TA01-1 1503

Nonlinear Decoupling in the Presence of Sensor and Actuator Deadtimes

Wright, Raymond A.; Dow Chemical Co.
Kravaris, Costas; Univ. of Michigan

This work concerns the synthesis of nonlinear controllers for multivariable nonlinear systems in the presence of sensor and actuator deadtimes. The system is described in terms of a control-affine state-space model, with deadtimes appearing in the inputs and the outputs, but not in the states. The objective is to synthesize an output feedback controller for a decoupled closed-loop system with linear input / output behavior. The first step in the solution of the control problem involves deriving conditions for feasibility of closed-loop deadtimes, for which a causal controller achieving the control objectives would exist. For this purpose, the original system is converted into lower block triangular (LBT) form, after rearrangement and partitioning, using standard graph-theoretic methods. In this form, simple sufficient conditions for feasibility of closed-loop deadtimes are derived, which rely only on the structural properties of the system. The second step involves derivation of a control law so that the closed-loop system is input / output linear and decoupled, with deadtimes equal to the smallest ones that satisfy the feasibility conditions. An explicit state-space realization for the control law is derived using the LBT form of the system description and the model-state feedback structure.

TA01-2 1508

Robust Feedback Linearization and Fuzzy Control

Pfeiffer, Carlos F.; Univ. of Texas at Austin
Edgar, Thomas F.; Univ. of Texas at Austin
Fernandez, Benito; Univ. of Texas at Austin

Three design techniques for global nonlinear controllers are discussed and linked together: feedback linearization, sliding mode control and fuzzy heuristic control. It is shown how feedback linearization and sliding mode control can be combined to design a robust feedback linearization controller, and how some properties of this kind of controller can be used to obtain guidelines for the application of fuzzy heuristic controllers. The techniques are applied to a stirred tank reactor system.

TA01-3 1515

On the Recoverability of Nonlinear State Feedback Laws by Extended Linearization Control Techniques

Cloutier, James R; Air Force Research Lab.
Stansbery, Donald T.; Questech, Inc.
Sznaier, Mario; Pennsylvania State Univ.

Extended linearization is the process of factoring a nonlinear system into a linear-like structure $dx/dt = A(x)x + B(x)u$ which contains state-dependent coefficient (SDC) matrices. An extended linearization control technique is any technique which (a) treats the SDC matrices A(x) and B(x) as being constant and (b) uses a linear control synthesis method on the linear-like structure to produce a closed-loop SDC matrix which is pointwise Hurwitz. This paper investigates the recoverability of nonlinear state feedback laws using extended linearization control techniques with particular focus on the state-dependent Riccati equation (SDRE) method. By recoverable it is meant that a given nonlinear state feedback law of the form $u = k(x)$ can be obtained (or recovered) from a given control design method. Conditions relating to recoverability by extended linearization control methods are provided. An example is then presented where it is attempted to recover an optimal feedback law. It is shown that there exists no extended linearization control technique that is capable of recovering the given law. It is then shown how the feedback law can be recovered by using two control techniques which are variations of the SDRE method.

TA01-4 1520

An Adaptive Nonlinear Output Feedback Controller for Robot Manipulators

Hajjir, Hosam; Carleton Univ.
Schwartz, Howard M.; Carleton Univ.

An adaptive controller is proposed, for the tracking control of robotic manipulators that does not require the measurement of joint velocities. An observer is used to generate an estimate of the joint velocities and an observer-based identifier is used to update the parameter vector estimate. The controller is proven to guarantee uniform ultimate boundedness of the tracking error. Simulation results are given to show the effectiveness of the control algorithm and to illustrate the theoretical properties of the proposed method.

TA01-5 1525

Nonlinear Feedback Controller Design of a Pneumatic Muscle Actuator System

Repperger, Daniel W; Air Force Research Lab.
Johnson, K. R.; Air Force Research Lab
Phillips, C. A.; Wright State Univ.

A study is conducted on several paradigms to provide closed-loop position control of an actuator powered by a pneumatic muscle system. This actuator has many advantages including having extremely high power/weight and power/volume ratios, being light-weight, autonomous, and safe. An implementation as a tracking controller using a gain scheduling method is presented.

TA01-6 1530

Control of the Czochraski Crystal Growth Process - Almost Disturbance Decoupling with Global Asymptotic Stability

Bao, Xiangyu; Univ. of Virginia
Lin, Zongli; Univ. of Virginia
Zhang, H.; SUNY at Stony Brook
Prasad, V.; SUNY at Stony Brook
Shamash, Y.A.; SUNY at Stony Brook

The nonlinear heat-melt dynamics of a Czochraski crystal growth process is identified to be in the global normal form with globally asymptotically stable zero dynamics. Nonlinear feedback laws are then constructed that achieve almost disturbance decoupling with global asymptotic stability at a desired operating point. The design relies on the recent developments in nonlinear control theory, and is in contrast with traditional crystal growth process control design methods which are based on linearization through Taylor series expansion and hence always result in stabilization results with unknown (possibly small) basin of attraction.

TA02-1 1535

Stabilizing Receding Horizon Control of Nonlinear Systems: a Control Lyapunov Function Approach

Jadbabaie, Ali; California Inst. of Tech.
Yu, Jie; California Inst. of Tech.
Hauser, John; Univ. of Colorado at Boulder

In this paper, a modified version of the receding horizon control of nonlinear systems is proposed. The new approach is based on a finite horizon optimal control problem with a terminal cost. This method can be treated as an extension of recent results of De Nicolao et al. to the case where a Control Lyapunov Function (CLF)-based stabilizing control law is available. The terminal cost is chosen to be a CLF which is also an upper bound on the cost-to-go if the stabilizing control law is applied. The control law is computed a priori using a Control Lyapunov Function. Effectiveness of the results is illustrated by applying this approach to the planar model of a ducted fan with a CLF obtained using Quasi LPV methods.

TA02-2 1540

Globally Convergent Adaptive Control of Spacecraft Angular Velocity without Inertia Modeling

Ahmed, Jasim; Univ. of Michigan
Bernstein, Dennis S.; Univ. of Michigan

The problem of a spacecraft tracking a desired angular velocity trajectory is addressed using adaptive feedback control. The control law, which has the form of a sixth-order dynamic compensator, does not require knowledge of the inertia or center of mass of the spacecraft. A Lyapunov argument is used to show that tracking is achieved globally. A constant spin about a body fixed axis is commanded to illustrate the control algorithm. Finally, periodic commands are used to identify the inertia matrix of the spacecraft.

TA02-3 1545
An Adaptive Control Approach to Satellite Formation Flying with Relative Distance Constraints
Lawton, Jonathan R.; Brigham Young Univ.
Beard, Randal W.; Brigham Young Univ.
Hadaegh, Fred Y.; California Inst. of Tech.

In this paper we present a spacecraft control for rigid fleet rotations. This is done by creating a fleet template which is slowly rotated to generate desired trajectories for each individual spacecraft. By rotating the template slow enough each spacecraft is able to track these trajectories to within a given tolerance in the presence of actuator saturation. Simulations for a three spacecraft fleet are given.

TA02-4 1550
A Quasi On-Line Tuning Structure for Optimum Delayed Feedback Vibration Absorber
Jalili, Nader; Northern Illinois Univ.
Olgac, Nejat; Univ. of Connecticut

An automatic tuning structure is presented for a recently introduced active vibration suppression methodology, Delayed Feedback Vibration Absorber (DFVA). The DFVA, is an improved version of Delayed Resonator (DR) vibration absorber. Optimum DFVA offers minimum peak frequency response within a given wide band excitation frequency range. This work introduces a new scheme for the tuning of the DFVA against parametric uncertainties in the system. This is achieved through a nested identification and control optimization procedure. Feasibility of the proposed methodology is demonstrated through simulations. Results show that using only three iterations of a nested identification/optimization, the frequency response properties are improved better than 25%.

TA02-5 1555
Enhanced Motion and Sizing of Bank in Moving-Bank MMAE
Vasquez, Juan R.; Air Force Inst. of Tech.
Maybeck, Peter S.; Air Force Inst. of Tech.

The focus of this research is to provide methods for generating precise parameter estimates in the face of potentially significant parameter variations such as system component failures. The standard Multiple Model Adaptive Estimation (MMAE) algorithm uses a bank of Kalman filters, each based on a different model of the system. Parameter discretization within the MMAE refers to selection of the parameter values assumed by the elemental Kalman filters, and dynamically redeclaring such discretization yields a moving-bank MMAE. A new online parameter discretization method is developed based on the probabilities associated with the generalized Chi-squared random variables formed by residual information from the elemental Kalman filters within the MMAE. This new algorithm is validated through computer simulation of an aircraft navigation system subjected to interference/jamming while attempting a successful precision landing of the aircraft.

TA02-6 1563
Adaptive Control of Nonlinear Attitude Motions Realizing Linear Closed Loop Dynamics
Schaub, Hanspeter; Texas A&M Univ.
Akella, Maruthi; Texas A&M Univ.
Junkins, John L.; Texas A&M Univ.

An adaptive attitude control law is presented that realizes linear closed-loop dynamics in the attitude error vector. The Modified Rodrigues Parameters (MRPs) are used as the kinematic variables since they are nonsingular for all possible rotations. The desired linear closed-loop dynamics can be of either PD or PID form. Only a crude estimate of the moment of inertia matrix is assumed to be known. An open-loop nonlinear control law is presented which yields linear closed-loop dynamics in terms of the MRPs. An adaptive control law is developed which asymptotically enforces these desired linear closed-loop dynamics in the presence of large inertia and external disturbance model errors. Since the unforced closed-loop dynamics are nominally linear, standard linear control methodologies can be employed to satisfy design requirements. The adaptive control law is shown to track the desired linear performance asymptotically without requiring apriori knowledge of either the inertia matrix or external disturbance.

TA03-1 1568
A Numerical Projection-Based Approach to Nonlinear Model Reduction and Identification (I)
Lee, Jay H.; Purdue Univ.
Pan, Yangdong; Purdue Univ.
Sung, Su Whan; Purdue Univ.

