FA01-1 2975

Fuel Optimized Rotation for Satellite Formations in Free Space

Beard, Randal W.; Brigham Young Univ.
Hadaegh, Fred Y.; California Inst. of Tech.

This paper considers the problem of rotating a formation of satellites from one orientation to another, using an optimal amount of fuel. The formation is constrained to have the same shape at the beginning and end of a maneuver. However, the shape is unconstrained throughout the maneuver. This implies that to optimize fuel, each spacecraft travels in a straight line, from its beginning to end position. A cost function, motivated by the entropy function from information theory, is used to trade off fuel minimization verses equalizing the fuel across the constellation to avoid fuel starvation.

FA01-2 2980

Dynamic Re-Optimization of a Fed-Batch Fermentor using Heuristic Dynamic Programming

Iyer, Mahesh S.; Texas Tech Univ.
Wunsch, II, Donald; Texas Tech Univ.

Traditionally, fed-batch biochemical process optimization and control uses complicated theoretical off-line optimizers, with no on-line model adaptation or re-optimization. This study demonstrates the applicability, effectiveness, and economic potential of a simple phenomenological model for modeling, and an Adaptive Critic Design, Heuristic Dynamic Programming, for on-line re-optimization and control of an aerobic fed-batch fermentor. The results are compared with those obtained using a Heuristic Random Optimizer.

FA01-3 2986

On-Line Optimization of a Fed-Batch Bioreactor

Dhir, Sanjeev; Aspen Technology, Inc.
Rhinehart, R. Russell; Oklahoma State Univ.
Morrow, K. John; Texas Tech Univ.
Wiesner, Theodore F.; Texas Tech Univ.

The mathematical optimization of growth conditions of biochemical systems like bacterial and fungal systems in a bioreactor has been the focus of research for past many years. Mathematical optimization requires the availability of a process model. Greater the accuracy of the process model, more reliable the optimization results are. Lack of process models with high accuracy has always been a bottleneck for such an optimization problem. More so, there are so many different cell types being used in the biotech industry today that modeling each of them rigorously on individual basis is a daunting task. This problem has been addressed by proposing a simple but working model of the process. The dynamic optimization of the process is carried out with adjustment of model parameters at each sampling time. An essential component of online optimization problem solver will be an optimization subroutine that finds global optimum fast enough to be effective for a dynamic process. Also the information about most sensitive model parameters and an algorithm that could take care of process nonlinearties while taking care of process model mismatch is required. A method called Heuristic Random Optimizer (HRO) (Li and Rhinehart 1998) has been used for on-line optimization of the process. Fuzzy logic based algorithm has been used for updating the model parameters. This scheme has been implemented on a fed-batch reactor and a hybridoma cell line 4W4 has been studied upon. A Significant improvement in the product yields has been observed using the above-mentioned mechanism.

FA01-4 2991

The Soft-Constrained Time-Optimal Control of Linear Systems and its Boundedness

Bikdash, Marwan U.; North Carolina A&T State Univ.

A general analysis of the asymptotic behavior of the Soft-Constrained Time-Optimal (SCTO) control of linear systems is presented. The analysis purports to show that (1) this control is bounded like its hard-constrained counterpart; and (2) there is a basic tradeoff between the control bounds and the speed of the response. The tradeoff is characterized. Moreover, if the "No Infinite Maneuver in Finite Optimal Time" (NIMIFOT) condition holds, then the boundedness of the SCTO control can be established and its main behavior characterized.

FA01-5 2996

Global Natural Theta-Tracking Control of Lagrangian Systems

Gruyitch, Lyubomir; Univ. de Technologie Belfort-Montbeliard

The Lagrange differential equation is used in its general vector form without any information either about system parameters and nonlinearities or about external disturbances so that their real forms and values are allowed to be completely unknown. A demanded system global tracking quality is defined by a vector differential equation in terms of the error vector of the general coordinate vector q. In order for a tracking control to exist for such a system and under such a lack of information, the system should obey a qualitative dynamical property called its global natural q-trackability. The necessary and sufficient conditions for global natural q-trackability are presented. They compose a part of the whole set of the necessary and sufficient conditions for a control to be global natural q-tracking control of the system, which guarantees the requested tracking quality. The natural q-tracking controller is simple for a technical realization. The paper results are based on new issues in the framework of the Lagrangian systems such as a novel physical principle called the Physical Continuity and Uniqueness Principle, the concept of global q-natural trackability and the concept of the natural q-tracking control.

FA01-6 3001

GP Based Design Method for Control Systems via Hamilton-Jacobi-Bellman Equations

Imae, Joe; Iwate Univ.
Takahashi, Junya; Iwate Univ.

The control design problem to find the optimal feedback controller minimizing the performance index is considered to be one of the most difficult problems to solve. The well-known dynamic programming argument shows that the solutions of this problem have to satisfy the Hamilton-Jacobi-Bellman (H-J-B) equation. We note that the H-J-B equation is highly nonlinear and extremely difficult analytically/numerically to obtain the solutions. In this paper, we deal with the design problem of feedback control synthesis via the Hamilton-Jacobi-Bellman (H-J-B) equation. Making use of the emergent property of Genetic Programming (GP), we propose a new approach for obtaining the value functions approximately. Some numerical examples are demonstrated to illustrate the practicability of our control design method.

FA02-1 3003

Fundamental Properties of Rigid Serial Manipulators for Control Design

Chen, Ye-Hwa; Georgia Inst. of Tech.
Kuo, Chen-Yuan; Arizona State Univ.

We investigate certain fundamental properties of serial-link mechanical manipulators, as related to the control design. The manipulator has rigid links with revolute and/or prismatic joints. These properties include the upper bounds of the inertia matrix, Coriolis and centrifugal term, and gravitational term. The generic properties are readily applicable to control design.

FA02-2 4553

Adaptive Control of Manipulators with Supervision of the Sampling Rate and Free-Parameters of the Adaptation Algorithm

De La Sen, Manuel; Univ. Del País Vasco
Almansa, A.; Univ. Del País Vasco

An adaptive control scheme for mechanical manipulators is proposed. A supervisor is used to improve the system performances

during the adaptation transients. The supervisor exerts two supervisory actions. The first one consists basically in updating the free-design adaptive controller quadratic loss function is maintained sufficiently small. The second supervisory action consists basically of a on-line adjustment of the sampling period within an interval centered in a nominal value of the sampling period. The sampling period is selected so that the transient of the tracking error is improved.

FA02-3 3008
A Modular Scheme for Adaptive Control of Underwater Vehicle-Manipulator Systems
Antonelli, Gianluca; Univ. Degli Studi di Napoli Federico II
Caccavale, Fabrizio; Univ. Degli Studi di Napoli Federico II
Chiaverini, Stefano; Univ. Degli Studi di Napoli Federico II

A novel adaptive control law for the end-effector tracking problem of Underwater Vehicle-Manipulator Systems (UVMS) is presented in this paper. By exploiting the serial-chain structure of the UVMS, the overall control problem is decomposed in a set of elementary control problems, each of them formulated with respect to a single rigid body in the system. The proposed approach results in a modular control scheme which simplifies application to multibody systems with a large number of links, reduces the required computational burden, and allows efficient implementation on distributed computing architectures. Furthermore, the occurrence of kinematic and representation singularities is overcome, respectively, by expressing the control law in body-fixed coordinates and representing the attitude via the unit quaternion. To show the effectiveness of the proposed control strategy, a simulation case study is developed for a vehicle in spatial motion carrying a six-degrees-of-freedom manipulator.

FA02-4 3013
A Composite Adaptive Output Feedback Tracking Controller for Robotic Manipulators
Zergeroglu, Erkan; Clemson Univ.
Dixon, Warren E.; Clemson Univ.
Haste, Deepak V.; Clemson Univ.
Dawson, Darren M.; Clemson Univ.

This paper provides a solution to the composite adaptive output feedback tracking control problem for robotic manipulators. The proposed controller utilizes an update law that is a composite of a gradient update law driven by the link position tracking error and a least squares update law driven by the prediction error. In order to remove the controller's dependence on link velocity measurements, a linear filter and a new prediction error formulation are designed. The controller provides semi-global asymptotic link position tracking performance.

FA02-5
Withdrawn

FA02-6 3018
Adaptive Control of Systems with Backlash Hysteresis at the Input
Khorrami, Farshad; Polytechnic Univ.

A new compact dynamical model for backlash inverse is presented. This model may be utilized for both backlash at the input or at the output. Two cases are considered: the case where the backlash spacing is known as well as the case of unknown backlash spacing. For the latter case, an adaptive update law is developed to compensate for the unknown spacing. The adaptive backlash inverse controller is a break-away from existing backlash compensators which are mostly implemented in discrete-time and utilize complex control algorithms. The advocated results are applied to a one degree-of-freedom system affected by backlash. The stability of the closed-loop system is shown using Lyapunov arguments. Simulation results show that the control methodology greatly improves tracking performance over a PD type controller.

FA03-1 3023
Nonlinear Robust Switching Controllers for Nonlinear Uncertain Systems
Leonessa, Alexander; Georgia Inst. of Tech.
Haddad, Wassim M.; Georgia Inst. of Tech.
Chellaboina, Vijaysekhar; Georgia Inst. of Tech.

A nonlinear robust control-system design framework predicated on a hierarchical stability-based switching controller architecture is developed. Specifically, using equilibria-dependent Lyapunov functions a hierarchical nonlinear robust control strategy is developed that robustly stabilizes a given nonlinear system over a prescribed range of system uncertainty by robustly stabilizing a collection of nonlinear controlled uncertain subsystems.

FA03-2 3028
Generalized Lyapunov and Invariant Set Theorems for Nonlinear Dynamical Systems
Chellaboina, Vijaysekhar; Georgia Inst. of Tech.
Leonessa, Alexander; Georgia Inst. of Tech.
Haddad, Wassim M.; Georgia Inst. of Tech.

