of reduced order approximation to within a specified nu-gap distance from a nominal model is considered in this paper. A condition for the existence of such an approximation is given in terms of two Lyapunov inequalities and a coupling rank constraint. When this condition is satisfied, a corresponding reduced order model can be constructed explicitly. From the perspective of behaviour in closed-loop, approximation in the nu-gap metric is appealing, since the nu-gap between two open-loop systems is a measure of the maximum possible difference in closed-loop behaviour with a given compensator. Key Words: Model Reduction, nu-Gap Metric, H-infinity Loop-Shaping, Feedback Systems, LMIs

17:20 Implicitly Restarted Lanczos Algorithm for Model Reduction .... 3671 Papakos, Vasilios Imperial College Jaimoukha, Imad M. Imperial College

Abstract: The Lanczos algorithm is increasingly used for model reduction of large scale stable systems. Two features of the algorithm, however, limit its applicability; the tendency of the reduced model to poorly approximate low frequency dynamics and the fact that the approximation is not guaranteed to be stable. This paper tackles these issues via a computationally efficient implicit restart scheme based on balanced truncation which preserves the attractive features of the Lanczos algorithm.
Abstract: A new class of systems: dynamical systems with controllable singularities, is considered. This class refers to systems that admit introduction of the impulsive control actions during singular phases of their motion, such as changes in dimension, discontinuities in the state, and other nonsmooth types of motion. A well-posed representation of the discontinuous in the behavior of these systems is given in terms of differential equations with measure and the corresponding generalized (discontinuous) solution of the new type is introduced. This representation, which admits discontinuity of the entire state, is put into correspondence with the detailed multi-scale system description via a space-time transformation followed by a limit procedure. Finally, using the framework developed, an approach to constructive optimal controller synthesis for this class of systems is presented.

16:20
A Necessary and Sufficient Condition for High-Frequency Robustness of Non-Strictly-Propert Feedback Systems .......... 3687
Cobb, Daniel  Univ. of Wisconsin, Madison

Abstract: We consider stability and robustness of feedback systems, where the plant and compensator need not be strictly proper. In an earlier paper [1] we described a certain functional R-infinity which, when negative, guarantees closed-loop instability as a result of parasitic interactions in the feedback loop. In our main result, Theorem 5, we prove that, when R-infinity>0 there exist perturbations of plant and compensator from a narrow class which result in closed-loop stability and convergence. Hence, we may view R-infinity>0 as a necessary and sufficient condition for closed-loop robustness in non-strictly-proper feedback loops.

16:40
Mechanical Systems with Unilateral Constraints:
Controlled Singularity Approach ............................................. 3692
Bentsman, Joseph  Univ. of Illinois, Urbana-Champaign
Miller, Boris M.  Russian Academy of Sciences

Abstract: Admitting the introduction of the impulsive control actions during singular phases of the dynamical system motion, such as changes in dimension, and discontinuities in the state, a well-posed representation of the discontinuous limiting motion of mechanical systems with unilateral constraints in terms of differential equations with measure is developed. This representation is mapped into a detailed multi-scale system description via a space-time transformation. The resulting framework, which includes the equations of the detailed and limit dynamics connected via the space-time transformation, is used to describe a difficult to model class of systems - mechanical systems with impulsive control actions introduced by a collision-type system interaction with nonstationary controllable constraints.

17:00
Sub-Optimal Linear Quadratic Control for Singularly Perturbed Systems ............................................... 3698
Li, Yan  Nanyang Tech. Univ.
Wang, Jian Liang  Nanyang Tech. Univ.
Yang, Guang-Hong  Temasek Labs

Abstract: This paper proposes a new methodology to design suboptimal controllers for singularly perturbed systems. The controller is given in terms of the solution of a set of inequalities. An algorithm is given to solve these inequalities through LMI (Linear Matrix Inequality) formulation. An example exhibits that the results are very close to the exact optimal solutions. The main features of this approach are that it takes advantage of LMI to deal with singularly perturbed systems with less conservativeness and can be extended to other robust and multi-objective control problems for singularly perturbed systems. In addition, it is suitable for both standard and nonstandard singularly perturbed systems.

17:20
Stabilization of Oscillations Amplitudes via Relay Delay Control ......................................................... 3704
Fridman, Leonid M.  Chihuahua Inst. of Tech.
Strygin, V.  Voronezh State Univ.
Polyakov, A.  Voronezh State Univ.

Abstract: Time delay does not allow to realize an ideal sliding mode, but implies oscillations in the space of state variables. The delayed relay control algorithms for stabilization of oscillation’s amplitudes are suggested.

17:40
Reduced-Order H-Infinity Controller
Design for Descriptor Systems ............................................. 3710
Yung, Chee-Fai  Natl. Taiwan Ocean Univ.
Chen, Mei-Chi  Natl. Taiwan Ocean Univ.

Abstract: State-space formulas to the reduced-order H-infinity controllers for descriptor systems are given. The approach taken is mainly based on the solutions of two generalized algebraic Riccati equations (GARE), while exploiting the structure of the deflating subspace of the pencil (E, W-infinity), where W-infinity is an admissible solution to a GARE that is the descriptor systems counterpart of a certain ARE (algebraic Riccati equation) first developed by Petersen et al.,1991, International Journal of Robust Nonlinear Control, vol. 1, 171-185). This approach has the advantage that, by proper selection of the bases of the deflating space and suitable assumptions, the reduced-order controller may be in a normal form, namely the E-matrix of the controller is nonsingular.

17:00
ThP11
Descriptor Systems
Chair: Bentsman, Joseph  Univ. of Illinois, Urbana-Champaign
Co-Chair: Cobb, Daniel  Univ. of Wisconsin, Madison

16:00
Dynamical Systems with Controllable Singularities: Multi-Scale and Limit Representations and Optimal Control ................. 3681
Bentsman, Joseph  Univ. of Illinois, Urbana-Champaign
Miller, Boris M.  Russian Academy of Sciences

16:40
Mechanical Systems with Unilateral Constraints:
Controlled Singularity Approach ............................................. 3692
Bentsman, Joseph  Univ. of Illinois, Urbana-Champaign
Miller, Boris M.  Russian Academy of Sciences

17:00
Sub-Optimal Linear Quadratic Control for Singularly Perturbed Systems ............................................... 3698
Li, Yan  Nanyang Tech. Univ.
Wang, Jian Liang  Nanyang Tech. Univ.
Yang, Guang-Hong  Temasek Labs

Abstract: This paper proposes a new methodology to design suboptimal controllers for singularly perturbed systems. The controller is given in terms of the solution of a set of inequalities. An algorithm is given to solve these inequalities through LMI (Linear Matrix Inequality) formulation. An example exhibits that the results are very close to the exact optimal solutions. The main features of this approach are that it takes advantage of LMI to deal with singularly perturbed systems with less conservativeness and can be extended to other robust and multi-objective control problems for singularly perturbed systems. In addition, it is suitable for both standard and nonstandard singularly perturbed systems.

17:20
Stabilization of Oscillations Amplitudes via Relay Delay Control ......................................................... 3704
Fridman, Leonid M.  Chihuahua Inst. of Tech.
Strygin, V.  Voronezh State Univ.
Polyakov, A.  Voronezh State Univ.

Abstract: Time delay does not allow to realize an ideal sliding mode, but implies oscillations in the space of state variables. The delayed relay control algorithms for stabilization of oscillation’s amplitudes are suggested.

17:40
Reduced-Order H-Infinity Controller
Design for Descriptor Systems ............................................. 3710
Yung, Chee-Fai  Natl. Taiwan Ocean Univ.
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Abstract: State-space formulas to the reduced-order H-infinity controllers for descriptor systems are given. The approach taken is mainly based on the solutions of two generalized algebraic Riccati equations (GARE), while exploiting the structure of the deflating subspace of the pencil (E, W-infinity), where W-infinity is an admissible solution to a GARE that is the descriptor systems counterpart of a certain ARE (algebraic Riccati equation) first developed by Petersen et al.,1991, International Journal of Robust Nonlinear Control, vol. 1, 171-185). This approach has the advantage that, by proper selection of the bases of the deflating space and suitable assumptions, the reduced-order controller may be in a normal form, namely the E-matrix of the controller is nonsingular.

17:00
ThP13
Estimation Applications
Chair: Johansson, Rolf  Lund Inst. of Tech.
Co-Chair: Zheng, Wei Xing  Univ. of Western Sydney

16:00
Detecting Leaks and Sensor Biases by Recursive Identification with Forgetting Factors ............................................. 3716
Sun, Xi  Univ. of Alberta
Chen, Tongwen  Univ. of Alberta
Marquez, Horacio J.  Univ. of Alberta

Abstract: In industrial processes, pipes and tanks may leak and sensors may have biases since corrosion, measuring noises and instrument faults exist. In order to maintain production in normal and safe conditions, detecting possible faults of production equipment on time is crucial. In this paper, a process model is proposed to describe boiler tube leak problem. Based on this model, least-squares methods with constant and time-varying forgetting factors are presented to detect the leakage and sensor bias. The application in a boiler system shows that the proposed methods can de-
16:20
Development of Inferential Distillation Models using Multivariate Statistical Methods .......................... 3722
Evangelista, M. A.  CEFET-PR
Neves, Jr., F.  CEFET-PR
Arruda, L. V. R.  CEFET-PR
Ramos, A. E. M.  CEFET-PR

Abstract: Chemical processes often have many variables that are being monitored every minute or every second. This can result in “data overload” and useful information that is buried within the collection of data is lost. Techniques that provide a quick method to extract information from large sets of data can prove to be very beneficial. In many cases, however, the data collected from processes are redundant, or highly correlated. In this paper, inferential models for estimating product compositions are built using Partial Least Squares (PLS) regression, based on simulated time series data. The PLS method removes the correlation problem by projecting the original variable space to an orthogonal latent space. A debutanizer column is used as a case study and the results of the PLS method are compared to another two multivariate statistical methods, which are Multiple Linear Regression (MLR) and Principal Components Regression (PCR).

16:40
Fuel Mass Estimation in Aircraft Tanks using Neural Nets .... 3728
Zakrzewski, Radoslaw R.  Goodrich Corporation

Abstract: Determination of fuel mass in aircraft tanks is a nonlinear estimation problem, in which a set of noisy sensor readings is transformed into a single estimate. In the typical commercial aircraft currently in service, this model-based transformation is approximated by a sum of one-dimensional look-up tables representing contributions from individual fuel quantity probes. Significant improvements in accuracy may be achieved by replacing this decomposed approach with a multi-dimensional optimal estimator. In this paper, feedforward neural nets are trained to approximate the unknown optimal estimator. A simulation example demonstrates the benefits offered by the neural net technique compared to the traditional method. Issues related to certification of safety-critical software containing neural net modules are also addressed.

17:00
Set Membership Pose Estimation of Mobile Robots based on Angle Measurements ................................. 3734
Di Marco, Mauro  Univ. di Siena
Garulli, Andrea  Univ. di Siena
Gianintra, Antonio  Univ. di Siena
Vincio, Antonio  Univ. di Siena

Abstract: This paper addresses the problem of estimating position and orientation of a mobile robot navigating in an environment for which a landmark-based map is available. A set theoretic approach to the problem is proposed. Estimates of robot position and heading are derived in terms of uncertainty regions, under the hypothesis that the errors affecting all sensors measurements are unknown but bounded. A recursive estimation procedure for the specific case of localization based on angle measurements is presented. Simulation and experimental results prove the effectiveness of the proposed approach.

17:20
Model-Based Estimation of Cylinder Pressure Sensor Offset using Least-Squares Methods ....................... 3740
Tunestål, Per  Lund Inst. of Tech.
Hedrick, Karl J.  Univ. of California, Berkeley
Johansson, Rolf  Lund Inst. of Tech.

Abstract: Two methods for estimating the sensor offset of a cylinder pressure transducer are developed. Both methods fit the pressure data during pre-combustion compression to a polytropic curve. The first method assumes a known polytropic exponent, and the other estimates the polytropic exponent. The first method results in a linear least-squares problem, and the second method results in a nonlinear least-squares problem. The nonlinear least-squares problem is solved by separating out the nonlinear dependence and solving the single-variable minimization problem. For this, a finite difference Newton method is applied. Using this method, the cost of solving the nonlinear least-squares problem is only slightly higher than solving the linear least-squares problem. Both methods show good statistical behavior. Estimation error variances are inversely proportional to the number of pressure samples used for the estimation. The method is computationally inexpensive, and well suited for real-time control applications.

17:40
Computer Vision-Based Estimation of Aircraft Dynamics ...... 3746
Garfìl, Pini  Technion-Israel Inst. of Tech.
Rotstein, Hector  Technion-Israel Inst. of Tech.

Abstract: This paper discusses the estimation of an aircraft motion from the optical flow observed by a downward-looking body-fixed camera. The estimation is based on the so-called “subspace constraint,” which arises when points stationary on the environment are tracked on the image plane. The constraint can be combined with the aircraft dynamics, given rise to a nonlinear estimation problem. In this paper the problem was solved using an implicit extended Kalman filter. The suggested algorithm was implemented in a simulation, which verified that the angle of attack, the angle of sideslip and the angular body pitch, yaw and roll rates could be estimated.

2001 IEEE CDC FRIDAY, DECEMBER 7
Palm ABC

FrA01
Nonlinear Control Applications I
Chair: Fantoni, Isabelle  Univ. de Tech. de Compiègne
Co-Chair: Olfati-Saber, Reza  Univ. de Tech. de Compiègne

08:30
Stabilization of a Planar Prismatic-Prismatic-Revolute Manipulator based on an Energy Approach .................. 3752
Fantoni, Isabelle  Univ. de Tech. de Compiègne

Abstract: This paper presents the control of an underactuated planar robot, with two prismatic and one revolute joints. We propose a controller based on an energy approach and the passivity properties of the system.

08:50
Position and Attitude Control of an Underwater Vehicle using Variable Constraint Control .......................... 3758
Ikeda, Takayuki  Tokyo Inst. of Tech.
Fukaya, Masakazu  Tokyo Inst. of Tech.
Mita, Tatsuo  Tokyo Inst. of Tech.

Abstract: We present a nonlinear feedback control of position and attitude of an underwater vehicle subject to nonholonomic constraints. Its kinematic model is given by time derivative of position coordinates and of Euler parameters describing the underwater vehicle orientation. One forward velocity and three angular velocities serve as inputs of the vehicle. The method adopts Euler parameters for orientation description and control strategy called variable constraint control (VCC). Euler parameters are employed
in order to avoid singularities in orientation description which occur in other representations, such as Euler angles. Since we do not make any coordinate or input transformations, there are no transformation type singularities. Moreover, it is shown by means of theoretical analysis and simulation that singularities occurring during control are avoidable.

09:10
Global Stabilization of a Flat Underactuated System: The Inertia Wheel Pendulum
Olfati-Saber, Reza California Inst. of Tech.

Abstract: Inertial Wheel Pendulum (IWP) is a planar pendulum with a revolving wheel (that has a uniform mass distribution) at the end. The pendulum is unactuated and the wheel is actuated. Our main result is to address global asymptotic stabilization of the inertia wheel pendulum around its up-right position. Simulation results are provided for parameters taken from a real-life model of the IWP.

09:30
Nonlinear Coupling Control Laws for a 3-DOF Overhead Crane System
Dawson, Darren M. Clemson Univ.

Abstract: In this paper, we consider the regulation control problem for a three-degree-of-freedom (3-DOF), underactuated overhead crane system. Motivated by recent passivity-based controllers for underactuated systems, we design several controllers that asymptotically regulate the planar gantry position and the payload angle. Specifically, utilizing LaSalle's Invariant Set Theorem, we first illustrate how a simple proportional-derivative (PD) controller can be utilized to asymptotically regulate the overhead crane system. Motivated by the desire to achieve improved transient performance, we then design two nonlinear controllers that increase the coupling between the planar gantry position and the payload angle.

09:50
Friction Compensation in the Furuta Pendulum for Stabilizing Rotational Modes
Fang, Yongchun Clemson Univ.

Abstract: This paper is devoted to the problem of friction compensation in the underactuated Furuta pendulum. It is of interest to construct and stabilize the non-trivial periodic motions of the system. It is assumed that the friction phenomenon has a dynamical nature, which is covered by the LuGre friction model. Based on this assumption, it is shown how to construct an interesting class of periodic solutions for the Furuta pendulum via feedback. Finally, it is shown how to achieve an analytical solution to the asymptotic orbital stabilization problem in the presence of friction.

10:10
Nonlinear Control and Reduction of Underactuated Systems with Symmetry III: Input Coupling Case
Olfati-Saber, Reza California Inst. of Tech.