In this paper, we propose a general method for nonlinear model reduction and identification, inspired by the concept of subspace identification. We propose to use the artificial neural networks to find a nonlinear projection operator that serves to define the reduced state out of the full state or out of an input-output time series. We investigate the viability of the method for both deterministic and stochastic systems.

TA03-2 1573
Multi-Level Pseudo-Random Signal Design and "Model-on-Demand" Estimation Applied to Nonlinear Identification of a RTP Water Reactor (I)
Braun, M. W.; Arizona State Univ.
Rivera, Daniel E.; Arizona State Univ.
Stenman, Anders; Linkoping Univ.
Foslien, Wendy; Honeywell Tech. Center
Hrenya, C.; Honeywell Tech. Center

Guidelines are presented for specifying the design parameters of multi-level pseudo-random sequences in a manner useful for "plant-friendly" nonlinear system identification. These multi-level signals are introduced into a Rapid Thermal Processing wafer reactor simulation and compared against a well-designed pseudo-random binary sequence (PRBS). The resulting data serves as a database for a "Model-on-Demand" (MoD) predictor. MoD estimation is attractive because it requires less engineering effort to model a nonlinear plant, compared to global nonlinear models such as neural networks. The improved fit of multi-level signals over the PRBS signal, as well as the usefulness of the MoD estimator, is demonstrated on validation data.

TA03-3 1578
Parameter Identification and On-Line Estimation of a Reduced Kinetic Model (I)
Littell, Jonathan D.; Villanova Univ.
Muske, Kenneth R.; Villanova Univ.
Dell'Orco, Phillip C.; Los Alamos National Lab.
Le, Loan A.; Los Alamos National Lab.
Flesner, Raymond L.; Los Alamos National Lab.

In this work, we present the estimation techniques used to update the model parameters in a reduced kinetic model describing the oxidation-reduction reactions in a hydrothermal oxidation reactor. This model is used in a nonlinear model-based controller that minimizes the total aqueous nitrogen in the reactor effluent. Model reduction is accomplished by combining similar reacting compounds into one of four component groups and considering the global reaction pathways for each of these groups. The reduced kinetic

model developed for this reaction system provides a means to characterize the complex chemical reaction system without considering each chemical species present and the reaction kinetics of every possible reaction pathway. For the reaction system under study, model reduction is essential in order to reduce the computational requirement so that on-line implementation of the nonlinear model-based controller is possible and also to reduce the amount of information required for the model.

TA03-4 1583
Nonlinear Model Reduction of Chemical Reaction Systems (I)
Vora, Nishith P.; Univ. of Minnesota
Daoutidis, Prodromos; Univ. of Minnesota

In this paper, we consider a broad class of non-isothermal, spatially homogeneous reaction systems, with fast and slow reactions. The dynamic model of such systems exhibits stiffness (time-scale multiplicity) but is not in a standard singularly perturbed form. For such systems, we address the derivation of reduced order nonlinear models of the slow dynamics, through i) the identification of algebraic constraints that need to be satisfied in the slow time scale (e.g. reaction equilibrium constraint in the case of fast reversible reactions), and ii) the derivation of state-space realizations of the resulting differential algebraic system that describes the slow dynamics.

TA03-5 1588
Quasi-Steady State Assumptions in the Modeling of Bioreactors: Model Reduction and Validation (I)
Weijers, S.; Eindhoven Univ. of Tech.
Weiss, Martin; Eindhoven Univ. of Tech.

The quasi-steady state assumption is a usual and convenient way to obtain reduced order models. However its applicability is in general strongly dependent on field expertise and ad hoc considerations. The paper is an attempt to introduce a systematic procedure for identifying possible quasi-steady state assumptions and to check their consistency for the case of dynamical models of bioreactors. The result is a combination of symbolic and numerical manipulations. The procedure is tested on the model of a bioreactor with one substrate species, one biomass species, and aeration.

TA03-6 1593
Model Reduction and Control of a Class of Distributed Parameter Processes (I)
Mahadevan, Nagabhushan; Univ. of South Carolina
Hoo, K. A.; Univ. of South Carolina
Adzievski, Kuzman; South Carolina State Univ.

Mathematical models that describe distributed parameter systems are composed of systems of partial differential and algebraic equations (PDAE's). The solution of these systems is usually a high order (infinite dimensional) model. For controller synthesis and due to practical considerations, a reduced –order model (finite) is preferred. This work addresses the development of reduced -order , finite dimensional model by proposing to use multi-resolution methods that not only provide a control –relevant model but also yield a representation of the system's multi-scale and local behavior. A simple system – heat transfer along a flat metal plate, is used to demonstrate the proposed solution and is compared to the solution obtained using singular functions approach.

TA04-1 1598
On Integral-Input-to-State Stabilization
Liberzon, Daniel; Yale Univ.
Sontag, Eduardo D.; Rutgers Univ.
Wang, Yuan; Florida Atlantic Univ.

This paper continues the investigation of the recently introduced integral version of input-to-state stability (iISS). We study the problem of designing control laws that achieve iISS disturbance attenuation. The main contribution is a concept of control Lyapunov function (iISS-CLF) whose existence leads to an explicit construction of such a control law. The results are compared with the ones available for the ISS case.

TA04-2 1603
A Note on the Integral to Integral Uniform Output to State Stability Property
Krichman, Mikhail; Rutgers Univ.

This paper considers an ``integral-to-integral'' version of uniform output to state stability (iiUOSS), which happens to be equivalent to UOSS property in case the control system is forward complete.

TA04-3 1608
Lyapunov Analysis of Semistability
Bhat, Sanjay P.; Indian Inst. of Tech.
Bernstein, Dennis S.; Univ. of Michigan

Semistability is the property whereby the solutions of a system converge to stable equilibrium points determined by the initial conditions. Important applications of this notion of stability include lateral aircraft dynamics and the dynamics of chemical reactions. A notion central to semistability theory is that of convergence in which every solution converges to a limit point that may depend upon the initial condition. We give sufficient conditions for convergence and semistability of nonlinear systems. By way of illustration, we apply these results to study the semistability of linear systems and some nonlinear systems.

TA04-4 1613
Analysis of a Complex Activator-Inhibitor Equation
Justh, Eric; Univ. of Maryland
Krishnaprasad, P. S.; Univ. of Maryland

Basic properties of solutions and a Lyapunov functional are presented for a complex activator-inhibitor equation with a cubic nonlinearity. Potential applications include control of coupled-oscillator arrays (for quasi-optical power combining and phased-array antennas), and control of MEMS actuator arrays (for micro-positioning small items).

TA04-5 1618
Stabilization of Relative Equilibria for Systems on Riemannian Manifolds
Bullo, Francesco; Univ. of Illinois at Urbana-Champaign

This paper describes a systematic procedure to exponentially stabilize relative equilibria of mechanical systems. We review the notion of relative equilibria and their stability in a Riemannian geometry context. Potential shaping and dissipation are employed to obtain full exponential stabilization to the desired trajectory. Two necessary conditions are that the effective potential be positive definite over a specified subspace and that the system be linearly controllable.

TA04-6 1623
An Off-Axis Circle Criterion for Feedback Systems Containing a Single Time-Invariant Nonlinearity
Okuyama, Yoshifumi; Tottori Univ.
Takemori, Fumiaki; Tottori Univ.

This paper describes a graphical evaluation of the robust stability for control systems in a frequency domain in which Popov's criterion was expressed in an explicit form. The control system described herein is a feedback system containing a single time-invariant nonlinearity in the forward path. By applying the small gain theorem that concerns L2 gain in regard to a nonlinear subsystem with a free parameter, a robust stability condition for control systems with a sector nonlinearity is presented. Using this concept, we will show a representation of an off-axis circle criterion on a Nyquist diagram, and propose an evaluation method of the stability from the relative position with the vector locus of the open loop frequency response

characteristic. In this paper, the relationship between the robust stability condition and the usual gaphical method of Popov's criterion is also discussed.

TA05-1 1627
State-Space Formulation and Controller Design of Three-Dimensional Channel Flows (I)
Kang, S. M.; Univ. of California at Los Angeles
Ryder, V.; Univ. of California at Los Angeles
Cortelezzi, L.; McGill Univ.
Speyer, Jason L.; Univ. of California at Los Angeles

Robust reduced-order feedback control of near wall turbulence of three dimensional Poiseuille flow in a periodic channel is investigated. Control of near-wall disturbances is achieved through wall-transpirations, and measurements of wall-shear stresses are fed back to the controller. Linear-Quadratic-Gaussian/loop-transfer-recovery synthesis and model reduction techniques are used to construct the robust feedback controllers from the linearized three dimensional Navier-Strokes equations. The quadratic cost function is composed of the total wall-shear stresses. Using Galerkin's method, the system, controller, and output are decomposed into a set of independent systems, controllers, and outputs for each pair of streamwise and spanwise wave numbers. This decomposition allows reduced-order controllers for each wave number pair to be implemented in parallel. It is assumed that the controllers and sensors will be distributed in fine enough resolution to provide the measurements and control needed. This preliminary study develops a controller for a single pair of wave numbers. The single wave number pair controller produces closed loop poles that show a more rapid decay of disturbances than the open loop system.

TA05-2 *
Active Control of Wall Bounded and Free Shear Flows (I)
Koumoutsakos, Petros; ETH Zentrum

In this work we discuss active control strategies for drag reduction in wall bounded flows (turbulent channel flow, bluff body flows) and mixing in free shear flows (jet flow). In the first case we present feedback control algorithms based on the identification and manipulation of vorticity and its generation at the solid boundaries of incompressible flows. In the case of free shear flows we discuss open-loop control schemes, derived from the parameter optimization of control devices using evolution strategies.