In this paper we develop generalized Lyapunov and invariant set theorems for nonlinear dynamical systems wherein all regularity assumptions on the Lyapunov function and the system dynamics are removed. In particular, local and global stability theorems are given using lower semicontinuous Lyapunov functions. Furthermore, generalized invariant set theorems are derived wherein system trajectories converge to a union of largest invariant sets contained in intersections over finite intervals of the closure of generalized Lyapunov level surfaces. The proposed results provide transparent generalizations to standard Lyapunov and invariant set theorems.

FA03-3 3033
Universal Formulas for CLF's with Respect to Minkowski Balls
Malisoff, Michael; Rutgers Univ.
Sontag, Eduardo D.; Rutgers Univ.

This note provides explicit, algebraic stabilizing formulas for clf's when controls are restricted to certain Minkowski balls in Euclidean space. Feedbacks of this kind are known to exist by a theorem of Artstein, but the proof of Artstein's theorem is nonconstructive. The formulas are used to construct approximation solutions to some stabilization problems.

FA03-4 3038
Asymptotic Stability for Systems with Multiple Hysteresis Nonlinearities
Pare, Thomas E.; Stanford Univ.
Hassibi, Arash; Stanford Univ.
How, Jonathan P.; Stanford Univ.

Absolute stability criteria for systems with multiple hysteresis nonlinearities are given in this paper. If the linear subsystem satisfies a simple two part test involving a linear matrix inequality and a simple residue condition, then the nonlinear system is proven to be asymptotically stable. The main stability theorem uses a combination of passivity, Lyapunov, and Popov stability theories to show that the state describing the linear system dynamics must converge to an equilibrium position of the nonlinear closed loop system. The stationary sets that contain all possible equilibrium points are detailed for common types of hystereses, and simple examples are used to illustrate the benefits of the new results.

FA03-5 3044
Stability of a Reset Control System under Constant Inputs
Beker, Orhan; Univ. of Massachusetts Amherst
Hollot, Christopher V.; Univ. of Massachusetts Amherst
Chen, Qian; Univ. of Massachusetts Amherst
Chait, Yossi; Univ. of Massachusetts Amherst

Reset controllers are standard linear compensators equipped with mechanism to instantaneously reset their states. With respect to pure linear control, there is evidence that this reset action is capable of improving control system tradeoffs. This paper's objective is to analyze the stability of a particular example of reset control system when excited by constant inputs. Our main result shows that the equilibrium point of the closed-loop dynamics is asymptotically stable.

FA03-6 3046

Controller Design for a Nonovershooting Step Response with Saturating Nonlinearities

Wu, Wei; Texas A&M Univ.
Jayasuriya, Suhada; Texas A&M Univ.

Proposed in this paper is a design procedure for improved system performance when actuator saturation is present. A new controller architecture together with the basic methodology suggested by Horowitz (1983) and the idea of nonovershooting transfer functions developed by Jayasuriya (1996) provide the essential framework for the technique. The design procedure is quite simple and simulation results compare very favorably with those of Horowitz (1983). The method is applicable to type n systems as well as conditionally stable systems.

FA04-1 3051

A Stability Result with Application to Nonlinear Regulation: Theory and Experiments

Langson, Wilbur S.; Univ. of Illinois at Urbana-Champaign
Alleyne, Andrew G.; Univ. of Illinois at Urbana-Champaign

In the present work we consider the control of a class of nonlinear systems described in a pseudo-linear form. The pseudo-linear representation of the system is described and a stability analysis is performed which leads to sufficiency conditions under which local and global asymptotic stability is present. These results are then applied to study stability and convergence properties of closed loop systems which arise when the State Dependent Riccati Equation (SDRE) technique (Banks & Manha, 1992, Cloutier, 1997) is used. It is shown that the SDRE technique yields globally asymptotically stabilizing controls for a class of nonlinear systems satisfying certain growth conditions. Additionally, many of the benefits of Linear Optimal Control, such as a tradeoff between state regulation and input effort, are readily transparent in the nonlinear scheme. The application example is a Nonlinear Benchmark problem first proposed by Kokotovic (1991). A real time experimental controller is applied to the simulated dynamics to demonstrate practical feasibility of the SDRE technique.

FA04-2 3057

Bifurcation Control of Nonlinear Systems with Time-Periodic Coefficients

Sinha, Subhash C.; Auburn Univ.
David, Alexandra; Auburn Univ.

In this study a technique for the bifurcation control of nonlinear systems with periodic coefficients is presented. In such systems, bifurcations occur when one of the Floquet multipliers becomes +1 (symmetry breaking, transcritical or fold bifurcation), -1 (flip bifurcation), or a pair of complex multipliers reaches magnitude 1 (secondary Hopf bifurcation). The stability of the bifurcated periodic or quasi-periodic orbit is guaranteed by employing a nonlinear state-feedback control. First the Lyapunov-Floquet transformation is applied such that the linear part of system equations becomes time-invariant. Then through an application of time-periodic center manifold reduction and time-dependent normal form theory one can obtain a completely time-invariant form of the nonlinear equation for codimension one bifurcations. The time-invariant normal form is suitable for the application of control strategies developed for autonomous systems. Then by transforming the results back to the original variables, one obtains the gains for the time-varying controller. The control strategy is illustrated through an example of a parametrically excited simple pendulum undergoing a symmetry breaking bifurcation.

FA04-3 3062

Criteria for Chaotic Behavior by Perturbed Lag-Element

Sugiki, Akihiko; Tokyo Denki Univ.
Hatakeyama, Shoshiro; Tokyo Denki Univ.
Furuta, Katsuhisa; Tokyo Inst. of Tech.

This paper proposes a technique for evaluating the presence of chaos in the case that chaotic nonlinear feedback systems are slightly perturbed by uncertain elements. The main strategy of the proposed technique is to treat the perturbation effects on systems as those on limit cycles estimated by the describing function method. This paper considers two types of perturbing element, 1st and 2nd order lag elements, on the Brockett chaotic system and then provides an analytical technique for the problem addressed.

FA04-4 3067

Output Feedback Control for PWM Systems: Online Continuation Method Approach

Iwata, Takaaki; Tokyo Inst. of Tech.
Yamakita, Masaki; Tokyo Inst. of Tech.
Furuta, Katsuhisa; Tokyo Inst. of Tech.

A new output feedback controller for PWM systems based on continuation method is presented. This algorithm solves the PWM-type deadbeat control problem numerically. By using this algorithm, iterations for solving the nonlinear equation always starts from a good solution candidate and therefore it can be used online. The validity of the proposed control method is demonstrated by a numerical simulation of experimental device imitating a satellite.

FA04-5 3072

Modeling and Controller Design of a MAGLEV Guiding System for Application in Precision Positioning

Chen, Mei-Yung; National Taiwan Univ.
Wang, Ming-Jyh; National Taiwan Univ.
Fu, Li-Chen; National Taiwan Univ.

In this paper, we have analyzed the dynamics of a mag-netic guiding system and derived its analytical model with full DOFs (degrees-of-freedom). Then, an adaptive control-ler which deals with unknown parameters is proposed here to regulate the five DOFs in this system. The guiding system including sensors and drivers systems is actually imple-mented. From the experimental results, satisfactory perfor-mance including stiffness and resolution have been achieved. This validates, the design of system hardware and demon-strates feasibility of the developed controller.

FA04-6 3077

Saturation Technique for Constructing Observer of Multi-Output Nonlinear Systems

Shim, Hyungbo; Seoul National Univ.
Son, Young I.; Seoul National Univ.
Seo, Jin H.; Seoul National Univ.

We present an explicit form of nonlinear observer for a class of multi-input multi-output systems. Observer construction for multi-output nonlinear systems is not a trivial extension of single-output case, especially when the global error convergence is of interest. In this paper, we confine the class such that the subsystem for each output has a triangular dependence on the states of that subsystem itself, and the overall system has a block triangular form for each subsystem. Hence, the contribution is to expand the existing results in the literature since interconnections between the subsystems are allowed. The construction is based on the saturation of some estimates, which is originated by Khalil and Esfandiari for the use of semi-global output feedback control.

FA05-1 3082

Cross-Machine Direction (CD) Response Modeling with Two-Dimensional Sheet Variation Measurements (I)

Chen, Shih-Chin; ABB Industrial Systems Inc.
Subbarayan, Ravi; ABB Industrial Systems Inc.

The performance of cross-machine direction (CD) control applications for sheet-forming processes highly depends on the accuracy of models that characterize the responses of all CD actuators. This paper describes a new method to identify CD actuator responses by utilizing two-dimensional sheet variation measurements. The new modeling method not only reduces the required testing duration and product deviations, it also identifies individual two-dimensional responses for all CD actuators simultaneously.

FA05-2 3087

CD Control Sensitivity Analysis (I)

Fu, Calvin; Valmet Automation (Canada) Ltd.
Nuyan, Seyhan; Valmet Automation (Canada) Ltd.

This paper presents the cross-machine direction (CD) control capability and sensitivity with respect to the control actuator response uncertainty and mapping errors. Contrary to common belief, the profile spectrum longer than 2-actuator wavelength may not be controllable for certain types of CD processes. If there is actuator response shape uncertainty or mapping error, the control may become unstable. In this case, control with even a conservative tuning may not stabilize the process; it only slows down the time to reach instability. Applying robust control without fully understanding the stability requirements compromises the control performance unnecessarily. Several simulations are performed to illustrate the theoretical basis of the results. Finally, a CD control performance assessment tool based on control capability and sensitivity analysis is also briefly discussed and guidelines to robust control design indicated.