Abstract: In this paper, we address nonlinear control and reduction of high-order underactuated mechanical systems with kinetic symmetry and input coupling. In some aerospace vehicles, the effects of the control of the attitude dynamics appears in the translational dynamics. We present a general framework for decoupling of these effects. The decoupling is done by applying a change of coordinates in explicit form that transforms the original system into a cascade nonlinear system. We obtain three types of cascade normal forms, namely, nonlinear systems in strict feedback form, strict feedforward form, and nontriangular quadratic form. For a class of underactuated systems that are differentially flat, we obtain the flat outputs automatically as a by-product of the decoupling change of coordinates.

159
Abstract: We study the global asymptotic stabilization by output feedback for systems whose dynamics are in a feedback form where the nonlinear terms admit an incremental rate depending only on the measured output. The output feedback we consider is of the observer-controller type where the design of the controller follows from standard robust backstepping. The novelty is in the observer which is high-gain like with a gain coming from a Riccati equation. This works generalizes a contribution of Praly and Kanellopoulos presented at the 39th IEEE CDC (200) where the dynamics were supposed to be linear in the unmeasured state components.

10:10
Stabilization of Cascades using Integral Input-to-State Stability (I) ................................................. 3814
Arcak, Murat Rensselaer Polytechnic Inst.
Angeli, David Univ. of Florence
Sontag, Eduardo D. Rutgers Univ.

Abstract: We analyze nonlinear cascades in which the driven subsystem is integral ISS, and characterize the admissible integral ISS gains for stability. This characterization makes use of the convergence speed of the driving subsystem, and allows a larger class of gain functions when the convergence is faster. We show that our integral ISS gain characterization unifies different approaches in the literature which restrict the nonlinear growth of the driven subsystem and the convergence speed of the driving subsystem.

FrA03
Constrained Nonlinear Systems I
Chair: Sepulchre, Rodolphe  Univ. de Liège
Co-Chair: Suarez, Rodolfo  Univ. Auton. Metro.-Iztapalapa

08:30
Bounded Robust Control of Constrained Multivariable Systems ................................................. 3820
El-Farra, Nael H. Univ. of California, Los Angeles
Christofides, Panagiotis D. Univ. of California, Los Angeles

Abstract: This work focuses on output feedback control of a class of multi-input multi-output nonlinear systems with time-varying uncertain variables and input constraints. A robust dynamic output feedback controller is constructed through combination of a stabilizing bounded robust multivariable state feedback controller with high-gain observers and saturation filters. The state feedback component is designed through Lyapunov-based inverse optimal control techniques and provides an explicit characterization of the state feedback stability region. Using singular perturbation techniques, the output feedback controller is shown to enforce asymptotic stability and robust asymptotic reference-input tracking, with an arbitrary degree of attenuation of the effect of uncertainty on the outputs of the constrained closed-loop system, for initial conditions in arbitrarily large compact subsets of the state feedback stability region, provided that the observer gains are sufficiently large. The proposed output feedback controller design is demonstrated for the robust stabilization of a chemical reactor example.

08:50
Global Analysis of a Continuous-Time Flow which Computes Time-Optimal Switchings ..................... 3826
Grognard, Frederic Univ. Catholique de Louvain
Sepulchre, Rodolphe Univ. de Liège

Abstract: The minimum-time bounded control of linear systems is generically bang-bang and the number of switchings does not exceed the dimension of the system if the eigenvalues of the system matrix are real. This paper proposes a synthesis method for such problems based on dynamical systems that 'compute' the optimal sequence of switching times.

09:10
Suboptimal Control of Constrained Nonlinear Systems via Receding Horizon State Dependent Riccati Equations (I) .... 3832
Szaiber, Mario Penn State Univ.
Suarez, Rodolfo Univ. Auto. Metro., Iztapalapa

Abstract: Feedback stabilization of systems subject to constraints has been a long-standing problem in control theory. In contrast with the case of LTI plants where several techniques for optimizing performance have recently appeared, very few results are available for the case of nonlinear systems. In this paper we propose a new controller design method, based on the combination of Receding Horizon and Control Lyapunov Functions, for nonlinear systems subject to input constraints. The main result of the paper shows that this control law renders the origin an asymptotically stable equilibrium point in the entire region where stabilization with constrained controls is feasible, while, at the same time, achieving near-optimal performance.

09:30
Compact Convex Control Value Sets ................................................. 3838
Suarez, Rodolfo  Univ. Autó. Metro., Iztapalapa
Solís-Daun, Julio  Univ. Autó. Metro., Iztapalapa
Aguirre, Baltazar  Univ. Autó. Metro., Iztapalapa

Abstract: In this paper, we address the global stabilization problem for affine systems by means of feedback controls taking values in compact convex control value sets U. Working along the line of Artstein-Sontag’s control Lyapunov function (clf) approach, we obtain a one-parameterized family of continuous bounded feedback controllers that globally asymptotically stabilize a system, provided a clf is known. We obtain first the global stabilization result for smooth compact and strictly convex control value sets; then, we present a procedure for approximating polytopes that allows us to extend the results to convex control value sets. The designed family of controllers is suboptimal with respect to the clf and set U.

09:50
Suboptimality Analysis of Constrained Nonlinear Model Predictive Control ................................................. 3844
Li, Yadong  Shanghai Jiaotong Univ.
Xi, Yugen  Shanghai Jiaotong Univ.
Li, Shaoqyuan  Shanghai Jiaotong Univ.

10:10
Predictive Control of Uncertain Nonlinear Systems via Polynomial Lyapunov Functions ......................... 3844
Coutinho, Daniel Unive. of Newcastle
Trofino, Alexandre UFSC
Fu, Minyue  Unive. of Newcastle

Abstract: In this paper, we consider the problem of guaranteed cost control for a class of uncertain nonlinear systems. We derive LMI conditions for the regional robust stability and performance problem based on Lyapunov functions which are polynomial functions of the state and uncertain parameters. Based on the stability results, we discuss the synthesis problem for a class of affine control systems. Numerical examples are presented to illustrate our method.
Abstract: Active control of surface figure is a key technology for the future lightweight large space reflectors. Less than a few hundred actuators adjusting the surface shape could be still controlled by using a centralized computing element. If, however, there are thousands of actuators distributed in the surface, the actuator, control, and computing hardware should be distributed as well. This paper discusses how an efficient control of a gossamer structure shape can be achieved using large distributed actuator arrays. The controller is designed taking into account slow actuator dynamics and spatial response shape. Flexible dynamics are considered as an uncertainty. The closed-loop robustness is verified using multiresolution analysis. Integrating thousands of actuators in a structure in a practically affordable way requires mass producible lightweight actuators. Such plastic MEMS actuators are described in the paper.

09:10
Stable Robust Control of Flexible Structure Systems .......... 3872
Ge, Shuzhi S. Natl. Univ. of Singapore
Hong, Fan Natl. Univ. of Singapore
Lee, Tong H. Natl. Univ. of Singapore

Abstract: In this paper, stable robust control is investigated for a class of flexible structure systems. The systems are characterized by coupled ordinary and partial differential equations with non-homogeneous boundary conditions. By selecting certain sliding surface, the convergence of system's motion on the surface as time tends to infinity provides additional homogeneous boundary conditions, which subsequently makes the boundary value problem solvable using the traditional variable separation method. Adaptive control and variable structure control techniques are used to solve the problem. It is shown that the overall systems stability can be achieved and the solution to the boundary value problem is trivial which implies that the system will finally settle at the equilibrium.

09:30
Observer Design using Low-Pass Filtered Outputs .......... 3878
Busawon, Krishna K. Univ. of Northumbria
Danaher, S. Univ. of Northumbria
Kabore, Pousga ABB Corporate Research

Abstract: In this paper, we propose an observer design using filtered measurements for single-output linear observable systems. The measurements are filtered using a low-pass filter with a specified cutoff frequency. Consequently, the observer is called Low-Pass Filtered Observer (LPFO) observer.

09:50
The Problem of State Estimation via Asynchronous Communication Channels with Irregular Transmission Times ......................... 3880
Matveev, Alexey S. St. Petersburg Univ.
Savkin, Andrey V. Univ. of New South Wales

Abstract: We study a linear discrete-time partially observed system perturbed by white noises. The observations are transmitted to the controller via communication channels with irregular transmission times. Various measurement signals and even parts of a given sensor output may incur independent delays; messages transferred via the channels may be lost or corrupted. The minimum variance state estimation problem is solved. It is shown that the proposed state estimator is exponentially stable under natural assumptions.
Abstract: For the purpose of recursive joint estimation of state and parameters in continuous-time state space systems, the algorithm proposed in this paper improves the consistency of a recently developed adaptive observer for multi-input-multi-output (MIMO) linear time varying (LTV) systems. The new algorithm makes use of a time varying gain matrix for parameter estimation, instead of the constant gain matrix used by the previously reported algorithm. It is exponentially stable, converges in the mean for both state and parameter estimations. The covariance matrix of the parameter estimation error can be made arbitrarily small by choosing a sufficiently small forgetting factor.

9:30
Advanced Gain Scheduling Techniques for the Design of Parameter-Dependent Observers .......................... 3892
Bara, G. Iulia  CRAN-INPL
Daafouz, Jamal CRAN-INPL
Kratz, Frédéric  LVR UPRES EA

Abstract: In this paper, we present a systematic framework for the design of affine gain scheduled observers for affine LPV systems. The stability of the estimation error is based on the existence of an affine parameter-dependent Lyapunov function. The main contribution of this paper is the fact that the observer synthesis is formulated as a more easily tractable condition. This is achieved by the application of the multiconvexity concept and the introduction of a slack variable which eliminates the coupling between the observer matrices and the parameter-dependent Lyapunov function.

9:50
A Block Algorithm for the Sylvester-Observer Equation Arising in State-Estimation .................................. 3898
Carvalho, João B Northern Illinois Univ.
Datta, Biswa Nath Northern Illinois Univ.

Abstract: We propose a new algorithm for solving the Sylvester-observer equation $XA - FX = GC$ arising in the construction of the Luenberger observer. The algorithm is a block-generalization of Van Dooren’s scalar algorithm, therefore is based in the reduction to the observer-Hessenberg form. It is more efficient than Van Dooren’s and the recent block algorithm by Datta and Sarkissian. Furthermore, the algorithm, which is composed of BLAS-3 operations like matrix-matrix multiplications, QR factorizations and solution of triangular systems with multiple right hand sides, is well-suited for implementation on today’s powerful high performance computers using the high-quality software package LAPACK.

10:10
Distributed Interacting Multipattern Data Association Tracking Algorithm ............................................. 3904
Hong, Läng Wright State Univ.

Abstract: A distributed interacting multipattern data association tracking algorithm is developed in this paper. Multipattern data association is based on a novel approach for tracking multiple targets using multiple patterns extracted from measurement sequences. To save the communication bandwidth, the distributed interacting multipattern data association tracking algorithm is based on exchanges of combined target tracks, which creates a unique difficulty in developing an optimal fusion algorithm. The difficulty is overcome by developing an equivalent platform model which then propagates the fused tracks needed for the distributed fusion algorithm.
complement matrix of data product moments shows that the estimate of the extended observability matrix can be obtained by using the SES procedure. Viewing that fact that the Schur complement yielded by the subspace extraction coincides with the error covariance in the least squares (LS), our interpretation will pave the way for the derivation of the recursive algorithm of the 4SID method.

09:50
Confidence Regions and Experiment Design for Non-Parametric Estimation ............................................. 3930
Heath, Will P. Univ. of Newcastle

Abstract: When estimating the response of a linear system at a specific frequency under ideal conditions the presence in the excitation signal of other frequencies has no effect on the bias and variance of the estimate. Nevertheless such additional excitation may have a detrimental effect on the ability to choose confidence regions. This is discussed for the case of finite data experiments with both white and coloured noise. The choice of confidence regions for plants in closed-loop is also considered. In particular the legitimate use of a priori and a posteriori information is discussed.

10:10
Principal Component Analysis for Errors-in-Variables Subspace Identification ............................................. 3936
Wang, Jin Univ. of Texas, Austin
Qin, S. Joe Univ. of Texas, Austin

Abstract: This paper develops a new subspace identification algorithm using principal component analysis (PCA) that gives consistent model estimates under the errors-in-variables (EIV) situation. PCA naturally falls into the category of EIV formulation, which resembles total least squares and allows for errors in both process input and output. We propose to use PCA to determine the A, B, C, and D matrices and the system order for an EIV formulation. Standard PCA is modified with instrumental variables in order to achieve consistent estimates of the system matrices. The proposed subspace identification method is demonstrated using one simulated process and a real industrial process for model identification and order determination.

10:30
New Parallel Distributed Compensation using Time Derivative of Membership Functions: A Fuzzy Lyapunov Approach ........ 3942
Tanaka, Kazuo The Univ. of Electro-Comm.
Hori, Tsuyoshi The Univ. of Electro-Comm.
Wang, Hua O. Duke Univ.

Abstract: This paper presents a new type of parallel distributed compensation via a fuzzy Lyapunov function approach. The new PDC controller feedbacks the time derivative of premise membership functions. We show that the new PDC proposed here fully takes the advantage of fuzzy Lyapunov function. An example illustrates the utility of the new PDC stabilization.

08:30
Fuzzy Modeling and Control
Chair: Wang, Hua O. Duke Univ.
Co-Chair: Farinwata, Shehu S. Ford Research Lab.

09:00
In-Variables Subspace Identification ............................................. 3940
Wang, Jin Univ. of Texas, Austin
Qin, S. Joe Univ. of Texas, Austin

Abstract: This paper presents a new type of parallel distributed compensation via a fuzzy Lyapunov function approach. The new PDC controller feedbacks the time derivative of premise membership functions. We show that the new PDC proposed here fully takes the advantage of fuzzy Lyapunov function. An example illustrates the utility of the new PDC stabilization.

10:00
Nonlinear Hybrid Adaptive Fuzzy Identification and Control ... 3948
Gazor, Saeed Queen's Univ.
Hojati, Mehrdad Isfahan Univ. of Tech.

Abstract: A combined direct and indirect adaptive control scheme for adjusting an adaptive fuzzy controller parameters is presented in this paper. First, using adaptive fuzzy building blocks, with a common set of parameters, we design an adaptive controller and an adaptive identification model for a general class of the uncertain structure nonlinear dynamic systems. We then propose a hybrid adaptive (HA) law for adjusting the parameters, which utilizes a combination of the tracking error and the modeling error. Performance analysis using a Lyapunov synthesis approach proves the superiority (fast tracking error convergence, fast and improved parameter convergence) of the HA law. Furthermore, these advantages are achieved at a negligible increasing in the implementation cost and the computational complexity, over the conventional method [the direct adaptive (DA) law]. We also prove a theorem that shows the properties of this hybrid adaptive fuzzy control system.
of the isolated link and the interconnection subsystems that represent the dynamics of each isolated link in relation to the other links in the system. This model is then used to design a Lyapunov-based fuzzy logic controller for the system by solving Linear Matrix Equalities. It is shown that this controller is closed loop stable and a controller for the system may be designed using bounds.

Abstract: In this paper, Banach space duality theory and operator theory are combined to show that the optimal performance index in a behavioral framework, particularly, we focus the case in which each disturbance is scalar. First, we introduce a modified image representation in order to denote exogenous disturbances. Next, we consider an interconnection between a plant described by such an image representations and a control law. We provide an explicit necessary and sufficient condition for this interconnection to be H2 optimal and to satisfy H-infinity norm condition. This condition is used to obtain parameterizations and concrete algorithms of mixed H2/H-infinity control laws for behavioral systems. At last, we give an illustrative example to show the validity of our result.

08:50
Multi Criteria Controller Design for Uncertain MIMO Systems using Global Non-Convex Optimization
Fransson, Carl M.
Lennartson, Bengt
Wik, Torsten
Holmström, Kenneth
Chalmers Univ. of Tech.
Chalmers Univ. of Tech.
Chalmers Univ. of Tech.
Mälardalen Univ.

Abstract: A controller design procedure for MIMO systems with explicit plant uncertainties is suggested. In the proposed method, the closed loop analysis is integrated in the controller synthesis by an outer optimization loop that optimizes the low frequency performance of the closed loop system subject to additional performance and robustness criteria constrained by specifications. Modifications of the specifications then clearly shows the trade off between performance and robustness in different frequency regions. The controller synthesis is based on PID weighted H-inf loop shaping where the structured singular value (mu) is used in the optimization to guarantee that the performance specifications are met in spite of the uncertainties. The optimization problems are costly, non-convex and ill-conditioned and we use a combination of new global and standard local optimization algorithms available in the TOMLAB optimization environment to solve the problem. The method, which does not rely on a good initial guess and converges robustly in finite time, is applied to a 2x2 model of a distillation column and the example shows how a slight modification of specifications on the sensitivity function and control activity may give large improvements in the load disturbance rejection.

Finally, under a certain continuity assumption, it is shown that there exist maximal vectors, which leads to an exact solution to the multiobjective H2/H-infinity problem.