TA05-3 1632
On the Applicability of Linear Feedback for Nonlinear Systems in Fluid Mechanics (I)
Bewley, Thomas R.; Univ. of California at San Diego

This paper examines the application of linear optimal control theory to a low-order nonlinear chaotic convection problem. Linear control feedback is found to be fully effective only when it is switched off while the state is far from the desired equilibrium point, relying on the attractor of the system to bring the state into a neighborhood of the equilibrium point before control is applied. Linear estimator feedback is found to be fully effective only when a) the Lyapunov exponent of the state estimation error is negative, indicating that the state estimate converges to the uncontrolled state, and b) the estimator is stable in the vicinity of the desired equilibrium point. The aim in studying the present problem is to understand better some possible pitfalls of applying linear feedback to nonlinear systems in a low-dimensional framework. Such an exercise foreshadows problems likely to be encountered when applying linear feedback to infinite-dimensional nonlinear systems such as turbulence. It is important to understand these problems and the remedies available in a low-dimensional framework before moving to more complex systems such as turbulence.

TA05-4 4532
Disturbance Energy Amplification in Three-Dimensional Channel Flows (I)
Bamieh, Bassam A.; Univ. of California at Santa Barbara
Dahleh, Mohammed; Univ. of California

We investigate energy amplification in parallel channel flows, where background noise is modeled as stochastic excitation of the linearized Navier-Stokes equations. This amplification is quantified as an H2 norm of an infinite dimensional system. We show analytically that the energy of three-dimensional streamwise-constant disturbances achieves O(R^3) amplification. Our basic technical tools are analytical calculations of the traces of solutions of operator Lyapunov equations, which yield the covariance operators of the forced random velocity fields. The dependence of these quantities on both the Reynolds number and the spanwise wave-number are computed. We show how the amplification mechanism is due to a coupling between normal velocity and vorticity disturbances, which in turn is due to non-zero mean shear and disturbance spanwise variation. The implications of very large norms, and the corresponding frequency response shapes are interpreted in the context of predicting transition to turbulence and the accompanying coherent structures.

TA05-5 1637
Controlling Nonlinear Water Waves: Boundary Stabilization of the Korteweg-De Vries-Burgers Equation (I)
Liu, Wei-Jiu; Univ. of California at San Diego
Krstic, Miroslav; Univ. of California at San Diego

The problem of global exponential stabilization by boundary feedback for the Korteweg-de Vries-Burgers equation on the domain $[0,1]$ is considered. We derive a control law of the form $u(0)=u_x(1)= u_{xx}(1)-k[u(1)^3+u(1)]=0$, where k is a sufficiently large positive constant, and prove that it guarantees L^2-global exponential stability, H^1-global asymptotic stability, and H^1-semiglobal exponential stability. The closed-loop system is shown to be well posed.

TA05-6 *
Dynamics, Visualization and Control of Mixing (I)
Mezic, Igor; Univ. of California

Abstract not available.

TA06-1 1642
Neural Networks for Control (I)
Hagan, Martin T.; Oklahoma State Univ.
Demuth, H. B.; Univ. of Idaho

The purpose of this tutorial is to provide a quick overview of neural networks and to explain how they can be used in control systems. We introduce the multilayer perceptron neural network and describe how it can be used for function approximation. The backpropagation algorithm (including its variations) is the principal procedure for training multilayer perceptrons; it is briefly described here. Care must be taken, when training perceptron networks, to ensure that they do not overfit the training data and then fail to generalize well in new situations. Several techniques for improving generalization are discused. The tutorial also presents several control architectures, such as model reference adaptive control, model predictive control, and internal model control, in which multilayer perceptron neural networks can be used as basic building blocks.

TA06-2 *
Neural Networks for Diesel Engine Control (I)
Jaliwala, Salim A.; Cummins Engine Co. Inc.

What does evolution of the species, survival of the fittest, ten billion neurons and Ivan Pavlov's classical experiments have in common with diesel and natural gas engines?Ê To find out, you are invited to this presentation, whichÊ will take you behind the scenes to show you how artifical neural networks and genetic algorithms are being

used to - (a) control and fine tune engines automatically, (b) learn and detect engine misfires and other component malfunctions (c) develop virtual sensors, (d) characterize engine duty cycles, and (e) find optimum control settings. Specifically, this presentation will provide examples to demonstrate concepts such as self-organizing memory, 2-D visualization, feature fill-in, genetic reinforcement learning, optimization, and non - intrusive learning.

TA06-3 1657
Neural Network Control in the Metals Industry (I)
Wilson, Edward; SAI International

Because of their capabilities for adaptation, nonlinear function approximation, and parallel hardware implementation, neural networks have proven to be well suited for some important control applications. This paper briefly presents three examples of neural-network control applications on laboratory and industrial hardware. An overall problem-solving approach is presented as well as suggestions for neural-network research that will benefit industrial control optimization.

TA06-4 1659
Control of the NASA 16-Foot Transonic Tunnel with the Self-Organizing Map (I)
Motter, Mark A.; NASA Langley Research Ctr.

A predictive, multiple model control strategy is developed based on an ensemble of local linear models of the nonlinear system dynamics for a transonic wind tunnel. The local linear models are estimated directly from the weights of a self-organizing map (SOM). Multiple self-organizing maps collectively model the global response of the wind tunnel to a finite set of representative prototype controls. These prototype controls partition the control space and incorporate experiential knowledge gained from decades of operation. Each SOM models the combination of the tunnel with one of the representative controls, over the entire range of operation. The SOM based linear models are used to predict the tunnel response to a larger family of control sequences which are clustered on the representative prototypes. The control sequence which corresponds to the prediction that best satisfies the requirements on the system output is applied as the external driving signal. Each SOM provides a codebook representation of the tunnel dynamics corresponding to a prototype control. Different dynamic regimes are organized into topological neighborhoods where the adjacent entries in the codebook represent the minimization of a similarity metric which is the essence of the self organizing feature of the map. Thus, the SOM is additionally employed to identify the local dynamical regime, and consequently implements a switching scheme that selects the best available model for the applied control. Experimental results of controlling the wind tunnel, with the proposed method, during operational runs where strict research requirements on the control of the Mach number were met, are presented. Comparison to similar runs under the same conditions with the tunnel controlled by either the existing controller or an expert operator indicate the superiority of the method.

TA06-5 1661
Applications of Neural Networks for Transducer Calibration and Signal Processing of Transducer Data Containing Periodic Interference (I)
Schultz, Roger L.; Halliburton Energy Services

In this paper two practical industrial neural network applications will be presented. A new method of calibrating quartz transducers will be described in which a neural network is used to accomplish a dynamic calibration of a transducer pair for a range of temperatures and pressures. In order to compensate for the undesirable transient thermal effects on the pressure transducer performance, tapped delay lines containing previous and subsequent temperature and pressure sensor outputs are used as inputs to the neural network. This new method allows the time-dependent qualities of the quartz-oscillator transducer to be included in the calibration scheme. A second application in which real-time adaptive neural network filtering is used to enhance the detection of subsurface explosives detonation in an oilwell will also be presented. In the oilfield, accelerometers are used to monitor the surface structure of an oilwell to detect the detonation of subterranean explosives which are used to perforate well casings and formations so oil production from the perforated zones may commence. The method presented here shows how neural network filtering may be used to dramatically improve the detection of weak subsurface signals in the presence of heavy noise contamination in the monitored signal.

TA07-1 1663
Self-Tuning Torque Control of Brushless Motors
Aghili, Farhad; McGill Univ.

A ripple-free feedforward torque control (electronic commutation) of brushless motor is applicable if the torque-angle relationship associated with the motor phases is accurately known. In this paper, we propose a linear estimator technique, based on the electric model of the motor, which requires the measurements of phase current, voltage and motor angle to extract the Fourier coefficients of the phase torque-angle profile. The torque tracking error asymptotically converges to zero, if the estimated parameters are used in the computation of phase currents dictated by any ripple-free commutation law. Experimental results have demonstrated convergence of the estimated parameters to their true values.

TA07-2 1668
Induction Motor Control System Performance under Magnetic Saturation
Abdel Fattah, Hossam A.; Case Western Reserve Univ.
Loparo, Kenneth; Case Western Reserve Univ.
Emara, Hassan M.; Cairo Univ.

The response of an induction motor speed control system with a saturating main magnetic path is studied using simulation. The performance of different types of vector control laws and a feedback linearizing scheme are considered on an (a,b) model of the induction motor which includes saturation. Cases where magnetic saturation drastically affects the control system performance are identified, in particular the sensitivity of feedback linearizing schemes to magnetic saturation is investigated.

TA07-3 1673
Rule-Based Balanced Energy Controller
Atmur, Robert; The Boeing Co.

The aim of this paper is to present a non-linear rule based balanced energy control scheme, its synthesis and digital implementation. The plant under consideration is a rotating shaft magnetically suspended by means of two multi-axis hybrid active magnetic bearing (AMB) actuators in order to control five degrees of freedom. The problem is to provide improved step and impulse response performance over any Proportional and Differential (PD) control and provide a closed-form rule-based equation for the rigid body control solution. This paper focuses on the development of a closed-form solution to the problem of rigid body control of AMBs and the realization of this control method using energy as the domain of control analysis. Included is the comparison of modeled and measured impulse response at various system sample rates. Some experimental results are presented, corresponding to the response of a 40,000 RPM flywheel system supported with this control method. This method provides a new view on the problem of closed loop control.

TA07-4 1677
Dynamic Control of Permanent Magnet Synchronous Motors in Automotive Drive Applications
Stewart, Paul; Univ. of Sheffield
Kadirkamanathan, Visakan; Univ. of Sheffield

Due to factors such as high power density and efficiency, low torque ripple and maintenance, and extremely wide operating speed range,

permanent magnet AC motors (PMAC) are the subject of intense development for traction drive applications. Maximum torque production for both traction performance and electronic gear changing requires the operating condition to be as close to voltage saturation as possible in the flux-weakening region. A fully dynamic model reference flux-weakening controller with feedback linearization decoupling is presented, which allows the maximum torque speed trajectory to be followed dynamically, without saturation of the current controllers.