FA05-3 3092

Evaluating the Performance of Cross-Directional Control Systems (I)

Duncan, Stephen R.; Univ. of Oxford
Dumont, Guy A.; Univ. of British Columbia
Gorinevsky, Dimitry M.; Honeywell Tech. Center

Methods have been developed for monitoring the performance of SISO control systems, which compare the variance of the output achieved from the plant to an estimate of the variance that could be achieved by minimum variance control. The methods require knowledge of only the inherent delay within the process. This paper extends these ideas to analyze the performance of cross-directional control systems for sheet processes such as paper machines, which are large multivariable systems. Because such systems are inherently ill-conditioned, the performance is compared against that of a generalized minimum variance controller designed to avoid controlling poorly controllable spatial and dynamic modes. The results of applying the algorithm to data from a paper machine are presented.

FA05-4 3097

Practical Estimation of CD Control Performance (I)

Kayihan, Ferhan; IETek

Sheet and web forming processes cover a wide range of industries including pulp and paper, plastics, metal, glass and fabrics among others. A common aspect of all of these manufacturing processes is the spatiotemporal characteristics of the web with correlated multidimensional behavior. Both the design and performance assessment of cross directional (CD) controllers are current research and development interest especially since the recent commercial introduction of full width sensors that provide on-line mapping of complete sheet property profiles. With practically 100 % knowledge of property values it is now possible to expect CD controllers to be more effective in regulating process variability. CD control can be classified into "static" and "dynamic" components where the former targets the stabilization of long-term (average) profile while the latter aims to remove short-term (transition) profile variations. Assessment of CD controller performance must quantify total potential and practical variability reduction margin from known process data and information. Traditionally, for practical reasons and implementation ease, control performance assessment procedures estimate minimum variance based solely on measured process data. For sheet and web processes, certain amount of "static" CD control assessment can be done from mean profiles obtained by all available sensors including scanners. However, so far there has not been much theoretical advancement on "dynamic" CD control related minimum variance estimation procedures. One possible reason for the slow progress is the difficulty associated with strong interdependence between control performance, process characteristics and the specifics of disturbances. At present, a practical approach to explore possible ways to quantify full CD control performance and to estimate a minimum variance condition is to use model-based prediction. Although this approach is significantly more laborious than the conventional data based calculations, the results are expected to be that much more reliable where a measure of realizable improvement margin can be provided. Considering the unique role of sheet machines in determining final product quality, extra effort is easily justified. A model based minimum variance estimation for CD control will be proposed. In addition to measured data, process characteristics including slice (actuator) behavior and constraints will be considered to design an "optimum" controller to minimize variance under similar disturbance conditions. As "perfect" CD controllers cause picketing of the actuators, minimum or optimum variance will be defined in terms of practical limits and constraints. Additional metrics measuring transient CD correlations will be proposed and tested to track control effectiveness.

FA05-5 3098

Spatial Loopshaping: a Case Study on Cross-Directional Profile Control (I)

Stewart, Greg E; Univ. of British Columbia
Gorinevsky, Dimitry M.; Honeywell Tech. Center
Dumont, Guy A.; Univ. of British Columbia

In this paper, recent developments in control of spatially-invariant processes are applied to an industrial problem of cross-directional profile control in web manufacturing. Approximating such processes in terms of a spatial frequency decomposition allows the extension of traditional concepts of loopshaping to the two-dimensional dynamical and spatial frequency domain. The approach is applied to a cross-directional paper weight process. The designed controller is implemented on a real industrial control system with a hardware-in-the-loop paper machine simulator and demonstrates the performance predicted by the design.

FA05-6 3104

Selection of the Most Appropriate Control Strategy by using a Stability Model: Application to Pulp and Paper Wastewater Treatment

Soehartanto, Totok; LAG-ENSIEG
Beteau, Jean-François; LAG-ENSIEG

The anaerobic digestion is a very efficient process to treat effluents which contain a very high organic load like the effluent of the pulp and paper industry.This paper present a new tool for selection of the most appropriate control strategy to solve stability problems, economical efficiency and performances classified by priority order. This study based on an original stability analysis.

FA06-1 3106

Tutorial on Inferential Control and its Applications (I)

Joseph, Babu; Washington Univ.

In this tutorial, we discuss approaches to control of one or more primary variables in a process using secondary measurements. This approach is useful when the primary variable is not easily measured,

or has large time delays or lags associated with it. It is also useful when the secondary measurements contain information about disturbances that affect the primary variable. We start by discussing some classical approaches to this problem. Then we present inferential control strategies that use process models to predict the effect of the disturbance variable on the primary output and use this prediction to regulate the process. Next we present a framework for incorporating the inferential control strategy within the framework of the often-used model predictive control (MPC). This framework, termed as model predictive inferential control (MPIC), is general enough to accommodate multiple secondary measurements as well as nonlinear estimators and controllers. The concept is also extended to end product quality control in batch processes using intermediate measurements available during the middle of the batch. The advantages of inferential control are established using the Shell challenge case study problem, which employs linear transfer function models. Problems of collinearity among the secondary measurements (which frequently arises) is addressed using principal component analysis (PCA) during the construction of the dynamic estimator. Numerous applications demonstrate the advantages of the inferential control strategy.

FA06-2 3119
ASPECT: Methodology for Inferential Sensing and Assessment of Quality Control (I)
Schnelle, Jr., David; E.I. Dupont de Nemours & Co.

ASPECT is an acronym for Advanced Statistical Process Estimation and Control Technology. DuPont has developed ASPECT as a prototype to help better understand the application of inferential sensing and how it applies to "quality" control. ASPECT is: ·An application methodology that provides a structured approach to the problem of quality control. ·Software tools developed in support of that methodology. ASPECT helps plant engineers evaluate the merits of various quality control approaches. It also provides a means to quantify and understand the opportunity for moving from one level of quality control to the next. The ASPECT software is a complete, simple to use, integrated environment for data gathering, empirical modeling and inferential sensing applications. This short presentation will discuss ASPECT's role in evaluating alternative approaches to quality control approaches and will cover ASPECT's capabilities with respect to inferential sensing. It will briefly cover several application of ASPECT in support process analitical applications.

FA06-3 3121
Control of a Distillation Column using a Virtual Analyzer (I)
Ramchandran, Soundar; Solutia, Inc.

Inferential control is used frequently in industrial practice of process control. For example, in distillation columns, tray temperatures are used to infer compositions of the distillate and/or bottoms products. Direct measurements for many controlled variables such as compositions, may be difficult and/or costly. Often, inferential control a reasonable estimate that is sufficient to establish good control of the process. It is understood that inferential control is feasible only when the inference measurement has a significant effect on the actual variable that is being controlled. This paper will discuss application of an inferential controller that predicts an inferred feed composition using a "virtual" analyzer, which is based on a neural network model.

FA06-4 3123
Implementation of Nonlinear Inferential Sensors (I)
Weitzel, Dale; Aspen Technology, Inc.

In industrial applications of inferential sensing, the most popular technology deployed is Neural Network technology. However, the industry needs more than one modeling option for building inferential sensors. Statistical tools such as PLS must be provided to the user as options. Use of Fuzzy functions and a hybrid of PLS and neural network are also becoming popular because of the robustness in predictions. First principle models are also used where data is not reliable. Successful implementation of an inferential sensor project requires a range of choices in modeling tools and good project engineering. This paper focuses on empirical model based inferential sensor and the implementation steps to accomplish a successful inferential sensing project.

FA06-5 3125
Automatic Generation of Models for Inferential Control (I)
Piche, Steve; Pavilion Technologies

Over the past few years, we have implemented many models for inferential control. These models have been developed from historical data using statistical regression or neural network models. In addition, techniques for on-line biasing and robust model implementations have been developed. Recently the methodology has been encapsulated in a novel software program. This software allows easy creation of models for inferential control.

FA07-1 3127
Single-Antenna GPS-Information-Based Aircraft Attitude Redundancy (I)
Deyst, John J.; Massachusetts Inst. of Tech.
Kornfeld, Richard P.; Massachusetts Inst. of Tech.
Hansman, Jr., R. John; Massachusetts Inst. of Tech.

The use of velocity information from a single antenna GPS receiver to infer aircraft roll attitude has been demonstrated both in cockpit simulations and in flight tests. Pilot ratings indicate that the method provides roll attitude information equivalent to what is available from an artificial horizon and is completely adequate for maintaining stable flight when the horizon is obscured by weather. In addition, the system has been demonstrated on precision approaches to runways and has been judged superior to the artificial horizon for uncoordinated flight, such as single engine failure situations in twin engine aircraft. The presentation will discuss this method, both in terms of its utility as an independent backup for artificial horizons and as a redundant source of acceleration information for diagnosing inertial system failures. Flight test results will be presented including videos taken in the cockpit of a general aviation aircraft.

FA07-2 3132
What is a Super Mechano System? (I)
Furuta, Katsuhisa; Tokyo Inst. of Tech.
Xu, Yongcai; Tokyo Inst. of Tech.

Super Mechano-System is the Grand-in-Aid for COE research project sponsoed by Japanese Ministry of Education, Science, Sprots and Culture with the aim of creating a New Mechanical System which can self-organize its structure and functions adapting to the varying environment. The system has not only hyper redundancy with autonomous intelligence but also is said to be the Cyber Mechanism and achieves efficient and high speed movement designed based on the fusion of control and mechanisms. This paper is only to describe the project.

FA07-3 3137
On the Synthesis of the System Graph for 3D Mechanics (I)
Diaz-Calderon, Antonio; Carnegie Mellon Univ.
Paredis, Christiaan J. J.; Carnegie Mellon Univ.
Khosla, Pradeep K.; Carnegie Mellon Univ.

