CACSD-M-Plenary Hapuna Ballroom

CACSD-MA-1 8:30 CACSD-630

Modelica -A Language for Physical System Modeling, Visualization and Interaction

Elmqvist, Hilding,
Mattsson, Sven E. Dynasim AB
Otter, Martin DLR Oberpfaffenhofen

Modelica is an object-oriented language for modeling of large, complex and heterogeneous physical systems. It is suited for multi-domain modeling, for example for modeling of mechatronics including cars, aircrafts and industrial robots which typically consist of mechanical, electrical and hydraulic subsystems as well as control systems. General equations are used for modeling of the physical phenomena. No particular variable needs to be solved for manually. A Modelica tool will have enough information to do that automatically. The language has been designed to allow tools to generate efficient code automatically. The modeling effort is thus reduced considerably since model components can be reused and tedious and error-prone manual manipulations are not needed. The principles of object-oriented modeling and the details of the Modelica language as well as several examples are presented.

CACSD-M-Panel Mauka

Perspectives of CACSD

CACSD-MA-PN-1 CACSD-297

Perspectives of CACSD: Embedding the Control System Design Process into a Virtual Engineering Environment

Gruebel, Georg DLR Oberpfaffenhofen

The high computation and visualization power now available at the control engineers's desk opens the perspective of embedding CACSD Technology into a Virtual Engineering environment. This enables concurrent interaction of control engineering with multidisciplinary high-fidelity system dynamics modeling, and supports a fundamental change of the conventional control system design tuning process in a computation framework of fast nonlinear simulation, automatic search for feasible solutions, and interactive multiobjective optimization to trade-off conflicting design requirements. Such an environment promotes active decision support to foster the control engineer's role as the prime maker in system dynamics design.

CACSD-MA1 Koa

Computational Tools for Modeling Uncertain Systems

CACSD-MA1-1 10:00 CACSD-1

Symbolic and Numerical Software Tools for LFT-Based Low Order Uncertainty Modeling

Varga, Andras,
Looye, Gertjan DLR Oberpfaffenhofen

One of the main difficulties in applying modern control theories for designing robust controllers for linear uncertain plants is the lack of adequate models describing structured physical model uncertainties. We present a systematic approach for the generation of uncertainty models described by linear fractional transformations (LFTs) and report on recently developed symbolic and numerical software to assist the generation of low order LFT-based uncertainty models. The kernel of the symbolic software is a Maple library for generation and manipulation of LFT models. Additional numerical tools for order reduction of LFT models are based on MATLAB and Fortran implementations of numerically reliable algorithms. Three examples of uncertainty modeling of aircraft dynamics illustrate the capabilities of the new software to solve high order uncertainty modeling problems.

CACSD-MA1-2 10:20 CACSD-7

Computer-Aided Uncertainty Modeling of Nonlinear Parameter-Dependent Systems, Part I: Theoretical Overview

Belcastro, Christine M.,
Morelli, Eugene A.,
Lim, Kyong B. NASA Langley Res. Cen.

Robust control system analysis and design is based on an uncertainty description, called a linear fractional transformation (LFT), which separates uncertainties from the nominal system model. These models include both parametric and non-parametric uncertainties for many practical problems. LFT formulation for these mixed uncertainty systems involves formulation of a linear parameter varying (LPV) model, construction of a low-order parametric LFT model, and validation of a mixed uncertainty model with respect to measurement data. this paper provides an overview of uncertainty modeling methods and software tools being developed for application to mixed uncertainty systems. these methods and tools provide a computer-aided uncertainty modeling capability that makes current robust and LPV Control methods accessible to a broad class of practical problems.

CACSD-MA1-3 10:40 CACSD-16

Computer-Aided Uncertainty Modeling of Nonlinear Parameter-Dependent Systems, Part II: F-16 Example

Belcastro, Christine M.,
Lim, Kyong B.,
Morelli, Eugene A. NASA Langley Res. Cen.

Robust control System analysis and design is based on an uncertainty description, called a linear fractional transformation (LFT), which separates the uncertain (or varying) part of the system from the nominal system. System uncertainties to be represented in LFT form include both parametric and non-parametric uncertainties for many practical problems. LFT formulation for these mixed Uncertainty systems involves: formulation of a linear parameter varying (LPV) model, construction of a low-order parametric LFT model, and validation of a mixed uncertainty model with respect to measurement data. This paper presents an F-16 aircraft example problem that illustrates the development of a validated mixed uncertainty model for this vehicle.

CACSD-MA1-4 11:00 CACSD-24

Software for Modeling, Analysis, and Control Design for Multidimensional Systems

D'Andrea, Raffaello Cornell Univ.

In this paper we describe a Matlab toolbox for modeling, analysis, and control design for multidimensional systems. The software may be obtained from the author's home page.

CACSD-MA1-5 11:20 CACSD-28

The Validation of Model Sets on the Basis of Closed-Loop Feedback System Generated Data

Dullerud, Geir E. Univ. of Illinois, Urbana-Champaign
Smith, Roy Univ. of California, Santa Barbara

Model validation provides a useful means of assessing the ability of a model to account for a specific experimental observation, and has application to modeling, identification and fault detection. In the robust control context this amounts to determining whether or not there exists an element of the model set that can account for the observed experimental datum. Efficient algorithms have been developed for model validation with frequency domain, discrete-time, and sampled-data frameworks. The focus of this paper is on the application of this theory to feedback systems. We outline these algorithms and discuss how they form part of a computationally based set of integrated tools for modeling, identification, and control system design.

CACSD-MA1-6 11:40 CACSD-34

Model Reduction of Complex Systems in the Linear-Fractional Framework

Lall, Sanjay California Inst. of Tech.
Beck, Carolyn Univ. of Illinois, Urbana-Champaign

This paper discusses model reduction for systems in several different classes; in particular time-varying, multidimensional or uncertain systems, and nonlinear systems in the linear-fractional framework. We describe in detail the unifying viewpoint that this framework provides to all of these classes, and discuss the numerical methods used to construct reduced-order models. The methods used are extensions of the well-known method of balanced truncation, with provably good properties in the induced-norm.

CACSD-MA2 Milo

Hybrid Systems and Real-Time Simulation

CACSD-MA2-1 10:00 CACSD-97

An Environment for Model-Checking of Logic Control Systems with Hybrid Dynamics

Kowalewski, S.,
Bauer, N.,
Preussig, J.,
Stursberg, O.,
Treseler, H. Univ. of Dortmund

This paper presents the modeling environment VERDICT which intends to make the method of formal verification applicable to logic controlled chemical plants. The tool offers textual and graphical editors to set up models of plant and controller. The plant model can be specified as hybrid dynamical or (timed) discrete systems, which are then translated automatically into models that are verifiable with existing model-checking tools. Furthermore, VERDICT allows to include the controller model by specifying it in IL code directly. The contribution illustrates the different features of the framework, the underlying modeling paradigm, and some aspects of the analysis using a simple technical example.

CACSD-MA2-2 10:20 CACSD-103

Modular Verification of a Fault-Tolerant Active Structure Controller: An Example

Wong-Toi, Howard Cadence Berkeley Labs

The decomposition of a system into modular components, together with abstractions of the components, can allow a computationally difficult global verification task to be broken into a number of smaller, more manageable verification subtasks. We provide the first known non-trivial application of modular verification in conjunction with the model-checking paradigm for verifying hybrid systems. We verify a fault-tolerant active structure control system. The control system is a version of one originally presented and analyzed in [ECB94,ECB97]. While the minimization method of [ECB94,ECB97] is automated, it also requires the abstractions to have exactly the same behaviors as their implementations. Our verification methodology differs in that we must provide explicit abstractions of the system components. However, we allow abstractions that are more abstract than the components themselves. General guidelines are given for the development of suitable abstractions

CACSD-MA2-3 10:40 CACSD-109

Fast Marching for Hybrid Systems

Branicky, Michael S.,
Hebbar, Ravi Case Western Reserve Univ.

This paper describes an approach to solving optimal hybrid control problems using level set methods. Level set methods are a powerful set of techniques for generating equipotential contours with applications in the realm of fluid mechanics, computer vision, material science, robotics and geometry. This paper specifically deals with the problem of determining an optimal control path in a hybrid system by extending a particular level set algorithm, known as the fast marching method, to a hybrid setting. Several representative examples are solved.

CACSD-MA2-4 11:00 CACSD-115

Real-Time Distributed Software-In-The-Loop Simulation for Distributed Control Systems

Kwon, Wook Hyun,
Choi, Seong-Gyu Seoul Nat. Univ.

In this paper, a realization method is suggested for real-time distributed software-in-the loop (DSIL) simulation for distributed control systems. The realization is composed of several personal computers (PCs) for sub-plants and their controllers, an Ethernet network connecting them, and a general-purpose computer-aided control system design (CACSD) tool for the easy design of controllers. Requirements on real-time DSIL simulation are investigated in terms of network-related control issues and CACSD tool issues. CEMTool, a CACSD tool which is suitable for real-time DSIL simulation, is proposed for easy programming of control

algorithm and plant dynamics and for their easy connection. To reduce a sampling interval and guarantee real time, a network scheduling algorithm is suggested for real-time DSIL simulation. It is demonstrated via an experiment of turbine-generator system that this real-time DSIL simulation is very useful for distributed control system design.

CACSD-MA2-5 11:20 CACSD-120

Simulation and Animation in Simulink and VRML

Ravn, Ole,
Larsen, Thomas D.,
Andersen, Nils A. Tech. Univ. of Denmark

The paper describes a solution that enables the control system designer to easily and seamlessly integrate visualization into simulations studies. The design target has been that no more than 10 percent of the modelling effort should be devoted to modelling the visualization part of the simulation. The visualization module (VRML Animation Toolset) in the prototype implementation is interfaced to Simulink, but the design aims at making the concept simulation platform independent. The visualization module can also be connected to real systems using the Real-Time Workshop (RTW) thus enabling a visual comparison of the simulation system performance and the true system performance. The paper also explains the underlying simulation centered architecture and the links to the prototype implementation.

CACSD-MA2-6 11:40 CACSD-126

Development of Software for the Hard Real-Time Controller Using Feature-Oriented Reuse Method and CASE Tools

Choi, Byoung Wook,
Jang, K.B.,
Kim, C.H.,
Wang, K.S. LG Ind. Sys.
Kang, K.C. Pohang Univ. of Sci. & Tech.

Elevator control systems are very sophisticated, hard real-time systems that have to do various activities within specified timing constraints. Also, they have numerous differences of functions and system specifications due to adopting user's requirements. So, it makes difficult to develop new models especially on requirement changes with satisfying timing constraints. In order to make hard real-time control system more reliable and easier to achieve time-to-market; a new software development process focused on software reuse is introduced. This process has been applied from the first phase of the software life-cycle. It is called Feature-Oriented Reuse Method (FORM). Using FORM, we could describe those complicated elevator systems in more understandable form, utilize reusability of requirement specifications, adopt new requirements, and finally develop reliable control systems. FORM a software process is not only having visual modeling tool to analyze and develop software but also a dynamic behavior simulator utilizing state simulation engine and logic analyzer. This paper present real-time elevator model resulted from each software development process for the elevator controller and promising simulation results showing dynamic behavior.

CACSD-MA3 Mauka
Automatic Code Generation for Automotive Applications

CACSD-MA3-1 10:00 CACSD-200

Automatic Code Generation Requirements for Production Automotive Powertrain Applications

Toeppe, Steve,
Bostic, Dave,
Ranville, Scott,
Rzemien, Kevin Ford Motor Co.

Automatic code generation for production automotive powertrain applications introduces many challenges for the tool vendor. Resource efficiency, reliability, and product process development issues need to be addressed. Automatic code generation used for rapid prototyping systems usually will not satisfy the requirements necessary for production oriented code generation. Some of the requirements critical to automatic code generation are not immediately obvious to a tool vendor who is not active in the user's industry. The purpose of this paper is to address some of the most common requirements for production automotive powertrain code generation

CACSD-MA3-2 10:20 CACSD-207

Using BEACON to Generate Embedded Software from Simulink Models

Englehart, Matthew Applied Dynamics Int.