TA07-5 1682
Control and Analysis of Synchronous Reluctance Motors
Lyshevski, Sergey; Purdue Univ. at Indianapolis
Nazarov, Alexander; Purdue Univ. at Indianapolis

Nonlinear mathematical models of synchronous reluctance motors are developed in the machine (abc) and in the quadrature, direct and zero (qd0) variables. Kirchhoff's voltage law and Newton's second law are used to find the differential equations which map the circuitry and torsional-mechanical dynamics. The Park transformation is applied in model developments to derive the differential equations in the rotor reference frame. A robust controller with nonlinear error and state feedback maps is designed to guarantee robust tracking, to ensure stability, as well as to attain disturbance rejection. Modeling results are given.

TA07-6 1687
Experimental Comparative Studies on Neural Network Controllers for DC-Motor Micromaneuvering
Chan, To; Polytechnic Univ.
Tzes, Anthony; Polytechnic Univ.
Wang, Pei-Kai; Polytechnic Univ.

The performance attributes of a structure-free and a model-based neural network (NN) controller for dc-motor micromaneuvering purposes are compared in experimental studies in this article. The former NN has a generic structure independent of the friction model, where its input vector consists of the time history of the motor angular shaft velocity within a time window. The NN provides the nonlinear control mapping to the supplied motor input through adjustment of its weights using the sign gradient descent algorithm. The model-based NN has a predetermind structure that depends on the utilized friction model. This NN provides a feedforward term which compensates for the inherent friction while rejecting noise via an additional linear velocity error feedback term. Application of both NN-based controllers on a dc-motor system reveals that the model-based NN has a superior performance measured in terms of its: a) convergence, b) implementation computational requirements, and c) integral square error after the weights' convergence.

TA08-1 1692
Hysteresis Control of Nonlinear Single-Acting Actuators as Applied to Brake/Throttle Switching (I)
Gerdes, J. Christian; Stanford Univ.
Hedrick, J. Karl; Univ. of California at Berkeley

This paper expands upon some of the design techniques of Gerdes and Hedrick (1999) in order to analyze a class of switched nonlinear systems with hysteresis. Physically, this class represents systems in which the input is supplied by two single-acting actuators (one capable of "pushing," the other of "pulling"), each possessing first-order nonlinear dynamics. The basic control structure proposed involves multiple sliding surface control together with a hysteresis element designed to reduce chattering problems. The physical motivation for such a system comes from the problem of coordinating throttle and brake actuation in vehicle longitudinal control. This paper describes a choice of controller gains which guarantee a desired level of performance in the presence of model uncertainty, the hysteresis element and the rate limit saturation exhibited by single-acting actuators upon release. The paper concludes with experimental verification that the hysteresis controller eliminates chatter without degrading tracking performance.

TA08-2
Withdrawn

TA08-3 4538
Hydraulic Brake System Modeling and Control for Active Control of Vehicle Dynamics (I)
Kuang, Ming L. ; Ford Motor Co.
Fodor, Michael; Ford Motor Co.
Hrovat, D.; Ford Motor Co.
Tran, M. ; Lockheed Martin Missiles & Space Co.

Active control of vehicle dynamics has become one of the top competitive features in today's automobiles. Vehicle dynamic control systems include antilock brakes (ABS), traction control (TC) and yaw control. The realization of these systems relies on the control of hydraulic brakes as well as other vehicle systems. Modeling of the hydraulic brake system is essential to the design of vehicle dynamic control systems. This paper describes the derivation of a hydraulic brake system model using the bond graph technique, and the design of a feedback control system with an adaptive gain schedule PD controller. In addition, simulation and experimental results are presented to illustrate the model validation and the controller performance.

TA08-4 1697
Driver Assisted Yaw Rate Control (I)
Brennan, Sean; Univ. of Illinois at Urbana-Champaign
Alleyne, Andrew G.; Univ. of Illinois at Urbana-Champaign

A yaw rate controller was developed that utilizes the rear wheels of a vehicle to improve steering performance. The driver retains control over the front wheels, while a Model Reference Controller (MRC) commands the rear wheels. Experimental results were obtained by implementing the MRC on a scale vehicle. These results indicate significant performance improvement over proportional yaw-rate controller methods often used for rear-wheel control. Specifically, the MRC method was found to be less sensitive to model non-linearities such as actuator dynamics and steering linkage kinematics

TA08-5 1702
Adaptive Robust Control for Active Suspensions (I)
Chantranuwathana, Supavut; Univ. of Michigan
Peng, Huei; Univ. of Michigan

This paper presents a nonlinear active suspension controller, which achieves high performance by compensating for the hydraulic actuator dynamics. The control design problem is decomposed into two loops. At the top is the main loop, which calculates the desired force signal by using a standard LQ design process. An Adaptive Robust Control technique is used to design a force controller such that it is robust against actuator uncertainties. Both State feedback and output feedback algorithms are presented. Simulation results show that the proposed controller works well compared with conventional controllers.

TA08-6 1707
Semi-Physical Modeling of the Vertical Vehicle Dynamics (I)
Halfmann, C.; Darmstadt Univ. of Tech.
Nelles, Oliver; Darmstadt Univ. of Tech.
Holzmann, H.; Darmstadt Univ. of Tech.

Globalization and growing new markets force the car manufacturers to work faster and more efficient in developing new safety and comfort features for their vehicles. Hence, time-consuming expensive testing is more and more replaced by computer simulations. Normally, these simulations are based on complex physical models describing the dynamic behavior of the vehicle and its components. Sometimes, physical modeling of the nonlinear behavior of certain vehicle components can be very difficult. In these cases, neural networks may be used to model the systems' nonlinearities. This paper discusses the advantages of combining

physical modeling with neural networks to a semi-physical process model. The vertical vehicle dynamics are used as example.

TA09-1 1712
Global Boundary Stabilization and Regularization of Burgers' Equation (I)
Balogh, Andras; Univ. of California at San Diego
Krstic, Miroslav; Univ. of California at San Diego

In this paper we consider several results from our recent work concerning stabilization and regularization of Burgers' equation. We consider the viscous Burgers equation under recently proposed nonlinear boundary conditions which guarantee global asymptotic stabilization and semiglobal exponential stabilization in H^1 sense. We show global existence and uniqueness of classical solutions with initial data which are assumed to be only in L^2. To do this, we establish a priori estimates of up to four spatial and two temporal derivatives, and then employ the Banach fixed point theorem to the integral representation with a heat kernel. Our result is global in time and allows arbitrary size of initial data. It strengthens recent results by Byrnes, Gilliam, and Shubov, Ly, Mease, and Titi, and Ito and Yan. We include a numerical result which illustrates the performance of the boundary controller.

TA09-2 1717
Optimal Location of Sensors and Actuators for an Active Noise Control Problem (I)
Fahroo, Fariba; Naval Postgraduate School
Demetriou, Michael A.; Worcester Polytechnic Inst.

In this work we consider the problem of optimal location of actuators and sensors for optimizing their performance in reducing the noise field in a cavity. The control strategy is based on a static output feedback control, and the optimization problem is formulated as minimizing the quadratic cost function which is averaged over the random intitial conditions. The solution of the optimization problem requires solving a matrix Riccati equation and a Lyapunov equation. We demonstrate the effectiveness of the control strategy and its dependence on location of the sensors and actuators in several numerical examples.

TA09-3 1722
Numerical Investigation on Optimal Actuator / Sensor Location of Parabolic PDE's (I)
Demetriou, Michael A.; Worcester Polytechnic Inst.

The objective of this investigation is to provide a methodology for obtaining the optimal location of actuators and sensors in systems (thermal/fluids/material processing) whose dynamics are described by parabolic partial differential equations. The method to be employed for this optimal actuator/sensor location is based on optimal/robust control. First, an optimal state feedback gain, parametrized by the unknown actuator locations, is found by minimizing an appropriately chosen (control) performance index. Minimization of the optimal value of the quadratic cost is then performed with respect to (spatial) locations in order to attain the minimum of this location-parametrization performance index. Its minimum then yields the optimal actuator location. The incorporation of partial measurements, which introduces the sensor location(s) into the control problem, is achieved by forcing the resulting system to be a dissipative one, i.e. have a strictly positive real transfer function. This is done so that when either a simple static output feedback, even with a non optimal static gain, or a sector-bounded nonlinear output feedback, would guarantee closed loop stability. Numerical examples with simulation results are presented to support this investigation.

TA09-4 1727
Robust Output Feedback Control of Parabolic PDE Systems with Time-Dependent Spatial Domains (I)
Armaou, Antonio; Univ. of California at Los Angeles
Christofides, Panagiotis D.; Univ. of California at Los Angeles

We synthesize robust static output feedback controllers for systems of quasi-linear parabolic partial differential equations with time-dependent spatial domains and uncertain variables. The controllers are successfully applied to a typical diffusion-reaction process with moving boundary and uncertainty.

TA09-5 1734
Infinite-Dimensional Geometric Regulation in Solid Freeform Fabrication (I)
Skordeli, Eleni; Tufts Univ.
Doumanidis, Charalabos; Tufts Univ.

In this article, a distributed-parameter geometry control scheme is established to obtain a desired surface topology in material deposition processes, by modulating the feed and motion of a moving mass source. This is based on dynamic geometry shaping by a real-time optimization technique. The control strategy is founded on an analytical model of such material addition, using superposition of unit deposition distributions, composed of elementary spherical primitives. This real-time surface geometry model, with its parameters identified by in-process profile measurements, is used for Smith-prediction of the material shape in the unobservable deposition region. The methodology is tested in geometric command following on a fused wire deposition welding station, using optical sensing by a scanning laser stripe. The infinite-dimensional modeling and control methhodology is applicable to solid freeform fabrication methods, generating 3-D solid objects by material deposition in successive layers made of adjacent beads.