09:30
On Optimal Reconstruction of Discrete Data Transmissions
Voulgaris, Petros G.
Univ. of Illinois, Urbana Champaign

Abstract: In this paper we present a deterministic worst-case framework for accurate reconstruction of discrete (source) data as an alternative to the traditional probabilistic approaches in the communications area. This framework can be explored based on robust control ideas and formulations. Some of the particular problems touched upon are: (i) necessary and sufficient conditions for causal (no delay) and noncausal (with delay) reconstruction under deterministic magnitude bounded noise for SISO and MIMO channels, (ii) reconstruction based on linear estimation, (iii) performance optimization under channel fading and (iv) combined precoding and estimation optimization under power constraints. The L_1 control theory is proposed as a natural key player in this approach.

10:10
Synthesis and Characterization of Pareto-Optimal Solutions for the Mixed H2/H-infinity Control Problem
Takahashi, Ricardo H. C.
Univ. Fed. de Minas Gerais
Palhares, Reinaldo M.
Pontifical Catholic Univ. of Minas Gerais
Dutra, Daniel A.
Univ. Fed. de Minas Gerais
Gonçalves, Leila P. S.
Pontifical Catholic Univ. of Minas Gerais

Abstract: The mixed H2/H-infinity control problem, nevertheless a continued research on it, does not have, up to now, an exact solution. This paper develops a methodology for multiobjective problem solution characterization, employing group properties of the Pareto set. A multiobjective genetic algorithm is built on the basis of these properties. The solutions that are found for the H2/H-infinity control problem are both consistent and less conservative, when compared to other algorithms.
ties are in general mutually independent. The very goal, “raison d’être” of control by its definition is to ensure requested output tracking to a controlled plant. It is explained why a stability property need not be either necessary or sufficient for output tracking, and vice versa, in general. Control should ensure demanded qualitative system performances in two different spaces, the dimensions of which are generally also different. This implies duality of the control task. It is shown in the paper how the stability problem can be embedded into the output-tracking problem. By solving the tracking control synthesis problem, we solve simultaneously the stabilizing control synthesis problem. A Lyapunov-like output tracking concept is explained. It is shown under which conditions it reduces to the Lyapunov stability concept or to the Lyapunov-like state-tracking concept. The paper presents recently introduced new control issues: (natural) trackability and natural tracking control of nonlinear plants. It exposes the necessary and sufficient conditions for natural output trackability and for natural tracking control ensuring both output tracking and stability.

08:50
Theoretical Aspects in Practical Tracking.
Application to a Robot Control (I) .......................................... 4009
Kökös, Annemarie Inst. Supérieur d’Électronique du Nord

Abstract: The first part of this paper presents a new definition of the practical tracking with vector settling time and vector reachability time for a mechanical system. The sufficient conditions are established in order to guarantee that a mechanical system controlled by a control algorithm exhibits the requested practical tracking. The control problem is tackled in the second part of the paper. Among the different mechanical systems, an industrial robot is chosen in order to synthesise the output tracking control. The mathematical model of the robot includes the friction forces and the external perturbations. The proposed controller does not use information about them. It ensures the requested practical tracking quality. The simulations are realised for a rotational three-degree-of-freedom robot. They verify that the control algorithm implementation guarantees the theoretical results.

09:10
Robust Optimal Tracking and Regulation for Linear Systems: The H2/H-Infinity Approach (I) .............................. 4015
da Silveira, Marcos Azevedo PUC-Rio

Abstract: This paper presents existence, unicity, regularity and approximation results for robust tracking and regulation problems for finite and infinite dimensional linear systems modeled by H2/H-infinity mixed problems. These results were obtained by the use of weighted Hardy spaces.

09:30
Adaptive Fast Terminal Sliding Mode Tracking
Control of Robotic Manipulator (I) ........................................... 4021
Feng, Yong Central Queensland Univ.
Yu, Xinghuo Central Queensland Univ.
Man, Zhihong Nanyang Tech. Univ.

Abstract: This paper proposes an adaptive fast terminal sliding mode tracking control for robotic manipulators. The upper bounds of system uncertainties are estimated through an adaptive mechanism and used for the design of the controller. In order to eliminate the chattering, a method of softening control is adopted. Meanwhile, the tracking precision problem of the fast terminal sliding mode control of the manipulator is explored. The mathematical relationship between the tracking precision of the system and the width of the saturation function used for elimination of chattering is formulated. Through the specification of the tracking precision, appropriate saturation functions can be designed. Simulation results are presented to validate the analysis.

09:50
Tracking Control of a Nonlinear System with Input-Dependent Delay (I) ................................................. 4027
Dieulot, Jean-Yves LAIL
Richard, Jean-Pierre LAIL

Abstract: A class of nonlinear systems with input dependent parameters and time delays has been considered, for which the output is oscillatory. As for d-flat systems, the open-loop motion planning problem can be solved using an explicit parametrization of trajectories; however, it is shown that the structure of the system brings out some constraints on the input and therefore limits the possible choice of trajectories. An example is provided, in which the trajectory is piecewise polynomial, where the open loop control and the corresponding constraints are explicitly given.

10:10
Trajectory Learning and Output Feedback
Control of Nonlinear Discrete-Time Systems ......................... 4032
Sadegh, Nader Georgia Inst. of Tech.

Abstract: Output tracking control of a general class of nonlinear discrete-time systems is considered. A block input-output realization of the plant is first introduced that transforms the system into one with equal number of inputs and states. This realization is subsequently used to formulate a novel output feedback controller for regulation or tracking. The proposed controller only requires measurement of the system’s outputs, and is applicable to both minimum and nonminimum phase plants of arbitrary relative degree. For applications involving a finite-duration or periodic desired outputs, a new recursive algorithm based on the Newton-Raphson method is proposed to learn the feedforward input. A simulation example of a nonlinear nonminimum phase system is presented to further illustrate and evaluate the performance of the proposed control scheme.
optimization algorithm SOAR to random search for a moderately hard combinatorial-optimization problem.

09:10

Experimental Design Theoretic Genetic Algorithm for Input-Output Block Assignment Problem .......................... 4049
Yeung, L. F.  City Univ. of Hong Kong
Chan, Kit Y.  City Univ. of Hong Kong
Wu, Angus  City Univ. of Hong Kong

Abstract: In this paper, a procedure for system decomposition is developed for decentralized control systems. Optimal input-output pairing techniques are used to rearrange a large system into a structure that is closer to the block-diagonal decentralized form. The problem is transformed into a block-assignment problem. A new and efficient genetic algorithm based on experimental design theoretic is developed to solve this hard IP problem.

09:30

Speed and Accuracy Comparison of Techniques to Solve a Binary Quadratic Programming Problem with Applications to Synchronous CDMA ..................................... 4051
Hasegawa, Fumihiro  Univ. of Connecticut
Luo, Jie  Univ. of Connecticut
Pattipati, Krishna  Univ. of Connecticut
Willett, Peter  Univ. of Connecticut

Abstract: We compare methods for solving the NP-hard binary quadratic programming (BQP) problem. Various methods are discussed, including box-constrained quadratic programming, branch and bound, coordinate descent, group decision making and semi-definite relaxation. An algorithm from target-tracking, the Probabilistic Data Association Filter (PDAF), is modified to the BQP application. Simulation results show that this and several other methods can significantly outperform the decision feedback detector (DFD) or its group counterpart, GDFD.

09:50

Computation of Matrix nth Roots and the Matrix Sector Function .................................................. 4057
Hasan, Mohammed A.  Univ. of Minnesota, Duluth
Hasan, Ali A.  College of Elec. Eng./Bani Walid
Ejaz, Khaled B.  Univ. of Minnesota, Duluth

Abstract: Several linear and higher order methods to compute $\sqrt[n]{A}$ roots of a given real or complex matrix are presented in this paper. These include Newton-like, subspace, and Krylov type methods. As a special case, the matrix sector function and other roots of an identity matrix are computed and shown to be an efficient numerical tool for computing a block eigendecomposition of a given matrix.

10:10

Parallel Methods for Computing the Matrix Sign Function with Applications to the Algebraic Riccati Equation .......... 4063
Hasan, Mohammed A.  Univ. of Minnesota, Duluth
Hasan, Ali A.  College of Elec. Eng./Bani Walid
Ejaz, Khaled B.  Univ. of Minnesota, Duluth

Abstract: In this paper several methods of solving the algebraic Riccati equation (ARE) are presented. Functional iterations with acceleration techniques are introduced. Also variations of Newton method, the subspace iteration, and Krylov sequence are proposed for solving the ARE. The relation between the matrix sign function and the solution of the algebraic Riccati equation is stated, and several iterative schemes for the matrix sign function are described. Specifically, higher order rational functions for computing the matrix sign function of complex matrices has been developed, where parallel implementation of the matrix sign function is developed through partial fractions expansion. A QR inverse free method for computing the matrix sign function for symmetric matrices is derived. the matrix sign function is then used to solve the algebraic Riccati equation. The performance of these methods is demonstrated by several examples.

08:30

Adaptive Periodic Control for Chlorine Residual Maintenance in Drinking Water Distribution Networks ............ 4069
Wang, Zhong  Univ. of Cincinnati
Polycarpou, Marios M.  Univ. of Cincinnati
Uber, James G.  Univ. of Cincinnati
Shang, Feng  Univ. of Cincinnati

Abstract: Increasingly stringent requirements on the levels of chlorine residual and disinfectant by-products in drinking water distribution networks have created a need for feedback control approaches. The feedback water quality control problem is formulated in an adaptive control framework with special consideration on the periodic variation of parameter uncertainty due to varying consumer demands. The approach is based on approximating the input/output dynamic behavior of chlorine concentration as a periodic time-varying, discrete-time linear model with uncertain or unknown coefficients. The periodic parametric uncertainty is represented by a Fourier series with on-line parameter estimation of the unknown coefficients. Simulation examples are used to illustrate the performance of the algorithm in a real water distribution network.

08:50

Control Design and Experimental Results of Sensor based Direct Process Control for Bar Turning ............................. 4075
Fan, Chun  Florida State Univ.
Collins, Jr., Emmanuel G.  Florida State Univ.
Liu, Charlie  Florida State Univ.
Wang, Ben  Florida State Univ.

Abstract: This paper describes an in-process measurement and control system called radial error feedback geometric adaptive control (REFGAC) system for bar turning in CNC turning centers. REFGAC system was design to compensate for the radial error caused by deflection under cutting force. To compensate for the radial error, Kalman filters for prediction together with PID control laws were designed, based on models of the deflection of the bar. Experimental results showed that the dimensional and geometric accuracy of the workpiece is substantially improved by this radial error feedback geometric adaptive control technique.

09:10

Sensitivity Analysis and Stochastic Optimization for Open-Loop Batch Operating Policy Determination .................. 4081
Muske, Kenneth R.  Villanova Univ.
Badiani, Manish  Villanova Univ.

Abstract: The determination of the optimal open-loop operating policy for batch reaction systems under uncertainty is considered. Adjustment of the nominal optimal open-loop operating policy based on worst-case and chance-constrained stochastic optimization approaches are discussed and demonstrated using a commercial pharmaceutical synthesis reaction system. These optimization approaches are compared to a first-order correction based on sensitivity analysis. The results from this study indicate that accounting for parametric uncertainty based on sensitivity analysis provides a poor approximation to stochastic programming.

09:30

PID Tuning for Integrating Processes with Sensitivity Specification .................................................. 4087
Wang, Ya-Gang  Nanyang Tech. Univ.
Cai, Wen-Jian  Nanyang Tech. Univ.

Abstract: PID control is widely used to control stable processes, however, its application to integrating processes is less common. In the paper, simple formulas are derived to tune the PID controller for integrating processes with time delay to meet sensitivity specifi-
culation. With the proposed PID tuning method, we can obtain a loop transfer function with desired sensitivity specification, which guarantees both robustness and performance. Simulation examples are given to show the superior performance of the proposed tuning method to other methods.

09:50
Panel Discussion

10:10
Nonlinear Control of Continuous Fermentation
Processes in Conditions of Uncertainties ........................................... * Tzeneva, Raynitchka Peninsula Technion

FrA12
Discrete-Event Systems
Chair: Rudie, Karen Queen’s Univ.
Co-Chair: Lin, Feng Wayne State Univ.

08:30
An Optimal Effective Controller for Discrete Event Systems ... 4092
Chen, Yi-Liang Rockwell Scientific Co.
Lin, Feng Wayne State Univ.

Abstract: An approach to the online synthesis of an optimal effective controller for discrete event systems is presented. The optimal effective controller can achieve the prescribed (cumulative) effectiveness measure while minimizing the total cost incurred for the execution of events. This approach is constructed over a generalized control framework for automata-based discrete event systems, which allows event enforcement in addition to the (original) event disablement/enablement as the control mechanism. The optimal effective control policy generated by this approach is proved to be the least restrictive among all the possible optimal effective control policies for the given online expansion tree of the system behavior.

08:50
Strong Co-Observability Conditions for Decentralized
Supervisory Control of Discrete Event Systems ...................... 4098
Takai, Shigemasa Wakayama Univ.
Ushio, Toshimitsu Osaka Univ.

Abstract: We study nonblocking decentralized supervisory control of discrete event systems. A notion of normality which is a weaker version of strong decomposability has been defined in our previous work. However, a nonblocking decentralized supervisor which achieves the supremal Lm(G)-closed, controllable, and normal sublanguage may still be unnecessarily restrictive. The main purpose of this paper is to synthesize a more permissive nonblocking decentralized supervisor. We introduce stronger versions of C&P co-observability and D&A co-observability, called strong C&P co-observability and strong D&A co-observability, respectively. Strong C&P co-observability and strong D&A co-observability are weaker than normality. Moreover, strong D&A co-observability is preserved under union. So a nonblocking decentralized supervisor always exists under the AND rule for the supremal Lm(G)-closed, controllable, and strongly D&A co-observable sublanguage. We present a procedure for computing this supremal sublanguage.

09:10
Undecidable Problems of Decentralized
Observation and Control ............................................................ 4104
Tripakis, Stavros VERIMAG

Abstract: We introduce a new notion of decentralized observability for discrete-event systems, which we call joint observability. We prove that checking joint observability of a regular language w.r.t. one observer is decidable, whereas for two (or more) observers the problem becomes undecidable. Based on this result, we show that a related decentralized control problem is also undecidable. We finally provide an extensive study relating our work to existing work in the literature.
Abstract: In a wide variety of settings, the measurement of nuclear magnetic resonance (NMR) effects has proven to be a remarkably effective for investigating unknown structures on both large and small scales. Over the years a large body of technique has been developed for improving the sensitivity and resolution of NMR measurements and many recent advances in biochemistry and medicine are dependent on the sophisticated signal processing techniques now used routinely. From a system theoretic perspective, problems in this area can be thought of as identification problems involving bilinear systems. They are distinguished from linear system identification problems by the fact that the quality of the identification is strongly dependent upon the form of the excitatory input applied to the system. Many ingenious techniques, such as the "two dimensional" Fourier transform procedure have been developed based on particular types of input patterns. Because of the low signal to noise ratios inherent in NMR, the optimization of such methods requires the use of stochastic models for the dynamics and measurement processes. In this paper we take a fresh look at problems in this area with the view of finding computational procedures that will determine the inputs which will optimize specific performance measures. In particular, we explore performance measures related to conditional entropy, and in this way develop a formalism for establishing the mathematical limits on what can be accomplished with better input design.

Abstract: This paper presents a new tool to analyze the effect of error recovery systems on closed-loop flight control systems. In particular, this paper develops closed-loop models and analyzes the mean-square stability effect of error recovery rollback, reset, and cold restart systems in digital control systems. The error recovery mechanisms are triggered by transient or intermittent faults which could be caused, for example, by high intensity electromagnetic radiation. The tool is illustrated by analyzing a stabilizing controller for the longitudinal dynamics of the AFTI/F-16 aircraft. This example compares different recovery methodologies by determining the minimum interarrival spacing between upsets which maintains closed-loop mean-square stability.

Abstract: In this paper, the problem of optimally controlling production in a single part unreliable, manufacturing flow line, subjected to a constant rate of demand for parts, while minimizing a given combined measure of storage and production backlog costs, is considered. For Markovian, two-state machines, an analytic solution of the associated Hamilton-Jacobi-Bellman equation is beyond reach. Instead, the focus here is on a suboptimal class of decentralized hedging policies parameterized by a set of lemp/ihcritical inventory levels), one for each machine in the transfer line. Thus, each machine strives to achieve as quickly as possible a given critical level of processed parts in the associated storage bin, which, once reached, will attempt to maintain by producing exactly at the current rate of demand for parts until failure or starvation occurs. Once starvation ceases or the machine is repaired, it will resume the same production strategy. Our objective is to optimize the choice of the processed parts critical levels. For doing so, we first recall a decomposition technique based on two decoupling approximations, respectively the machine decoupling approximation and the demand averaging principle. The decomposition technique yields particularly simple models in so-called partially homogeneous flow lines, i.e. lines such that mean repair rates for machines, after failure, are all identical. Under the partially homogeneous assumption, an efficient dynamic programming solution to the optimization problem is developed. Existence of an optimum distribution of critical levels is established for the finite transfer line case. In addition, for a discretized finite state version of the homogeneous infinite transfer line problem, existence of an optimal feedback policy which is stationary is established. Finally, under specific structural assumptions, qualitative properties of optimal critical levels profile for the homogeneous continuous states, but finite, transfer line are derived. From these properties, homogeneous infinite (continuous state) transfer line behavior is inferred. Results of numerical experiments are reported.