This paper presents a methodology for deriving the system graph of a 3D mechanism from CAD models. That is, a linear graph that captures the energy flow in a system. This work is part of a larger research effort in composable simulation. In composable simulation, CAD models of system components are augmented with simulation models describing the component's dynamic behavior in different energy domains. By composable simulation we mean then the ability to automatically generate system-level simulations through composition of individual component models. From the system

graph, the system-level dynamic equations can be derived independently of the underlying energy domains.

FA07-4 3142
Information Quality Control for Network-Centric Ship Maintenance (I)
Phoha, Shashi; Pennsylvania State Univ.

Modern requirements of precision and quality are driving the failure monitoring, diagnosis and prognosis (mdp) of complex operational equipment beyond the reach of human senses and experience. Architectures for electronic delivery of on-line equipment mdp services by electronic sensing and dynamic damage assessment models are increasingly considered essential for both performance and affordability. For network centric maintenance planning we presume a reactive network of embedded sensors. The sensed information is used for predicting remaining life, real-time constraining of operational parameters, life extension of operating machinery, and for dynamic maintenance scheduling [Dai 94, Ray 94, Phoha 96a, Phoha 96b]. This paper explores the issues of information quality control in a network centric equipment health monitoring and maintenance planning enterprise. The objectives are operational damage mitigation and dynamic maintenance scheduling over a ubiquitous information infrastructure. Typically, the health monitoring of equipment is done on site, historic and diagnostic databases and tools are archived, logistics and schedule data are available from plant management or repair depots and the dynamic models of damage and operational performance are often proprietary and available only from vendors of equipment or at depots. Real-time manipulation of this heterogeneous and dispersed information requires complex interactions of internal representations of sensor data, performance requirements, electronic technical manuals, resources and equipment models, with rich semantics. This research formulates and prototypes an intelligent multi-user mechanism called an Information Broker for context dependent time critical manipulation of dispersed and transient maintenance data embedded in autonomous systems where semantic heterogeneity is the norm. This paper presents the fundamentals of a relational calculus which models a prespecified set of relations across the electronic data sources as a distributed search tree of metadata terms. The semantic distance between metadata terms is quantified to represent semantic precision. The incoming health monitoring and operational data are classified into observable or predictable maintenance event sets. As a maintenance event is identified, the information broker is called upon to support unstructured information queries to find related diagnostic tools, built-in-tests (BIT), procedures, policy and planing information with specified precision. An Information Broker has been prototyped as part of a real-time maintenance decision support tool, deployable on-board the USS Yorktown for on-line condition assessment, interactive fault isolation and maintenance decision support for power plants and electric motors. The tool, extendable to all critical components of the ship, will allow maintenance decisions at all levels to be based on up to date and accurate information of the evolving physics and dynamics of accumulating damage in operational environments.

FA07-5 3147
Composing and Sharing Hybrid Dynamic Models in an Agent-Based Concurrent Engineering Environment (I)
Howley, Brian T.; Stanford Univ.
Cutkosky, Mark R.; Stanford Univ.
Biswas, G.; Stanford Univ.

Sharing design information in a distributed engineering team is a challenging problem. Ideally, the information exchange should be flexible enough to accommodate different levels of abstraction required for different engineering design and analysis tasks. We propose a solution in which specialists, and the programs they use, are modeled as agents who share a common communication language and ontology. The ontology includes both a symbolic representation of the equations describing system behavior and the conditions (such as parameter ranges) over which the model is valid. We use the a hybrid modeling paradigm to generate consistent models at multiple levels of abstraction and demonstrate the approach with design analysis tasks for a stepper motor actuated positioning system.

FA07-6 3154
A Multi Agent Architecture for Building High Assurance Systems (I)
Perraju, Tolety Siva; GTE Laboratories

High Assurance encompasses availability, security, safety and any other features that affect the predictability of the system. Techniques from disciplines like fault tolerant computing, real time systems and reliability engineering are applied to improve one or many of the features listed above. This adhoc approach severely limits the systems capabilities and often leads to brittle systems. High Assurance Systems Engineering attempts to adopt a holistic approach to the problem of designing mission critical systems. Multi Agent System architectures are a new paradigm in conceptualizing, designing and implementing systems. Agent architectures are characterized by the concepts of situatedness, autonomy and flexibility. These characteristics are essential for building high assurance mission critical systems. In this paper, we propose a multi agent based approach for designing High Assurance Systems.

FA08-1 3158
Robust Reduced Order Two-Degree-of-Freedom Tractor-Semitrailer Lateral Control
Mammar, Said; INRETS

This paper addresses the problem of tractor-semitrailer lateral control using two degrees of freedom H_infinity optimization. The synthesis procedure allows the separate processing of the robust stabilization problem and reference signal or disturbance rejection. The closed loop part achieves the robust stability requirement in the Gap metric, while the prefilter part processes the reference signal and is designed to achieve model matching. LMI based H_infinity optimization is used in order to obtain reduced order controllers. The model used for control development is first presented, then the synthesis steps are detailed. The performances and the robustness of the controller are finally investigated by considering several maneuvers such as lane keeping and lane change with parameter variations.

FA08-2 3163
Experimental Study of Dynamic Look Ahead Scheme for Vehicle Steering Control
Chen, Chieh; National Chiao Tung Univ.
Tan, Han-Shue ; Univ. of California at Berkeley

A popular automatic steering control approach for passenger cars is to decouple the yaw motion from lateral motion by using yaw rate feedback. It has been shown recently that by re-defining the control position at a frequency-dependent distance ahead of the vehicle, the yaw dynamics can also be decoupled. In this paper, open-loop experimental tests are conducted at different vehicle speeds to verify the effectiveness of this dynamic look-ahead scheme. A fully equipped Buick LeSabre Sedan is utilized as a test platform in this experimental study. Both vehicle yaw rate and lateral acceleration frequency response data are obtained in the experimental tests by applying frequency sweeping techniques at different vehicle longitudinal velocities. It is shown that a decoupled input-output vehicle dynamics can be obtained by applying the dynamic look-ahead scheme to the open-loop frequency response data.

FA08-3 3168
Design of a Vehicular Suspension Controller by Static Output Feedback
Camino, Juan F.; Univ. of Campinas
Zampieri, Douglas E; Univ. of Campinas
Peres, Pedro L. D.; Univ. of Campinas

A static output feedback controller is applied to the design of an active suspension model for a quarter-car vehicle, using only the

suspension travel displacement and velocity as output variables. The feedback design proposed makes use of recent Linear Matrix Inequalities results from the literature, also allowing to consider the presence of uncertain parameters. Simulations are carried out taking into account the model uncertainty. The results are shown to be as good as the classical Linear Quadratic Regulator which supposes full state availability and precisely known parameters.

FA08-4 3173

Nonlinear H_Infinity Control for Integrated Suspension System via Parameterized LMI Characterizations

Tuan, Hoang Duong; Nagoya Univ.
Ono, Eiichi; Toyota Central R&D Labs. Inc.
Apkarian, Pierre; ONERA-CERT
Hosoe, Shigeyuki; Nagoya Univ.

The automotive hydro-pneumatic integrated suspension model is nonlinear with large dimensions. As a consequence, the nonlinear H-infty control methodology based on the traditional Hamilton-Jacoby-Isaacs equation is impractical in this application. An alternative so-called Parameterized Linear Matrix Inequality (PLMI) approach is proposed for solving this hard nonlinear H-infty control problem. The validity of the proposed approach is confirmed not only by detailed and realistic simulations but also by extensive experiments. Specifically, the proposed nonlinear control method outperforms the more classical feedback linearization control technique

FA08-5 3178

Investigation of Signal Replication Techniques for Road Simulators: a Quarter-Car Case Study

Hu, Jiankun; Monash Univ.
Wu, H. R.; Monash Univ.
Chou, C. T.; The Univ. of Delft Tech.
Verhaegen, M.; The Univ. of Delft Tech.

In this report, Generalized Predictive Control (GPC) and Least Mean Squares (LMS) based signal processing techniques are investigated for the design of high-fidelity signal replication systems applicable to road simulators. The performance of these two design methodologies are tested and compared in a simulation environment with a quarter car as an example. The quarter-car model is established by experimental data. Several tips are also given to solve problems arising in using the LMS algorithm.

FA08-6 3180

An Experimental Study on Cartesian Tracking Control of Automated Excavator System using TDC-Based Robust Control Design

Lee, Soo-Jin; Korea Adv. Inst. of Sci. & Tech.
Chang, Pyung Hun; Korea Adv. Inst. of Sci. & Tech.
Kwon, Young-Min; Hyundai Research Inst. of Mabookri

The Cartesian control of automated excavators has been noted for its difficulty, especially due to severe nonlinearities in hydraulic actuators that can be hardly observed in electric motors. The nonlinearities tend to become even more severe as the size of an excavator increases and the speed of end-effector becomes faster, which conventional controls have been unable to handle adequately. In a conviction that modern robust controls can resolve this problem, we approached this problem: by adopting Time-delay control(TDC) as the baseline control, and by enhancing it with compensators on the basis of insights obtained from the plant dynamics. The resulting control law has been applied to straight-line motions of a 13 ton hydraulic excavator with the bucket(end-effector) speed of 0.5 m/sec, a speed level at which skillful operators work. The accuracy achieved was within 3 cm for surfaces with various inclinations and over broad ranges of joint motions, which is far better than that of an expert. These promising results not only justify our approach to this problem, but also convince us that we now have an effective means for the control of automated excavator systems.

FA09-1 3186

Anti-Windup Design for Manual Flight Control (I)

Barbu, Corneliu; Univ. of California at Santa Barbara
Reginatto, R.; Univ. Federal de Rio Grande Do Sul
Teel, Andrew R.; Univ. of California at Santa Barbara
Zaccarian, L.; Univ. of Rome

We address the windup problem arising from actuator rate and magnitude limits in the context of manual flight control for an open loop unstable aircraft. We present a new anti-windup solution tailored for this problem and we compare our result with an optimal solution.