Computer Aided Control System Design (CACSD) toolsets are used to model, design, and analyze physical plants and the functional requirements of their associated controllers. Embedded Software Development (ESD) toolsets are used during later stages of product development; their purpose is to support the design, generation, and testing of software for embedded controllers. The algorithms that the embedded controllers implement are often initially designed and analyzed in a CACSD toolset. There are obstacles to the migration of a control law algorithm specified in a CACSD toolset to a controller implementation specified in a ESD toolset. While the mechanics associated with translation between the toolsets' formats and languages present an obvious barrier, a subtle yet pervasive issue is the integration of the objectives of the two classes of toolsets. In response to this problem, Applied Dynamics has developed a methodology to be used to build bridges between CACSD and ESD toolsets. This methodology consists of a software-design level layered on top of the CACSD modeling layer. At present, this methodology has its initial realization as a tool that converts a controller algorithm in Mathworks' Simulink and Stateflow CACSD toolset into a controller implementation in Applied Dynamics' BEACON ESD toolset. This initial tool serves as a testbed for refinement of the underlying methodology.

CACSD-MA3-3 10:40 CACSD-213

Production Quality Code Generation from Simulink Block Diagrams

Hanselmann, Herbert,
Kiffmeier, U.,
Koester, L.,
Meyer, M.,
Ruekgauer, A. dSpace GmbH

This paper describes a new code generator that meets both the requirements of production code developers in terms of efficiency and reliability, and of the system engineer doing the control design. It works with MATLAB/Simulink block diagrams, supports automatic scaling, and generates highly-efficient production-ready C code for microcontrollers. The development environment is enhanced by a number of supporting tools to analyze fixed-point effects, profile code sizes and execution times, validate models with automated test series, output ASAP2[1] calibration information, and generate documentations.

CACSD-MA3-4 11:00 CACSD-219

Towards a More Efficient Approach to Automotive Embedded Control System Development

Smith, Michael H.,
Elbs, Martin ETAS Inc.

With current and future demands on automotive embedded control systems for added functionality and decreased time-to-market, greater emphasis is being placed on engineering tools to facilitate ECU development. Manufacturers are constantly searching for greater efficiency in the ECU development cycle, including flexibility, ease-of-use, hardware and software reusability, and standardization (for hardware interfaces, software and modeling tools, etc.). This paper describes the requirements of a tool set that will effectively meet these demands. Software tools that allow graphical specification of control systems and models should permit users to create and simulate target independent-and hence, reusable-plant models and control functions. At the same time, this simulation environment should be compatible with rapid prototyping hardware, as well as support implementation-specific requirements, such as fixed-point arithmetic or different variable types. Support for operating system specific functions (such as timing and interrupts) is also an essential element for an integrated ECU development platform. Including the OS tasks in the control specification/simulation environment can eliminate additional coding steps for both rapid prototyping and the production ECU, as well as verify timing, sequencing, and possibly execution speed. Hardware-in-the-loop platforms and dedicated real-time vehicle simulators allow concurrent development of both control and system hardware (e.g. the actual engine) as well as better initial function and parameter calibration. Finally, the ECU development tool set must support automatic production code generation. A common development platform creates an environment in which the various engineers (software, controls, hardware, etc.) can communicate efficiently in a common language where transfer of information and code is uninhibited by the inherent problems of disparate (proprietary, non-standardized, etc.) software tools. The essential aspects of an efficient ECU development process are supported by example through the tools of ETAS Inc. and the development of a gasoline engine ECU for a demonstration vehicle. ?

CACSD-MA3-5 11:20 CACSD-225

A Qualitative Analysis of Automatic Code Generation Tools for Automotive Powertrain Applications

Wybo, David,
Putti, David Motorola Virtual Garage

This paper reports the results of an evaluation of commercially available automatic code generation tools used for automotive powertrain software development. The evaluation was done in conjunction with a specific automotive customer, using a customer supplied powertrain feature. This evaluation was not done from a modeling and simulation perspective, but rather from a software perspective. The automatically generated code is compared with hand written code and analyzed for both its quality and efficiency.

CACSD-MA3-6 11:40 CACSD-231

Software Architectures for OSEK/VDX Applications Using MATRIXx TM and AutoCode TM

Martin, Todd A. Integrated Systems, Inc.

This paper will describe the convergence of automatic code generation from graphical diagrams and Real Time Operating System (RTOS) technology. The two fields have developed for some time independently of each other but recent developments in both fields have initiated a melding of the two. Particularly, in the field of automatic code generation the concept of configurable code generators which allow the user to make compromises between speed and program size as well as the format and style of the code have allowed this technology to branch out of its more traditional rapid-prototyping and desktop simulation strongholds. In the area of operating systems, the relatively recent launch of the OSEK specification has provided the foundation for automotive manufacturers and suppliers to make use of commercially available operating systems for their applications. This paper presents several techniques which allow a configurable C code generator, such as AutoCode, to efficiently use the utilities provided by an OSEK compliant RTOS to develop portable and reusable software for automotive Electronic Control Units.

CCA-MA4 Makai
Metal Processing

CCA-MA4-1 10:00 CCA-1

Modeling for Control of Blast Furnace

Tsumura, Kouji Univ. of Tokyo

In this paper, we propose a method to give models of complex systems for controller design by using numerical simulators. We apply this method to a two-dimensional region simulator for blast furnace and show a process of leading a model for control. Furthermore we compare the dynamics of the model with the simulator and analyze the performance of this method.

CCA-MA4-2 10:20 CCA-7

Directional Considerations When Tracking Time-Variant Parameters

Waller, Matias,
Saxen, Henrik — Abo Akademi Univ.

The need for directional considerations when tracking time-variant parameters became apparent during the development of a predictive model for an industrial blast furnace, and a method capable of such considerations is suggested. The method utilizes the structure of the Kalman filter, but does not require any prior knowledge of the variations in the parameters. Instead, some simplifications motivated in the context of parameter estimation and identification are introduced, which make an approach to determine individual gains in the update of the parameters plausible. Along with simulations, the application of the method to a challenging full-scale process, which exhibits an a priori unknown time-variant behavior, clearly illustrate the potential of the proposed method.

CCA-MA4-3 10:40 CCA-13

Hybrid Neural Network Multivariable Predictive Controller for Handling Abnormal Events in Processing Applications

Mathur, Anoop,
Parthasarathy, Sanjay,
Gaikwad, Sujit — Honeywell Tech. Cen.

We describe an innovative hybrid controller that uses neural networks and Multivariable Predictive Control (MPC) to handle abnormal events in process applications. The controller detects abnormal situations, such as grinding mill spills or mill power excursions in mineral processing, or incipient flooding in separation columns and then reconfigures the multivariable controller to stabilize the operations. Neural networks are typically used to detect and classify the abnormal situation and knowledge of process dynamics and interactions is used to reconfigure the multivariable predictive controller parameters to stabilize the operations. Thus the MPC can be configured and tuned to provide good control around the 'normal' operating range, and when an upset occurs and is detected a new set of tuning parameters are used.

CCA-MA4-4 11:00 CCA-18

On the Possibility of Looperless Rolling on Hot Rolling Process

Katori, Hideo,
Hirayama, Ryu,
Ueyama, Takatsugu — Nippon Steel Corp.
Furuta, Katsuhisa — Tokyo Inst. of Tech.

The possibility of looperless control of finishing mill on hot rolling process is stated in this paper.

CCA-MA4-5 11:20 CCA-23

Strip Gage and Tension Control At Cold Tandem Mill Based on I.L.Q. Design Theory

Kadoya, Y.,
Ooi, T.,
Washikita, Y. — Sumitomo Metal Ind.
Seiki, Y. — Toshiba Corp.

Automatic Gage Control (A.G.C..) system is important for the cold tandem mill rolling of steel. A new gage and tension control system based on Inverse Linear Quadratic (I.L.Q.) design theory which is superior to the conventional cross control law in point of preventing undesirable strip vibration, is studied. First, the I.L.Q. controller for the first stand of the cold tandem mill is designed. Next, the I.L.Q. control law is analyzed, and the original controller was modified. Finally, we confirmed that the modified I.L.Q. controller is able to improve the strip gage accuracy through the simulation and the experimental test. The focus of this study is the analysis of the function of the control loops, using parametric representation of the control law.

CCA-MA4-6 11:40 CCA-29

Application of Multivariable Technique in Temperature Control of Reheating Furnaces

Wang, Zhongjie,
Shao, Cheng,
Chai, Tianyou — Northeastern Univ.

Taken account of reheating furnaces being multivariable systems with strong coupling and large time delay, this paper applied decoupling technique and Smith compensation to control of the furnace temperature. Experiments indicate that this proposed strategy can improve the performance of furnace temperature control greatly

CCA-MA5 Hau
Flight Control I

CCA-MA5-1 10:00 CCA-33

Receding Horizon FIR Filter with Estimated Horizon Initial State and its Application to Aircraft Engine Systems

Han, Soo Hee,
Kim, Pyung Soo,
Kwon, Wook Hyun — Seoul Nat. Univ.

This paper proposes a new version of the discrete-time receding horizon FIR filter (RHFF) using the estimated horizon initial state. The estimated horizon initial state is obtained from the best linear unbiased estimator (BLUE) scheme. The proposed RHFF for the current state can be represented in either an iterative form or a batch form. The proposed RHFF is always time-invariant and has unbiasedness and remarkable deadbeat properties. The proposed RHFF is shown to be equivalent to the existing RHFF with unknown horizon initial state. For the validity of the proposed RHFF, the problem of a third-order dynamic model of an F-404 aircraft engine system is considered via simulation studies.

CCA-MA5-2 10:20 CCA-39

Bayesian Belief Networks for Fault Identification in Aircraft Gas Turbine Engines

Mast, Timothy A.,
Reed, Aaron T.,
Yurkovich, Stephen — Ohio State Univ.
Ashby, Malcolm,
Adibhatla, Shrider — GE Aircraft Engines

This paper describes the methodology for usage of Bayesian Belief Networks (BBNs) in fault detection for aircraft gas

turbine engines. First, the basic theory of BBNs is discussed, followed by a discussion on the application of this theory to a specific engine. In particular, the selection of faults and the means by which operating regions for the BBN system are chosen are analyzed. This methodology is then illustrated using the GE CFM56-7 turbofan engine as an example.

CCA-MA5-3 10:40 CCA-45

Control Structure Design Methods Applied to a Jet Engine

Harefors, Melker Volvo Aero Corp.

Future jet engines will be more complex with more variables to control to meet increasing demands on functionality. The interaction between the engine and aircraft systems will also increase, with mission- specific control and with control of thrust direction. To utilize the potential of these engines, it is also necessary to use more advanced control concepts than are conventionally used today. Multivariable controllers are most often at the core of these advanced control concepts. Important parts of a multivariable control design are to select suitable inputs and outputs and how to configure the control laws. This is referred to as Control Structure Design (CSD). Some methods to accomplish this have been evaluated at Volvo Aero. A model of a typical jet engine has been used as application in this evaluation. The general impression from this work is that the tested methods are very usable to select between a large number of possible structures. However, it is essential to combine the use of the methods with application knowledge and understanding of the control objectives.