Abstract: A single origin and single destination traffic network with multiple routes and sections is considered. The state variables are assumed to be traffic densities in these sections. For dynamic routing of traffic, accurate measurement of these variables is needed. This requires the placement of numerous sensors, one at each section, which is a costly solution. In this work, a simpler solution is presented based on a single sensor placed at the destination node and the use of an extended Kalman filter for estimation of traffic densities in individual route sections. Two sets of simulations are provided for illustration.

Abstract: We first present a suitable object knowledge representation based on a mixture of stochastic and set membership models and considering an approximation resulting in ellipsoidal calculus by means of a normal assumption for stochastic laws and ellipsoidal outer or inner bounding for uniform laws. Then we build an efficient estimation process integrating visual data online and perform online and optimal exploratory motions for the camera. The control schemes are based on the maximization of the a posteriori predicted information.
Abstract: This paper studies the problem of controlling a planar rigid body containing a sliding block, which represents an underactuated mechanical system with two unactuated degrees of freedom and the unactuated degrees of freedom and the unactuated degrees of freedom. The main result of the paper is the construction of a point-to-point discontinuous feedback controller for the system by utilizing nonlinear feedback linearization. The flight phase and taking off at the end of stance phase, are achieved via sequential stages: stance phase, flight phase and touchdown. During the stance phase, the two objectives of control, constant locomotive speed and taking off at the end of stance phase, are achieved via control based on nonlinear feedback linearization. The flight phase needs no active control. Combining dynamics of the three stages, we construct the Poincare map numerically for a flipping step, and then use a neural network to stabilize the fixed point on the Poincare map corresponding to an unstable cyclic flipping gait.

Abstract: This paper addresses the problem of regulating the dynamic model of a nonholonomic underactuated autonomous underwater vehicle (AUV) to a point with a desired orientation. A time-invariant discontinuous controller is proposed that yields convergence of the trajectories of the closed-loop system in the presence of parametric modeling uncertainty. Controller design relies on a non-smooth coordinate transformation in the original state space followed by the derivation of a Lyapunov-based, adaptive, smooth control law in the new coordinates. Convergence of the regulation system is analyzed and simulation results are presented.

Abstract: In this paper, we address nonlinear control and reduction of a class of high-order underactuated mechanical systems with kinetic symmetry called Class-I systems. Class-I systems are underactuated systems with actuated shape variables, decoupled inputs, and integrable normalized momentums (all to be defined). We show that all Class-I underactuated systems can be transformed into cascade systems in strict feedback form with a zero-dynamics that is a Lagrangian system itself.

Abstract: This paper deals with the design of robust integral control for single-input single-output (SISO) nonlinear systems with well defined normal form and exponentially stable zero dynamics. We develop further the universal controller design that was initiated in the work of Khalil [2000 IEEE Trans AC]. The modification to the controller of [2000 IEEE Trans AC] is done in two steps. First, the integrator equation is modified to include not only the tracking error, but a linear combination of the tracking error and its derivatives, up to a certain order. Next, an additional input, in the spirit of classical anti-reset windup is added to the integrator to prevent it from winding up. Analytical results are given for both regional as well as semi-global regulation. The performance of the proposed controller is illustrated through simulations.

Abstract: This paper studies adaptive control of nonlinearly parameterized systems with uncontrollable linearization. Using a novel pa-
rameter separation technique and the tool of adding a power integra-
tor, we develop a feedback domination design approach for the ex-
licit construction of a smooth adaptive controller which solves the
longstanding open problem of global adaptive regulation. A signifi-
cant feature of our adaptive regulator is its minimal-order property,
namely, no matter how big the number of unknown parameters is,
the order of the dynamic compensator is identical to one, and is
therefore minimal. As an important consequence, global state regula-
tion of feedback linearizable systems with nonlinear parameterization
is solved by one-dimensional adaptive controllers, without imposing
any convex or concave condition on the parameters.

14:20
Adaptive Control of Multivariable Systems
with Reduced Prior Knowledge (I) ......................... 4198
Ortega, Romeo
Hsu, Liu
Astolfi, Alessandro

Abstract: We show in this paper that it is possible to globally adap-
tively stabilize linear multivariable systems with reduced prior
knowledge of the high frequency gain. In particular we relax the
restrictive (non–generic) symmetry condition usually required to
solve this problem. Instrumental for the establishment of our result
is the use of the new immersion and invariance approach to adap-
tive control recently proposed in the literature. The controllers ob-
tained with this technique are not certainly equivalent --though
smooth and without projections--and the resulting Lyapunov func-
tions contain cross-terms between the plant states and the pa-
rameter errors.

14:40
Optimality for Underwater Vehicles (I) ...................... 4204
Chyba, Monique
Leonard, Naomi Ehrich
Sontag, Eduardo D.

Abstract: In this paper, we study time-optimal trajectories for fully
actuated planar underwater vehicles, with constraints on input
forces. Using the Maximum Principle, we focus on the structure of
singular extremals and their possible optimality

15:00
Lyapunov Design for Global Tracking
of Underactuated Ships (I) ............................. 4210
Jiang, Zhong-Ping

Abstract: It is well-known that ship control is a hard problem. In this
paper, we consider the global tracking problem for a simplified ship
model with only two propellers. By application of Lyapunov's direct
method and exploitation of the inherent cascade-interconnected
structure of the ship dynamics, two constructive tracking designs
are presented. In contrast to the existing cascade approach of Le-
feber-Nijmeijer, our approach produces an explicit Lyapunov func-
tion which can be used for robustness analysis and robustification.
Unmeasured thruster dynamics is addressed for the first time.
Computer simulations demonstrate the efficiency of the proposed
tracking method.

15:20
Geometric First-Order Controllability Conditions
for Affine Connection Control Systems ..................... 4216
Hirschorn, Ron M.
Lewis, Andrew D.

Abstract: Strong conditions, involving first-order symmetric prod-
ucts, are given for controllability of affine connection control sys-
tems. The conditions generalise, at the first-order level, earlier
conditions for affine connection control systems, and involve the
use of a vector-valued quadratic form as the essential ingredient
in the statement of the results.

FrM03
Constrained Nonlinear Systems II
Chair: Kolmanovsky, Ilya V.
Co-Chair: Sepulchre, Rodolphe

14:40
A Generalized Reference Governor for Nonlinear Systems ... 4222
Gilbert, Elmer G.
Kolmanovsky, Ilya V.

Abstract: Reference governors are auxiliary systems that accept
and, when needed, modify input commands to enforce pointwise-
in-time state and control constraints. This paper proposes a new
approach to reference governor design for nonlinear systems with
unmeasured disturbance inputs. The approach relies on safety
properties provided by sublevel sets of equilibria-parametrized func-
tions. Unlike the prior literature, however, these functions need
not be Lyapunov functions and the corresponding sublevel sets
need not be positively invariant. Furthermore, the equilibria-
parametrized functions need not be smooth, only continuous.

14:00
LMI-Based Closed-Loop Economic Optimization of Stochastic
Process Operation under State and Input Constraints .......... 4228
van Hassem, Dennis H.
Scherer, Carsten W.
Bosgra, Okko

Abstract: In this paper we will solve a closed-loop steady-state
economic optimization problem for process operation by means of
convex optimization techniques. The objective is the simultaneous
optimization of controller parameters and steady-state operating
condition maximizing the economic profit of the plant. The main
point is, given the economic objective of the plant, to replace back-
off selection by back-off optimization together with optimal tuning
of controller parameters.

14:20
Direct Adaptive Pole Placement Control with Input
Magnitude and Rate Constraints – An Analysis
of its Input Matching Property .......................... 4234
Cheng, J.-W. John
Wang, Yi-Ming

Abstract: This paper analyzes a direct adaptive pole placement
control for linear stable minimum-phase systems with input magni-
tude and rate constraints. The key feature is the derivation of a
governing equation relating the prediction error to the “input discre-
pancy” between the adaptive control and corresponding non-
adaptive one, independent of how parameter estimates were ob-
tained. With the governing equation, one is able to establish the
input matching property of the adaptive constrained control, i.e.,
asymptotic convergence to zero of the “input discrepancy”.

14:40
Stability and Dissipativity Theory for Discrete-Time
Nonnegative and Compartmental Dynamical Systems ........ 4236
Haddad, Wassim M.
Chellaboina, VijaySekhar
August, Elias

Abstract: Nonnegative and compartmental dynamical systems are
derived from mass and energy balance considerations that involve
dynamic states whose values are nonnegative. These models are
widespread in engineering, biomedicine, and ecology. In this paper
we develop several results on stability and dissipativity of discrete-
time linear and nonlinear nonnegative dynamical systems. Specifi-
cally, using linear Lyapunov functions we develop necessary and
sufficient conditions for Lyapunov stability and asymptotic stability
for nonnegative systems. In addition, using linear storage functions
and linear supply rates we develop new notions of dissipativity the-
ory for nonnegative dynamical systems.
Abstract: Internal and external stabilization of linear systems subject to input saturation has been an active research area in recent years. Especially for internal stabilization and external stabilization where the external signals come to the system in an input-additive way, more or less complete results are available. This paper considers the same simultaneous stabilization problem but in a more general framework, namely, linear systems with both state and input subject to constraints on the magnitude. For such systems, semi-global and global internal stabilization problems have been formulated and solved recently. This paper is concerned with the problem of achieving simultaneous internal and external stabilization. Specifically, we deal with a model where the external signals are not input-additive. Necessary and sufficient conditions are identified under which the global and semi-global stabilization problems are solvable in both the internal and external sense.

Robust Control of Linear Systems in Presence of Input Saturation and Unmodelled Dynamics

Canale, Massimo
Milanese, Mario
Politecnico di Torino
Politecnico di Torino

Abstract: In this paper we give a necessary and sufficient condition for an Internal Model Control (IMC) structure to be robustly L2 stable with respect to H-infinity bounded model uncertainty and in presence of input saturation. This condition is used for the design of a controller that is the best H-infinity approximation to "perfect" linear control among all controllers guaranteeing L2 stability in the presence of actuator saturation.

Electrostatically Actuated Microcantilevers

Skelton, Robert E.
Ashikari, Rajesh
Pinaud, Jean-Paul
Chan, Wai-leung
Helton, J. William
Univ. of California, San Diego
Univ. of California, San Diego
Univ. of California, San Diego
Univ. of California, San Diego
Univ. of California, San Diego

Abstract: In this paper, we design a modal controller for conservative flexible systems that use distributed sensing. A spatial filter design based on the eigenfunctions coupled with a velocity observer prevents spillover instabilities in the closed-loop system. The proposed control is proven to stabilize a discrete set of controlled modes without destabilizing the remaining, residual modes. We then apply the theory to a single flexible link robot arm and experimentally demonstrate the feasibility of the proposed control strategy. The experiments use high speed video feedback with image processing to determine the spatial beam curve. The controller quickly damps the first modal response without causing instability in the remaining modes.

Modeling and Observer Design for an Array of Electrostatically Actuated Microcantilevers

Napoli, Mariateresa
Bamieh, Bassam
Univ. of California, Santa Barbara
Univ. of California, Santa Barbara

Abstract: In this paper we present a mathematical model for the dynamics of an array of capacitively actuated micro-cantilevers. We propose a system where the current measured at each cantilever is used as the sensing signal of the cantilever state through an observer. We show that such an array is a spatially invariant system with distributed control and sensing. For the common case of periodically excited cantilevers, we show that the underlying dynamics are those of a periodic system described by a Mathieu equation. We exploit the spatial invariance of the problem to design an optimal distributed observer, where the temporal periodicity is handled using the lifting technique.
Abstract: A systematic method of selecting sensors and actuators is produced, efficiently selecting inputs and outputs that guarantee a desired level of performance in the H_infinity sense. The method employs an efficiently computable necessary and sufficient existence condition, using an effective search strategy. The search strategy is based on a method to generate all so-called minimal dependent sets. This method is applied to tensegrity structures. Tensegrity structures are a prime example for application of techniques that address structural problems, because they offer a lot of flexibility in choosing actuators/sensors and in choosing their mechanical structure. The selection method is demonstrated with results for a 3 stage planar tensegrity structure where all 26 tendons can be used as control device, be it actuator, sensor, or both, making up 52 devices from which to choose. In our set-up it is easy to require devices to be selected as collocated pairs, and to analyze the performance penalty associated with this restriction. Two performance criteria were explored, one is related to the dynamical stiffness of the structure, the other to vibration isolation. The optimal combinations of sensors and actuators depend on the design specifications and are really different for both performance criteria.

FrM05
Time-Varying Systems
Chair: Colaneri, Patrizio Politecnico di Milano
Co-Chair: Carpanese, Nevio Univ. of Padova

13:40
Inclusion Principle for Time-Varying Systems ............... 4286
Stanković, Srdjan S. Univ. of Belgrade
Šiljak, Dragošlav D. Santa Clara Univ.

Abstract: In this paper the inclusion concept is applied to dynamic time-varying linear continuous-time dynamic systems. Starting from general definitions, which include restriction and aggregation as special cases, inclusion conditions are derived. Properties of different inclusion types are discussed. It is proved that any inclusion can be considered as a composition of one restriction and one aggregation.

14:00
Ackerman-Like Formula for Linear Time-Varying Systems .... 4292
Lee, Ho Chul Pusan Natl. Univ.
Choi, Jae Weon Pusan Natl. Univ.
Zhu, J. Jim Ohio Univ.

Abstract: This paper deals with the eigenvalue assignment for linear time-varying systems to achieve feedback stabilization. For this, we introduce the novel eigenvalue concepts. Then, we propose the Ackerman-like formula for linear time-varying systems. It is believed that this technique is the generalized version of the Ackerman formula for linear time-invariant systems. The advantages of the proposed Ackerman-like formula are that it does not require the transformation of the original system into the phase-variable form nor the computation of eigenvalues of the original system.

14:20
Output Feedback Design for LTV Systems via Stabilizing Receding Horizon H-Infinity Control with a Terminal Penalty . 4298
Kawai, Yasunori Kanazawa Univ.
Azuma, Takehito Kanazawa Univ.
Fujita, Masayuki Kanazawa Univ.

Abstract: This article concerns with the output feedback synthesis problems using stabilizing receding horizon H_infinity control with a terminal penalty. We derive conditions based on completing the square argument of a particular quadratic form.

15:20
Input/Output Selection for Planar Tensegrity Models .......... 4280
de Jager, Bram Eindhoven Univ. of Tech.
Skelton, Robert E. Univ. of California, San Diego

Abstract: A bias-correction method for closed-loop identification, introduced in the literature as the bias-eliminated least squares (BELS) method, is shown to be equivalent to a basic instrumental variable estimator applied to a predictor for the closed-loop system. This predictor is a function of the plant parameters and the known controller. Corresponding to the related method using a least squares criterion, the method is referred to as the tailor-made IV method for closed-loop identification. The indicated equivalence greatly facilitates the understanding and the analysis of the BELS method.

Abstract: Many models of systems important in practice have the form of an interconnection of a known linear model and an unknown nonlinear function. One example of such a system is a model of thermoacoustic instability affecting gas turbine engines and rockets (so-called thermoacoustic feedback loop). In this paper, we propose a computationally attractive algorithm for identifying static nonlinearity in a thermoacoustic feedback loop which is either in a limit cycle or is being driven by Gaussian noise. The algorithm is based upon functional analytic treatment of the describing function method and lends itself nicely to a class of limit cycle or noise driven feedback systems where the nonlinearity is of a special type. We present examples as well as a simulations with the thermoacoustic feedback loop as an application of the identification algorithm.

Abstract: In this paper we consider closed loop identification of an irrigation channel. These disruptions can be reduced by using closed loop identification. The gates in the irrigation channel are controlled using feedback from water levels, and the excitations are provided by set point changes. Only relatively small set point changes and short experiment times are needed in order to obtain a reliable model. The obtained models are validated against data sets with large variations in flow, and there is very good agreement between the simulated model output and the observed water levels. Hence, models of irrigation channels can be obtained using closed loop identification which causes only minor disruptions to the normal operation of the channel.