TA09-6 1739
A Moving Boundary Diffusion Based Model for the Corrosion of Concrete Wastewater Systems: Simulation and Experimental Validation (I)
Bohm, Michael; Univ. of Berlin
Devinny, Joseph; Univ. of Southern California
Jahani, Fereidoun; Univ. of Southern California
Mansfeld, Florian; Univ. of Southern California
Rosen, I. Gary; Univ. of Southern California
Wang, Chunming; Univ. of Southern California

An experiment is constructed which provides data from which the efficacy of a moving boundary reaction-diffusion based model for the sulfide corrosion of concrete can be established. The model is derived and its finite dimensional approximation is discussed. A diffusion rate is identified using data supplied by the experiment. The results of the experiment and the comparison of experimental data with simulation studies based upon the model are discussed.

TA10-1 1744
Simulation of a Load Dispatch Control System
Kallappa, Pattada A.; Pennsylvania State Univ.
Ray, Asok; Pennsylvania State Univ.
Phoha, Shashi; Pennsylvania State Univ.

This paper focuses on the specific issue of machinery health and availability of individual power generating units on a power distribution grid. It addresses the general problem of automatic load dispatch and control in electric power distribution systems while highlighting this issue. This unified concept of load dispatch control and health management is incorporated into the decision-making process of a remotely located Control Center. The goal is to improve overall efficiency and availability of the entire grid. Fuzzy logic is introduced to realize an availability-improving controller for load dispatch. Preliminary results of simulation experiments are presented to demonstrate the feasibility of this concept.

TA10-2 1749
Design of a Test Rig for Measurement of Stiffness and Damping Characteristics of Computer Keyboard Keys
Nagurka, Mark L.; Marquette Univ.

Marklin, Richard; Marquette Univ.
Liu, Kai; Marquette Univ.

This paper describes the development of a special-purpose test rig for the measurement of stiffness and damping characteristics of computer keyboard keys. The ultimate aim of this project is to gain a more complete understanding of the tactile "feel" of computer keyboard keys by quantifying their mechanical impedance. To achieve this goal, a computer-controlled test rig that can measure key displacement, velocity, and contact force has been designed. The objectives of the measurement and data analysis, and a description of the hardware and software configuration, including the data acquisition method and motion control system, are presented.

TA10-3 1754
3D Modeling Visualization for Studying Controls of the Jumbo Container Crane
Klaassens, J. B.; Delft Univ. of Tech.
Honderd, Ger; Delft Univ. of Tech.
EL Azzouzi, Abdessalam; Delft Univ. of Tech.
Cheok, Ka Chai; Oakland Univ.
Smid, G.E.; Oakland Univ.

The jumbo container cranes at the European Container Terminal (ECT) in Rotterdam are subject of a long term study to automate the international seaport and make container handling more efficient. In this paper appropriate details of the 3D dynamical behavior of the container is modeled. Simulation and visualization are carried out to study the crane behavior under disturbing conditions like unbalanced center of gravity and varying side winds. The software is used to evaluate time-optimal trajectories and control schemes for the dynamics of the electrical drives, and of the swing and skew of the container.

TA10-4 1759
A Simulation Study on Adaptability to Environmental Variations Based on Ecological Systems
Tian, Ya-Jie; Kyoto Inst. of Tech.
Sannomiya, Nobuo; Kyoto Inst. of Tech.
Nakamine, Hiroshi; Kyoto Univ. of Education

Many ecological systems have an ability to adapt themselves to environmental variations and the adaptability varies with the structures of systems. In this paper, as an example of ecological systems, two kinds of fish school models with different characteristics are presented for investigating the adaptability to environmental variations. The model parameters are estimated by using the observation data obtained from water tank experiments. Various simulations are carried out for the case where an obstacle is set in the behavior space. The adaptability to environmental variations is examined by using the simulation results.

TA10-5 1764
Fire Control Architecture Modeling and Animation
Coleman, Norm; US Army, TACOM-ARDEC
May, Ricky; US Army, TACOM-ARDEC
Yip, Pak; US Army, TACOM-ARDEC
Lin, Ching-Fang; American GNC Corp.
Feng, Xu; American GNC Corp.
Zhou, Zhi-Qiang; American GNC Corp.

A reference architecture model of a typical fire control system has been established with the Real-time Object-Oriented Modeling (ROOM) environment, ObjecTime. A GUI communicates with the reference architecture to test a specific design based on the architecture implementation. The GUI also communicates with an independent ballistics calculation program to send the target parameters and receive the ballistics calculation results.

TA10-6 1769
A Synthetic Environment for Simulation and Visualization of Dynamic Systems
Innocenti, Mario; Univ. of Pisa
Pollini, Lorenzo; Univ. of Pisa

The present paper illustrates some strategies for dynamic systems simulation. Hardware in the loop, man in the loop and software integration are key points for rapid prototyping and safe design of complex man machine interfaces, from nuclear plants operation panels to deep submerged underwater vehicles to hypersonic airplanes cockpits. Specific software appears to be needed in order to give designers tools to analyze and simulate complex integrate projects. Problems of high performance, realistic environment and vehicles simulation are addressed, with particular attention to synthetic worlds creation and visualization. A new software is presented, capable of handling most of the simulation and visualization requirements highlighted in the paper.

TA11-1 1774
Measures of Modal and Gross Controllability/Observability for Linear Time-Varying Systems
Choi, Jae Weon; Pusan National Univ.
Lee, Ho Chul; Pusan National Univ.
Zhu, J. Jim; Louisiana State Univ.

For linear time-varying systems described by the triple (A(t),B(t),C(t)) where A(t),B(t),C(t) are the system, input, and output matrices, respectively, we propose novel concepts for measures of modal and gross controllability/observability.

TA11-2 1776
Finite-Time Control for Uncertain Linear Systems with Disturbance Inputs
Amato, F.; Univ. Degli Studi di Napoli Federico II
Ariola, Marco; Univ. Degli Studi di Napoli Federico II
Abdallah, Chaouki T.; Univ. of New Mexico
Dorato, Peter; Univ. of New Mexico

In this paper we consider the static output feedback, finite-time disturbance rejection problem for linear systems with time-varying norm-bounded uncertainties. The first result provided in the paperis is a sufficient condition for finite-time state feedback disturbance rejection in the presence of constant disturbances. This condition requires the solution of an LMI. Then we consider the more general output feedback case, which is shown to be reducible to the solution of an optimization problem involving Bilinear Matrix Inequalities. Finally we deal with the case in which the disturbance is time-varying and generated by a linear system.

TA11-3 1781
On Finite-Time Control of Inner Systems
Ludlage, Jobert; Eindhoven Univ. of Tech.
Weiland, Siep; Eindhoven Univ. of Tech.
Stoorvogel, Anton A.; Eindhoven Univ. of Tech.

It is well known that non-minimum phase zeros of dynamical systems restrict the achievable performance of closed-loop transfer functions. If performance is specified in terms of finite time proerties, then it it is not evident that the zero structure of transfer functions limits the achievable performance of the controlled system. In this paper it is shown that the Hankel singular values of the inner factor of the system transfer function provide relevant information for achievable (finite time) performance of the controlled system. The solution of two tracking problems is presented and discussed. Simulation examples illustrate the results.

TA11-4 1786
Analysis and Control of Finite Time-Variation Systems
O'Brien, Jr., Richard; United States Naval Academy

In this paper, the class of finite time-variation systems is considered. These linear, time-varying systems admit a state space realization and the coefficient matrices of this realization are constant outside a finite interval. Controller synthesis based on a finite time-variation

model is a compromise between a finite horizon, time-varying control problem and a infinite horizon, time-invariant control problem. Moreover, system theoretic concepts of poles and frequency response can be defined in a natural and useful manner.

TA11-5 1791
Temporal Difference Methods for the Maximal Solution of Discrete-Time Coupled Algebraic Riccati Equations
Costa, Oswaldo Luiz V.; Univ. of Sao Paulo
Aya, Julio Cesar Ceballos; Univ. of Sao Paulo

In this paper we present an iterative technique for deriving the maximal solution of a set of discrete-time coupled algebraic Riccati equations (CARE), based on temporal difference methods. CARE are related to the optimal control of Markovian jump linear systems and have been extensively studied over the last few years. We trace a parallel with the theory of temporal difference algorithms for Markovian decision processes to develop a lambda-policy iteration like algorithm for the maximal solution of these equations. For the special cases in which lambda=0 and lambda=1 we have the situation in which the algorithm reduces to the iterations of the Riccati difference equations (value iteration) and quasi-linearization method (policy iteration) respectively. The advantage of the proposed method is that an appropriate choice of lambda between 0 and 1 can speed up the convergence of the policy evaluation step of the policy iteration method by using value iteration.

TA11-6 1796
Finite-Time Instability of Time-Varying Linear Singular Systems
Kablar, Natasa A.; Lola Inst.
Debeljkovic, D. L. J.; Univ. of Belgrade

The main features of finite-time instability concept are presented for both time-invariant and time-varying linear singular systems operating in free and forced regime. New results for above-mentioned class of systems are in the form of sufficient conditions, derived by using Lyapunov-like approach. Paper presents generalization of previously gathered results and their extension in treating finite-time instability.

TA12-1 1801
Using Scales in the Multi-Objective Approach
Kim, Kyung-Soo; KAIST
Jabbari, Faryar; Univ. of California at Irvine

Scales are used to reduce the conservatism encountered in most multi-objective approaches. While the most general case (i.e., matrix scales) results in a nonconvex problem, use of scalar scales lead to convex searches in the analysis and state feedback problems. Numerical examples to show the effectiveness of the suggested approach, and output feedback synthesis are also discussed.

TA12-2 1803
Finite-Time Stability of Linear Singular Systems: Bellman-Gronwall Approach
Debeljkovic, D.L.J.; Univ. of Belgrade
Kablar, Natasa A.; Lola Inst.

This paper examines continual linear singular systems. It has been formulated, derived and proved Bellman-Gronwall lemma that can be efficiently used in Non-Lyapunov stability and instability examination of above mentioned class of systems.