CCA-MA5-4 11:00 CCA-51

Receding Horizon Control of the Caltech Ducted Fan: A Control Lyapunov Function Approach

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

This paper deals with the application of receding horizon methods to the simplified model of a flight control experiment developed at Cal Tech. The dynamics of the system are representative of a Vertical Landing and Take off (VTOL) aircraft, such as a Harrier around hover. The adopted control methodology is a hybrid of receding horizon techniques and Control Lyapunov Function (CLF) based ideas. First a CLF is found, and then, by using the CLF as the terminal cost in the receding horizon optimization, stability is guaranteed. It is shown that if the horizon length is long enough, a simple choice of CLF, i.e., the one obtained from Jacobian linearization of the dynamics at hover, will achieve a good performance. However, if due to computational costs, longer time horizons are not possible, stability can be guaranteed by applying the CLF obtained using Quasi-LPV methods, as a terminal costs. Several numerical simulations for different time horizons are presented to illustrate the effectiveness of the discussed methods.

CCA-MA5-5 11:20 CCA-57

QFT Based Robust/Fault Tolerant Flight Control Design for a Remote Pilotless Vehicle

Wu, Shu-Fan Nanjing Univ. of Aeronautics & Astronautics
Grimble, Michael J. Univ. of Strathclyde
Wei, Wei Nanjing Univ. of Aeronautics & Astronautics

Quantitative Feedback Theory (QFT) was applied successfully to enhance the robust stability and tracking performance of the pitch flight control system for a remote pilotless vehicle (RPV), within its full flight envelope. The influence of control surface loss or damage to the dynamic derivatives of the aircraft model can be treated as an extension of the model uncertainty robustness problem. QFT is applied to the analysis and design of the fault tolerant flight control system allowing for possible control surface damages.

CCA-MA5-6 11:40 CCA-63

Fault Tolerant Controller Design for Large Space Structures

Ahmad, S. S. Allied Signal Power Systems Inc.
Lew, J. S.,
Keel, Lee H. Tennessee State Univ.

This paper utilizes robust modeling and control techniques to solve the problem of synthesizing a controller that ensures closed loop stability as well as maintaining the desired performance of large space structures under various predicted failure conditions. The approach is divided into two parts. First, we develop a family of MIMO models that includes various predicted failure states in the structures. Then a controller that guarantees robust stability and performance of the entire closed loop family is designed by using the -synthesis technique. The key ingredients of this approach are 1) use of the interval transfer function to model the structures with predicted damage and 2) utilization of the properties of interval transfer functions to simplify the -synthesis procedure. Steps to validate the proposed approach are carried out by simulation

CCA-MA6 Lehua

Integrated Design of Passive and Active Elements in Control Systems

CCA-MA6-1 10:00 CCA-69

Generation of Structural Design Constraints for Spaceborn Precision Pointing Systems

Becker, Gregory,
Cubalchini, Ronald,
Tham, Quang,
Anagnost, John Raytheon Systems Co.

This paper formulates the problem of generating structural design constraints for spaceborne precision pointing systems as a robust performance problem. This problem is relevant during the initial requirement flow-down and preliminary design phase for these types of systems. Using a nominal controller design, which satisfies the performance requirements on a nominal plant model, frequency dependent uncertainty weights are chosen such that a compromise between simplicity in control architecture and feasibility of mechanical design are made. The analysis problem is formulated as a structural singular value test. The procedure is demonstrated on a single-axis model of a gimbal inertial pointing system when the inertial measurement device is either on or off gimbal.

CCA-MA6-3 10:40 CCA-75

Integrated Structural and Control Design for Structural Systems via LMIs

Mayzus, Alexander,
Grigoriadis, Karolos Univ. of Houston

Iterative redesign techniques are proposed to integrate the design of the structural parameters and the active control parameters for vector second-order lumped-parameter structural systems. The objective is to minimize the required active control effort to satisfy given output variance constraints and robust performance constraints;. The problem is formulated as an iterative sequential control design followed by control/structure redesign. Each step of the iterative algorithm is formulated as a Linear Matrix Inequality (LMI) optimization problem that can be solved effectively using available LMI solvers. Convergence of the proposed algorithm to a solution that provides improved control effort and robust stability compared to the single-step structural and control design is guaranteed. Both static state-feedback and dynamic output feedback problems are considered.

CCA-MA6-4 11:00 CCA-80

Redesign of Closed Loop System for Integrated Design of Structure and its Vibration Control System

Adachi, Kazuhiko,
Sakamoto, Koji,
Iwatsubo, Takuzo Kobe Univ.

This paper aims at proposing a new integrated design method of structure-control combined system: such as several types of mechanical systems equipped with vibration control system in order to suppress the structural vibration. When the proposed method is applied to the design of a structure-control combined system, the closed loop pole placement of the reduced order model of the combined system is specified in advance as a design requirement. The proposed method is constructed from two steps: in the first step, output feedback control system is designed for the initial closed loop system in order to realize the specified closed loop pole placement; and next step, structural and vibration control system design parameters are simultaneously optimized to minimize the objective function subject to constraints on the pole placement. Scalar objective function is defined as a linear combination of several measures of the optimality of the structure design and the vibration control system design. According to the proposed method, the closed loop pole placement of the reduced order model is preserved through the iterative optimum design process. The effect of the proposed method is shown by the numerical example. Not only structural design parameters but also vibration control system design parameters are successfully optimized under the objective function minimization.

CCA-MA6-5 11:20 CCA-86

Integrated Design of Structure and Control System Considering Performance and Stability

Kajiwara, Itsuro,
Nagamatsu, Akio Tokyo Inst. of Tech.

Integrated optimum design of structure and control system is expected to achieve the higher performance of various mechanical systems. Recently, a lot of efforts to develop the integrated optimization methods have been tried in order to improve the dynamic characteristics of the combined structure/control systems. The objective of this paper is to present some concepts of the integrated optimum design in vibration control problems. Some integrated optimization problems are introduced with the applications conducted by the authors.

CCA-MA6-6 11:40 CCA-92

Integrated Optimal Design of Passive and Active Elements for Hard Disk Servo Systems

Obinata, Goro,
Saito, Koji,
Hiramoto, Kazuhiko,
Doki, Hitoshi Akita Univ.

So as to achieve high density and high speed access of magnetic disk drives, integrated optimization method is applied for designing the head-suspension assemblies. Approximation is used to the model of a head-suspension assembly, which makes it possible to enjoy a nice analytical result on Ricatti equations. Using this trick, we can obtain an explicit expression of the optimal controller in state space form. Based on this setup, the simultaneous optimization problem both on active and passive parameters is reduced to a simpler one. A numerical example is given to show that a better performance of a magnetic disk drive can be obtained by the simple design procedure.

CCA-MA6-7 12:00 CCA-97

Integrated System Design by Separation

Iwasaki, Tetsuya Tokyo Inst. of Tech.

This paper shows, by a numerical example, that there is a certain separation property in the design of mechanical control systems. In particular, we point out that the control bandwidth of a servo-tracking system, achievable by a dynamic output feedback controller with reasonable amount of control effort, is closely related to the frequency range where the open-loop transfer function exhibits positive-realness. A finite frequency positive-real property is characterized in terms of linear matrix inequalities. Finally, a systematic procedure for designing a mechanical system having such property is proposed, utilizing powerful convex programming techniques.

CACSD-MM1 Koa
Numerical Methods for Systems

CACSD-MM1-1 2:00 CACSD-40

On Invariant Subspaces of Hamiltonian Matrices

Mehrmann, Volker,
Xu, Hongguo Tech. Univ. of Chemnitz

The existence and uniqueness of Lagrangian invariant subspaces of Hamiltonian matrices is studied. Necessary and sufficient conditions are given in terms of the Jordan structure and certain sign characteristics that give uniqueness of the subspaces even in the presence of purely imaginary eigenvalues. These results are applied to obtain in special cases existence and uniqueness results for Hermitian solutions of continuous time algebraic Riccati equations.

CACSD-MM1-2 2:20 CACSD-46

Numerical Solution of Linear Quadratic Control Problems for Descriptor Systems

Benner, Peter — Univ. of Bremen
Byers, Ralph — Univ. of Kansas
Mehrmann, Volker,
Xu, Hongguo — Tech. Univ. of Chemnitz

We discuss the numerical solution of linear quadratic optimal control problems for descriptor systems. The classical solution approach for these problems requires the computation of deflating subspaces of structured pencils. We extend the recently developed methods[6] for Hamiltonian matrices to the general case of embedded pencils as they arise in descriptor systems.

CACSD-MM1-3 2:40 CACSD-52

The Photon Diffusion Equation: Forward and Inverse Problems

Syrmos, Vassilis L.,
Yin, J.,
Yun, D.Y.Y. — Univ. of Hawaii, Manoa
Misra, Pradeep — Wright State Univ.

In this paper, we compute the solution to the photon diffusion equation using a state-space system. The state-space system under consideration is obtained by applying a FEM technique to the photon diffusion equation. Computing the photon density in the medium is commonly called in computational tomography (CT), the forward problem. In the second part we investigate and present some preliminary results on the inverse problem. The inverse problem entails the identification of anomalies (benign or malignant) inside the medium. We investigate the inverse problem using an optimization setup. Specifically, we use a baseline homogeneous experiment that represents the healthy tissue to compare with the actual data. We then form an error signal between the heterogeneous and homosorption coefficient of the true medium. We minimize using the two-norm of the error signal.

CACSD-MM1-4 3:00 CACSD-58

Two Point Boundary Value and Periodic Eigenvalue Problems

Van Dooren, Paul — Univ. Catholique de Louvain

In this paper we link the discrete-time periodic eigenvalue problem with two point boundary value problems over the same interval. This gives a new formulation of periodic eigenvalue problems which also leads to a new and more economical scheme for computing periodic eigenvalues.

CACSD-MM1-5 3:20 CACSD-64

Solving Linear and Quadratic Matrix Equations on Distributed Memory Parallel Computers

Benner, Peter — Univ. of Bremen
Quintana-Orti, Enrique S.,
Quintana-Orti, Gregorio — Univ. Jaime

We discuss the parallel implementation of numerical solution methods for linear and quadratic matrix equations occurring frequently in control theory. In particular we consider equations related to analysis and synthesis of continuous-time, linear time-invariant control systems. These are the Sylvester equation, the Lyapunov equation, and the continuous-time algebraic Riccati equation. We assume the coefficient matrices to be dense and the state-space dimension to be roughly of order 100-1000. For such problem classes, methods based on the sign function and related methods prove to be very efficient and usually outperform methods based on the QR or QZ algorithms even in sequential computing environments. We discuss the implementation of these methods on distributed memory parallel computers employing MPI and ScaLAPACK.

CACSD-MM2 Milo
Object Oriented Modeling and Simulation

CACSD-MM2-1 2:00 CACSD-132

An Object-Oriented Model for Hybrid Control Systems

Carpanzano, Emanuele,
Ferrarini, Luca,
Maffezzoni, Claudio — Pol. di Milano

In the present paper a formal framework based on the object-oriented paradigm for hybrid control systems modelling is illustrated. One of the peculiar elements of the proposed approach is modularity, which is realized through the definition of a basic hybrid module, that can be recursively aggregated. Particular attention has been paid in the formal definition of the basic module, classifying its discrete state transitions in apparent, instantaneous and actual transitions. In addition, the composition rules for modules have been formalized, aiming at providing a consistent mathematical framework, especially for the propagation and management of events. As a test application, the control system of the impact of a robotic arm on a stiff surface is discussed.

CACSD-MM2-2 2:20 CACSD-138

Recipe-Driven Batch Processes: Event Handling in Hybrid System Simulation

Fritz, Martin — Software Design & Manag. GmbH
Liefeldt, Andreas,
Engell, Sebastian — Univ. of Dortmund

This contribution describes the integration of different simulation methods for batch processes under one single user interface and based upon one core model. We discuss two different simulation concepts with respect to event detection and handling of hybrid systems, especially of recipe-driven batch processes. The notation of event handling is central to both approaches. Examples demonstrate in which cases a discrete-event simulation of hybrid systems can produce results which are equivalent to those from continuous simulation and under which conditions it fails.

CACSD-MM2-3 2:40 CACSD-144

Combining Information Technology Components and Symbolic Equation Manipulation in Modeling and Simulation of Mechatronic Systems

Diaz-Calderon, Antonio,
Paredis, Christiaan J. J.,
Khosla, Pradeep K. — Carnegie Mellon Univ.