FA09-2 3191

LPV-Based Control of Systems with Amplitude and Rate Actuator Saturation Constraints (I)

Wu, Fen; Dynacs Engineering Co. Inc.
Grigoriadis, Karolos M.; Univ. of Houston

The control of systems with amplitude and rate actuator saturation constraints is examined using a linear parameter-varying (LPV) framework. The proposed methodology uses amplitude and rate saturation indicator parameters to schedule accordingly the parameter-varying controller and to provide graceful performance degradation in the presence of saturation. Parameter-dependent Lyapunov functions are utilized to develop controller synthesis conditions in terms of Linear Matrix Inequalities that can be solved efficiently using recently developed interior-point algorithms. The proposed approach is applied to address a flight control problem subject to aircraft's control surface deflection constraints.

FA09-3 3196

Robust Stabilization of Exponentially Unstable Linear Systems with Saturating Actuators (I)

Hu, Ting-Shu; Univ. of Waterloo
Lin, Zongli; Univ. of Virginia

For an exponentially unstable linear system subject to actuator saturation, a family of linear feedback laws is constructed that achives semi-global practical stabilization on the null controllable region in the presence of bounded disturbance. This is in the sense that, for any (arbitrarily large) compact subset X_0 of the null controllable region, any (arbitrarily small) set X_infinity containing the origin in its interior, and any (abitrarily large) bound on the disturbance, there is a feedback law from the family such that any trajectory of the closed-loop system enters and remains in the set X_infinity in a finite time as long as it starts from the set X_0.

FA09-4 3201

Control of Systems with Actuator Amplitude Nonlinearities: an LMI Approach (I)

Kapila, Vikram; Polytechnic Univ.
Sparks, Andrew G.; Air Force Research Lab.
Pan, Haizhou; Polytechnic Univ.

In this paper, we develop a static, full-state feedback and a dynamic, output feedback control design framework for continuous-time, multivariable, linear, time-invariant systems subject to time-invariant, sector-bounded, input nonlinearities. The proposed framework directly accounts for robust stability and robust performance over the class of input nonlinearities. Specifically, the problem of feedback control design in the presence of time-invariant, sector-bounded, input nonlinearities is embedded within a Lure-Postnikov Lyapunov function framework. Next, a set of linear matrix inequalities are constructed whose solution guarantees closed-loop asymptotic stability, with guaranteed domains of attraction, in the face of time-invariant, sector-bounded, actuator nonlinearities. An illustrative numerical example is presented to demonstrate the effectiveness of the proposed approach.

FA09-5 3206

Robustness of Interconnected Systems with Controller Saturation and Bounded Delays (I)

Kulkarni, V. V.; Univ. of Southern California
Bohacek, S. K.; Univ. of Southern California
Safonov, Michael G.; Univ. of Southern California

Stability of a data network topology, in which a source updates its data transmission rate based on delayed congestion information on its own path only, is examined. Delays associated with feedback information are taken to be known constants and bounded uncertainty is associated with feedback information. Use of linear matrix inequality (LMI) and integral quadratic constraint (IQC) techniques to derive sufficiency conditions for stability of such systems is demonstrated.

FA09-6 3211
Local Stability Control Design for Systems with Saturating Actuators using the Popov Criteria (I)
Pare, Thomas E.; Stanford Univ.
Hindi, Haitham; Stanford Univ.
How, Jonathan P.; Stanford Univ.
Banjerdpongchai, David; Chulalongkorn Univ.

This paper details local control design approaches for systems with actuators that are subject to saturation. Three design algorithms are presented which produce output feedback controllers that either maximize regions of attraction, maximize disturbance rejection, or optimize an L2-gain performance metric. In all cases, the stability analyses are based on the Popov stability criterion and the design techniques are given in terms of LMI/BMI algorithms that are readily solved with available software.

FA10-1 3216
Performance Assessment of a Neural Self-Tuning PI Controller to be used at a Water Treatment Plant
Boehme, Thomas; Univ. of Sunderland
Cox, Chris; Univ. of Sunderland
Lowdon, Alan; Northumbrian-Lyonnaise Tech. & Res. Ctr.

The paper presents the results of a simulation study used as the first step in applying a neuro self-tuning PI controller at a water treatment plant. The training of the adaptive loop, which requires backpropagation of the error through the plant to the controller, is discussed. The benefits of neural control are then demonstrated by comparison with a fixed gain PI strategy for a process whose transfer function structure and parameters change instantaneously at specified time instants.

FA10-2 3221
Fuzzy-Neural-Network-Based Quality Prediction System for Sintering Process
Liao, Jun; Nanyang Tech. Univ.
Er, Meng Joo; Nanyang Tech. Univ.
Lin, Jianya; Zhejiang Univ.

In this paper, based on the property of sintering process, a hybrid Fuzzy Neural Network (FNN) and Genetic Algorithm (GA) system is proposed to solve the difficult and challenging problem of constructing a system model from the given input and output data to predict the quality of chemical components of the finished sinter mineral. A Dual Input Fuzzy Neural Network (DIFNN) is proposed to represent the fuzzy model and realize the fuzzy inference. The learning process of DIFNN is divided into off-line and on-line learning. In off-line learning, GA is used to train DIFNN and construct a system model based on the training data. During on-line operation, the algorithm inherited from the principle of backpropagation is used to adjust the network parameters and improve the system precision in each sampling period. The process of constructing a system model is introduced in details. The result obtained from the actual prediction demonstrates the performance and capability of the proposed system.

FA10-3 3226
Application of a Fuzzy Controller for the Isomerized Hop Pellets Production
Alvarez, Estrella; Vigo Univ.
Navaza, J. M.; Santiago Univ.
Riverol Canizares, Carmen; Vigo Univ.

This paper presents an application of a fuzzy logic control to isomerized hop pellet production. The hop is very important in the brewing industries because a hop of high quality provides a good aroma to the beer and gives consistency to the foam. The isomerized pellets in this case study, are produced by warming stabilized pellets to approximately 50 ºC and holding them for one to two weeks. The alpha acids are almost completely isomerized under these conditions. The fuzzy controller was shown to have a high degree of robustness producing good results such that the quality of the product is guaranteed. A comparison with other control approaches widely used in industry is performed using a nonlinear computer model.

FA10-4 3231
Fuzzy Wide-Range Control of Fossil Power Plants for Life Extension and Robust Performance
Kallappa, Pattada A.; Pennsylvania State Univ.
Ray, Asok; Pennsylvania State Univ.

This paper presents a fuzzy-logic-based methodology of life extending control for robust wide-range operation of fossil power plants. These operations include load-following, scheduled shutdown, and hot startup. The objectives of life extending control are performance enhancement and structural durability of both aging and new fossil power plants.

FA10-5 3236
Neural-Network-Based Adaptive Control with Application to Power Systems
Chen, Dingguo; Oregon State Univ.
Mohler, Ronald R.; Oregon State Univ.
Chen, L.; Oregon State Univ.

This paper first addresses the power system stability issue involving the regular, generator-angle, transient stability and load-driven voltage instability. Transient stabilization of simplified power systems equipped with a FACTS device, Thyristor Controlled Series Capacitor (TCSC), is studied with the consideration of the unknown load. A number of novel techniques are developed to synthesize robust, near time-optimal, neural controllers. The simulations illustrate the performance of the synthesized neural controllers. The results developed can be readily generalized to more general nonlinear systems.

FA10-6 3241
Closed-Loop Drug Infusion using Neural Networks
Lendl, Markus; Univ. Erlangen-Nurnberg
Geldner, Gotz; Univ. of Ulm
Unbehauen, Rolf; Univ. Erlangen-Nurnberg

Closed-loop systems have been proofed as adequate for automated drug administration. They provide significant advantages for the patient as well as for the anesthesiologist. In essence three different types of implementing the control unit have been established: The classical linear controller (e.g. PID, adaptive PID), rule-based systems (e.g. fuzzy logic) and model-based controller (e.g. PK/PD models). Major drawbacks of these implementations can be found in the limited flexibility or the expendable procedures for determining appropriate rules and/or model parameters. Our novel approach, applying neural networks in a predictive model-based design, is able to overcome the depicted difficulties. The performance has been verified by clinical investigations using the short acting non-depolarizing muscle relaxants mivacurium. The obtained results encourage further research using hypnotic drugs.

FA11-1 3245

Model-Based Torque Controller for Dynamical Engine Test Stands
Schmidt, Martin; Darmstadt Univ. of Tech.
Kessel, Jens-Achim; Darmstadt Univ. of Tech.

Dynamical engine test stands are an advanced tool for the development of internal combustion engines (ICE). As Hardware-In-the-Loop simulators, they combine the flexibility of software simulations with the reliability of measurements. Test stand performance and accuracy of the simulation depend on the performance of the test stand's torque control. This paper presents a new model based control approach The mechanical model of the test stand is used for inertia compensation. Crank Angle Synchronous Moving Average (CASMA) filtering designed according to the known signal characteristics of ICEs estimates the required speed and acceleration signals. The combination of the mechanical model and CASMA filtering leads to an improved overall dynamical control performance.

FA11-2 3250
Modeling and Control of a Double Articulated Vehicle with Four Steerable Axles
de Bruin, D.; Eindhoven Univ. of Tech.
Van Den Bosch, P. P. J.; Eindhoven Univ. of Tech.

This paper describes the modelling of double articulated busses and controller design for lateral guidance of these vehicles. The busses are assumed to have all wheel steering and independent drives on each wheel of the semi-trailers and the rearwheels of the tractor. These independent drives together with the steering angles yield 7 possible control inputs. For lateral guidance however, 4 inputs are enough. It is shown that the steering angles are the most benificial inputs. A controller has been designed to guide the busses along the buslanes. This controller shows good performance under varying road conditions.