Abstract: In this contribution optimal experiment design for system identification is studied. The main contribution is the development of an adaptive method for the direct design of FIR filters for the input spectrum design problem. The application is identification for control, thus the accuracy of the identified model is measured in terms of the closed-loop performance of the system using the controller designed from the model. Under the assumption that the identified parameters are sufficiently close to their true values, we show that this problem may be formulated as a convex optimization problem with linear matrix inequality constraints. Thus, a global solution (if feasible) is guaranteed and the solution may further achieve any demanded accuracy. The problem formulation is particularly suited for a practical implementation, thus the extension of the experiment design problem into an iterative/adaptive identification -- experiment design framework is straightforward. The adaptive approach is further studied in a simulation example, where the rapid convergence of the method is noted, and the superior result compared to an arbitrary experiment design is clear. The example support the use of the approximations taken in the theoretical approach.

Abstract: The design problem of proportional and proportional-plus-integral (PI) controllers for nonlinear systems is studied in this paper. First, Takagi-Sugeno fuzzy model with parameter uncertainties is used to approximate the nonlinear systems. Then a numerically tractable algorithm based on the technique of iterative linear matrix inequalities is developed to design a proportional (static output feedback) controller for the robust stabilization of the system in Takagi-Sugeno fuzzy model. Thirdly, we transform the problem of PI controller design to that of proportional controller design for an augmented system and thus bring the solution of the former problem into the configuration of the developed algorithm. Finally, the proposed method is applied to the design of robust stabilizing controllers for the excitation control of power systems. Simulation results show that the transient stability can be improved by using a fuzzy PI controller when large faults appear in the system, compared to the conventional PI controller designed by using linearization method around the steady state.

Abstract: A novel type of least-squares (LS) based method in combination with the bias correction principle is proposed for direct identification of plants under feedback control. Its centerpiece is a more computationally efficient scheme for estimating the noise covariance vector that specifies the source of the noise-induced bias in the LS estimate. The attractive feature of the proposed method is that it can achieve the good estimation accuracy at a significantly reduced numerical cost. A numerical example is presented to demonstrate the effectiveness of the proposed method.
The theory development.

The plant. A numerical simulation example is presented to illustrate the theory development.

Abstract: This paper studies the problem of designing an H-infinity fuzzy feedback controller which globally stabilises this class of fuzzy system models. A design algorithm for constructing the H-infinity fuzzy feedback controller is given. A numerical simulation example is given to illustrate the framework.

Fuzzy Adaptive Control for Nonlinear Systems – Real-Time Implementation for a Robot Wrist

Reda, Boukezzoula
Galichet, Sylvie
Fouloy, Laurent

Univ. of Savoie
Univ. of Savoie
Univ. of Savoie

Abstract: In this paper, an adaptive Takagi-Sugeno fuzzy controller for continuous nonlinear systems is proposed. The controller is designed under the constraint that only the output of the plant is measured. A state observer is thus introduced in the global control structure. The nonlinear plant is approximated with a Takagi-Sugeno fuzzy system whose parameters are adjusted via adaptive laws. Based on this representation, the control law is designed according to the Lyapunov and passivity theories. Stability of the algorithm is established with tracking errors converging to zero. Finally, in order to illustrate the feasibility of the proposed methodology, a real-time implementation for controlling a robot wrist is presented.

Fuzzy H-infinity Output Feedback Control of Nonlinear Systems under Sampled Measurements

Nguang, Sing Kiong
Shi, Peng

Univ. of Auckland

Abstract: This paper studies the problem of designing an H-infinity fuzzy feedback control for a class of nonlinear systems. A nonlinear systems is first described by a continuous-time fuzzy system model under sampled output measurements. The premise variables of the fuzzy system model are allowed to be unavailable. We develop a technique for designing an H-infinity fuzzy feedback control which globally stabilises this class of fuzzy system models. A design algorithm for constructing the H-infinity fuzzy feedback controller is given. A numerical simulation example is given to show the potential of the proposed techniques.

Robust Adaptive Fuzzy Controller for MIMO Nonlinear Uncertain Systems

Chiang, Chiang-Cheng
Wang, Wen-Hao

Tatung Univ.
Tatung Univ.

Abstract: Based on the combination of the H-infinity optimal control with fuzzy logic control and the simple adaptation laws, this paper presents a new and feasible design algorithm to synthesize a robust adaptive fuzzy controller which can easily tackle the output tracking control problem of MIMO nonlinear uncertain systems without the knowledge of the upper bounds on the norm of the uncertainties. Keywords: H-infinity optimal control, fuzzy logic control, output tracking, unmatched uncertainties, adaptation law.

Optimization and Applications

Chair: Simaan, Marwan A.
Co-Chair: Pepyne, David L.

13:40
Optimal Non-Linear Distributed Control of Spatially-Invariant Systems

Karlsson, Niklas
Bamieh, Bassam

Univ. of California, Santa Barbara
Univ. of California, Santa Barbara

Abstract: We consider optimal distributed control for linear distributed systems with non-quadratic performance criteria expressed as a power series. Using power series methods, we derive a recursive procedure to obtain the successive power series terms of the optimal value function and state feedback. In the case of spatially-invariant systems we show how the state feedback power series terms represented as tensors can be easily constructed using multi-dimensional Fourier transforms.

An Ordinal Optimization Framework for Robust Design

Djafari, Theodore E.
Pepyne, David L. L.
Cushing, David M.

Univ. of Massachusetts
Harvard Univ.
Univ. of Massachusetts

Abstract: In this paper we consider systems with parameter uncertainty and suggest an ordinal optimization framework for robust design. To illustrate the approach we focus attention on the problem of robust stability margin design. Our formulation exploits frequency domain properties and polynomial value set ideas. A recently developed parameterization of stable polynomials is used to characterize the controller search space. Robust control design is then carried out by: 1) employing easily computable stability margin lower bounds to estimate the performance and 2) using ordinal optimization to deal with the lack of known structure in the search space. Preliminary numerical results are provided to illustrate the framework.
appropriate technical conditions the estimator sequence is shown to converge to 0 with geometric rate almost surely. This result is in striking contrast to classical stochastic approximation theory where the typical convergence rate is the inverse of square root of n. For the proof a discrete-time version of the ODE-method is developed and used. The paper is motivated by the study of simultaneous perturbation stochastic approximation (SPSA) methods applied to noise-free problems and to direct adaptive control.

15:00
An Adjoint Method based Approach to Data Assimilation for a Distributed Parameter Model for the Ionosphere .......... 4406
Rosen, I. Gary  Univ. of Southern California
Wang, Chunming  Univ. of Southern California
Hajj, George  Jet Propulsion Lab
Pai, Xiaoping  Jet Propulsion Lab
Wilson, Brian  Jet Propulsion Lab

Abstract: A computational method for the estimation of the forces (drivers) which enter into the collisional plasma hydrodynamic equations for the ionosphere is developed. The ionospheric model used in this effort is for mid- and low-latitudes and consists of solving the continuity and momentum partial differential equations in four dimensions (three spatial dimensions and time) to compute the O+ density in the ionosphere and plasmasphere. We have developed codes for solving the forward model on a fixed grid and for solving the adjoint equations used in computing the gradients required for the estimation of the unknown driving forces. We describe our nonlinear least squares formulation of the data assimilation problem for the identification of the E x B drift and our development of the adjoint method for the computation of the requisite gradients.

15:20
Simple Explanation of the No Free Lunch Theorem of Optimization ............................................. 4409
Ho, Yu-Chi  Harvard Univ.
Pepyne, David L.  Harvard Univ.

Abstract: The No Free Lunch Theorem of Optimization (NFLT) is an impossibility theorem telling us that a general-purpose universal optimization strategy is impossible, and the only way one strategy can outperform another is if it is specialized to the structure of the specific problem under consideration. Since virtually all decision and control problems can be cast as optimization problems, an appreciation of the NFLT and its consequences is essential for controls engineers. In this paper we present a framework for conceptualizing optimization problems that leads useful insights and a simple explanation of the NFLT.

FrM09
Tracking Control Performances at the Dawn of the New Millennium
Chair: Gruyitch, Lyubomir T.  Univ. de Tech. de Belfort-Montbèliard
Co-Chair: Kokosy, Annemarie  Inst. Supérieur d’Élec. du Nord
Organizer: Kokosy, Annemarie  Inst. Supérieur d’Élec. du Nord
Organizer: Gruyitch, Lyubomir T.  Univ. de Tech. de Belfort-Montbèliard

13:40
Stability and Tracking Performance of Dynamic Visual Feedback Control for Nonlinear Mechanical Systems (I) ....... 4415
Maruyama, Akira  Nachi-Fujikoshi Corp.
Kawai, Hiroyuki  Kanazawa Univ.
Fujita, Masayuki  Kanazawa Univ.

Abstract: This paper investigates a robot motion control problem with visual information. Firstly the model of the relative rigid body motion and the nonlinear observer are shown in order to derive the visual feedback system. Secondly a design algorithm for the 3-D visual feedback control problem which contains the manipulator dynamics are considered. Finally we discuss stability and L2-gain performance analysis for the 3-D visual feedback system contains the manipulator dynamics. L2-gain performance analysis can be regarded as a tracking performance measure for the moving target object.

14:00
Trajectory Tracking of Underactuated Underwater Vehicles (I) .................................................. 4421
Alonge, Francesco  Univ. of Palermo
D’ippolito, Filippo  Univ. of Palermo
Raimondi, Francesco M.  Univ. of Palermo

Abstract: This paper deals with control strategies for underactuated underwater vehicles whose target is the tracking of a space trajectory. A cascade control strategy is employed which brings to a control law consisting of: a) a kinematic control law, derived from the vehicle kinematic model, which forces this model to track the reference trajectory; b) a dynamic control law which forces the system to track the reference signals given by the kinematic control law. Conditions for asymptotic tracking of the trajectory are given with reference to the standard dynamical model of the above vehicle. An observer of the marine current is also added in order to process the control law. Simulation tests illustrate the proposed approach.

14:20
Tracking with Stability for a Vehicle Braking in a Corner (I) ... 4427
d’Andréa-Novel, B.  Ecole des Mines de Paris
Ellouze, M.  Ecole des Mines de Paris

Abstract: In this paper, we present a control method based on nonlinear constrained optimization combined with singular perturbation theory, to deal with the problem for a vehicle braking in a corner, to follow a yaw rate reference trajectory and a longitudinal acceleration reference trajectory. The control laws are elaborated from an horizontal model. Moreover, using a simplified reference model and slightly modifying the control law, we show that the longitudinal velocity error asymptotically converges to zero and that the lateral velocity remains bounded.

14:40
Constrained Natural Tracking Control Algorithms for Bilinear DC Shunt Wound Motors (I) ....................... 4433
Gruyitch, Lyubomir T.  Univ. de Tech. Belfort-Montbèliard
Mounfield, Jr., William Pratt  M & M Technologies, Inc.

Abstract: Natural tracking control algorithms are discovered and compared for bilinear, shunt wound, direct current electric motors. Natural tracking controllers can be applied to shunt wound DC motors because they can possess the plant natural trackability property. Natural trackability assures the existence of a natural tracking controller which forces the system to exhibit elementwise exponential tracking of time varying desired outputs by needing a minimum amount of information about the dynamics of the plant to be controlled, yet without needing information about its internal dynamics and the disturbances. Bilinear, shunt wound motors can physically experience the loss in control if the field current is forced through zero due to commands or external disturbances. Different natural tracking control algorithms are simulated under conditions which force the motor’s field current through zero; the motor response follows the theory for a loss of natural trackability.

15:00
Sensor Management with Respect to Danger Level of Targets (I) .............................................. 4439
Vanheeghe, Philippe  LAIL
Duflos, Emmanuel  LAIL/ISEN
Dumont, Pierre-Emmanuel  ISEN
Nimier, Vincent  ONERA

Abstract: The sensor management problem for tracking in a multiple-targets and multiple sensors environment is a critical one in the case of non cooperative targets. This problem is widely depicted in the literature. In this paper the definition and the utilization of the danger level of a target is described. An algorithm based on this danger level of the target is described in order to determine an optimal strategy for the sensor management.
Abstract: This paper studies the performance achievement problem for a class of discrete event systems modeled with place-transitions Petri nets using Lyapunov methods. After reviewing some preliminaries about the stability and stabilization/regulation theory of discrete event systems modeled with place-transitions Petri nets, the performance achievement problem is addressed. Some examples illustrate how the methodology is applied in order to get the desired performance. The proposed approach shows to be easy, constructive and convenient.

FrM10
Iterative Learning Control
Chair: Moore, Kevin L. Utah State Univ.
Co-Chair: Rogers, Eric Univ. of Southampton

13:40
On Dα-Type Iterative Learning Control ....................... 4451
Chen, YangQuan Utah State Univ.
Moore, Kevin L. Utah State Univ.

Abstract: The classical Arimoto D-type iterative learning control (ILC) updating law uses the first order derivative (with transfer function s) of tracking error. By using the fractional order derivative, it is proposed in this paper to use a fractional order ILC updating law where the fractional order derivative (with transfer function s^α, α ∈ (0, 1)) of tracking error is employed. The basic idea is explained in some detail together with a frequency domain design method. For implementation, a direct discretization technique is introduced. An example is given to show the benefits of the D^α-type ILC. Several remarks on future research topics are briefly discussed in the final section.

14:00
LMI based Stability Analysis and Controller Design
for a Class of 2D Discrete Linear Systems ..................... 4457
Rogers, Eric Univ. of Southampton
Lam, James Univ. of Hong Kong
Gaikowski, Krzysztof Univ. of Zielona Gora
Xu, Shengyuan Catholic Univ. of Louvain
Wood, Jeffrey Univ. of Southampton
Owens, David H. Univ. of Sheffield

Abstract: Linear repetitive processes are a distinct class of 2D linear systems with applications in areas ranging from long-wall coal cutting through to iterative learning control schemes. The main feature which distinguishes such processes from other classes of 2D linear systems is that information propagation in one of the two distinct directions only occurs over a finite duration. This, in turn, means that a distinct systems theory must be developed for them. In this paper we give an LMI based interpretation of stability (both open and closed loop) for the sub-class of so-called discrete linear repetitive processes and apply this theory to solve currently open problems relating to robustness and stability margins for these processes. Also it is shown that this approach to these processes provides a (potentially very powerful) method of extracting information as to expected performance by means of the recently developed concept of a pole for them which uses the behavioral setting for control systems theory. (This feature is not present in the LMI approach to the analysis of other classes of 2D linear systems.)

14:20
Performance Achievement for a Class of Discrete Event Systems (I) ................................................. 4445
Retchkiman, Zvi Inst. Politecnico Nacional

Abstract: This paper studies the performance achievement problem for a class of discrete event systems modeled with place-transitions Petri nets using Lyapunov methods. After reviewing some preliminaries about the stability and stabilization/regulation theory of discrete event systems modeled with place-transitions Petri nets, the performance achievement problem is addressed. Some examples illustrate how the methodology is applied in order to get the desired performance. The proposed approach shows to be easy, constructive and convenient.

14:40
An Iterative Learning Nonlinear Observer-Based Approach to Fault Detection and Accommodation in Nonlinear Systems ...... 4469
Chen, Wen Simon Fraser Univ.
Saif, Mehrdad Simon Fraser Univ.

Abstract: This paper presents a general framework for fault detection and accommodation using iterative learning strategy. An Iterative Learning Observer (ILO) updated online by past system output errors as well as input is constructed for the purpose of fault detection. This observer is different from conventional Luenberger observer where the observer's state is only a function of the most recent input, output and the estimation error. Furthermore, using Iterative Learning (IL) approach, an automatic control reconfiguration scheme for accommodation of faults is also described. One of the main features of the proposed scheme is that the control reconfiguration is achieved automatically based only on the response of the overall systems, and the IL controller does not require a fault detection and isolation subsystems. An example is employed to verify the effectiveness of the IL observer and IL fault accommodation scheme.

15:00
The Fallacy of Causal Iterative Learning Control ............... 4475
Goldsmith, Peter B. Univ. of Calgary

Abstract: The goal of Iterative Learning Control (ILC) is to improve the accuracy of a system that repeatedly follows a reference trajectory. This paper proves that if the ILC law is restricted to causal operators, then the ultimate ILC error can be achieved in a single trial using conventional feedback control. The feedback operator is a known function of the ILC operators alone. Hence, there is no reason to use causal ILC, even if the plant is completely unknown. This equivalent feedback exists whether or not the ILC itself includes feedback. The equivalence is proved for nonlinear time-varying systems, except for the case of ILC convergence with zero error, which is proved for linear discrete-time systems.

15:20
Iterative Learning Control of Nonlinear Non-Minimum Phase Systems and its Application to System and Model Inversion . 4481
Markusson, Ola Royal Inst. of Tech.
Hjalmarsson, Häkan Royal Inst. of Tech.
Norrlöf, Mikael Linköping Univ.