We present a hybrid representation for modeling of mechatronic systems. This representation consists of a linear graph and block diagrams and supports our concept of composable simulation. By composable simulation we mean

the ability to automatically generate simulations from individual component models through manipulation of the corresponding physical components in a CAD system. The approach is based on an augmented system graph that represents the topology of the system. This graph captures all the interactions between different energy domains (including rigid-body mechanics, electrical, hydraulic, and information technology domains.) This form of virtual prototyping will reduce the design cycle significantly by providing immediate feedback to the designer with minimal intervention of simulation and modeling specialists.

CACSD-MM2-4 3:00 CACSD-151

Hybrid Modeling in Modelica Based on the Synchronous Data Flow Principle

Otter, Martin — DLR Oberpfaffenhofen
Elmqvist, Hilding,
Mattsson, Sven Erik — Dynasim AB

The unique features of the object-oriented modeling language Modelica to model combined continuous time and discrete event systems are discussed. A hybrid Modelica model is described by a set of synchronous differential, algebraic and discrete equations leading to deterministic behaviour and automatic synchronization of the continuous and discrete parts of a model. The consequences of this view are discussed and demonstrated at hand of a new method to model ideal switch elements such as ideal diodes ideal thyristors or friction. At event instants this leads to mixed continuous/discrete systems of equations that have to be solved by appropriate algorithms.

CACSD-MM2-6 3:40 CACSD-158

Physical Modeling with Multipoles

Mann, Herman — Czech Tech. Univ.

Importance of physical modeling, called also 'virtual prototyping', grows with the increasing power of computers as well as with the growing demands on control-system dynamics. The paper advocates for the multi-pole approach to physical modeling in contrast to the well-known bond-graph approach. As the topological representation of multipole models is isomorphic with the geometrical representation of the modeled real systems, these models can be easily set up based on mere inspection of the systems. The relationship between multipole and bond-graph approaches is explained using linear graphs. A definition of multiports as a mapping of the subsystem energetic interactions from the geometric onto the topological space is introduced. It is shown that it is the oversimplified representation of multiports what makes the bond graphs cumbersome and ambiguous.

CACSD-MM3 Mauka
Automatic Code Generation

CACSD-MM3-1 2:00 CACSD-237

Safety-Critical Software Generation

Erkkinen, Tom J. — Applied Dynamics Int.

Safety-critical software development is a field of active growth and research. Many of the emerging software standards and guidelines used by industries such as medical, automotive, and aerospace are placing increased emphasis on safety and reliability. Recently, the United Kingdom Ministry of Defense (MOD) has established a set of software requirements documents that are perhaps the most stringent set of standards ever developed [1,2]. The aforementioned MOD standards require the use of safe language subsets because, Currently all real languages have features which are poorly defined ... thus need a safe subset. Also required by the MOD, is the use of software analysis techniques in addition to testing. Static analysis ..... shall be performed on the whole of the source code to verify that the source code is well formed and free of anomalies that would affect the safety of the system. Accompanying these standards are computer-aided engineering tools that support both the production and validation of embedded software. Tools used in high-integrity development environments must provide users with significant benefits that greatly outweigh the significant risks associated with their introduction. Gaining certification body approval for using something new is an important consideration for any tool's adoption. In nearly every application and industry, engineering tools and development packages are selected based on expected productivity gains. In the safety-critical community the packages with the best chance for success are those that achieve the productivity gains by either focusing on early error detection or error prevention. This paper presents safety-critical software development practices and identifies characteristics needed for tools used in this process, including those used for automated coding and unit testing.

CACSD-MM3-2 2:20 CACSD-243

Component-Node-Network: Three Levels of Optimized Code Generation with ASCET-SD

Honekamp, Uwe,
Reidel, Justus,
Werther, Kai,
Zurawka, Thomas,
Beck, Thomas — ETAS GmbH

ETAS' CACSD tool ASCET-SD (Advanced Simulation and Control Engineering Tool) is specifically designed for control system design in automotive applications. It supports the entire design cycle from the early stages (i. e. graphical block diagrams) over rapid prototyping, target identical prototyping to eventually optimized code generation for various microcontroller targets. This paper focuses on code generation aspects on three levels of complexity (component, node, network), each of which must be addressed properly in order to obtain optimal results. On the component level the generation of the control algorithm itself with a focus on numerical issues is discussed. The node level addresses data and code structures for the entire program to be run on a microcontroller. When combining several nodes (ECUs) to a network, timing and communication aspects have to be considered.

CACSD-MM3-3 2:40 CACSD-249

On the Compilation of Statecharts Models into Target Code for Embedded Systems

Erpenbach, Edwin,
Stroop, Joachim,
Rammig, Franz J. — Univ. of Paderborn

Synchronous languages have proven to be very adequate for the modeling of embedded systems. Although several synchronous languages have shown to be well suited for automatic compilation, specific target architectures, especially those with limited computational and memory resources as they are commonly used within embedded systems, are not generally addressed. Following the semantics of a synchronous language, a model starts execution from an initial state, receives signals from the environment and iterates until it reaches a stable state, i.e. until no further action can be triggered without an external signal being sensed. Synchronous models thus react to a stimulus with a chain of actions, where the number of iteration steps in the chain reaction is not explicitly defined. Detection of stability which is a time consuming task therefore plays an important role in the compilation of synchronous models. This paper focuses on the language statecharts but describes how knowledge about the worst-case number of iteration steps (wcnis) that synchronous models execute to reach a stable state can be used to avoid time consuming run-time detection of stability and significantly improve the quality of programs generated from such models in general. Moreover, the paper describes a method for determining the wcnis a given statecharts model executes to reach a stable state. The method described has been integrated in a code generator for Statemate models and experimental results are presented.

CACSD-MM3-4 3:00 CACSD-255

Using the Adaptive Blockset for Simulation and Rapid Prototyping

Ravn, Ole Tech. Univ. of Denmark

The paper presents the design considerations and implementational aspects of the Adaptive Blockset for Simulink which has been developed in a prototype implementation. The basics of indirect adaptive controllers are summarized. The concept behind the Adaptive Blockset for Simulink is to bridge the gap between simulation and prototype controller implementation. This is done using the code generation capabilities of Real Time Workshop in combination with C s-function blocks for adaptive control in Simulink. In the paper the design of each group of blocks normally fund in adaptive controllers is outlined. The block types are, identification, controller design, controller and state variable filter. The use of the Adaptive Blockset is demonstrated using a simple laboratory setup. Both the use of the blockset for simulation and for rapid prototyping of a real-time controller are shown.

CACSD-MM3-5 3:20 CACSD-261

Redefining the Process for Development of Embedded Software

Bryant, Steven E. Army-Space and Missile Def. Com.
Key, Kent Military Tech., Inc.

The Common Hardware and Software Integration Environment (CHaSI-E) is being developed in support of the Atmospheric Interceptor Technology (AIT) program to enhance the engineer's ability in providing rapid development of flight software that is derived directly from the system simulation, but is customized to support the specific processor architecture definition. This tool essentially allows the algorithm designers and testers to also fulfill the classical roles of the software developers and testers. As such, program cost and risk is reduced significantly. Developing algorithms within the environment will allow direct software traceability to the System Simulation Analysis segment of the design process. In addition, it will provide rapid response to processor/architecture changes allowing re-target of the real-time code for execution on the new hardware without manual regeneration of code. The process oriented design methodology will attain repeatability, reliability, and traceability beyond what is achievable with current software/hardware development processes. Preservation of this evolving corporate knowledge basis will be preserved independent of potential personnel turnover within a given company.

CACSD-MM3-6 3:40 CACSD-267

MIRCOS – Microcontroller-Based Real Time Control System Toolbox for Use with MATLAB /Simulink

Rebeschiess, Sven Tech. Univ. of Berlin

This paper presents the new toolbox MIRCOS (MIcrocontroller-based Real time COntrol System) for graphical programming and real time operation of the standard 16-bit microcontroller 80C166 using Matlab and Simulink. With the toolbox presented here, Rapid Control Prototyping is possible on this widely available hardware. The system can also be used for Hardware-in-the-Loop Simulations. The complete controller synthesis, the automatic generation and implementation of the control program on the microcontroller, and the control task itself can be carried out under Matlab's comfortable user interface. Furthermore, the full functionality of Matlab and Simulink can be used in MIRCOS, for instance for parameter hand-off or visualization without interrupting or impeding the control task running on the 80C166.

CCA-MM4 Makai
PID Control

CCA-MM4-1 2:00 CCA-103

PID Control Design and H-Infinity Loop Shaping

Panagopoulos, Helene,
Astrom, Karl J. Lund Inst. of Tech.

This paper shows that traditional methods for design of PID controllers can be related to robust H_\infty control. In particular it is shown that the specifications in terms of maximum sensitivity and maximum complementary sensitivity are related to the weighted H_\infty norm introduced by Glover and McFarlane (1989). It is also shown that the Vinniecomb metric can be used to classify the classes of systems that can be stabilized with the design methods in Panagopoulo's Licentiate thesis (1998), see http://www.control.lth.se/~hp.

CCA-MM4-2 2:20 CCA-109

Robust PID* (n-2) Stage PD Cascade Controller

Kitti, Tirasesth,
Jongkol, Ngamwiwit,
Prasit, Julsereewong,
Thanit, Trisuwannawat King Mongkut's Inst. of Tech.
Michihiko, Iida Tokai Univ.

This paper presents a design technique for the two degree of freedom (2-DOF) control system using PID (Proportional-

Integral-Derivative) x (n-2) stage PD as a cascade controller for a class of nth order plant. It is intended to satisfy both transient and steady state response specifications based on the root locus approach. This controller can be used instead of the conventional PID controller for the higher order plant to obtain better performance. The transfer function of a class of nth order plant should not include zeros, the poles of the plant should have negative real part. The overall system is approximated as a stable and robust second order system. The performances of the controlled system are satisfied by this design technique, Moreover, this technique can also be applied to the plant with small dead time. The cascade controller gain can be adjusted to meet faster responses with a little or no overshoot. Robustness properties given by this controller proposed in this paper have also been demonstrated by numerical examples

CCA-MM4-3 2:40 CCA-115

Tuning PID Controller for a Plant with Under-Damped Response

Shen, Jing-Chung Nat. Huwei Inst. of Tech.

In this paper, a tuning formula is derived for PID control of a second-order plus dead time plant with under-damped response. For deriving the tuning rule, the dominant pole assignment method is applied to design the PID controllers for a variety of plants. Then the correlation between the controller parameters and the parameters of the plants is found and the tuning formula is derived. Several simulation examples are given to show the effectiveness of this formula.

CCA-MM4-4 3:00 CCA-121

Tuning of PID Controller for Unstable Process

Tan, Wen,
Yuan, Yingqin,
Niu, Yuguang North China Electric Power Univ.

Loop-shaping H_∞ controller is designed for unstable process. It is observed that the H_∞ controller for such process can be approximated with a PID controller. Moreover, we note that the 'design indicator' is a function of the normalized delay. This fact leads us to derive the direct relation between the PID controller's parameters and the plant constants, and the results can be regarded as a PID tuning rule for unstable process. The tuning rule has only one parameter which reflects the trade-off between performance and robustness of the closed-loop system. Simulation results show that it works for first-order delayed unstable process with the normalized delay smaller than unity.

CCA-MM4-5 3:20 CCA-125

Generalized Minimum Variance Self-Tuning Pole-Assignment Controller with a PID Structure

Yamamoto, Toru Okayama Pref. Univ.
Inoue, Akira Okayama Univ.
Shah, Sirish L. Univ. of Alberta

In this paper, a new self-tuning PID controller design scheme is proposed. The PID parameters are calculated on-line based on the relationship between the PID and generalized minimum variance control (GMVC) laws. In designing GMVC system, user-specified polynomials are computed by considering the pole-assignment in the control system. Therefore, this scheme has approximate minimum variance properties with specified closed-loop time-constant. The newly proposed control scheme can also deal with unknown and /or varying process time-delays. The proposed control scheme is experimentally evaluated on a SISO air pressure control system. Experimental results illustrate the effectiveness of this new scheme.