FA11-3 3255
Pseudo-State System Modeling and a Discrete-Time Separation Principle for LQG Control
Grimble, Michael John; Univ. of Strathclyde

An approach to modelling discrete-time systems is introduced that is motivated by transfer-function models represented in polynomial matrix form. An internal variable, referred to as the pseudo-state, captures the important signal flow information and the control and filter structures are related to this quantity. This requires the development of a new separation principle for output feedback optimal control systems.

FA11-4 *
The Proper Orthogonal Decomposition in Optimal Control of Fluids
Ravindran, S. S.; NASA Langley Research Center

Abstract not available.

FA11-5 3260
Design and Control Oriented Modeling of Microfluidic System Components
Mehta, Ashish; Univ. of Cincinnati
Helmicki, Arthur J.; Univ. of Cincinnati

A first principles based modeling approach is presented. The equations for conservation of mass, momentum and energy are developed for quasi-one-dimensional fluid flow through MEMS fluid components. The equations are cast in terms of common flow variables, geometric and fluid properties. The results are validated against published data. Analyses and simulations are carried out to qualitatively and quantitatively characterize dynamic and steady-state component/subsystem/system properties that would affect the design and control of such systems.

FA11-6 3265
Feedforward Active Noise Controller Design in Ducts without Independent Noise Source Measurements
Hu, Jwu-Sheng; National Chiao Tung Univ.
Lin, Jyh-Feng; National Chiao Tung Univ.

Feedforward control architectures have been widely used in active noise control systems to achieve broadband noise reductions. The basic principle of the control algorithm requires that the feedforward signal, usually the noise source, be independent from the actuator's output. Fail to meet this requirement implies that the overall system contains an acoustic feedback loop and stability and robustness issues become important. This paper investigates this problem in a 1-D sound field (e.g., ducts) using a unidirectional sound wave as the feedforward signal. Controller design based on a distributed parameter model is studied. Several experiments are conducted to illustrate the design procedure as well as verify the effectiveness of broadband noise reductions.

FA12-1 3270
Inverse Filtering and Deconvolution
Saberi, Ali; Washington State Univ.
Stoorvogel, Anton A.; Eindhoven Univ. of Tech.
Sannuti, Peddapullaiah; Rutgers Univ.

This paper studies a well known problem called inverse filtering and deconvolution problem from different angles. Exact, almost, optimal, and suboptimal deconvolution problems are formulated and studied. Necessary and sufficient solvability conditions are given for each formulated problem.

FA12-2 3275
A Robust Direct Approach for Calculating Measurement Error Covariance Matrix
Morad, Kamalaldin; Univ. of Calgary
Svrcek, William Y.; Univ. of Calgary
Mckay, Ian; Hyprotech Ltd.

Calculation of the measurement error covariance matrix is an essential requirement in data reconciliation methods. It is common practice to assume that the measurement errors are normal and have a known covariance matrix. A new robust method of measurement error covariance matrix calculation is presented. This approach directly treats the measured process variables but uses an M-Estimator to reject the outliers and tunes the measured values for deviations from steady-state.

FA12-3 3280
Loopshaping using Pontryagin's Minimum Principle
Davison, Daniel E.; Univ. of Michigan
Kabamba, Pierre T.; Univ. of Michigan
Meerkov, Semyon M.; Univ. of Michigan

Optimal control theory and loopshaping are usually regarded as unrelated control design strategies. In this paper, the two strategies are connected in the sense that optimal control theory is used to find optimal loopshapes. In particular, Pontryagin's Minimum Principle is applied in a novel manner: It is used in the frequency domain to find the magnitude sensitivity function that maximizes disturbance rejection (as measured by the output variance) while subject to several constraints of practical importance. The results are applied to an aircraft control problem.

FA12-4 3282
Exact Decomposition of the Algebraic Riccati Equations of Deterministic and Stochastic Multimodeling Optimal Control and Filtering Problems
Coumarbatch, Cyril; Rutgers Univ.
Gajic, Zoran R.; Rutgers Univ.

In this paper we show how to exactly decompose the algebraic Riccati equations of deterministic and stochastic multimodeling in terms of one pure-slow and two pure-fast algebraic Riccati

equations. In addition, we show how to completely decompose the optimal Kalman filter of the multimodeling structures in terms of puer-slow and pure-fast well-defined reduced-order, independent Kalman filters.

FA12-5 3287
Discrete-Time LQ Optimal Repetitive Control
Koroglu, Hakan; Bilkent Univ.
Morgul, Omer; Bilkent Univ.

LQ optimal repetitive control is developed in single-input single-output discrete-time signal/system framework. For a given plant and a stabilizing controller, the LQ optimal repetitive control system can be obtained by the addition of a plug-in unit to the existing control system. The overall behaviour (stochastic behaviour, stability robustness etc.) of the new system can be improved by the appropriate choice/tuning of the design parameters.

FA12-6 3292
An Iterative Method for Mixed H_2/H_Infinity Control Design with Uncommon LMI Solutions
Shimomura, Takashi; Osaka Univ.
Fujii, Takao; Osaka Univ.

This paper attempts to solve the state-feedback H2/H-infinity control problem by a newly-developed LMI technique that allows for uncommon LMI solutions. In order to obtain a common controller ensuring the two performance criteria while allowing uncommon LMI solutions, we figure out what portion of the LMI solution should be constrained. Then, utilizing the freedom of the unconstrained portion, we propose an iterative method to obtain an updated controller gain which further improves the H2 performance under the H-infinity constraint. An illustrated example is included.

FA13-1 3297
The Analysis of Optimization Based Controllers
Primbs, James A.; California Inst. of Tech.

Many control techniques employ on-line optimization in the determination of a control policy. We develop a framework which provides sufficient convex conditions, in the form of Linear Matrix Inequalities (LMIs), for the analysis of constrained quadratic based optimization schemes. These results encompass standard robustness analysis problems for a wide variety of receding horizon control schemes, including polytopic, structured, and measurement uncertainty for schemes with or without end constraints, observers, or input and output constraints. A simple example illustrates the methodology.

FA13-2 3302
Direct Unfalsified Controller Design - Solution via Convex Optimization
Woodley, Bruce R.; Stanford Univ.
How, Jonathan P.; Stanford Univ.
Kosut, Robert L.; SC Solutions, Inc.

This paper presents an algorithm for designing optimal unfalsified discrete linear time invariant (LTI) output feedback controllers directly from measured data. The approach uses a performance specification that corresponds to minimizing the time domain error between the desired and unfalsified closed loop transfer functions. No assumptions about the plant are explicitly required - the only information needed is a plant input-output time history of length n. In particular, no assumptions are made about the linearity of the system. The identified controller is unfalsified with respect to the performance specification by all observed data. With some minor assumptions, the design problem can be written as a linear program (LP) that can be solved very efficiently to find the global optimum. The approach is demonstrated with a laboratory experiment.

FA13-3 3307
Analysis of a Microsensor Automatic Gain Control Loop
M'Closkey, Robert T.; Univ. of California at Los Angeles
Vakakis, Alex; Univ. of Illinois at Urbana-Champaign

We present the analysis of a nonlinear control system that is used to excite and maintain a specified amplitude of a lightly damped degree of freedom in the Jet Propulsion Laboratory microgyroscope. One- and two-degree-of-freedom models are considered. The analysis suggests that the perturbing effect of an additional weakly coupled degree of freedom does not quantitatively effect the operation of the automatic gain control.

FA13-4 3312
Towards Optimization-Based Nonlinear Output Feedback Control Design
Collins, Jr., Emmanuel G.; Florida A&M - Florida State
Sadhukhan, Debashis; Florida A&M - Florida State
Haddad, Wassim M.; Georgia Inst. of Tech.

This paper proposes a control Lyapunov function-based optimization approach to the design of state and output feedback laws for systems with polynomial nonlinearities. To obtain a less computationally intensive algorithm, the optimization problem uses a heuristic criteria to enforce the negative definiteness of the Lyapunov function. The approach is illustrated with an example , and directions of future research are discussed.

FA13-5 3317
Iterative Feedback Tuning with Guaranteed Stability
De Bruyne, Franky; Australian National Univ.
Kammer, Leonardo C.; Australian National Univ.

This paper presents an identification-based mechanism for introducing guaranteed stability when using a data-driven model-free iterative control design method known as Iterative Feedback Tuning. Also, the use of unbiased estimates of the Hessian is shown to significantly improve the user control over the tuning procedure.

FA13-6 3322
Smart Integral Control
Friedland, Bernard; New Jersey Inst. of Tech.

A method of achieving integral action with regard to disturbances and unknown constant parameters is presented. The method is similar to C.D. Johnson's ``disturbance accomodating control'' but is structured so that the disturbance correction or parameter estimation function can be designed without affecting the disturbance-free control. Simulation examples illustrate the method for a one-degree of freedom servo with a randomly-varying load disturbance, and for a two-degree of freedom servo with two sources of friction.

FA14-1 3327
Identification and Control of Nonlinear Systems using Multiple Models: Relay Feedback Approach (I)
Cheng, Yu-Chang; National Taiwan Univ. of Sci. & Tech.
Yu, Cheng-Ching; National Taiwan Univ. of Sci. & Tech.

In this work the relay feedback autotuning is extended to handle process nonlinearity. Local models from relay feedback tests are scheduled using the Takagi-Sugeno fuzzy modeling. The characteristics of the fuzzy implications are analyzed and an even simpler model is explored. The importance of the selection of the scheduled parameters is emphasized. One transfer function example and a recycle plant are used to illustrated the advantage of the simple model scheduling method. More importantly, the improved control performance can be achieved using already known process knowledge.