Abstract: In this contribution we present a model based method for reference tracking in the Iterative Learning Control (ILC) framework. The method can be applied to nonlinear, possibly non-minimum phase, systems. The idea is to use the inverse of a linearized model in the ILC update. In the non-minimum phase case, the batch property of ILC is explored by means of non-causal filtering. Apart from reference tracking, this method is useful for system and model inversion -- a problem that arises in many disciplines where nonlinear systems and models are involved, e.g. maximum likelihood identification and input design for identification for control. The method is illustrated on a numerical example.
Abstract: In this paper a globally stabilizing feedback boundary control law for an arbitrarily fine discretization of a one-dimensional nonlinear PDE model of unstable burning in solid propellant rockets is presented. The PDE has a destabilizing boundary condition imposed on one part of the boundary. We discretize the original nonlinear PDE model in space using finite difference approximation and get a high order system of coupled nonlinear ODEs. Then, using backstepping design for parabolic PDEs, properly modified to accommodate the imposed destabilizing nonlinear boundary condition at the burning end, we transform the original system into a target system that is asymptotically stable in l2-norm with the same type of boundary condition at the burning end, and homogeneous Dirichlet boundary condition at the control end. The design is accompanied by a simulation study that shows that the feedback control law designed using only one step of backstepping (using just two temperature measurements) can successfully stabilize the actual system for a variety of different simulation settings.

Drag Reduction in Flow Over a Flat Plate using Active Feedback Control

Baker, James
Univ. of California, Los Angeles
Myatt, James
Wright Patterson Air Force Base
Christofilides, Panagiotis D.
Univ. of California, Los Angeles

Abstract: This paper focuses on two-dimensional incompressible Newtonian fluid flow over a flat plate and studies the problem of reducing the frictional drag exerted on the plate using active feedback control. Several alternative control configurations, including both pointwise and spatially uniform control actuation and sensing, are developed and tested through computer simulations. All control configurations use control actuation in the form of blowing/suction on the plate and measurements of shear stresses along the plate. The simulation results indicate that the use of active feedback control, which employs reasonable control effort, can significantly reduce the frictional drag exerted on the plate compared to the open-loop values.

Fluid Dynamical Systems as Hamiltonian Boundary Control Systems

Van der Schaft, Arjan J.
Univ. of Twente
Maschke, Bernhard M.
Univ. Claude Bernard Lyon-1

Abstract: It is shown how the geometric framework for distributed-parameter port-controlled Hamiltonian systems as recently provided by the authors can be adapted to formulate ideal isentropic compressible fluids with non-zero energy flow through the boundary of the spatial domain as Hamiltonian boundary control systems. The key ingredient is the modification of the Stokes-Dirac structure introduced before to a Dirac structure defined on the space of mass density 3-forms and velocity 1-forms, incorporating three-dimensional convection. Some initial steps towards stabilization of these boundary control systems, based on the generation of Casimir functions for the closed-loop Hamiltonian system, are discussed.

Analysis and Computations of Neumann Boundary Optimal Control Problems for the Stationary Boussinesq Equations

Lee, Hyung-Chun
Ajou Univ.

Abstract: This article deals with Neumann boundary optimal control problems associated with the Boussinesq equations. These problems are first put into an appropriate mathematical formulation. Then the existence of optimal solutions is proved. The use of Lagrange multiplier techniques is justified and an optimality system of equations is derived. Finally, some numerical results are given.

15:00
Rocket Nozzle Flow Control using Proper Orthogonal Decomposition

Lucia, David J.
Air Force Inst. of Tech.
Pachter, Meir
Air Force Inst. of Tech.
Beran, Phillip S.
Air Force Research Lab

Abstract: This paper investigates the use of Proper Orthogonal Decomposition-based reduced order Computational Fluid Dynamics models for model-based controller design. An open-loop optimal control problem is posed and solved concerning the regulation of a rocket engine thrust profile. The control synthesis uses a numerical flow field solver as the plant model. Controllers are synthesized using a reduced order model of the flow field generated via Proper Orthogonal Decomposition. A quasi-one-dimensional supersonic convergent-divergent nozzle with varying back pressure is used as a model problem. Treating the nozzle flow as one-dimensional, the reduced order model was used to synthesize a controller that controls thrust along an ascent trajectory by varying nozzle throat area and fuel mass flow rate. The effects of reduced order model accuracy on controller performance are quantified.
14:00
Threshold-Based Control for Make-to-Stock Models: A Synergy between Large Deviations and Perturbation Analysis .............. 4523
Paschalidis, Ioannis Ch. Boston Univ.
Li, Yong Boston Univ.
Cassandras, Christos G. Boston Univ.
Zhang, Ping Boston Univ.

Abstract: We consider a model of a make-to-stock manufacturing system. External demand is met from the finished goods inventory; unsatisfied demand is backlogged. We adopt a base-stock production policy which produces if inventory falls below a certain threshold and idles otherwise. We set this threshold to guarantee stockout or delay probabilities to stay below given constants (service level constraints). These can be set by solving a utility maximization problem which trades-off Quality of Service with expected inventory costs. We combine analytical (large deviations) and simulation-based (perturbation analysis) techniques. We demonstrate that there is a natural synergy between these two approaches.

14:20
On-Line Predictive Techniques for Differentiated Services Networks ............................................. 4529
Panayiotou, Christos G. Boston Univ.
Cassandras, Christos G. Boston Univ.

Abstract: In this paper we propose two on-line predictive algorithms that can provide performance estimates under a set of parameters in the context of differentiated services. These algorithms are based on sample path constructability techniques. The first one (ASA) depends on exponential lifetime distributions, while the second one (ML) is distribution independent. The information provided by these algorithms can be used to solve the admission control problem and to allocate resources to the various traffic streams.

14:40
Panel Discussion

15:00
Model Predictive Control for Perturbed Max-Plus-Linear Systems: A Stochastic Approach 4535
van den Boom, Ton J. J. Delft Univ. of Tech.
De Schutter, Bart Delft Univ. of Tech.

Abstract: Model predictive control (MPC) is a popular controller design technique in the process industry. Conventional MPC uses linear or nonlinear discrete-time models. Recently, we have extended MPC to a class of discrete event systems that can be described by a model that is ‘linear’ in the (max,+) algebra. In our previous work we have only considered MPC for the perturbations-free case and for the case with bounded noise and/or modeling errors. In this paper we extend our previous results on MPC for perturbed max-plus-linear systems to a stochastic setting. We show that under quite general conditions the resulting optimization problems turn out to be convex and can be solved very efficiently.

15:20
Search Space Reduction in Ordinal Optimization for Performance Evaluation of DEDS ............................................ 4541
Park, Kyung-Joon Seoul Natl. Univ.
Choi, Chong-Ho Seoul Natl. Univ.

Abstract: Simulation plays a vital role in analyzing DEDS. However, using simulation to analyze complex systems can be time-consuming and expensive. Particularly, in the case of precise performance evaluation, computing budget, time constraint, and pseudo random number generator limitations can become prohibitive. Ordinal optimization is an effective approach for improving the efficiency of simulation and optimization of DEDS. However, the ordinal optimization approach does not pay much attention to the problem of large search space. In this paper, for the reduction of search space, we propose a combined approach, ordinal optimization with orthogonal arrays. With this approach, the problem of large search space in stochastic optimization can become more manageable. Consequently, the proposed method can be more efficient for the reduction of simulation burden compared to the conventional ordinal optimization method.
14:40
Decentralized Network Resource Allocation as a Repeated Noncooperative Market Game ....................... 4565
Maheswaran, Rajiv T.  Univ. of Illinois, Urbana-Champaign
Başar, Tamer  Univ. of Illinois, Urbana-Champaign

Abstract: Market-based methods are an emerging paradigm for controlling large decentralized systems. We introduce in this paper a bidding mechanism for allocation of network resources among competing agents, and study it from a game-theoretic perspective. We prove the existence and the uniqueness of Nash equilibrium and present an update algorithm that allows users to converge to the Nash equilibrium in a decentralized manner using feedback of only the common information available to the resource. The necessary conditions for local stability of relaxed versions of the algorithm are derived and verified by simulations.

15:00
An Optimization Model for a Company with Constraints on Risk Control ........................................... 4571
Chouli, Tahir  Univ. of Calgary
Taksar, Michael  SUNY, Stony Brook
Zhou, Xun Yu  Chinese Univ. of Hong Kong

Abstract: We investigate a model of a corporation which faces constant liability payments and which can choose a production/business policy from an available set of control policies with different expected profits and risks. The objective is to maximize the expected present value of the total dividend distributions. The main purpose of this paper is to deal with the impact of constraints on business activities such as inability to completely eliminate risk (even at the expense of reducing the potential profit to zero) or when such a risk cannot exceed a certain level. We analyze the case in which there is no restriction on the dividend pay-out rates. By delicate analysis on the corresponding Hamilton-Jacobi-Bellman equation we compute explicitly the optimal return function and determine the optimal policy.

15:20
Risk-Sensitive Inventory Control Problems ......................... 4577
Avila-Godoy, Guadalupe M.  Univ. de Sonora
Fernández-Gaucherand, Emmanuel  Univ. of Cincinnati

Abstract: We study an inventory control problem, under a stochastic demand process and with risk (i.e., variance) sensitive optimality criteria. Using convexity and semimodularity-type arguments, we present sufficient conditions for an optimal base-stock policy to exist, in the finite horizon problem. For the infinite horizon case, we show that there exists an ultimately stationary base-stock optimal policy. A much abridged version of this paper, and without any results for the infinite horizon case, was presented

16:20
Robust Nonlinear Motion Control of a Helicopter ................. 4586
Isidori, Alberto  Univ. di Roma
Marconi, Lorenzo  Univ. di Bologna
Serrani, Andrea  Univ. di Ancona

Abstract: We consider the problem of controlling the vertical motion of a nonlinear model of a helicopter to a reference signal, while stabilizing the lateral and horizontal position and maintaining a constant attitude. The reference to be tracked is given by a sum of a constant and a fixed number of sinusoidal signals, and it is assumed not to be available to the controller. This represents a possible situation in which the helicopter is required to synchronize its vertical motion with that of an oscillating platform, as the one given by a sea carrier subject to wave-induced oscillations. We design a nonlinear controller which combines recent results on nonlinear adaptive output regulations and robust stabilization of systems in feed-forward form by means of saturated controls. Simulation results show the effectiveness of the method and its ability to cope with large uncertainties on the plant, the actuator model and the exogenous reference signal.
Abstract: The paper adopts the energy shaping method to rotational motion control of a spacecraft. The configuration manifold considered in this paper is the 3-sphere. The quaternion and its conjugate momentum are used for global representation of motion in the canonical form. The design algorithm presented is validated for three typical attitude control objectives: stabilization in an inertial coordinate system, slew maneuver with obstacle avoidance, and active libration damping for a Low Earth Orbit spacecraft.

FrP02
Observation and Control of Time-Delay Systems: From Non-Linear to Linear
Chair: Lafay, Jean Francois Ecole Centrale Nantes
Co-Chair: Sename, Olivier INPG
Organizer: Sename, Olivier INPG
Organizer: Lafay, Jean Francois Ecole Centrale Nantes

Accessibility of Nonlinear Time-Delay Systems (I) ......................... 4622
Marquez, Luis A. CICESE
Moog, Claude H. IRCyN UMR CNRS 6597

Abstract: This paper considers nonlinear control systems with constant time-delays. An introductory analysis of the accessibility is presented.

On the Existence of the Linearizing State-Feedback for Nonlinear Delay Systems (I) .................................................. 4628
Germani, Alfredo Univ. degli Studi dell’Aquila
Manes, Costanzo Univ. degli Studi dell’Aquila

Abstract: This paper presents some results on the problem of exact linearization with delay decoupling for nonlinear delay systems. Geometrical conditions are found that ensure existence of a coordinate transformation and of a static feedback that transform the input-state delay equation into a linear equation without delay, easy to stabilize. Only standard tools of differential geometry are used in this work.

Sliding Mode Control of TDS via Functional Surfaces (I) ............... 4630
Gouaisbaut, Frederic LAIL
Dambrine, Michel LAIL
Richard, Jean-Pierre LAIL

Abstract: In this paper, we present a way of designing a sliding mode controller for a system with delay on the state. In such a situation, designing a controller without taking into account the delay may lead to unstable or chaotic behaviors or, at least, to highly chattering behaviors. Even if the general framework of differential inclusions has been proposed in this case, the concrete control results are scarce. This paper considers time-delay systems with linear nominal model and nonlinear input perturbations. The delay is known. The sliding surface is a functional one, i.e. it takes into consideration the whole state of the system (present and past values). The convergence of the system into the surface and the asymptotic stability of the reduced system is proved by using a Lyapunov-Krasovskii approach. The largest value of the admissible delay bound is obtained via LMI’s approach. An illustrative example is provided.
Abstract: This paper considers an off-line reference management technique for systems with state and control constraints. The benefits of the approach are to guarantee the satisfaction of the specified constraints, that is, the primary purpose of reference governors, and explicitly taking the performance improvement into account. The infinite number of constraints involved in the problem formulation are reduced into a finite number. The main idea is to restricting the state variable at the final instance of finite-time reference management to a certain invariant subset of the state space such that fulfilling constraints for the primal control system is equivalent to restricting the state dynamics to this set.

Abstract: We present a controller design method for output regulation for linear systems subject to actuator saturation. The feedback law is constructed from the stabilizing feedback law in such a way that a stabilizing feedback law that achieves a larger domain of attraction leads to a feedback law that achieves output regulation on a larger subset of the asymptotically regulatable region and, a stabilizing feedback law on the entire asymptotically null controllable region leads to a feedback law that achieves asymptotic output regulation on the entire asymptotically regulatable region. In this paper, the control signal is continuous in time. This complements the result in [3] where the control signal is discontinuous at the switching surfaces.

Abstract: We present a necessary and sufficient condition for an ellipsoid to be an invariant set of a linear system under a saturated linear feedback. The condition is given in terms of linear matrix inequalities and can be easily used for optimization based analysis and design.

Abstract: We present a method for estimating the domain of attraction for a discrete-time linear system under a saturated linear feedback. A simple condition is derived in terms of an auxiliary feedback matrix for determining if a given ellipsoid is contractively invariant. Moreover, the condition can be expressed as LMIs in terms of all the varying parameters and hence can easily be used for controller synthesis. The following suprising result is revealed for systems with single input: suppose that an ellipsoid is made invariant with a linear feedback, then it is invariant under the saturated linear feedback if and only if it can be made invariant with any saturated (nonlinear) feedback.

Abstract: This article applies the Lyapunov stability theory to microelectromechanical systems (MEMS) analysis and design taking into account electromagnetic and electromechanical features. Due to the mathematical rigor and unique systematic capabilities, the Lyapunov theory has been widely used. However, it is important to bridge the gap with practical applications to MEMS. Multidisciplinary studies are needed to be carried out to illustrate the diverse applications of nonlinear systems theory for analysis and control of MEMS because desired level of validity and performance can be attained through synergy of nonlinear control, electromagnetics, and electromechanics. Micro-electromechanical systems integrate microstructures and microdevices, and the component models are described by nonlinear deterministic/stochastic time-invariant/time-varying multivariable ordinary and partial differential equations as well as difference equations. Focusing our efforts on microelectromechanical motion devices, we apply Lyapunov’s stability theory. These microscale motion devices, integrated with ICs, comprise MEMS. It must be emphasized that the circuitry dynamics is very fast compared with the electromechanical transients. Therefore, the motion devices behavior has the dominant effect. To address systematic analysis, it must be emphasized that the electromagnetic features and operating principles of MEMS must be thoroughly studied. Thus, analysis and design should be performed researching electromagnetic – electromechanical – circuitry aspects. For example, the pulse-width-modulation technique is used to design high-performance ICs, optimal energy conversion and torque maximization problems require particular currents and voltages applied to the phase micro-windings (distinct control laws must be designed), etc. Fundamental, analytical, numerical, and experimental results are documented in this paper.
Abstract: In a typical disk drive servo system, two or more types of controllers are used for track seeking, track following and track settling modes. This leads to the problem of mode switching among these controllers. We present in this paper a unified control scheme, the discrete-time composite nonlinear feedback control, which can perform all the above functions in hard disk drive servo systems with actuator saturations. The proposed scheme is composed by combining a linear and nonlinear feedback laws. The linear feedback law is designed to yield a fast response, while the nonlinear feedback law is to increase the damping rate of the closed-loop system as the system output approaches the command input. In the face of actuator saturation, this control law not only increases the speed of closed-loop response but also improves the settling performance. Implementation results show that the proposed method out-performs the conventional proximate time-optimal servomechanism by 50% in settling time.