CCA-MM4-6 3:40 CCA-131

Simultaneous Design of Structure and Control Systems for Two-Degree-Of-Freedom-Controller

Tanaka, Hideyuki,
Sugie, Toshiharu,
Katayama, Tohru Kyoto Univ.

This paper discusses simultaneous design of plant structure and a controller with two-degree-of-freedom. We propose a new criterion for a feedforward property with a concrete design procedure of controllers, which is suitable for a simultaneous design problem. Numerical example demonstrates the effectiveness of the proposed criterion. It also shows that feedforward and feedback properties are not independent in case of simultaneous design.

CCA-MM5 Hau
Flight Control II

CCA-MM5-1 2:00 CCA-137

Adaptive Nonlinear Controller Synthesis and Flight Test Evaluation: On an Unmanned Helicopter

Prasad, J.V.R.,
Calise, A. J.,
Pei, Y. Georgia Inst. of Tech.
Corban, J.E. Guided Systems Tech., Inc.

Numerous simulation studies have recently revealed the potential benefits of a neural network-based approach to direct adaptive control in the design of flight control systems. Foremost among the potential benefits is greatly reduced dependence on high-fidelity modeling of system dynamics. However, the methodology has only recently been proven practical by demonstration in an actual flight system. This paper begins with an overview of the design of a nonlinear adaptive control system for flight test on an unmanned helicopter test bed. Next, the design of an outer loop trajectory tracking controller as well as simulation results are presented. The paper concludes with the presentation of preliminary flight test results of the rate command system that document the actual performance of the control system in flight.

CCA-MM5-2 2:20 CCA-143

Position Control by Feedback Linearization for a Simplified Helicopter Model

Rebeschiess, Sven,
Roloff, Marc Tech. Univ. Berlin

In this paper we describe a method for angular pitch control with feedback linearization for a laboratory helicopter model. Linear angular control can only be applied in a small angle interval. Better control can be obtained by using a linearizating transformation. This transformation tends to be very complex. For the application in this paper it can be shown that a

simplified transformation can be sufficient for achieving good control results.

CCA-MM5-3 2:40 CCA-146

Flight Control Design and Experiment of a Twin Rotor Helicopter Model via 2 Step Exact Linearization

Saeki, Masami,
Imura, Jun-ichi,
Wada, Yasunori Hiroshima Univ.

A flight controller is designed for a twin rotor helicopter model, and the property is examined by experiments. The model has a similar structure to that of VTOL aircraft. It is not linearizable by static state feedback but linearizable by dynamic state feedback. The design method accomplishes partial linearization by applying static feedback linearization to the main and the lower subsystems hierarchically. The controller has the same structure as the structure previously derived by back stepping. Experiments show the effectiveness.

CCA-MM5-4 3:00 CCA-152

Multivariable Gain and Phase Margin Analysis of a Fully Coupled Six-Degree-Of-Freedom Guided Missile

Bar-on, Jonathan R.,
Adams, Robert Raytheon Missile Systems

This paper presents a stability analysis of a fully coupled six-degree-of-freedom linear model of a guided missile system using single-input single-output and multivariable gain and phase margins. The analysis indicates that the multivariable margins decrease with the total angle of attack, whereas the classical margins exhibit little to no dependence on the total angle of attack. An example illustrating the effects of a realizable multivariable phase perturbation on the non-linear system is also presented.

CCA-MM5-6 3:40 CCA-158

A SDP Relaxation Approach to Air Traffic Control under Free Flight

Oh, Jae-Hyuk Massachusetts Inst. of Tech.

Under Free Flight, each individual aircraft will have the first responsibility to resolve its own conflicts. Therefore, a centralized air traffic controller (ATC) will issue a resolution command only when a physical conflict would be unavoidable if the ATC did not do so. Regarding the operation of an ATC under Free Flight, hence, determining when the ATC should issue a resolution command would be one of the most important problems. This paper presents a systematic and efficient algorithm as a solution to this problem. This algorithm is based on the well-known Semi-Definite Program (SDP) relaxation method.

CCA-MM6 Lehua
Micro Positioning

CCA-MM6-1 2:00 CCA-164

A Genetic Algorithm for the Tuning of a Discrete Adaptive Observer Implemented on an IBM Head/Disk Assembly

Thein, May-Win L.,
Rendon, Thomas,
Misawa, Eduardo A. Oklahoma State Univ.

This paper presents the application of a Discrete Adaptive Observer (DAO) to an IBM Head/Disk Assembly System. Because of the difficulties in tuning, a genetic algorithm is implemented off-line to obtain optimal observer parameters for the DAO. Simulations show that the genetic algorithm is successful in choosing appropriate observer gains. Furthermore, as a result of these optimal gains, the observer state and parameter estimates converge accurately and quickly.

CCA-MM6-2 2:20 CCA-170

Design of a Tracking System Using N-Delay Two-Degree-Of Freedom Control and its Application to Hard Disk Drives

Takakura, Shinji Toshiba Res. & Dev. Cen.

So far, Two-Degree-of-Freedom control systems have been used to realize desirable transient response in the tracking system of a Hard Disk Drive (HDD). It is easy to realize a high speed seek, if the actuator of the HDD has a resonance mode at a much higher frequency domain than the desired control domain. However, it is generally difficult to design an actuator that has a resonance mode in a high frequency domain. So, in order to realize a high speed seek, it is important to design a digital control system in consideration of the resonance mode of the actuator. In this case, if the Nyquist frequency of the control system is higher than the resonance mode of the actuator, the control system can be designed by using a method such as a H infinity control theory in consideration of the resonance mode. However, if the Nyquist frequency isn't higher than the resonance mode of the actuator, it is very difficult to realize a high speed seek without mechanical vibration using a conventional method. Then, in this paper the method of applying the N-Delay control theory to the design of the feedforward controller in a Two-Degree-of-Freedom control system, and searching for the optimum time allocation of the N-Delay controller based on an evaluation function are proposed. Using these methods, the frequency component of the feedforward control signal can be diminished at the desired frequency point higher than the Nyquist frequency. The validity of the proposed method is confirmed by the numerical and experimental results with a miniature 2.5-inch hard disk drive.

CCA-MM6-3 2:40 CCA-176

Integrated Design for High Robust Performance with Quick Time-Response: An Application to Head Positioning Control of a Hard Disk

Hara, Shinji,
Nishio, Masashi Tokyo Inst. of Tech.
Maruyama, Tsugito Fujitsu Lab. LTD.

This paper is concerned with properties of mechanical structures for which high robust control performance and quick time-response are achievable. We propose a method of integrated design using two indices of robust performance and gain cross-over frequency (servo bandwidth) based on normalized left coprime factorization. It is shown that the structure, in which all resonant modes are in phase and their mode gains are small values, leads to the better control performance than the current structure. We consider a head positioning control of a hard disk drive system in order to make

a justification for the proposed method, and the validity is shown by both simulations and experiments.

CCA-MM6-4 3:00 CCA-182

Following Control of a Hard Disk Drive by Using Sampled-Data H-Infinity Control

Hirata, Mitsuo,
Atsumi, Takenori,
Murase, Akiyo,
Nonami, Kenzo Chiba Univ.

In the head positioning control of hard disk drives, a digital control is widely used. Therefore, if a small sampling period could be used, the performance obtained by the digital controller is not so deteriorated compared with the one obtained by the analog controller. However, in hard disk systems, the sampling period cannot be chosen arbitrary. Because it is determined by the other factor which is nothing to do with control requirements in almost cases. In this paper, we apply the sampled-data H_infinity control synthesis to the head positioning control of the hard disk drive. This method enable us to design a desirable digital controller directly by taking into account of intersampling behaviors. Experimental results show that good following performances can be achieved by the long sampling period.

CCA-MM6-5 3:20 CCA-187

H2-Control with Acceleration Feedback for a Micro Positioning System

Robl, Christian,
Englberger, Gerhard,
Farber, Georg Tech. Univ. Munich

The precision and micro assembly requires special tools in order to fulfill the high demands in accuracy and control of the assembly process. Our new precise gripper tool with 2dof, the micro positioning system (MPS), enables micro assembly with standard industrial robots by compensating for vibrations and inaccuracies of the handling device. The new developed control system combines data of three diverse sensors to perform the corrective movement. The designed control system of the MPS consists of two closed-loop and one open-loop regulator. A classical control design with pole-zero cancellation is used to linearize the hysteresis of the piezo actuator. An H2-regulator using only acceleration feedback is the main part of the control system and generates a control signal proportional to the position for the actuator's corrective movement. The third regulator handles the reference input. The realized control system reduces vibrations to less than 30%, the position accuracy without disturbances is better than 2 microns according to experimental results. Key Words: H2-control with acceleration feedback, offset suppression, non-linear piezo actuator, micro assembly.

CCA-MM6-6 3:40 CCA-193

Multiobjectives Design of a Multirate Output Controller

Shen, Liang,
Er, Meng Joo Nanyang Tech. Univ.

Over the last decade, multirate control has been an area of active research. Multirate output controllers (MROCs) sample the plant outputs at a faster rate than they change the plant inputs. Consequently, they offer greater flexibility for controller design than conventional single-rate controllers. MROCs designed under H-infinity performance have offered a new dimension in the design process. In this paper, we introduce the concept of lifting technique, LMIs and multirate output sampling and calculate the H-infinity norm of the sampled-data control systems induced via multirate output sampling. Furthermore, in order to avoid dynamic parameters of MROCs, we use additional pole placement constraints to guarantee satisfactory transient behavior.

CACSD-MP1 Koa
Numerical Methods and Software

CACSD-MP1-1 4:20 CACSD-70

Initializing Newton's Method for Discrete-Time Algebraic Riccati Equations Using the Butterfly SZ Algorithm

Fassbender, Heike,
Benner, Peter Univ. of Bremen

The numerical solution of discrete-time algebraic Riccati equations is discussed. We propose to compute an approximate solution of the discrete-time algebraic Riccati equation by the (butterfly) SZ algorithm. This solution is then refined by a defect correction method based on Newton's method. The resulting method is very efficient and produces highly accurate results.

CACSD-MP1-2 4:40 CACSD-75

An Arithmetic for Rectangular Matrix Pencils

Benner, Peter Univ. of Bremen
Byers, Ralph Univ. of Kansas

This presentation is a generalization of previous work from square, regular n-by-n, pencils to singular and rectangular m-by-n pencils. We define arithmetic-like operations on matrix pencils that are a natural extension of sums, products and quotients of real numbers. The algebra of linear transformations may be regarded as a special case of this pencil arithmetic. The language of linear relations leads to an inverse free matrix sign function algorithm and gives a simplified description of solutions to discrete-time and continuous-time descriptor systems. A monodromy relation gives a convenient unified characterization of solutions to unforced, discrete descriptor systems that covers both the regular and singular case. An exponential relation (nearly) does the same for continuous-time descriptor systems as well.

CACSD-MP1-3 5:00 CACSD-81

Stability Radii of Polynomial Matrices

Genin, Yves,
Van Dooren, Paul Univ. Catholique de Louvain

We derive analytic expressions for the stability radius of polynomial matrices for all Holder norms and discuss numerical issues for computing these stability radii for the 1, 2 and infinity norm.