FA14-2 3332
An Example of Self-Tuning Controllers on Distributed System (I)
Sehic, Zerina; Univ. of Tuzla
Matko, Drago; Univ. of Ljubljana

Sehic, Zenan; Univ. of Tuzla

The paper deals with a theoretically known, but in practice seldom used procedure for the nonparametric model identification. The essential point of the method is in applying the Pseudo Random Binary signal and evaluating the crosscorrelation function between input and output signals which results in the estimated impulse response of the process. Tunning procedure is applied on the distributed system. The method was improved by applying the signals twice in succession, which resulted in all signals to become periodic. It turned out that the period of 127 (seven bit PRBS register) is sufficient for practical application. Automatic detection of inappropriate frequency range enable the procedure to be applied as selftunning method for PID controllers tunning due tunning rules. The procedure was applied as selftunning method for PID controller's tuning by Chien Hrones Reswick rules. Due to these rules the method is applicable to proportional overdamped processes only. Implemen-tation of procedure on the distributed system has advantage, that we have more selftunning controllers on the same hardware and time needed for parameters estimating is twice shorter. Implementation of the method in IDR 052 software for Mitsubishi Programmable Logic Controllers, SCADA program Factory Link from USDATA and application to the hydraulic plant are described.

FA14-3 3337

A New Non-Parametric Identification Procedure for Online Controller Tuning (I)

Crowe, J.; Roche Productions Ltd
Johnson, Michael A.; Univ. of Strathclyde

The automation of the Ziegler-Nichols Sustained Oscillation method through the use of an on-line relay experiment by Astrom and Hagglund has initiated a wide range of research investigations. Some of these studies have been related to rules for PID control design, but other studies have taken inspiration from the autotune culture and have sought alternative ways of performing the non-parametric identification task of the relay experiment. In this paper a new non-parametric method is described based on a digital phase-lock loop principle. The flexibility of the method to solve different frequency domain identification problems is explored. Simulation results to illustrate the accuracy obtainable are given. Illustrations to demonstrate the ways in which the new procedure can be used will be given in the presentation.

FA14-4 3342

Parameter Space Design of PID Limit Cycle Controllers (I)

Shenton, A. T.; Univ. of Liverpool

This paper develops an extension of the open-loop D-partition (OLDP) parameter-space PID controller design method for linear systems (Shenton and Shafiei 1994 , Shafiei and Shenton 1994 , 1997) to non-linear limit-cycle controllers. The technique allows direct consideration of the limit-cycle amplitude and frequency as well as stability robustness and nominal performance in the controller parameter space. The results show a considerably improved performance over current PI implementation and tuning methods. The outcome should prove popular in industrial practice since the scheme is simply implemented and the application of the design method is easily understood by non-specialist control engineers.

FA14-5 3347

Analysis of a Novel Method of Autotuning a Multivariable Plant Based on Quantization (I)

Goodwin, Graham C.; Univ. of Newcastle
Welsh, James S.; Univ. of Newcastle

Surveys of industry reveal that an alarmingly high proportion of industrial controllers are operated far from their optimal settings. There is thus strong motivation to develop automated tuning methods. One class of tuning methods that has found industrial acceptance is based on the use of relays. A related idea, that we have recently explored, replaces the relays by quantisers placed at the controller output. This approach retains the core merits of the relay method whilst overcoming some of the disadvantages. The current paper contributes to this approach by analysing noise performance, by comparing relay / quantiser tuning with periodic signal injection and by extending the results to multivariable plants.

FA14-6 3352

Closed Loop Tuning of the PID Controller by using MOMI Method (I)

Vrancic, Damir; Jozef Stefan Inst.
Juricic, Dani; Jozef Stefan Inst.
Strmcnik, Stanko; Jozef Stefan Inst.
Hanus, Raymond; Free Univ. of Brussels

A simple procedure for tuning PID controllers in the closed-loop is presented. It employs multiple integration of process input and output signals obtained during the change of the process steady-state. It is shown that the resulting controller parameters are exactly the same as those calculated from the process open-loop step response.

FA15-1 3357

Robust Stability and Performance Analysis using Shifted Quadratic and Nonquadratic Guaranteed Cost Bounds

Osburn, Scott L.; Univ. of Michigan
Bernstein, Dennis S.; Univ. of Michigan

In this paper we derive various shifted guaranteed cost bounds for robust stability and performance with real structured uncertainty. In particular, we obtain a shifted bounded real bound, a shifted Popov bound, a shifted linear bound, a shifted inverse bound, and a maximum entropy bound. Several examples are used to compare the shifted bounds with their unshifted counterparts, and to make comparisons between these new bounds.

FA15-2 3362

Mixed H_2/L_1 Controllers for Continuous-Time MIMO Systems

Amishima, Takeshi; Pennsylvania State Univ.
Sznaier, Mario; Pennsylvania State Univ.

In this paper we consider the problem of optimizing the H_2 norm, while keeping the L_1 norms of some other transfer functions under specified levels. We show that the optimal closed-loop impulse responses of transfer functions in the constraints have finite support, and thus non--rational Laplace transforms. To solve the difficulty of implementing non--rational controllers, we propose a method for synthesizing rational controllers with performance arbitrarily close to optimal.

FA15-3 3367

Robust Mixed H_2/H_Infinity Control for Linear Systems with Norm-Bounced Time-Varying Uncertainty

Aliyu, M. D. S.; King Fahd Univ. of Petroleum and Minerals

In this paper, the mixed H2/H-infinity control problem for uncertain linear systems with norm-bounded time-varying uncertainties is considered. A quadratic guaranteed cost control is developed. Sufficient conditions for the solvability of the problem are given in terms of a pair of cross-coupled Riccati equations. The results presented in the paper extend earlier results on quadratic stability using one criterion to the case of the mixed criteria.

FA15-4 3372

Model-Free Subspace-Based LQG-Design

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When only input/output data of an unknown system are available, the classical way to design a linear quadratic Gaussian controller for that system mainly consists of three separate parts. First a system identification step is performed to find the system parameters. With

these parameters a Kalman filter is designed to find an estimate of the state of the system. Finally, this state is then used in an LQ-controller. In the literature these three steps are hardly ever considered as one joint problem. Based on techniques from the field of subspace system identification the present paper gives a new, much more direct method to calculate a finite-horizon LQG-controller. The three steps of the LQG-controller design, i.e. system identification, Kalman filter and LQ-control design are replaced by a QR- and a SV-decomposition. The equivalence between the new subspace-based approach and the classical approach is proven.

FA15-5 3377

H_Infinity Control for Linear Systems with Controller Uncertainty

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Wang, Jian Liang; Nanyang Tech. Univ.
Lin, Chong; Nanyang Tech. Univ.

This paper is concerned with the problem of linear H_infinity controller design for linear time-invariant systems, in the presence of controller uncertainty. The controller to be designed is assumed to have time-varying, but norm-bounded addittive uncertainties. Design methods are presented for both state feedback and dynamic output (measurement) feedback, both of which degenerate to the standard H_infinity state and output feedback control designs, respectively, when the controller uncertainties become zero. The designed controller with uncertainty is such that the closed-loop system is quadratically stable and has an H_infinity disturbance attenuation bound. The existence of solution to the standard H_infinity control problem guarantees the existence of such H_infinity controllers with a certain level of controller uncertainities. The generalization to uncertain plant is also considered. A numerical example are given to illustrate the design procedures and their effectiveness.

FA15-6 3382

H_Infinity Control for a Class of Descriptor Systems with Uncertainties in the Derivative Matrix

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Wang, Jian Liang; Nanyang Tech. Univ.
Yang, Guang Hong; Nanyang Tech. Univ.

This paper considers the problem of H_infinity control for descriptor systems with the derivative matrix being subjected to norm-bounded perturbations. The analysis shows that, if the problem has a solution under some assumption, the uncertainty falls only into two particular structures. For the first structure, necessary and sufficient conditions are given in terms of the so-called quadratic admissibility with H_infinity performance by using LMI approach. For the other structure, a sufficient condition and necessary condition are given. Numerical examples are given to illustrate the use of the results.

FA16-1 3387

Stability of Constrained Linear Moving Horizon Estimation

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In this work we derive sufficient conditions for the stability of moving horizon state estimation with linear models subject to constraints on the estimate. The key result is that if the time-varying or steady-state Kalman filter covariance update is used to summarize the prior data, then the estimator is stable in the sense of an observer, even in the presence of constraints.

FA16-2 3392

Sensitivity Analysis of Cardiovascular Models for Minimally Invasive Estimation of Systemic Vascular Parameters

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A sensitivity analysis technology was used to evaluate two simple cardiovascular models for model parameter estimation using minimal measurable signals. The purpose of this study is to determine a simple model, which can be used with a left ventricular assist device (LVAD) model to identify the model parameters using signals from the LVAD, to characterize the systemic load. The control of LVAD can then be adjusted based on patient's demand, represented by the systemic load, with minimum invasive sensors. The results obtained from the nominal parameter values of normal patients suggested that a model with a constant capacitance for the left atrium is suitable for parameter estimation if aortic pressure, aortic flow, and left atrial pressure are measurable. If only aortic pressure and flow are available, a simplified model, excluding the left atrium from the original model, provides more accurate estimates. An extended Kalman filter was used with computer simulation data to identify parameters of the models for verifying the results from the sensitivity analysis.

FA16-3 3397

Nonlinear Filtering using Gauss-Hermite Quadrature and Generalised Edgeworth Series

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Continous-discrete nonlinear filter design using the quasi-moments introduced by Kuznetsov and others is developed in this paper. It is shown that the use of Gauss-Hermite Quadrature method presents a computationally efficient method for updating posterior densities arising in nonlinear filtering problems. A passive tracking problem in high measurement noise scenario is considered as an example for implementing this filter.

FA16-4 3402

Worst-Case State Prediction under Structured Uncertainty

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In this paper we provide an LMI-based formulation of a discrete-time predictive filter that computes a minimal ellipsoid of confidence for the state of a linear system subject to structured and time-varying uncertainties in all the system matrices.