TA12-3 1807
State Tracking through Optimized Trajectory Tracking
Nagy, Endre; Japan

A new computational method is presented in this paper for solution of the noncausal optimal tracking problem for discrete time systems. The method may be used for both linear systems (LQ tracking) and nonlinear systems. Solution of the problem may be obtained with a simple recurrent algorithm which is derived from an optimization procedure. For an LQ state tracker, a procedure is shown how to compute the time varying optimum feedback gain in function of state variables.

TA12-4 1812
Intelligent Algorithms for H_Infinity Optimal Placement of Actuators and Sensors in Structural Control
Chemishkian, Sergey; Echelon Corp.
Arabyan, Ara; Univ. of Arizona

Four algorithms are described to search and find spatial configuration for the placement of a finite number of actuators and sensors on a continuous flexible structure to reduce deformations in the structures to a minimum in H{inf} sense. The computational cost of the optimal mapping search is reduced through four techniques. First, the computationally expensive goal function based on the complete H{inf} design is replaced by a two-step hybrid function, which performs a computationally inexpensive pass-fail test and proceeds to the complete H{inf} design only if the test was passed. Second a target H{inf} norm used in the mentioned pass-fail test is adjusted based on the already evaluated mappings in order to increase the number of failed tests and reduce the number of complete H{inf} designs. Third, the exhaustive search as the basic search technique is replaced by a more intelligent genetic algorithm. Finally, the search is implemented on a parallel computer. The algorithms are benchmarked for two test cases: a model of a simply supported beam, and a model of the UCLA Large Space Structure.

TA12-5 1817
Nonlinear Programming Approach to Bi-Affine Matrix Inequality Problems in Multiobjective and Structured Control
Lee, Joon Hwa; Univ. of Seoul

In this paper, some nonlinear minimization problems are proposed for obtaining a solution of the biaffine matrix inequality (BMI) problem. An algorithm is also proposed for solving the nonlinear minimization problems. The algorithm can be easily implememted with the existing convex optimization codes. This nonlinear programming approach can be applied to all multiobjective and structured control problems such as the simultaneous stabilization by static or dynamic output feedback, the mixed H_{2}/H_{∞} control, and the decentralized control which can be reduced to BMI problems. The effectiveness is illustrated by numerical examples.

TA12-6 1822
Analytical Design for Open Loop Unstable Processes with Time Delay
Zhang, Weidong; Shanghai Jiaotong Univ.
Xu, Xiaoming; Shanghai Jiaotong Univ.

This paper presents an efficient method for designing the controller for open loop unstable processes with time delay. Based on the optimal control theory and robust control theory, the stabilizing controller of the closed loop system is parameterized, an optimal design index is introduced for controller design, and explicit formulas are derived analytically. The optimal controller can be equivalent to the Smith predictor. It is found that the classical Smith predictor can not be used for the control of open loop unstable processes. By using the rational interpolation technique to cancel the right half plane zero of the controller, an approximate method is developed to implement the new controller in the unity feedback control loop. Examples are given to illustrate the new method.

TA13-1 1827
Fuzzy Descriptor Systems: Stability Analysis and Design via LMIs
Taniguchi, Tadanari; The Univ. of Electro-Communications
Tanaka, Kazuo; The Univ. of Electro-Communications
Yamafuji, Kazuo; The Univ. of Electro-Communications
Wang, Hua O.; Duke Univ.

A fuzzy descriptor system is defined in this paper. Six kinds of stability conditions for the fuzzy descriptor system are derived and

represented in terms of linear matrix inequalities (LMIs). The stability analysis is reduced to a problem of finding a common Lyapunov function. An LMI design approach is employed to find stable feedback gains and a common Lyapunov function.

TA13-2 1832
Parallel Distributed Compensation for Takagi-Sugeno Fuzzy Models: Multiobjective Controller Design
Li, Jing; Duke Univ.
Niemann, David D.; Duke Univ.
Wang, Hua O.; Duke Univ.
Tanaka, Kazuo; The Univ. of Electro-Communications

This paper discusses multi-objective controller synthesis for the fuzzy T-S (Takagi-Sugeno) model. Various performance specifications are included. Both the state-feedback controller and the dynamic feedback controller are presented. They are in the format of a PDC (parallel distributed compensation) controller which is essentially a nonlinear controller. The controller synthesis is formulated as an LMI problem. The approach in this paper can also be applied to hybrid or switching systems.

TA13-3 1837
Nonlinear Model Following Control via Takagi-Sugeno Fuzzy Model
Taniguchi, Tadanari; The Univ. of Electro-Communications
Tanaka, Kazuo; The Univ. of Electro-Communications
Yamafuji, Kazuo; The Univ. of Electro-Communications
Wang, Hua O.; Duke Univ.

This paper presents a unified approach to nonlinear model following control that contains the regulation and servo control problems as special cases. A new parallel distributed compensation (PDC) for fuzzy reference models is proposed. The new PDC fuzzy controller mirrors the structures of Takagi-Sugeno fuzzy models that represent a nonlinear system and a nonlinear reference model. We present a linearization technique as a basic result. Conditions to linearize the error system between the feedback system and the nonlinear reference model are obtained in terms of linear matrix inequalities (LMIs). Design examples are illustrated to show the utility of the nonlinear model following control.

TA13-4 1842
Mamdani Fuzzy Controller on NBV Space
Yang, Yuguang; Shinshu Univ.
Endou, Noboru; Shinshu Univ.
Wasaki, Katsumi; Shinshu Univ.
Ohkubo, Keiji; Shinshu Univ.
Shidama, Yasunari; Shinshu Univ.

By regarding the set of fuzzy membership functions as a subset of normal bounded variation (NBV) space, we show it's compactness in weak* topology. We prove also that the Mamdani controller is a continuos functional on the set in the same topology. The results is an extension of [1], and makes it possible to consider pathological membership functions such as characteristic function. As an application, we discuss the existence of optimal solution in a fuzzy control.

TA13-5 1846
Robust Discrete-Time Fuzzy Control of Composite Nonlinear Systems by Tuning Consequent Membership Functions
Lin, Wei-Song; National Taiwan Univ.
Tsai, Chih-Hsin; National Taiwan Univ.

A discrete-time fuzzy controller is proposed to achieve the robust tracking control of composite multivariable nonlinear systems. The control strategy is to decouple the subsystems and to facilitate the robust property by fine-tuning the consequent membership functions of the fuzzy controllers. An on-line tuning mechanism enables the discrete-time fuzzy system to effectively deal with the equivalent uncertainty resulted by function approximation error, disturbance, measurement noise or effect of interconnection among subsystems. Using Lyapunov stability theory, the tracking error residual set of the overall system with the proposed controller has been proved to be uniform ultimate bounded. Simulation results of a two-link robot control demonstrate the effectiveness and robustness of the design.

TA13-6 *
Fuzzy Sliding Mode Design for Output Feedback Control
Peng, Pei-Yuan; United Technologies Research Ctr.

Abstract not available.

TA14-1 1851
A New Lagrangian Dual Global Optimization Algorithm for Solving Bilinear Matrix Inequalities
Tuan, Hoang Duong; Nagoya Univ.
Apkarian, Pierre; ONERA-CERT
Nakashima, Y.; Nagoya Univ.

A new global optimization algorithm for solving Bilinear Matrix Inequalities (BMI) problems is developed. It is based on a dual Lagrange formulation for computing lower bounds that are used in a branching procedure to eliminate partition sets in the space of nonconvex variables. The advantage of the proposed method is twofold. First, lower bound computations reduce to solving easily tractable Linear Matrix Inequality (LMI) problems. Secondly, the lower bounding procedure guarantees global convergence of the algorithm when combined with an exhaustive partitioning of the space of nonconvex variables. Another important feature is that the branching phase takes place in the space of nonconvex variables only, hence limiting the overall cost of the algorithm. Also, an important point in the method is that separated LMI constraints are encapsulated into an augmented BMI for improving the lower bound computations. Applications of the algorithm to robust structure/controller design are considered.

TA14-2 1856
Optimal Robust Disturbance Attenuation for MIMO Uncertain Systems in H_Infinity
Djouadi, Mohamed Seddik; Georgia Inst. of Tech.

In this paper, we consider the optimal robust disturbance attenuation problem (ORDAP) for multi-input multi-output (MIMO) uncertain plants. Duality theory is used to show existence of optimal feedback laws. Next, a key multiplication operator acting on particular vector-valued Hardy spaces is introduced. It is then proved that ORDAP for MIMO systems is equal to the operator induced norm of a specific operator. The latter is shown to be a combination of multiplication and Toeplitz operators. An ``infinite matrix'' representation with respect to a canonical basis is derived, and the norm of the relevant operator is approximated by special matrix norms.

TA14-3 1861
Optimal Structure Design using Branch and Bound
Sipila, Jaime D; Univ. of California at Los Angeles
M'Closkey, Robert; Univ. of California at Los Angeles
Packard, Andrew K.; Univ. of California at Berkeley

A branch and bound algorithm is used to determine optimal spring rates and damping coefficients in flexible structures although the formalism is easily adaptable to desigining passive control systems. The goal is to minimize the $\mathcal{H}_{\infty}$ norm from disturbance forces to displacements and velocities of selected degrees of freedom. The success of the branch and bound algorithm largely depends upon the quality of upper and lower bounds for the objective function. A comparison on two design problems is made between a tight, but computationally expensive, lower bound, and a simple, computationally cheap, lower bound. Our conclusion is that the extra investment in time to compute the tight bound is well worth the effort and leads to a dramatic savings in overall computation time.

TA14-4 1866
LMI Based Design of Mixed H_2/H_Infinity Controllers: the State Feedback Case
Halder, Bijit; Stanford Univ.
Kailath, Thomas; Stanford Univ.

A mixed H_2/H_infinity controller minimizes the H_2 norm of a closed-loop map over all admissible controllers while satisfying an H_infinity constraint on another closed-loop map. In this paper we shall develop an efficient iterative algorithm for numerical computation of the fixed-order mixed controllers. In the proposed technique we break up the original non-convex problem into a series of convex subproblems each of which can be converted into semidefinite programming problems that can be easily solved. Numerical examples are presented to demonstrate the improvement in the H_2 performance of the mixed H_2/H_infinity controller over the commonly used central H_infinity controller.