CACSD-MP1-4 5:20 CACSD-85

High-Performance Algorithms and Software for Systems and Control Computations

Sima, Vasile Res. Inst. for Inf.
Van Huffel, Sabine Katholieke Univ. Leuven

Many relevant industrially oriented control problems are, usually, ill-conditioned or highly dimensional, and the theoretically well- developed, traditional methods often fail. Moreover, for large-scale problems, it is extremely important to achieve the best computational efficiency, by exploiting any special structure, and by using the potential of modern high-performance computer architectures (vector, parallel, with memory hierarchies, etc.). Therefore, developing robust and efficient algorithms for control systems analysis and design is an objective of primary importance. Improved versions (in terms of numerical stability, efficiency, and functionality) of some basic algorithms for computer-aided control systems design have been recently developed. These algorithms have been incorporated in the latest version of the Fortran 77 subroutine library SLICOT - Subroutine Library in Control Theory.

CACSD-MP1-5 5:40 CACSD-91

Numerical Linear Control Library – a Mathematica-Based Integrated Environment with the Modern Control Algorithms

Datta, Biswa Nath,
Sarkissian, Daniil Northern Illinois Univ.

A Mathematica-based numerical library, called Numerical Linear Control Library", is presently being developed by the authors. A brief overview of this library is presented in this paper. The package will be valuable for the practicing control and vibration engineers in automobile, aerospace, chemical and vibration industries, and students and researchers in engineering, scientific computations and applied mathematics. The package will also play a role in transfer of technology to industries.

CACSD-MP2 Milo
Fault Detection and Diagnosis

CACSD-MP2-1 4:20 CACSD-164

Direct Identification of Optimal Nonlinear Parity Models

Gertler, Janos,
Hu, Yongtong George Mason Univ.

Parity relations are rearranged forms of the direct input-output model equations. In the presence of faults, they return nonzero residuals. With an appropriate transformation, these residuals may be structured to facilitate fault isolation. In this paper, we describe an alternative to algebraic transformation to obtain such residuals. First the Boolean structure of the residual-set is determined, then the models underlying each of the residual structures are determined by direct system identification. This technique may be applied to nonlinear models of any complexity. As an extension of this approach, the models for all possible residual structures are first determined and then the optimal residual set is selected in a structurally constrained local optimization procedure. The technique is demonstrated on a two-input four-output polynomial nonlinear system.

CACSD-MP2-2 4:40 CACSD-170

Estimation, Compression and Classification of Volterra Kernels with Application to Process Diagnosis

Aiordachioaie, Dorel,
Ceanga, Emil Dunarea de Jos Galati Univ.

The identification of non-linear systems whose input-output relationship can be summarized as the Volterra functional expansions of the system output with their inputs is considered in this paper. The Volterra series-like input-output expansion exists for an important large class of non-linear systems. Such expansions are fully specified by a set of Volterra kernels that can be estimated from the I-O measurements of the systems under study. In paper it is studied the possibilities for Volterra kernel's estimation of non-linearity by means of neural networks, for direct applications in pattern recognition and diagnosis problem. The neural methods presented here can be further developed to study more complicated models, and will therefore have future potential for modelling and identifying highly complex multi-input multi-output non-linear systems. The feasibility of these methods is demonstrated using simulated examples.

CACSD-MP2-3 5:00 CACSD-176

The Implications of the Object/Unified Modeling Language Approach to the Problem of Fault Detection and Isolation in Dynamical Systems

Fodor, George A. ABB
Grantner, Janos L. Western Michigan Univ.
Driankov, Dimiter Univ. of Linkoping

There is a growing trend to use object-based implementations and modeling in industrial control applications. However, the object -based approach imposes new theoretical and practical problems. Those problems are due to a higher abstraction level that is achievable with objects as compared to the more traditional, state-based fault detection and isolation methods (FDI) approaches. This paper presents a description of the problems and solutions to them in the framework of a discrete FDI method referred to as ontological control[5]. The results are also relevant in respect to domain-independent failure recovery methods, such as [8].

CACSD-MP2-4 5:20 CACSD-182

Change Detection in Signals Using Linear Regression Models

Popescu, Theodor Res. Inst. for Inf.

The problem of change detection in signals using linear regression models is addressed. The most algorithms presented make use of two AR models: the first one is a reference model and the second one is a current model updated via a sliding block. Changes are detected when a suitable distance between these two models is high. Three distance measures are considered in the paper: cepstral distance, log-likelihood ratio (justified by GLR) and a distance involving the cross-entropy of the two conditional probabilities laws (divergence test). Finally, a change detection algorithm using three models and the evolution of Akaike Information Criterion is presented. Some results on the application of the discussed algorithms in seismic signal segmentation are included.

CACSD-MP2-5 5:40 CACSD-188

Computer Aided Design of Failure Detection and Identification and Adaptive Reconfigurable Control Systems for Aerospace Applications

Boskovic, Jovan D.,
Gopinathan, Murali,
Mehra, Raman K. Sci. Systems Co., Inc.

The paper describes a systematic computer-aided design procedure for Failure Detection and Identification (FDI) and Adaptive Reconfigurable Control (ARC) for aerospace applications. The overall approach is based on a Decentralized FDI-ARC scheme integrating separate modules for sensor, control effector and engine FDI with that for structural damage FDI. One of the important issues in this context is information exchange among the modules. In the paper we focus on the module for FDI-ARC in the presence of control effector failures, and describe our approach as well as future work in this area.

CACSD-MP2-6 6:00 CACSD-194

Component-Based Modeling and Diagnosis of Process-Control Systems

Provan, Gregory,
Chen, Yi-Liang Rockwell Sci. Cen.

This paper describes a component-based modeling approach for diagnosing process-control systems. Our approach allows users to build diagnostic models for complex process-control systems based on a library of component models. Process-control systems are modeled in the form of causal networks and diagnoses are generated using a model-based diagnostic technology. We present our software tools for component-based model building and causal networks diagnostics.

CACSD-MP3 Mauka
CACSD Learning via Internet

CACSD-MP3-2 4:40 CACSD-651

Ryerson Initiatives in Integrating the Internet, Multimedia Components, and Hand-On Experimentation into Problem-Based Control Education

Zywno, Malgorzata S.,
Kennedy, Diane C. Ryerson Pol. Univ.

As our world moves into a new millennium, a shift in pedagogy toward a learner-centered approach is emerging. Problem-based learning and innovative approaches to student work assessment are introduced to foster critical thinking skills. New media technologies can aid in facilitating such a shift. In this paper, the power of integrating these technologies into the education process is demonstrated. The use of web-enhancement techniques for undergraduate engineering courses in control theory is described and illustrated, as are new approaches for student evaluation. Preliminary studies show that the students are better motivated and their achievement may be superior compared to when more traditional methods of instruction were used in delivering the course content. Formal assessment of the students' work supports findings reported in similar studies which show that the effects of web-enhanced learning lead to lower failure rates as well as a tendency for an upward shift in grade distribution.

CACSD-MP3-3 5:00 CACSD-273

DynaMit -Internet Based Education Using CACSD

Loehl, T.,
Pegel, S.,
Klatt, K.-U.,
Engell, Sebastian Univ. of Dortmund
Schmid, Christian,
Ali, A. Ruhr-Univ. Bochum

This contribution describes an Internet-based learning environment, which uses a standard Web-browser as the user interface. The browser's capabilities are extended to provide a link to CACSD tools to perform symbolical and numerical computations and simulations. The use of object-oriented paradigms in the design of the data structure leads to high flexibility, easy maintenance and short download times. The system is based on Web components, which integrate the MATLAB/SIMULINK/MAPLE V system for calculations in the background. The CACSD tools are completely hidden from the learner who can concentrate on the tutorial, the exercises and the experiments. The latter are realized in an integrated virtual laboratory, where virtual reality techniques are used to animate virtual laboratory plants and to interact with them.

CACSD-MP3-4 5:20 CACSD-279

The Virtual Lab for Controlling Real Experiments via Internet

Roehrig, Christof,
Jochheim, Andreas Univ. of Hagen

The aim of the Virtual Lab project is to provide students access via the Internet to various experiments in control engineering, which are situated in control laboratories at several universities. Three German universities are currently developing the Virtual Lab as a network of remotely accessible laboratories in order to set up a prototype experimental environment. Students under consideration are usually located at geographically distributed location (e.g. at home) and have remote access to our experiments. The Virtual Lab is based on a distance education concept due to the fact that certain students (e.g. professionals) may be interested in studying even at places which are far away from campus eliminating the necessity to be there in person. In the Virtual Lab they are able to gain some practice in control theory at their convenience thereby saving travel time and cost. An approach based on a client/server architecture written in Java is proposed. This paper discusses the requirements of remote experimentation and presents the technical structure and first results of the project.

CACSD-MP3-5 5:40 CACSD-285

Multimedia Courseware for Basic Control Theory

Jochheim, Andreas,
Gerke, Michael,
Laaser, Wolfram Univ. of Hagen

In this paper, we present a multimedia course for university level education in control theory with an additional simulation environment for training and control applications. The course is supposed to support home learning for students and practitioners. It is addressed to distance education and life-long learning as well. Here we introduced the CD-ROM based version of this learning environment, and we report some

methodical aspects and experiences during courseware development. Finally we present first steps of integration into an Internet-based virtual learning environment.

CACSD-MP3-6 6:00 CACSD-291

Using the World Wide Web for Teaching Control Systems Design

Henry, Jim Univ. of Tennessee at Chattanooga

The chemical engineering laboratories at the University of Tennessee at Chattanooga have been made available for students to use via the World Wide Web. Students can conduct lab experiments from remote sites. This paper describes the hardware and software that is used for this facility and discusses strengths and opportunities for improvement' that have been observed in this development.

CCA-MP4 Makai
Combustion Dynamics and Control

CCA-MP4-1 4:20 CCA-199

Linear and Nonlinear Analysis of Controlled Combustion Processes. Part I: Linear Analysis

Banaszuk, Andrzej,
Jacobson, Clas,
Khibnik, Alexander I. United Tech. Res. Cen.
Mehta, Prashant Cornell Univ.

The results of analysis using a reduced-order model of combustion instability derived at UTRC and experiments with active control using fuel modulation motivated a study of what performance is achievable using active control. Limitations due to lightly damped or unstable eigenvalues, delay, disturbances, and limited actuator authority and bandwidth are studied. In this part of the paper we focus on linear analysis of a combustion model and study effect of delay in the model and limited actuator bandwidth.

CCA-MP4-2 4:40 CCA-206

Linear and Nonlinear Analysis of Controlled Combustion Processes. Part I I: Nonlinear Analysis

Banaszuk, Andrzej,
Jacobson, Clas,
Khibnik, Alexander I. United Tech. Res. Cen.
Mehta, Prashant Cornell Univ.

The results of analysis using a reduced-order model of combustion instability derived at UTRC and experiments with active control using fuel modulation motivated a study of what performance is achievable using active control. Limitations due to lightly damped or unstable eigenvalues, delay, disturbances, and limited actuator authority and bandwidth are studied. In this part of the paper we focus on approximate nonlinear analysis of a combustion model with on/off actuators and study effect of delay and disturbances.

CCA-MP4-5 5:40 CCA-213

Role of Actuation in Combustion Control

Hathout, J.P.,
Fleifil, Mahmoud,
Annaswamy, Anuradha,
Ghoniem, A.F. Massachusetts Inst. of Tech.

This paper presents analysis of the effect of actuation on the combustor dynamics. Two different categories of actuators are studied: flow sources, e.g., acoustic speakers, and heat sources, e.g., fuel injectors. These sources are modeled in the conservation equations and a finite dimensional model is obtained. Two methods of analysis are used to gain insight into the physics of actuation, and its stabilizing/destabilizing effect on the combustor through feedback control. The first is the energy method which is used here in a novel way to explain intricate work exchanges between the different dynamic components of the system: the acoustics, the flame, and the actuator. The energy analysis is used also to quantify the ''useful'' and ''wasted'' work generated by actuators. A more revealing method of analysis is the dynamic representation of the combustor as an oscillator, and is shown to be the basis of any optimal control analysis.