FA16-5 3407

On Filtering Problems over Ito-Volterra Observations

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In this paper, the Kalman-Bucy filter is designed for an Ito-Volterra process over Ito-Volterra observations that cannot be reduced to the case of a differential observation equation. The Kalman-Bucy filter is then designed for an Ito-Volterra process over discontinuous Ito-Volterra observations.

FA16-6 3412

Maximum Likelihood Parameter Estimation from Incomplete Data via the Sensitivity Equations: the Continuous-Time Case

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The problem of estimating the parameters for continuous-time partially observed systems is discussed. New exact filters for obtaining Maximum Likelihood (ML) parameter estimates via the Expectation Maximization algorithm are derived. The methodology exploits relations between incomplete and complete data likelihood and gradient of likelihood functions, which are derived using Girsanov's measure transformations. The ML parameter estimates are described by a set of Lyapunov sensitivity equations.

FA17-1 3417

Underwater Vehicle Stabilization by Internal Rotors

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Leonard, Naomi Ehrich; Princeton Univ.

Internal rotors may usefully complement more conventional means of underwater vehicle actuation by extending the operating regime and improving reliability. In this paper we describe stabilizing control laws for an underwater vehicle using internal rotors. Our stabilizing control laws consist of two terms: the first term addresses the conservative part of the system by shaping energy to yield Lyapunov stability, while the second term adds dissipation to ensure asymptotic stability to the motion of interest.

FA17-2 3422
Robust Control of Underwater Vehicles: Sliding Mode vs. LMI Synthesis
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Campa, Giampiero; Univ. of Pisa

This paper presents a synthesis of a robust control for an autonomous underwater vehicle (AUV) using two different methods. The problem statement requires the design of a position and attitude control system for the vehicle such that robust trajectory following is achieved. A detailed nonlinear model of the vehicle was derived, an operating point for nominal design was selected, and a multivariable linear model of the vehicle was obtained by linearization around the operating point. The presence of structured uncertainties due to errors in the computation of hydrodynamic coefficients, dynamic linearization and truncation, unknown disturbances, is included in the control synthesis. Two robust controllers were designed, the first one nonlinear, using a Sliding Mode approach, and the second one linear, using linear matrix inequalities (LMI) synthesis techniques. The performance of the two controllers were extensively evaluated and compared in simulation with a full nonlinear model of the vehicle.

FA17-3 3427
Multivariable Submarine Control System Analysis and Design using an Interactive Visualization Tool
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Rodriguez, Armando A.; Arizona State Univ.

This paper describes an Interactive Modeling, Simulation, Animation, and Real-Time Control (MoSART) Environment which may be used for analyzing, designing, visualizing, and evaluating the performance of robust multivariable submarine control systems. The described MoSART environment is based on Microsoft Windows NT/95/98, Visual C++, Microsoft Direct-3D, and MATLAB/SIMULINK. The environment consists of several key modules: (i) a program user-interface (PUI) module, (ii) a real-time simulation (RTS) module, (iii) a graphical visualization and animation (GVA) module, and (iv) a help/instruct module. The environment also accommodates data exchange with MATLAB. This is useful for control system analysis and redesign. This makes the developed environment very extensible with respect to mathematical modeling and control. The developed an Interactive MoSART Submarine Environment is a valuable tool for enhancing both education and research. Examples are presented to illustrate its utility.

FA17-4 3432
Feedback Control for Planar Maneuvers of an Aerospace Vehicle with an Unactuated Internal Degree of Freedom
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We study feedback control laws that enable an aerospace vehicle to perform planar maneuvers. We make several key assumptions including: (1) maneuvers are planar, (2) a complete set of vehicle control forces and moments is available, (3) the vehicle is a rigid body with a single unactuated internal degree of freedom. The control objective is to design a feedback controller so that the controlled vehicle accomplishes a given planar maneuver, that is a change in the translational velocity vector and the attitude of the vehicle, while rapidly attenuating any relative motion of the internal degree of freedom. A time-invariant discontinuous feedback law is constructed that achieves these control objectives with exponential convergence rates. The effectiveness of the proposed feedback law is illustrated through a simulation example.

FA17-5 3437
Efficient Control Law Simulation for Multiple Mobile Robots
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Kotulski, Joseph; Sandia National Labs.
Kwok, Kwan S.; Sandia National Labs.
Feddema, John; Sandia National Labs.

In this paper we consider the problem of simulating simple control laws involving large numbers of mobile robots. Such simulation can be computationally prohibitive if the number of robots is large enough, say 1 million, due to the O(N^2) cost of each time step. This work therefore uses hierarchical tree-based methods for calculating the control law. These tree-based approaches have O(NlogN) cost per time step, thus allowing for efficient simulation involving a large number of robots. For concreteness, a decentralized control law which involves only the distance and bearing to the closest neighbor robot will be considered. The time to calculate the control law for each robot at each time step is demonstrated to be O(logN).

FA17-6 3441
A Testbed System for Nonlinear and Intelligent Control
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There has been a large amount of publications concerning nonlinear and intelligent control in recent years. It has become an important field of research. As each new algorithm becomes available, the need for realistic and accurate test bed systems is apparent. Some previous simulation models have not been real world systems, or a simplification of a much larger system. It is the goal of this document to present a much more complete description of one real world model so that others may use this model to test their control algorithms. The system analyzed in this document is a trailer truck system. The model, based on the physical system, extends the models of previous publications. A full dynamical representation is given. Tests show the models accuracy against the actual system.

FA18-1 3446
Optimal Design of Experiments for Control: a Preposterior Viewpoint
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Kabamba, Pierre T.; Univ. of Michigan
Khargonekar, Pramod P.; Univ. of Michigan

This paper considers using experimental design in model identification to increase the predicted probability of closed-loop performance. The methodology assumes a Bayesian modeling viewpoint, where experimental input-output data is used off-line to characterize the probability distribution of the model parameters. Our approach to design of experiments is to select experimental inputs that "shape" a preposterior distribution of the model parameters such that a certain region in the model parameter space containing a pre-specified percentage of the preposterior density, denoted as an HPD region, is a subset of the region of closed-loop performance. Roughly speaking, the resulting experiments reduce model parameter variance in directions orthogonal to the performance set boundary. A missile autopilot example is used to illustrate the results.

FA18-2 3451
An Indirect Approach to Closed-Loop Identification of Wiener Models
Chou, C. T.; Delft Univ. of Tech.
Verhaegen, Michel H.; Delft Univ. of Tech.

A Wiener model is a nonlinear block oriented model with a linear time-invariant block followed by a static nonlinear block. This paper presents a method to identify Wiener models with a general disturbance configuration in closed-loop using the indirect approach. The method is applied to data generated by a nonlinear simulation model of high purity distillation column.

FA18-3 3456
On the Identification of Nonlinear Maps in a General Interconnected System
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Packard, Andrew K.; Univ. of California at Berkeley
Poolla, Kameshwar; Univ. of California at Berkeley

This paper is concerned with the problem of identifying static nonlinear maps in a general, structured interconnected system. These static nonlinear maps are non-parametric in that they do not have a natural parameterization that is known or suggested from an analytical understanding of the underlying process. Our technique involves selecting the nonlinear maps so as to maximize the "smoothness" or "staticness" of these maps while respecting the available input-output data and the noise model. These techniques avoid bias problems that arise when imposing artificial parameterizations on the nonlinearities. Computationally, these methods reduce to iterative least squares problems together with Kalman smoothing. Preliminary examples reveal the promise of these techniques.

FA18-4 3462
Distillation Column Identification for Control using Wiener Model
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Identification of distillation columns for model based control is studied using Wiener type models. A recently developed parametric identification of Wiener model is extended and used to solve the problem. The method provides solutions to the four problems of identification. It is control relevant and can treat both open-loop and closed-loop data. First the identification method is outlined, then two cased studies will be presented, the first one is a simulated high purity distillation column based on first principle models, the second one is a crude unit atmospheric tower.

FA18-5 3467
Parameter Identification of a Brushless Motor Drive System using a Modified Version of the Fast Simulated Diffusion Algorithm
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Lyden, Colin; NMRC, University College

The implementation of an adaptive version of the fast simulated diffusion (FSD) algorithm, as a practical optimization tool in system identification, for optimal dynamical parameter extraction of a high performance brushless motor drive system (BLMDS) with a multiminima objective function is presented. A considerable reduction in the number of least squares cost evaluations is achieved with the modified FSD search for global minimum convergence resulting in substantial savings in computation time. The requirement for an accurate physical model of BLMDS nonlinear operation including inverter blanking as part of the identification strategy is briefly discussed. The restriction of the search procedure to quantized parameter space, because of false 'local' minima proliferation with cost surface noise near the global extremum, is briefly examined. The effectiveness of the modified FSD search technique, with remote initialization, in reaching the global minimizer for a range of known drive inertial loads is demonstrated. This is achieved by the use of step response current feedback, responsible for genuine local minima plurality, in the objective function formulation. Frequency and phase coherence of the drive model simulation, based on returned FSD parameter estimates, with BLMDS test data attest to FSD convergence accuracy which validates this parameter identification method.

FA18-6 3472
Adaptive Wavelet Networks for Nonlinear System Identification
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Ho, Daniel W. C.; City Univ. of Hong Kong

Wavelet transforms have recently emerged as a means of representing a function in a manner which readily reveals properties of the function in localized regions of the joint time-frequency space. In this paper, wavelet-based neural network (WNN) is introduced for nonlinear system identification, which uses a set of compactly or locally supported orthonormal scaling functions to represent a function. Adaptive weight updating law is derived based on Lyapunov stability theory . It is shown that even in the presence of modeling error between the system and the WNN model, the weight updating law guarantees the boundedness of identification error and the weights.