16:20
An H-Infinity Design Method for a Multi-Rate Servo Controller and Applications to a High Density Hard Disk Drive ............ 4693
Semba, Tetsuo
IBM Tokyo Research Lab

Abstract: This paper proposes a method of designing a multi-rate servo controller for a hard disk drive that operates at a higher sampling frequency than the position error signal (PES). It is desirable to increase the servo performance without increasing the capacity overhead caused by the tracking information on a disk. A zero-interpolator is introduced as an up-sampling scheme to convert the plant to a higher sampling rate. Then a conventional H-infinity method is applied to optimize the controller performance as well as to reduce the effects of aliasing noise caused by the up-sampling scheme. This method is also applied to the design of a dual-stage actuator system of a hard disk drive. The performances are compared with single-rate controllers and improvements of 15 - 50% were obtained. Experiments using a 2.5” hard disk drive were carried out and the effectiveness was confirmed.

17:00
Radial Tracking in High-Speed DVD Players ............ 4705
Bittanti, Sergio
Politecnico di Milano
Dell’Orto, Fabio
STMicroelectronics
Di Carlo, Andrea
STMicroelectronics
Savarese, Sergio M.
Politecnico di Milano

Abstract: The problem considered in this paper is the radial tracking of the optical pick-up in a DVD-ROM. For low-speed players, it is known that this problem can be solved by means of simple lead-lag regulators. For high-speed players the servo design is much more tricky, and a more sophisticated control scheme is required. The control scheme here proposed is constituted by a lead-lag filter, two notch filters and a low-pass filter. This set of filters is implemented in a parallel structure. This architecture is adequate to provide a good radial tracking. The performance of the controller are tested on a real plant, and experimental results are reported.

17:20
LPV Design for a CD Player: An Experimental Evaluation of Performance .................................................. 4711
Dettori, Marco
SC Solutions Inc.
Scherer, Carsten W.
Delft Univ. of Tech.

Abstract: In this paper we present the experimental evaluation of the performance achieved by a Linear Parameterically Varying (LPV) control design for a Compact Disc player servomechanism. Experimental results show that LPV techniques allow to obtain better performance than Linear Time Invariant (LTI) design. Furthermore, we show that the use of a parameter-independent Lyapunov matrix in the synthesis algorithm does not introduce conservatism in our design, as it would be theoretically expected. As a side result of this paper, we prove that in the case of a single scheduling parameter, the use of block-diagonal multipliers is not more conservative than that of full-block multipliers and we provide an alternative algorithm for the construction of a scheduling function which is suitable for real-time implementation.

18:00
Constrained Optimization based Control of Real Time Large Scale Systems: Airjet Object Movement System ........ 4717
Jackson, Warren B.
HP Labs
Fromherz, Markus P. H.
Xerox PARC
Biegelsen, David K.
Xerox PARC
Reich, Jim
Xerox PARC
Goldberg, David
Xerox PARC

Abstract: The control of real time, nonlinear, large-scale systems - systems with large aggregations of sensors and actuators - is seldom explored in actual operating physical systems. In such many-element systems, control issues such as actuation allocation, fusion of sensor data, and system identification emerge as challenging problems for large-scale system control. In this work, constrained optimization is used to solve these problems as applied to the control of an object moving system with 1,152 actuators and 32,000 sensors with a 2 ms control loop time. Solutions for allocating actuation among large numbers of actuators using hierarchical constrained optimization and fusing the output of many sensors into a small number of final measurements under tight real time constraints have been developed. This paper demonstrate that hyper-redundant systems are capable of system self-identification - the aggregate of properties of many elements can be used to measure detailed properties of individual elements. This work demonstrates that constrained optimization can effectively solve problems associated with control of many-element systems.
Abstract: In this paper some recent results on additional dynamics for transformed time delay systems are extended to the case of time varying systems. Special equations which describe this dynamics are derived. Additional restrictions on stability and robust stability imposed by the transformation are obtained.

16:20
Stability of Discrete State Delay Systems .............................  4727
Suh, Young Soo  Univ. of Ulsan

Abstract: A new method to solve a Lyapunov equation for a discrete delay system is proposed. Using this method, a Lyapunov equation can be solved from a simple linear equation and Nth power of a constant matrix, where N is the state delay. Combining a Lyapunov equation and frequency domain stability, a new stability condition is proposed. The proposed stability condition ensures stability of a discrete state delay system whose state delay is not exactly known but only known to lie in a certain interval.

16:40
Controller Design via Pade Approximation can Lead to Instability .......................................... 4733
Silva, Guillermo J. IBM Server Group
Datta, Aniruddha Texas A&M Univ.
Bhattacharyya, Shankar P. Texas A&M Univ.

Abstract: The Pade approximation is often used to approximate a pure time delay by a rational transfer function. In this paper, we show via examples that PID controllers that stabilize such an approximation may actually be destabilizing for the true system. Recent results, giving the entire set of stabilizing PID controllers for finite dimensional linear time invariant systems as well as for systems with time delay, are used to make a comparative study, through examples, of the stabilizing sets for the true plant and its Pade approximants.

17:00
Stability of Time Delay Systems using Numerical Computation of Argument Principles ...............................  4738
Suh, Young Soo  Univ. of Ulsan

Abstract: The paper proposes a new numerical method to check stability of general class of time delay systems. The proposed method checks whether there are characteristic roots whose real values are nonnegative through two steps. Firstly, rectangular bounds of characteristic roots whose real values are nonnegative are computed. Secondly, existence of roots inside the bounds are checked using numerical computation of argument principles. An adaptive discretization is proposed for the numerical computation of argument principles.

17:20
Stability of some Linear Stochastic Systems with Delays ......  4744
Florchinger, Patrick  Univ. Metz

Abstract: The purpose of this paper is to investigate the asymptotic stability in probability of a class of linear stochastic systems with both arbitrary discrete and distributed delays. The stability conditions are expressed in terms of the existence of some positive definite solutions to certain matrix Riccati-type equations.
Asymptotics for Complexity Regularized Transfer
Function Estimation with Orthonormal Bases
Solo, Victor
Univ. of New South Wales

Abstract: We prove some asymptotic properties of a complexity regularized transfer function estimator based on orthonormal bases.

Robust Rational Approximation for Identification
Bultheel, Adhemar
K. U. Leuven
Van Barel, Mark
K. U. Leuven
Rolain, Yves
VUB
Schoukens, Johan
VUB

Abstract: Using vector orthogonal polynomials as basis functions for the maximum-likelihood (ML) frequency domain identification of the rational form of a linear time invariant system is shown to circumvent all the well known numerical conditioning problems. For identification of very high order systems (e.g. 100/100), systems that operate over a wide frequency band, or even in the presence of over- and undermodelling, condition numbers of less than 10 are reported on real measurements and simulation.

Identifiability Analysis of Linear Time-Delay Systems
Orlou, Yuri
CICESE Research Center
Belkoura, Lotfi
Univ. des Sci. et Tech. de Lille
Richard, Jean-Pierre
Ecole Centrale de Lille
Dambrine, Michel
Ecole Centrale de Lille

Abstract: Identifiability analysis is developed for linear time-delay systems with delayed states, control inputs and measured outputs, all with a finite number of lumped delays. These systems are governed by linear functional differential equations with uncertain time-invariant parameters and delays. It is shown that the transfer function of such a system admits the on-line identification if a sufficiently nonsmooth input signal is applied to the system. Sufficiently nonsmooth signals are constructively defined by imposing different smoothness properties on the control input and the state of the system. This definition is verified independently of any underlying time-delay system. By applying the theory developed to linear time-delay systems whose states are available to measurements with an a priori known sensor delay, the system parameters and delays are proven to be, in principle, identifiable if and only if the system is weakly controllable. Just in case, the parameter identifiability is also enforced by a sufficiently nonsmooth control input.

Identification of Continuous-Time Systems
using the Markov-Laguerre Parameters
Zhou, Quan-Gen
Univ. of Toronto
Davison, Edward J.
Univ. of Toronto

Abstract: This paper presents a new realization-based method for identification of multivariable continuous-time systems. Unlike traditional schemes, this method uses a special form of the generalized Markov parameters, called the Markov-Laguerre parameters, to construct a state variable model. It is shown that these parameters may readily be obtained from input-output data by simple schemes. The resultant algorithm obtained thus avoids the difficulty of estimating the Markov parameters associated with traditional methods.

Interplay between Signal Processing and Control
Chair: Dasgupta, Soura
Univ. of Iowa
Co-Chair: Yamamoto, Yutaka
Kyoto Univ.
Organizer: Dasgupta, Soura
Univ. of Iowa
Organizer: Yamamoto, Yutaka
Kyoto Univ.

Abstract: Wavelet theory provides a new type of function expansion and and has found many applications in signal processing. Discrete wavelet transform of a signal x(t) in L2(R) is usually computed by the so-called pyramid algorithm. It however requires a proper initialization, i.e., expansion coefficients with respect to the basis of one of the desirable approximation subspaces. An interesting question is how we can obtain such coefficients when only sampled values of x(t) are available. This paper provides a design method for a digital filter that optimally gives such coefficients assuming certain a priori knowledge on the frequency characteristic of the target functions. We then extend the result to the case of non-orthogonal wavelets. Examples show the effectiveness of the proposed method.

A Blind Approach to Hammerstein Model Identification (I)
Bai, Er-Wei
Univ. of Iowa
Fu, Minyue
Univ. of New Castle

Abstract: This paper discusses discrete Hammerstein model identification using blind system identification approach. By sampling faster at the output for the sampled Hammerstein systems, it is shown that identification of the linear part can be achieved based only on the output measurements that makes Hammerstein model identification possible without knowing the structure of the nonlinearity and the internal variable. The fundamental identifiability problem is solved and several schemes are presented.

Spectral Analysis and Analytic Interpolation (I)
Georgiou, Tryphon T.
Univ. of Minnesota

Abstract: Consider a stationary stochastic input driving a known linear filter and assume knowledge of the resulting covariance of the state vector. We are interested in characterizing all input spectra which are consistent with the given state-covariance. We first identify the dependence of the state covariance on the filter equations and then characterize all admissible input power spectra via solutions to a related analytic interpolation problem.

Subband Coding for Fast Controller Implementation: The General Case (I)
Dasgupta, Soura
Univ. of Iowa

Abstract: This paper concerns a new wavelet packet based design methodology for efficient implementation of digital controllers that operate at very high sampling rates, but for reasons of compactness are fabricated on VLSI chips with limited surface area. The original problem was posed by us in the Proceedings of the last CDC. We argue that this brings about a fundamental tradeoff between sampling speed, accuracy due to signal quantization, and the chip area. Here we reconcile this tradeoff using multirate subband coding techniques, that exploit spectral disparities in the closed loop signals. A precise optimization problem was formulated at the last CDC, but only a very restrictive solution given. In this paper we provide a more general solution to the problem.
Abstract: In this note, we consider a new method for an important aspect of the visual tracking problem. Tracking in the presence of a disturbance is a classical control issue, but because of the highly uncertain nature of the disturbance, this type of problem is very difficult. A key issue in many visual tracking tasks is that of item registration. Image registration is the process of establishing a common geometric reference frame among several data sets taken at different times. In this note, we propose a method of registration based on the Monge--Kantorovich problem of optimal mass transport. We argue that such an approach can also be very useful for several problems in controlled active vision.

17:40 Algorithms for Scheduling of Hidden Markov Model Sensors (I) .................................................. 4818
Krishnamurthy, Vikram
Univ. of Melbourne
Wahlberg, Bo
Royal Inst. of Tech.

Abstract: Consider the Hidden Markov model estimation problem where the realization of a single Markov chain is observed by a number of noisy sensors. The sensor scheduling problem for the resulting Hidden Markov model is as follows: Design an optimal algorithm for selecting at each time instant, one of the many sensors to provide the next measurement. Each measurement has an associated measurement cost. The problem is to select an optimal measurement scheduling policy, so as to minimize a cost function of estimation errors and measurement costs.

18:00 A Novel Model Reduction Method for Sheet Forming Processes using Wavelet Packets ....................... 4820
Fan, Junqiang
Univ. of British Columbia
Dumont, Guy A.
Univ. of British Columbia

Abstract: Cross-directional control of sheet forming processes, such as a paper machine, can involve up to 600 inputs and 3000 outputs. For such large-scale systems, it is necessary to find proper model reduction strategies before starting controller design. This paper introduces a novel model reduction method for such processes based on an efficient modified wavelet packet algorithm. The large dimensional signals in spatial domain can be transformed into a small number of scaling and wavelet coefficients in wavelet domain, thus the dimension of the original input-output model is reduced without losing any significant information. Two additional benefits are obtained: (1) the system's controllability can be significantly improved because the system's condition number is greatly decreased, (2) the physical limits of the actuators can be directly transformed from the original model to the reduced model.

Abstract: This paper deals with unconstrained receding horizon control of nonlinear systems with a general, non-negative terminal cost. Earlier results have indicated that when the terminal cost is a suitable local control Lyapunov function, the receding horizon scheme is stabilizing for any horizon length. In a recent paper, the authors show that there always exist a uniform horizon length which guarantees stability of the receding horizon scheme over any sub-level set of the finite horizon cost when the terminal cost is identically zero. In this paper, we extend this result to the case where the terminal cost is a general non-negative function.

16:20 End-Point Parametrization and Guaranteed Stability for a Model Predictive Control Scheme .................. 4832
Weiland, Siep
Eindhoven Univ. of Tech.
Stoorvogel, Anton A.
Delft Univ. of Tech.
Tiagounov, Andrei A.
Eindhoven Univ. of Tech.

Abstract: In this paper we consider the closed-loop asymptotic stability of the model predictive control scheme which involves the minimization of a quadratic criterion with a varying weight on the end-point state. In particular, we investigate the stability properties of the (MPC-) controlled system as function of the end-point penalty and provide a useful parametrization of the class of end-point penalties for which stability of the controlled system can be guaranteed. The results are successfully applied for the implementation of an MPC controller of a binary distillation process.

16:40 Multiparametric Quadratic Programming ............................... 4851
Bemporad, Alberto
Univ. di Siena
Filippi, Carlo
Univ. di Padova

Abstract: Algorithms for solving multiparametric quadratic programming (mp-QP) were recently proposed in (Bemporad et al., to appear) and (Tondel et al., 2001) for computing explicit Model Predictive Control (MPC) laws. The reason for this interest is that the solution to mp-QP is a piecewise affine function of the state vector and thus it is easily implementable on-line. The main drawback of solving mp-QP exactly is that whenever the number of linear constraints involved in the optimization problem increases, the number of polyhedral cells in the piecewise affine partition of the parameter space may increase exponentially. In this paper we address the problem of finding 'approximate' solutions to mp-QP, where the degree of approximation is arbitrary and allows to trade off between optimality and a smaller number of cells in the piecewise affine solution.

17:20 Use of Exponential Data Weighting in Model Predictive Control Design ............................................. 4857
Wang, Liuping
Univ. of Newcastle

Abstract: The usual design procedures in model predictive control (MPC) use a rectangular type of moving horizon window. The
A Novel Motion Control Design Approach is presented.

Abstract: A new algorithm for the solution of the static output feedback stabilization problem is introduced. This approach contributes to the tracking difficulty in SIMO systems. Furthermore, the variation of the plant direction with frequency also affects the tracking error for SIMO systems are developed. The results show a significant improvement in the closed-loop stability for discrete-time systems.

16:00

A Comparison of Fundamental Model-Based and Multiple Model Predictive Control Algorithms

Auferheide, Brian
Prasad, Vinay
Bequette, B. Wayne
Rensselaer Polytechnic Inst.

Abstract: A multiple model strategy is implemented in a model predictive control framework. The model bank design requires minimal plant knowledge based on the ranges of gains, dominant time constants and time delays. The application example is the isothermal Van de Vusse reaction in a continuous stirred tank reactor, which exhibits challenging input multiplicity behavior. Disturbances include additive input and output noises and changes in system parameters. Results are compared with an Extended Kalman Filter (EKF)-based model predictive controller that uses a fundamental model with a disturbance parameter estimated online. The multiple model predictive controller performance is comparable to that demonstrated by the EKF-based model predictive controller.

16:20

A Novel Algorithm for the Solution of the Static Output Feed-Back Stabilization Problem

Astolfi, Alessandro
Colaneri, Patrizio
Politec. di Milano/Imperial College

Abstract: A new algorithm for the solution of the static output feedback (SOF) stabilization problem for linear SIMO or MISO systems is presented. The algorithm is based on an active disturbance rejection concept, where the disturbances are estimated using an extended state observer (ESO) and compensated in each sampling period. The dynamic compensation reduces the motion system to a double integrator which can be easily controlled using a nonlinear proportional-derivative controller. The proposed Active Disturbance-Rejection Controller (ADRC) consists of the ESO and the nonlinear PD controller and is designed without an explicit mathematical model of the plant. Hence the controller is inherently robust against plant variations. Through simulation, frequency response analysis, and hardware tests, it is shown that the proposed approach is superior to the current PID based technology. It stands out especially in handling set point change, large inertia and friction variations, and external torque disturbance, all of which is seen as “disturbance” by ADRC and is actively compensated. The improvement in transient response and steady state error is also quite evident.