TA14-5 1871
Low-Order Controller Design for Model Matching Optimization using Coprime Factors and Linear Matrix Inequality
Wang, Shaopeng; Rensselaer Polytechnic Inst.
Chow, Joe H.; Rensselaer Polytechnic Inst.
Minto, K. Dean; General Electric Co.
Rajamani, Ravi; General Electric Co.

This paper develops an algorithm to design low-order controllers for solving the model-matching problem of multi-input, multi-output (MIMO) systems. It extends a method proposed previously for single-input, single-output (SISO) systems. The design method requires only the solution of a convex optimization problem. The technique integrates several well-known results in control theory. An important step is the use of coprime factors so that based on strictly positive real (SPR) functions, feedback stabilization using MIMO low-order controllers becomes testing the feasibility of a convex programming problem. An LV100 engine model matching design is used to demonstrate the algorithm.

TA14-6 1876
A Design Method for Fixed-Order H_Infinity Controllers via Bilinear Matrix Inequalities
Imae, Joe; Iwate Univ.
Furudate, Takashi; Iwate Univ.

In this paper, we deal with fixed-order H_infinity controller design problems, based on bilinear matrix inequalities. BMI problems are nonlinear, non-differentiable and non-convex, and therefore very difficult numerically to obtain global solutions. First, we convert BMI problems into differentiable problems introducing so-called shift-parameters. Next, combining the shift-parameter scheme with quasi-Newton methods, a new computational technique has been proposed as BMI solvers. Lastly, we demonstrate the effectiveness of our approach by simulations, with applications to the design of fixed-order H_infinity controllers.

TA15-1 1881
Multiplier Based Discrete-Time Control with Time-Varying Uncertainties
Tchernychev, Andrei; Univ. of California at Irvine
Sideris, Athanasios; Univ. of California at Irvine

A novel multiplier approach for robust controller design in discrete-time systems with real, time-varying parametric uncertainty is presented. An important feature of our approach is that bounds on the rate of variation of the uncertain parameters are assumed and, unlike in most related approaches, dynamic multipliers are obtained that utilize this information. A convex minimization procedure formulated as an LMI problem is presented to obtain multipliers that satisfy the robustness conditions derived. Such conditions are transformed to an equivalent scaled H_infinity norm condition and a mu/km-synthesis approach is proposed to design robust controllers.

TA15-2 1886
A Structurally Constrained LMI Approach to Maximizing the Real Stability Radius by State Feedback
Shafai, Bahram; Northeastern Univ.
Uddin, Vali; Northeastern Univ.
Wilson, Bruce; Northeastern Univ.
Chen, Jie; Univ. of California at Riverside

This paper takes advantage of a recently reported result on robust stability and formulates an LMI based optimization problem to maximize the real stability radius of a system by state feedback. Since a Metzlerian system admits a closed form expression for its stability radius, one can impose its constrained structure in the stabilization of a general system and at the same time maximize the stability radius.

TA15-3 1888
LMI Characterization of Structural and Robust Stability
Geromel, Jose C.; UNICAMP
de Oliveira, Mauricio C.; UNICAMP
Hsu, Liu; COPPE/UFRJ

This paper introduces several stability conditions for a given class of matrices expressed in terms of Linear Matrix Inequalities (LMI), being thus simply and efficiently computable. Diagonal and simultaneous stability, both characterized by polytopes of matrices, are addressed. Using this approach a method particularly attractive to test a given matrix for D-stability is proposed. Lyapunov parameter dependent functions are built in order to reduce conservativeness of the stability conditions. The key idea is to relate Hurwitz stability with a positive realness condition.

TA15-4 1893
A Necessary and Sufficient `Extreme Point' Solution for Checking Robust Stability of Interval Matrices
Yedavalli, Rama K.; The Ohio State Univ.

This paper addresses a current topic of high interest, namely the issue of developing a finitely computable necessary and sufficient test for checking the robust stability of an interval matrix and provides a complete solution to the problem in the form of an `extreme point' result. The result uses the fact that the robust stability problem can be converted to a robust nonsingularity problem involving the original matrix and the associated bialternate sum matrix (which we label as the `tilde' matrix). The special nature of the `tilde' matrix is exploited with the introduction of a concept labeled `Real Axis Nonsingularity'. Another important concept introduced is that of `Virtual Matrix Family' which indirectly captures the `interior' of the uncertain matrix family. Using measures labeled `Weighted Real Axis Determinant' and `Real Axis Nonsingularity Scalar' which are positive for an asymptotically stable matrix, the proposed necessary and sufficient condition involves checking if a set of `Real Axis Nonsingularity Matrices' (formed in terms of the `Vertex' matrices in the `tilde' space) possess any positive real eigenvalues or not. This condition thus involves the eigenvalue information of the higher dimensional matrices in the `tilde' space. The proposed methodology is illustrated with a variety of examples. The importance of this result and the possible extensions are discussed.

TA15-5 1898
Some Improved Algorithms for Lower Bound of One-Sided Phase Mu
Ou, Jih Hwa; National Sun Yat-Sen Univ.
Lee, Li; National Sun Yat-Sen Univ.

In this paper, the computation for lower bound of one-sided phase μ is addressed. Though the existing power algorithm for such computation works well for many numerical examples, the algorithm does suffer its poor convergence at some problems. The paper presents new schemes, developed by generalizing those for mixed μ, to improve mainly the convergence behavior of the power algorithm.

TA15-6 1900

Robust Fault Diagnosis for a Class of Linear Systems with Uncertainty

Jiang, Bin; Nanyang Tech. Univ.
Wang, Jian Liang; Nanyang Tech. Univ.
Soh, Yeng Chai; Nanyang Tech. Univ.

In this paper, the fault diagnosis problem for a class of uncertain systems is discussed. The systems are transformed into two different subsystems. One is not affected by actuator faults, so the robust observer can be designed under certain conditions. The other whose states can be measured is affected by the faults. The observation scheme is then used for model-based monitoring and failure diagnosis. More specifically, a simple approach for fault detection and isolation (FDI) of actuator faults is presented. Finally, an example of an F16XL aircraft is used to illustrate the applicability of proposed method.

TA16-1 1905

Recursive Estimation for Tracking Radioactive Sources

Howse, James W.; Los Alamos National Lab.
Ticknor, Lawrence O.; Los Alamos National Lab.
Muske, Kenneth R.; Villanova Univ.

This paper describes a recursive estimation algorithm used for tracking the physical location of radioactive sources in real-time as they are moved around in a facility. The algorithm is a nonlinear least squares estimation that minimizes the change in the source location and the deviation between measurements and model predictions simultaneously. The measurements used to estimate position consist of four count rates reported by four different gamma ray detectors. There is an uncertainty in the source location due to the variance of the detected count rate. This work represents part of a suite of tools which will partially automate security and safety assessments, allow some assessments to be done remotely, and provide additional sensor modalities with which to make assessments.

TA16-2 1910

Integrated Vision/Inertial Navigation System Design using Nonlinear Filtering

Kaminer, Isaac; Naval Post-Graduate School
Pascoal, Antonio M.; Inst. Superior Tecnico
Kang, Wei; Naval Postgraduate School

This paper addresses the problem of navigation system design for autonomous aircraft landing. New nonlinear filter structures are introduced to estimate the position of an aircraft with respect to a possibly moving landing site, such as a Naval vessel, based on measurements provided by airborne vision and inertial sensors.. By exploring the geometry of the navigation problem, the navigation filter dynamics are cast in the framework of linear parametrically varying systems (LPVs). Using this set-up, filter performance and stability are studied in an H_{∞} setting by resorting to the theory of linear matrix inequalities (LMIs). The design of nonlinear, globally stable filters to meet adequate H_{∞} performance measures is thus converted into that of determining the feasibility of a related set of LMIs and finding a solution to them, if it exists. This is done by resorting to widely available numerical tools that borrow from convex optimization techniques. The paper develops the mathematical framework that is required for integrated vision / inertial navigation system design and details a design example for an air vehicle landing on an aircraft carrier.

TA16-3 1915

Wind Profile Extraction and Impact Point Prediction from Projectile Trajectory Measurements

Coleman, Norm; US Army, TACOM-ARDEC
Yip, Pak; US Army, TACOM-ARDEC
May, Ricky; US Army, TACOM-ARDEC
Lin, Ching-Fang; American GNC Corp.
Feng, Xu; American GNC Corp.

In this paper, the problem of wind profile extraction and impact point prediction from projectile trajectory measurements is formulated within the extended Kalman filtering framework. Factorized implementations of extended Kalman filtering, smoothing, and prediction algorithms are developed. Different wind models are discussed. The algorithms are demonstrated through simulation.

TA16-4 1920

Stable Multiple Model Adaptive Flight Control for Accommodation of a Large Class of Control Effector Failures

Boskovic, Jovan D.; Scientific Systems Co., Inc.
Mehra, Raman K.; Scientific Systems Co., Inc.

In this paper we propose a new parameterization for the modeling of control effector failures in flight control applications. The failures include float, lock-in-place, hard-over, and loss of effectiveness. It is shown that the resulting representation leads naturally to a multiple model formulation of the corresponding control problem that can be solved using a multiple model adaptive reconfigurable control approach. We derive stable multiple model adaptive reconfigurable control algorithms for the most complex case when one of the effectors undergoes float, lock-in-place or hard-over failure, while all others lose effectiveness. The stability of the overall reconfigurable control system is demonstrated using the Lyapunov method and the separation between identification and control arising in the context of indirect adaptive control. The approach is illustrated through numerical simulations of the F-18 aircraft carrier landing maneuver.