CCA-MP5 Hau
Guidance and Control of Aerospace Vehicles

CCA-MP5-1 4:20 CCA-219

Hypersonic Guidance via the State-Dependent Riccati Equation Control Method

Cloutier, James R.,
Zipfel, Peter H. Air Force Res. Lab.

In this paper, the State-Dependent Riccati Equation (SDRE) control method is used to design a guidance law for the midcourse phase of flight of a hypersonic vehicle. The guidance law converts flight path angle and heading angle commands to angle of attack and bank angle commands for input to an attitude autopilot.

CCA-MP5-2 4:40 CCA-225

Online Identification and Control of Aerospace Vehicles Using Recurrent Networks

Hu, Zhenning,
Balakrishnan, S.N. Univ. of Missouri, Rolla

Methods for estimating the aerospace system parameters and controlling them through two neural networks are presented in this study. We equate the energy function of Hopfield neural network to integral square of errors in the system dynamics and extract the parameters of a system. Parameter convergence is proved. For control, we equate the equilibrium status of a 'modified' Hopfield neural network to the steady state Ricatti solution with the system parameters as inputs. Through these two networks, we present the online identification and control of an aircraft using its nonlinear dynamics.

CCA-MP5-3 5:00 CCA-231

Motion Planning for Reduced Observability of Autonomous Aerial Vehicles

McFarland, Michael B.,
Zachery, Randy A.,
Taylor, Brian K. Air Force Res. Lab.

Techniques originally developed for robot motion planning are applied to compute ingress paths for autonomous air vehicles, such as cruise missiles or Uninhabited Aerial Vehicles (UAVs). This approach is particularly useful in multiobjective

optimization problems such as intercepting a target while also maneuvering to minimize observability of ground-based tracking stations. In this case, paths prescribing both position and orientation in three-dimensional space are chosen based on empirical measurements of the airframe's RADAR Cross-Section (RCS) as well as target state information. This six-degree-of-freedom motion planning formulation is an alternative to the traditional separation

CCA-MP5-4 5:20 CCA-236

Understanding Missile Autopilot Design Using the H-Infinity Loop Shaping Design Procedure

Urban, Thomas J.,
Iwaskiw, A. Pete,
Iglesias, Pablo Johns Hopkins Univ.

This paper presents different controller topologies for a missile autopilot. The controllers are based on a loop shaping design procedure due to McFarlane and Glover. The nature of the controllers obtained is discussed and a novel procedure for the selection of weights is given.

CCA-MP5-5 5:40 CCA-243

Integrated Missile Guidance and Control: A State Dependent Riccati Differential Equation Approach

Palumbo, Neil F.,
Jackson, Todd D. Johns Hopkins Univ.

The need to engage tactical ballistic missile (TBM) threats and high-performance anti-ship cruise missiles is dictating the design of enhanced performance missile interceptors that can provide a high probability of kill. It can be argued that current interceptor guidance and control (G&C) designs are suboptimal because each of the G&C components are designed separately before they are made to interact together as a single functional unit. Ultimately, integrated G&C (IGC) design techniques might improve interceptor performance because: 1) the implicit interdependency of the classically separate G&C components could provide a positive synergism that is unrealized in the more conventional designs, and 2) an IGC design is formulated as a single optimization problem thus providing a unified approach to interceptor performance optimization. The prototype IGC system discussed in this paper is designed via an approximate solution to the nonlinear disturbance attenuation problem. Furthermore, the integrated controller has been implemented in a high fidelity six-degree-of-freedom (6DOF) missile simulation that incorporates a fully coupled nonlinear aerodynamics model. A high-performance benchmark missile G&C system has also been designed and incorporated to provide performance comparisons. In addition to a discussion of the solution methodology, 6DOF Monte Carlo simulation results are presented that compare the integrated concept to the benchmark G&C system. The simulation results to date show the IGC paradigm reduces both the mean and 1-sigma miss statistics as compared to the benchmark system.

CCA-MP5-6 6:00 CCA-249

Air Traffic Control Using Genetic Search Techniques

Cheng, V.H.L.,
Crawford, L.S.,
Menon, P.K. Optimal Synthesis, Inc.

Genetic search techniques constitute an optimization methodology effective for solving discontinuous, non-convex, nonlinear, or non-analytic problems. This paper explores the application of such techniques to a non-analytic event-related air traffic control problem, that of runway assignment, sequencing, and scheduling of arrival flights at an airport with multiple runways. Several genetic search formulations are developed and evaluated with a representative arrival traffic scenario. The results exemplify the importance of the selection of the chromosomal representation for a genetic-search problem.

CCA-MP6 Lehua
Motion Control

CCA-MP6-1 4:20 CCA-255

Design of Speed Controllers to Suppress Torsional Vibrations Based on Frequency Characteristics

Matsui, Yoshihiro Tokyo Nat. College of Tech.
Nishida, Hideyuki,
Todaka, Yuji Fuji Electric Co.
Takeuchi, Tomoyoshi Univ. of Electro-Communications

In this paper, frequency characteristics of speed controllers to suppress torsional vibrations of mechanical system are investigated. Straightforward design methods of controllers based on the frequency characteristics are proposed. The methods are easily applicable to practical servo drive systems with inner torque control loop whose frequency bandwidth is not wide enough compared with the resonant frequencies, the second order mechanical resonant modes and so on. The validity of this methods is confirmed by computer simulations and experiments.

CCA-MP6-2 4:40 CCA-261

Performance Improvement of Multivariable Linear System with Unmeasured External Disturbance

Ling, Bo Foxboro Co.

In this paper, we present a system design criterion which improves the performance of the general multivariable linear system with unmeasured external disturbances. We use the Lyapunov function to find the upper bound of the Integral Square Error (ISE) which serves as a measurement of system performance in process control. We point out the relationship between the upper bound of ISE and the related convergence rate. The design criterion shows how the system matrix plays an important role in reducing overall ISE. The results presented can be used as a general system design criterion for a multivariable linear system with better disturbance rejection.

CCA-MP6-3 5:00 CCA-267

Error Feedback Sliding Mode Controllers in Output Regulation of Nonlinear Systems

Marconi, L.,
Passini, S.,
Bonivento, C. Univ. of Bologna

The output tracking control problem of MIMO systems, both minimum and nonminimum phase, is here discussed in sliding mode terms. The first goal of the paper is to address the problem of designing an error feedback controller able to

achieve the asymptotic tracking of an exosystem-generated reference trajectory. To this end two design techniques are illustrated. A second goal is to address the robustness of the proposed control scheme against parameter uncertainties and external disturbances.

CCA-MP6-4 5:20 CCA-273

A Minimum-Time Motion Planning Method Based on Phase Space Analysis

Koh, K.C.,
Aum, H.S. Sun Moon Univ.
Cho, H.S. KAIST

In this paper, we propose a minimum time motion planning algorithm considering jerk and acceleration constraints. The conventional planning methods are valid only for zero boundary conditions, thus they have limitations in real time applications. The proposed method is computationally efficient and can deal with a problem with non-zero boundary conditions so that it is adequate for real time motion planning. For the real-time implementation, the planning algorithm is derived in the phase space. In order to determine the jerk, a landing surface is introduced through bang-bang principle. To show the validity of the proposed method, a series of simulations are conducted. The algorithm has merits of providing a consistent and unified numeric solution for motion control system requiring the real time motion planning with jerk constraint and suffering from strong disturbance.

CCA-MP6-5 5:40 CCA-279

Adaptive Compensation for Pointing and Tracking System Applications

Kennedy, Peter J.,
Kennedy, Rhonda L. David H. Pollock Consultants
Agard, Ian Northrop Grumman Elec.

Tracking a target from a dynamic platform (I.e. aircraft, ground vehicle) requires a servo architecture that includes an outer track loop and an inner rate loop that stabilizes the line of sight (LOS). This paper focuses on the rate loop design and the effects of friction and cable restraint on it's performance. Adaptive friction and feedback compensators are designed to improve tracking performance. The adaptive feedback compensator is tuned so that the gimbal response follows that of a reference model.

CCA-MP6-6 6:00 CCA-285

Controller Design Involving Gain Scheduling for a Large Scale Pneumatic Muscle Actuator

Repperger, D.W. Air Force Res. Lab.
Phillips, C.A. Wright State Univ.
Krier, M. Air Force Res. Lab.

A gain-scheduled controller is designed for regulating the response of a large-scale pneumatic muscle actuator device which has inherently nonlinear dynamics. The tracking paradigm to test the controller design consists of a triangular-wave desired force input signal. To compute the appropriate scheduled gains, a complete static and dynamic analysis of the pneumatic muscle system's response was conducted within the dynamic range of its operation. The limited availability of pressure measurements also added a significant challenge to this problem, compromising the quality of the feedback signals available. Experimental data are presented on the efficacy of the controller designed for this application involving a force regulation tracking task.

CACSD-TuA1 Koa
Computer Algebra in CACSD

CACSD-TuA1-1 10:00 CACSD-640

A Computer Algebra Approach to Undersea Vehicle Dynamics

Kwatny, Harry G. Drexel Univ.
Salter, Eric Tech.-Sci., Inc.
Ammeen, Edward S. Naval Surface Warfare Cen.
Blankenship, Gilmer L. Univ. of Maryland

Symbolic computing can facilitate the application of modern nonlinear system analysis and design methods to engineering problems. Reasonably complex models can be efficiently assembled and manipulated. In this paper we illustrate the symbolic construction and manipulation of a model of an undersea vehicle. While the system considered here is within the realm of hand assembly, doing so is tedious and error prone. On the other hand, it is trivial with the symbolic computing tools described here. More complex, multibody configurations of undersea vehicles and robots can be dealt with using these techniques.

CACSD-TuA1-2 10:20 CACSD-303

Solution of Unilateral and Bilateral Diophantine Equations Using Symbolic Computation

Ogunye, Ayowale B. Air Products and Chem., Inc.

The polynomial equation approach of Kucera (1979), for the solution of unilateral and bilateral Diophantine equations, is implemented in a symbolic computing system (MapleV) in this paper. Procedures were developed to solve unilateral and bilateral Diophantine equations. This algebraic implementation would have been extremely difficult to carry out in a strict numeric computing environment. The use of MapleV has provided symbolic results quickly and efficiently, with a tremendous gain in time and with minimal effort.

CACSD-TuA1-3 10:40 CACSD-309

Symbolic Computation in Nonlinear Control System Modeling and Analysis

de Jager, Bram Eindhoven Univ. of Tech.

The paper discusses the use of symbolic computation for model formulation, model integration, model checking, and model analysis. The zero dynamics plays an important role in the areas of modeling, analysis, and control of linear and nonlinear systems. It also gives additional insight in the structure of the model employed and is an aid in modifying a model to satisfy some needs of the modeler. For nonlinear systems the analytical calculations to get the zero dynamics by paper and pencil may be quite involved. Symbolic computation has been used to overcome this difficulty. For a reasonable class of systems the computation can be performed without human aid or intervention, making the zero dynamics procedure a feasible and valuable addition to the toolbox of the modeler, analyst, or control system designer. For system models that are more than moderately complex symbolic

computation cannot be fully enjoyed due to the complexity of parts of the algorithms that is (double) exponential in some measure of the problem size, or due to expression swell that cannot be easily eliminated. This implies that symbolic computation will not replace other tools, like those based on numerics, but will complement them.

CACSD-TuA1-5 11:20 CACSD-315

Symbolic Manipulation of Rational Matrices and Applications

Karampetakis, N. P.,
Tzekis, P. Aristotle Univ. of Thesaloniki

Rational matrices are extensively used in the analysis, synthesis and design of control systems Kucera (1991), Vardulakis (1991) and Vidyasagar (1985). The main purpose of this work is to present useful symbolic computational tools for the study of the structure of rational matrices and furthermore for the solution of basic synthesis control problem.