17:00

Implementation of Tracking Controls for Constrained Discrete Time-Varying Systems via Receding Horizon Strategy

Kim, Ki Baek
Califomia Inst. of Tech./Korea Univ.

Abstract: In this paper, a receding horizon tracking control (RHTC) scheme is proposed for input and tracking-error constrained linear discrete time-varying systems. The control scheme is based on the minimization of a finite horizon cost function with finite terminal weighting matrices, which can easily be implemented by using linear matrix inequality (LMI) optimization. The proposed RHTC scheme is discussed in terms of the asymptotic property, feasibility, and closed-loop stability. It is shown that imposing the zero control weighting matrix can guarantee the asymptotic property and feasibility for some special systems and tracking commands, and the closed-loop stability for discrete-time systems.

17:20

Tracking Variable Periodic Signals with Fixed Sampling Rate

Cao, Zhenwei
Central Queensland Univ.
Ledwich, Gerard
Queensland Univ. of Tech.

Abstract: Recent research has shown that the repetitive control is very efficient in tracking periodic signals. However, the existing repetitive control algorithms require an integer number of samples in each period. In some industry applications where the signal period varies but other requirements on the data acquisition system force a fixed sample rate, the number of samples per period may be a non-integer. To address this problem, this paper presents a new adaptive repetitive control, consisting of two portions, the repetitive controller and the nominal controller. The repetitive controller uses a fictitious sampler operating at a variable sample rate maintained at multiple times of the signal frequency, while the nominal controller uses a fixed sampling rate. Interpolations are utilised to generate the fictitious samples required for the repetitive learning. The adaptation of the repetitive controller’s sampling rate is limited to a small value, so that the system stability can be maintained without any changes on the controller parameters. The experimental results on the control of a servomotor demonstrate the effectiveness of the proposed schemes.

17:40

Output-Feedback Tracking Control of a set of Affine Parameter-Dependent Systems

Liao, Fang
Nanyang Tech. Univ.
Wang, Jian Liang
Nanyang Tech. Univ.
Yang, Guang Hong
Natl. Univ. of Singapore

Abstract: Motivated by the aircraft control system design, this paper presents new tests for the stability and performance of a set of affine parameter-dependent linear systems. Based on these tests, the tracking controller design method via output feedback is provided. These tests and design method are based on the notion of affine quadratic stability/performance where the fixed Lyapunov function is replaced by an affine parameter-dependent Lyapunov function. Sufficient conditions to test and realize the stability/performance of this class of systems are given in terms of solv-
ability of linear matrix inequalities (LMIs). These tests and design methods are less conservative than existing methods.

18:00
Model Following Control System for Nonminimum
Phase Plants using Taylor's Expansion ......................... 4897
Kase, Wataru  Osaka Inst. of Tech.

Abstract: Exact model matching method cannot be used for a system having unstable zeros since unstable pole-zero cancellations occur in the overall systems. In this paper, we will propose an approximate cancellation of anti-stable zeros instead of exact cancellations. For this, we will show a design method of approximate polynomials for the inverse of anti-stable polynomials using Taylor's expansion. Then, we will show a design of model following control systems for a plant having unstable zeros based on the pole placement scheme.

FrP10
Learning and Control
Chair: Gorinevsky, Dimitry  Honeywell Inc.
Co-Chair: Gao, Zhiqiang  Cleveland State Univ.

16:00
Singularity-Free Indirect Iterative Learning Control .......... 4903
Jiang, Ping  Tongji Univ.
Unbehauen, Rolf  Univ. Erlangen-Nürnberg
Woo, Peng-Yung  Northern Illinois Univ.

Abstract: In this paper, we investigate trajectory tracking for a general multi-input nonlinear system, where there is no priori knowledge of the system parameters and the form of the nonlinear function. An identification-based indirect iterative learning control (ILC) scheme to repetitively estimate the linearity in a neighborhood of a desired trajectory is presented. How to avoid singularity for the system with unknown control direction during the learning process is discussed. A new parameter modification procedure for the ILC is presented such that the determinant of the estimate of the input coupling matrix is uniformly bounded.

16:20
Control for Cancelling Periodic Disturbances
with Uncertain Frequency ........................................... 4909
Brown, Lyndon J.  Univ. of Western Ontario
Zhang, Qing  Univ. of Western Ontario

Abstract: This paper presents a new algorithm to cancel periodic disturbances with uncertain frequency. The disturbances are canceled using a controller with an internal model structure in parallel with a traditional PI controller. It is shown that under ideal circumstances the time varying states of the internal model can be mapped to two time invariant variables, the magnitude or energy of the internal model and the difference between the nominal error frequency and the true error frequency. An additional integral controller then can be used to reduce this error to zero. The stability of the feedback control system including this algorithm is justified by singular perturbation theory. Simulations demonstrate the validity of the analytical results, the ability of this algorithm to identify the frequency of periodic disturbances and the capability of this feedback control system to reject periodic disturbances with uncertainty in frequency.

16:40
Time-Delayed Chaos Control with Repetitive Learning .......... 4915
Song, Yanxing  Central Queensland Univ.
Yu, Xinghao  Central Queensland Univ.
Xu, Jian-Xin  Natl. Univ. of Singapore
Chen, Guanrong  City Univ. of Hong Kong

Abstract: In this paper, a time-delayed chaos control method based on repetitive learning is proposed. The integration of the repetitive learning control principle and the time delayed chaos control technique en-
dynamics with uncertain parameters. The smart materials bonded along the links are used to active suppress the residue vibration. Simulation results are provided to show that both proposed approaches can control the system successfully and effectively.

FrP11
Flow Control II
Chair: Bamieh, Bassam
Univ. of California, Santa Barbara
Co-Chair: Rogers, Eric
Univ. of Southampton

16:00
Modeling Flow Statistics using the Linearized Navier-Stokes Equations
Jovanović, Mihailo
Univ. of California, Santa Barbara
Bamieh, Bassam
Univ. of California, Santa Barbara

Abstract: We develop a model for second order statistics of turbulent channel flow using an associated linear stochastically forced input-output system. The correlation operator of the velocity fields is computed by solving the appropriate Lyapunov equations of a Galerkin approximation of the original system. We use a variety of excitation force correlations and show the dependence of the velocity fields statistics on them. By using certain excitation correlations, we are able to closely match flow statistics computed from Direct Numerical Simulation (DNS) of channel flow. The implications of these results for the proper weight selection in optimal control problems for channel flow are discussed.

16:20
H-Infinity Control for Non-Periodic Planar Channel Flows
Baramov, Lubimor
Honeywell Prague Lab.
Tutty, Owen R.
Univ. of Southampton
Rogers, Eric
Univ. of Southampton

Abstract: This paper deals with finite-dimensional boundary control of the linearized 2D flow between two infinite parallel planes. Surface transpiration along a few regularly spaced sections of the bottom wall is used to control the flow. Measurements from several discrete, suitably placed shear-stress sensors provide the feedback. Unlike other studies in this area, the flow is not assumed to be periodic, and spatially growing flows are considered. An $H_{\infty}$ control scheme is designed to guarantee stability for the model set and to reduce the wall-shear stress at the channel wall. This design is tested by simulations with a nonlinear Navier-Stokes PDE solver in the loop, where the results show that the controller is effective in reducing shear disturbances.

16:40
On some Control Problems in a Shallow-Water Model
Belmiloudi, Aziz
INSA de Rennes

Abstract: In this work we develop methods of control for the modelization of long waves occurring in shallow water zones. The observation is the variability of the sea level. It is deduced from satellite measurements. The equations satisfied by the depth and the depth averaged velocity are of nonlinear shallow-water type. The result of existence and uniqueness of the solution for the direct problem is given in the case of Dirichlet non-homogeneous boundary conditions. We establish, by means of minimizing sequences, the existence of an optimal control in the case of small data and a very viscous fluid. In order to characterize it, we build a sequence of control problems corresponding to a linearization of the problem. We obtain the necessary conditions of optimality. The optimality conditions for the nonlinear problem is obtained as the limit of the penalization. Our approach can be used to develop a numerical scheme.

17:00
Robust Regulation of a River Reach
Goverened by Hayami Model
Chentouf, Boumediene
Sultan Qaboos Univ.
Xu, Cheng-Zhong
INRIA-Lorraine
Boulbrachene, Messaoud
Sultan Qaboos Univ.

Abstract: In this note, we study the problem of robust regulation of a river reach system described by Hayami model. We propose a low-gain boundary PI-controller which assigns the spectrum of the closed loop system in the open left half plane and assures exponential stability. Moreover, the output regulation is guaranteed independently of any constant (known or unknown) perturbation. Numerical examples are also given to illustrate the obtained theoretical results.

17:20
Nonlinear Observer Design for Water Level Control in Irrigation Canals
Besançon, Gildas
Inst. Natl. Polytec. de Grenoble
Dulhote, Jean-François
Inst. Natl. Polytec. de Grenoble
Georges, Didier
Inst. Natl. Polytec. de Grenoble

Abstract: This paper is devoted to nonlinear observer and control design for irrigation canals or dam-river systems. Such systems are known to be described by non-linear partial differential equations (Saint-Venant equations). Here, a finite-dimensional model, previously developed by collocation methods and used for control design, is now further used for flow rate and water infiltration observation. In particular, it is pointed out how the obtained estimates can successfully be used in the previously designed state feedback controller, resulting in a water level control law only using three level measurements along the canal. The results are illustrated in simulation, both on the considered simplified model and on more realistic representations of water flow dynamics.

17:40
Active Disturbance Rejection Control for Web Tension Regulation
Hou, Yi
Cleveland State Univ.
Gao, Zhiqiang
Cleveland State Univ.
Jiang, Fangjun
Cleveland State Univ.
Boulter, Brian T.
Cleveland State Univ.

Abstract: A new control method is proposed for tension regulation in a web transport system. It is based on a unique active disturbance rejection control (ADRC) strategy, which actively compensates for dynamic changes in the system, and unpredictable external disturbances. A simulation of an industrial application is used to provide realism. The results show the effectiveness of the proposed tension controller in coping with large dynamic variations commonly seen in web tension applications. The remarkable disturbance rejection capability of an ADRC is also demonstrated.

18:00
A Framework for Destabilization of Dynamical Systems and Mixing Enhancement
Bamieh, Bassam
Univ. of California, Santa Barbara
Mezic, Igor
Univ. of California, Santa Barbara
Farjad, Makan
Univ. of California, Santa Barbara

Abstract: A framework is presented for the destabilization of dynamical systems that are subject to disturbances and controls. Such destabilizing controllers are designed using a methodology analogous to "gain scheduling". At each point in the state space, the controller is designed to destabilize the local linearization of the system. The local destabilization objective is formulated as a Linear Quadratic Optimal (LQ) control problem with an indefinite performance objective, and is therefore similar to problems in differential games and $H_{\infty}$ norm calculations. Optimal feedback controls are found by solving the appropriate Ricatti equations. This problem formulation is motivated by the objective of mixing enhancement in nonlinear dynamical systems, which in turn motivates the consideration of these LQ problems with finite-time horizons and exponentially discounted performance objectives.
We prove that the worst-case marking of a GMEC specifica-
tion of independent critical places corresponds to the worst-case
marking of each critical place.

**17:20**

**Supervisory Control of Railway Networks with Petri Nets**

Giua, Alessandro  
Univ. di Cagliari

Abstract: In this paper we deal with the problem of designing con-
trol logic for railway networks using Petri nets. We first use the
framework of supervisory control theory, taking into account the
presence of uncontrollable and unobservable transitions, to derive
a maximally permissive control policy that ensures safeness. The
Corresponding controller takes the form of monitor places, possibly
with self-loops. In a second step, we investigate the liveness prob-
lem and present a heuristic technique based on structural analy-
sis that, whenever applicable, leads to live models. As an exam-
ple, we consider a segment of the railway network in Sardinia, Italy.

**17:40**

**Markov Nets: Probabilistic Models for Distributed and Concurrent Systems**

Benveniste, Albert  
IRISA-INRIA

Abstract: For distributed systems, i.e. large networked complex
systems, there is a drastic difference between a local view and
knowledge of the system, and its global view. Distributed systems
have local state and time, but do not possess global state and time
in the usual sense. In this paper, motivated by the monitoring of
distributed systems and in particular of telecommunications net-
works, we develop Markov nets as an extension of Markov chains
and hidden Markov models for distributed and concurrent systems.
By a concurrent system, we mean a system in which components
may evolve independently, with sparse synchronizations. We fol-
low a so-called true concurrency approach, in which neither global
state nor global linear time are available. Instead, we use only local
states in combination with a partial order model of time. Our basic
mathematical tool is that of Petri net unfoldings.
supported on a given disc D centered at zero in the complex plane.
Under these conditions, the expected value of the magnitude-
squared of the overall system transfer function at a fixed frequency
is seen to be maximized when each gain has the uniform distribution
over D and minimized when each gain has the impulse distribution
over D. This result is extended to show that an $H_2$ measure of the
gain is also maximized and minimized in the same way. The results
apply to general quotients of multilinear functions which includes sys-
tem transfer functions obtained using Mason's formula.

16:40
Randomized Algorithms for Robust Stability
and Control of Stochastic Hybrid Systems with
Uncertain Switching Policies ............................................. 5026
Ugrinovskii, Valery A. Australian Defence Force Acad.

Abstract: It has recently been suggested that the probabilistic
approach may offer some numerical advantages when applied to ro-
bust control problems. This paper investigates new possibilities
which this approach may offer in relation to robust stability and
control of hybrid systems with uncertain switching policies. We
consider a hybrid system modeled as a linear continuous-time sys-
tem with random structure. The changes in the system structure
are governed by a discrete state Markov process which has an un-
certain transition probability law. We show that a quadratic
Lyapunov function for the system can be efficiently constructed us-
ing a combination of randomization techniques and convex optimi-
ization. This leads to tractable methodologies for robust stability
analysis and robust control design for the class of uncertain hybrid
systems under consideration.

17:00
Randomized Searches and Nonlinear
Programming in Trajectory Planning .................................... 5032
Karatas, Timur Univ. of Illinois, Urbana-Champaign
Bullo, Francesco Univ. of Illinois, Urbana-Champaign

Abstract: This paper presents a novel trajectory planning algorithm
for nonlinear dynamical systems evolving in environments with
complex obstacles. The incremental search algorithm entails (i) a
global exploration strategy based on randomization and on a rap-
Idly-exploring heuristic, and (ii) a local planner based on collocation
and nonlinear programming. To numerically validate the design, we
consider a six degree of freedom vehicle model subject to satura-
tion limits on the control inputs and obstacles on the state vari-
ables. Experimental results indicate that the proposed scheme outperforms implementations based solely on nonlinear program-
ing or on randomization.

17:20
An Algorithm for Generating Transfer Functions
Uniformly Distributed Over H-Infinity Balls .......................... 5038
Lagoa, Constantino M. Pennsylvania State Univ.
Sznaier, Mario Pennsylvania State Univ.
Barmish, B. Ross Case Western Reserve Univ.

Abstract: Probabilistic methods have recently been the subject of
considerable attention in the context of robust performance as-
essment. However, in spite of their potential, these methods have
been limited to the case of parametric uncertainty; the problem of
sampling causal bounded operators is largely open. In this paper,
we take steps towards removing this limitation by providing a com-
putationally efficient algorithm aimed at uniform sampling over balls
contained in suitably chosen proper subspaces of $H_{\infty}$. As shown
in the paper, samples generated from these balls can be used, for
instance by Monte Carlo methods, to assess robust performance
for uncertainty models involving the $H_{\infty}$ norm.

17:40
Law of the Iterated Logarithm for a Constant-
Gain Linear Stochastic Gradient Algorithm .......................... 5044
Joslin, Jeff A. Univ. of Waterloo
Heunis, Andrew J. Univ. of Waterloo

Abstract: We characterize the finite-horizon limiting properties of a
constant-gain linear stochastic gradient algorithm as the adaptation
gain tends to zero, in the form of a functional law of the iterated
logarithm.

18:00
On Partially Observed Stochastic Shortest Path Problems .... 5050
Patek, Stephen D. Univ. of Virginia

Abstract: We analyze a class of partially observed stochastic shortest
path problems. These are terminating Markov decision process with
imperfect state information that evolve on an infinite time horizon and
have a total cost criterion. For well-posedness, we make reasonable
stochastic shortest path type assumptions: (1) the existence of a pol-
icy that guarantees termination with probability one and (2) the prop-
erty that any policy that fails to guarantee termination has infinite ex-
pected cost from some initial state. We also assume that termination
is perfectly recognized. We establish the existence of a stationary
optimal policy along with the existence of a unique bounded solution
to Bellman's equation. We also reveal the convergence properties of
value and policy iteration. For the case where policies exist that do
not guarantee termination, the dynamic programming operator fails
to be a contraction mapping with respect to any norm, somewhat
complicating the analysis.