TA16-5 1925

Forecasting Uncertain Hotel Room Demand

Rajopadhye, Mihir; Duke Univ.
Ben Ghalia, Mounir; Duke Univ.
Wang, Paul P.; Duke Univ.
Baker, Timothy; Bass Hotels & Resorts
Eister, Graig V.; Bass Hotels & Resorts

Economic systems are characterized by uncertainty in their dynamics. This increasing uncertainty is likely to promote bad decisions that can be costly in financial terms. This makes forecasting of uncertain economic variables an instrumental activity in any organization. This paper takes the hotel industry as a practical application of forecasting using the Holt-Winters method. The problem is to forecast the uncertain demand for rooms at a hotel for each arrival day. Forecasting is part of hotel revenue management system whose objective is to maximize the revenue by making decisions regarding when to make rooms available for customers and at what price. The forecast approach discussed in this paper is based on quantitative models and does not incorporate management expertise. Actual data from a hotel are used to illustrate the forecasting mechanism.

TA16-6 1930

Mode-Matched Filtering via the EM Algorithm

Johnston, Leigh A.; Univ. of Melbourne
Krishnamurthy, Vikram; Univ. of Melbourne

We show that a generalization of the EM algorithm, the Alternating Expectation Conditional Maximization (AECM) algorithm, can be used to derive a mode--matched filtering algorithm called the MMAECM. Mode--matched filtering methods are used for state estimation of jump Markov linear systems. Such models are used in a wide variety of areas in which the system switches between different modes of operation, as in target tracking. The optimal conditional mean estimator for jump Markov linear systems is of exponential complexity, hence algorithms are necessarily suboptimal. We derive the MMAECM according to the maximum a posteriori criterion. Performance of an online version of the MMAECM algorithm is compared to existing mode--matched filtering algorithms such as the Interacting Multiple Model algorithm and Generalized Pseudo Bayesian methods.

TA17-1 1935

High-Accuracy Trajectory Tracking of Industrial Robot Manipulator using Adaptive-Learning Scheme

Sun, Dong; Univ. of Toronto
Mills, James K.; Univ. of Toronto

More and more industrial robot operations demand high-accuracy trajectory performance which may not be achievable using conventional PID control. This paper describes a new adaptive control method with a learning ability in the repetitive tasks, called the Adaptive-Learning (A-L) scheme. The method is based on the proposed theory of two operational modes: the single operational mode and the repetitive operational mode. In the single operational mode, the control is an adaptive control with a new parameter adaptation law using information from the previous trials. In the repetitive operational mode, the control is a model-based iterative learning control. The advantage of the A-L scheme lies in the ability to guarantee convergence in both modes. Theoretical analysis and experimental evaluation on a commercial robot demonstrate the effectiveness of the A-L scheme in controlling an industrial robot manipulator.

TA17-2 1940

Trajectory / Force Control for Robotic Manipulators using Sliding-Mode and Adaptive Control

Lanzon, Alexander; Univ. of Cambridge
Richards, R. J.; Univ. of Cambridge

This paper presents a new robust trajectory/force controller for non-redundant rigid manipulators designed using sliding-mode and adaptive control techniques. Sliding-mode control is used to take care of the uncertain robot dynamics, whereas adaptive control is used to estimate the unknown environment stiffness. Experimental results show that trajectory tracking and force regulation are achieved with bounded errors. This paper assumes known location and geometry of the environment.

TA17-3 1945

Analysis of a Task-Space Regulator for Cooperative Manipulators

Caccavale, Fabrizio; Univ. Degli Studi di Napoli Federico II
Chiacchio, Pasquale; Univ. Degli Studi di Napoli Federico II
Chiaverini, Stefano; Univ. Degli Studi di Napoli Federico II

In this paper a system of two cooperative manipulators tightly grasping a rigid object is considered. Based on a suitable formulation of the cooperative task space, a regulation scheme has been recently proposed, which is based on the design of an individual regulator for each manipulator. Each regulator is designed according to the concept of kinetostatic filtering. In order to avoid the occurrence of representation singularities, the orientation errors are computed by using the unit quaternion. The analysis of the equilibria of the resulting closed-loop system is provided and its asymptotic stability is demonstrated via Lyapunov-like analysis.

TA17-4 1950

Force Control for Flexible Robots using Neural Networks

Borowiec, Joseph; Lucent Technologies
Tzes, Anthony; Polytechnic Univ.

Force control for flexible link robots using neural networks is considered in this article. The nonlinear dynamics of the robot manipulator are identified through a recurrent neural network (RNN), which is trained in an off--line manner. Inversion of the RNN--based model dynamics leads to a feedforward component. The feedback controller gains are derived from the minimization of a discrete linear quadratic cost functional, subject to the model dynamics inferred by the linearization of the neural network along the desired trajectory. Sufficient conditions for temporal gain switching bounds are provided. The proposed control scheme is employed in simulation studies on a two link rigid--flexible manipulator.

TA17-5 1955

Acceleration Feedback Control of Compliant Base Manipulators

Lew, Jae; Ohio Univ.

This paper introduces an active damping control scheme for a robotic manipulator attached to a compliance base. By applying the proposed control, the manipulator generates its inertial force to compensate for base oscillation while following a desired position. The control scheme uses acceleration feedback and one-sample delayed torque to decouple the system, and then computes the fast and slow controller for rigid body motion and base oscillation based on two-time scale theory. A computer simulation study shows very promising results for a test bed consisting of a two-link manipulator and a compliant base in XY motion.

TA17-6 1960

Toward Smooth Analysis of Robotic Contact Tasks Problem

Wu, Christine (Qiong); Univ. of Manitoba
Payandeh, Shahram; Simon Fraser Univ.

In robotic tasks where the manipulator has to make transition from free space motion to constrained one, there always exists an inevitable phase transition. A number of controllers have been proposed in the literature with various discussions on their practical implications. In this paper first a discussion on the nature of the structure of a practical contact transition controller is presented. Then a novel framework which can be used toward studying and analysis of such controllers for robotic contact tasks problem is proposed. This framework presents a natural set-up to study the performance of the controller. The framework is based on the Flippov's notion of differential inclusion and a definition of the smooth Lyapunov function.

TA18-1 1965

Minimal Communication in a Distributed Discrete-Event Control System

Rudie, Karen; Queen's Univ.
Lafortune, Stephane; Univ. of Michigan
Lin, Feng; Wayne State Univ.

Distributed discrete-event systems, in which agents (or local sites) are required to communicate in order to perform some specified monitoring and control tasks, are considered. Each agent is modeled as a finite-state machine that must be able to distinguish between its states to perform some required task. To help it disambiguate states, an agent uses a combination of direct observation (obtained from sensor readings available to that agent) and communicated information (obtained from sensor readings available to another agent). Since communication may be costly, a strategy to minimize communication between sites is developed. The complexity of the solution reflects the interdependence of the agents' communication protocols. That is, the decision to communicate an event relies on which event sequences are indistinguishable to an agent, which, in turn, is a result of what has already been communicated to that agent.

TA18-2 1971

Classification of Part Movements for Deadlock Avoidance in Manufacturing Systems

Lipset, Robert; Ohio Univ.
Judd, Robert P.; Ohio Univ.
Deering, Paul E.; Ohio Univ.
Zhang, Wenle; Ohio Univ.
Caw, Joseph; Ohio Univ.

A new method that classifies part movements to avoid deadlock in manufacturing systems which contain single capacity resources is presented. The proposed method determines whether a particular part movement is safe, unsafe, or undetermined. This classification is linear in complexity. Part movements that are classified as undetermined are analyzed using another procedure. This alternative procedure attempts to empty the system to determine whether the move is safe, unsafe, or undetermined. It is polynomial

in complexity. By adjusting a simple parameter, the size of the set of possible undetermined classifications returned can be made arbitrarily small by increasing the order of the algorithm. Examples showing the application of the method are provided.

TA18-3 1976

Control Computation and Complexity of Temporal-Safety in Discrete-Event Systems

Seow, Kiam Tian; Nanyang Tech. Univ.
Devanathan, Rajagopalan; Nanyang Tech. Univ.

This paper presents a basic computation method to solve a class of control synthesis problems associated with temporal-safety supervision of logical discrete-event systems. A worst-case complexity analysis is also given to enable an objective assessment of the proposed method.

TA18-4 1981

A Modified Method for Supervisor Specification and Synthesis of a Class of Discrete Event Systems

Ou, Yeong-Chang; National Chiao Tung Univ.
Hu, Jwu-Sheng; National Chiao Tung Univ.

In this paper, a model-refining method is proposed to alleviate the complexity regarding specification interpretation of DES control problems. The legal constraint language is defined in terms of illegal states and events in contrast with constructing the automaton of the specification language. This method could provide a more intuitive view of the DES control problem and would be suitable for practical implementation. One example, which was commonly used in the literature, is illustrated to show the efficiency of the proposed method. Furthermore, under this framework, it is shown that the supremal controllable sublanguage can take a simpler form by the concept of illegal state set. A state-based supervisor synthesis procedure is presented and a simple example is illustrated.

TA18-5 1986

An Original Petri Net State Estimation by a Reduced Luenberger Observer

Bourjij, Abdel; Univ. Henri Poincare-Nancy I
Koenig, D.; Univ. Henri Poincare-Nancy I

An original approach for Petri Net (PN) state estimation and verification is proposed and experimental results are given. This methodology is based on a reference model, for partially known discrete event systems modelled by generalized Petri nets. With the help of the theory of generalized state-space systems, an extended reduced Luenberger observer is proposed to reconstruct the marking and the firing count, and gives an alternate way for PN state computing. The necessary and sufficient existence conditions of this estimator are given and prooving. This diagnosis methodology is implemented on a basic example, and simulation results show the efficiency of this approach.

TA18-6 1990

From Stability to the Stabilization Problem of Discrete Event Systems Modeled by Petri Nets using Lyapunov Methods

Retchkiman, Zvi K.; Instit. Politecnico Nacional

This paper presents some preliminary results in the stabilization problem of discrete event systems modeled by Petri nets using Lyapunov theory. After recalling some known stability information about discrete event systems modeled by Petri nets, the stabilization problem is addressed. A new promising methodology based on vector Lyapunov functions shows that it is possible to restrict the systems state space in such a way that boundedness is guaranteed .