CACSD-TuA1-6 11:40 CACSD-321

A Computer Aided Technique to Derive the Class of Realizable Transfer Function Matrices of a Control System for a Prescribed Order Controller

Tagawa, Yasutaka Tokyo Univ. of Agric. and Tech.
Tagawa, Ryozaburo Hokkaido Univ.

Although it has been considered that a transfer function based method is difficult to use to treat multi-input, multi-output (MIMO) systems, the MIMO control system can be treated in a comparatively easy way using a characteristic transfer function matrix (CTFM) concept. In this paper, based on properties of the CTFM, a computer aided technique is presented for deriving the class of realizable transfer function matrices of a control system for a prescribed order controller. Then the possibility as a practical design tool is discussed.

CACSD-TuA2 Milo
CACSD Environments and Tools

CACSD-TuA2-1 10:00 CACSD-380

Polynomial Toolbox and State Feedback Control

Kucera, Vladimir Inst. of Inf. Theory and Autom.
Sebek, M. Czech Tech. Univ.
Henrion, Didier LAAS-CNRS

The design of linear control systems using state feedback and/or output injection can be conveniently accomplished in Matlab environment. The Control System Toolbox works with the state space system description using reliable algorithms of numerical linear algebra. An alternative is presented in this paper. Working with the transfer function system description in the form of polynomial matrix factorizations, the Polynomial Toolbox offers a wide range of reliable algorithms that can be used to design state feedback and/or output injection control systems. The problems of eigenstructure assignment, LQ regulation, and LG estimation are considered as an example.

CACSD-TuA2-2 10:20 CACSD-386

Implementation Issues of a Unified Information Model-Based CACE Integrated Environment

Varsamidis, Thomas,
Hope, Sian,
Jobling, Christopher P. Univ. of Wales

The creation of an open CACE integrated environment presupposes the existence of standardized mechanisms which equip the environment with enough flexibility for incorporating as wide a range of tools as possible. This paper discusses the central mechanism for the exchange of information between various tools integrated in a prototype CACE environment based on the Unified Information Model (UIM). Details of the data communication mechanism and how its has been implemented for a range of diverse tools are discussed. The impact to the user of the existence of this mechanism is considered, and its main merits, from an implementation point of view, are explained.

CACSD-TuA2-3 10:40 CACSD-392

Use of a Prototype CACE Integration Framework Based on the Unified Information Model

Varsamidis, Thomas,
Hope, Sian,
Jobling, Christopher P. Univ. of Wales

Individual CACSD tools offer specialized functionality to the tool users. Within the context of a CACSD design, however, the need for additional project-related functionality arises. One such task involves the exchange of information between different tools without user involvement in the process. Also, keeping track of a project's steps is a desired quality for the environment. Neither of the two requirements can be directly attributed to the responsibility of any CACSD tool. An integrated CACE environment provides a solution to both problems by supplying additional communication and storage services to the CACSD tools integrated in the environment. This paper presents the operation of a prototype CACE environment which has been based on the Unified Information Model, an information model which records the data structures involved in the complete CACSD lifecycle. The environment's services are explored and their contribution to assisting the engineer's task is outlined

CACSD-TuA2-4 11:00 CACSD-398

Bringing Metacomputing to Scilab

Desprez, Frederic INRIA Rhone-Alpes
Fleury, Eric LORIA, INRIA
Gomez, Claude,
Steer, Serge INRIA Rocquencourt
Ubeda, Stephane LIP-ReMaP

Scilab, developed in INRIA in the Meta2 project is a software similar to Matlab that allows scientific applications to be developed using an interactive environment on a workstation running Unix or Windows. In this paper, we present the current version of SCILAB//, a extension of this software that supports the execution of parallel jobs within SCILAB. Using simple commands and the same interface as SCILAB, SCILAB// allows users to start SCILAB on a parallel machine or a network of workstations (NOWS), therefore giving access to the computation power and huge aggregate memory sizes.

From the SCILAB interactive environment, users can spawn several other SCILAB processes, executing remote SCILAB scripts, which can then communicate between each other. Finally, processes can print/plot their results. There are many research directions around this project and we give an overview of the current and future developments.

CACSD-TuA2-5 11:20 CACSD-404

Sampled-Data Control Toolbox: A Software Package via Object-Oriented Programming

Fujioka, Hisaya,
Yamamoto, Yutaka Kyoto Univ.
Hara, Shinji Tokyo Inst. of Tech.

Sampled-Data Control Toolbox is a suite of MATLAB functions for the analysis and synthesis of sampled-data systems. It provides all the functionality necessary to carry out the analysis and synthesis of sampled-data systems, as well as purely continuous-time and discrete-time systems, and a wide variety of utilities to facilitate design. This paper shows the data structure, the list of functions and the function overloading. It also gives an example of H infinity control synthesis.

CACSD-TuA2-6 11:40 CACSD-410

MATLAB Based Tools for 2D Linear Systems with Application to Iterative Learning Control Schemes

Gramacki, J.,
Gramacki, A.,
Galkowski, K. Tech. Univ. of Zielona Gora
Rogers, E. Univ. of Southampton
Owens, D.H. Univ. of Sheffield

Repetitive processes are a distinct class of 2D systems of both theoretic and practical interest. For example, they arise in the study of industrial processes such as long-wall coal cutting operations and also in the modeling of classes of iterative learning control schemes. This paper describes the development of MATLAB based tools for control related analysis/controller design in the case of so-called discrete linear repetitive processes with particular emphasis on the iterative learning control application. Some areas for short to medium term further development are also briefly noted.

CCA-TuA3 Mauka
Control of Chemical Processes I

CCA-TuA3-1 10:00 CCA-893

Control of a Continuously Stirred Tank Reactor Using an Asymmetric Solution of the State-Dependent Riccati Equation

Cloutier, James R. Air Force Res. Lab.
Stansbery, Donald T. CACI/TEAS Group

The state-dependent Riccati equation (SDRE) method is used to control the nonlinear nonminimum-phase dynamics of a continuously stirred tank reactor (CSTR). The benefits of using the SDRE method are that it can be directly applied to the nonminimum-phase system and hard bounds can be imposed on the control activity. From simulation analysis, it is determined that a complicated state-dependent state weighting matrix Q (x) would be required in order to produce satisfactory responses to changes in the set point of the reactor. To avoid the problem of finding such a state weighting matrix, an asymmetric solution of the SDRE is used instead of the symmetric positive-definite solution. Since there are an infinite number of asymmetric solutions, the paper discusses the process that was used in obtaining the selected asymmetric solution. Simulations are performed which produce a level of confidence that the closed loop system is asymptotically stable and is robust to parameter variations in the chemical concentration level in the educt flow.

CCA-TuA3-2 10:20 CCA-899

Nonlinear Time-Scaling for Analysis and Controller Design of Reaction Systems

Moya, P. Univ. Pol. de Valencia
Netto, M.S.,
Ortega, R. CNRS
Pico, J. Univ. Pol. de Valencia

The models that describe the dynamics of reaction systems are usually complex and uncertain. To simplify their description it is useful to identify the states which are dependent/independent of the reactions and flows. This allows us, for instance, to design observers which are independent of the (highly uncertain) reaction functions and, in principle, simplify the controller design. The main contribution of this paper is to show the utility of {\em nonlinear state--dependent time--scaling} to carry out these objectives. First, we prove the existence of attractive invariant manifolds, which allows us to reduce the dimension of the system under study. Second, we design reaction--independent observers, which are simpler than the existing ones, and have a guaranteed convergence rate in all operating regimes. As an application we study a fifth order baker's yeast fed--batch fermentation process model, for which we reduce the essential dynamics to the plane. A simple input--output feedback linearizing controller is designed and its {\em asymptotic stability} established.

CCA-TuA3-3 10:40 CCA-905

Gain-Scheduled Control of a Fossil-Fired Power Plant Boiler

Hanstrup, Mads E.,
Stoustrup, Jakob,
Andersen, Palle,
Pedersen, Tom S. Aalborg Univ.

In this paper the objective is to optimize the control of a coal fired 250 MW power plant boiler. The conventional control system is supplemented with a multivariable optimizing controller operating in parallel with the conventional control system. Due to the strong dependence of the gains and dynamics upon the load, it is beneficial to consider a gain-scheduling control approach. Optimization using complex-mu synthesis results in unstable LTI controllers in some operating points of the boiler. A recent gain-scheduling approach allowing for unstable fixed LTI controllers is applied. Gain-scheduling which interpolates between unstable controllers is not allowed using traditional schemes. The results show that a considerable optimization of the conventional controlled system is obtainable. Also the gain-scheduled optimizing controller is seen to have a superior performance compared to the fixed LTI optimizing controllers operating alone.

CCA-TuA3-4 11:00 CCA-910

H-Infinity Control for a Boiler-Turbine Unit

Tan, Wen,
Niu, Yuguang,
Liu, Jizhen North China Electric Power Univ.

Loop-shaping H_∞ controller is designed for a nonlinear multivariable boiler-turbine system. Simulations show that the designed controller has good tracking, disturbance rejection properties, and robustness against the variations of the operation points due to the plant nonlinearity. In order to implement the complex H_∞ controller, we propose a method to reduce it to a multivariable PID controller. The final simplified controller is composed of three main channel PI controllers plus one off-channel PI controller. It reveals the underlying structure of the designed controller and that of the overall boiler-turbine control system. Simulation results show that it maintains the good properties of the original controller.

CCA-TuA3-5 11:20 CCA-915

Nonlinear MPC and Inferential Sensing for PVC Production

Havlena, V. Honeywell Tech. Cen.
Barva, P. Czech Tech. Univ.

Nonlinear model-based predictive controller with new features including range control, multirate sampling and two degrees of freedom control for PVC batch control/optimization is introduced. The lumped uncertainty design of semi-empirical batch model based on data-mining technologies is described. The controller is complemented by an inferential sensor to reduce the uncertainty about the reactivity of the batch. The knowledge of reactivity is used for batch time optimization under constraints given by shared cooling resources of the plant.

CCA-TuA3-7 12:00 CCA-921

Linear vs. Nonlinear Control of an Axial Flow Compressor

Fontaine, Dan Univ. of California, Santa Barbara
Liao, Shengfang,
Paduano, James D. Massachusetts Inst. of Tech.
Kokotovic, Petar Univ. of California, Santa Barbara

In this paper we compare linear and nonlinear controllers for an axial flow compressor. The control laws are designed for asymmetric interstage bleed valve actuation. We show that a nonlinear L_gV controller achieves a larger region of attraction than that achieved by an LQR controller.

CCA-TuA4 Makai

Electric Motors I

CCA-TuA4-1 10:00 CCA-927

A New RST Cascaded Predictive Control Scheme for Induction Machines

Maaziz, M.K.,
Boucher, P.,
Dumur, D. Service Autom. Supelec

The purpose of this paper is to present a new approach of design of an RST cascaded predictive structure to control rotor position, speed and rotor flux amplitude of an induction machine. The proposed cascaded version introduces in the structure of the inner and external loop a new formulation of the reference signals, which enables to track flux and position/speed nominal profiles, satisfying motor constraints. The corresponding cascaded generalized predictive control law with single reference control (CGPC/SRC) is coupled with the nonlinear input-output linearizing control properties. The global control law is also presented with a flux observer and the simulation results obtained in the case of nominal and mismatched parameters on the complete nonlinear model are discussed.

CCA-TuA4-2 10:20 CCA-933

Analysis, Design, and Control of Advanced Brushless Synchronous Machines with Power Converters

Lyshevski, Sergey E.,
Sinha, A.S.C. Purdue Univ., Indianapolis
Wylam, William,
Cho, Peter Delco Remy America, Inc.

The major goal of this paper is to perform the comprehensive and thorough studies of current developments in nonlinear analysis, design, control, and deployment of advanced electromechanical systems with synchronous machines (motors and generators.). The integration of power converters, sensors, and microprocessors depicts the realistic situation encountered in engineering practice, and this realism has stimulated the industry and academia interest in advanced analysis and design to provide a means for developing newest systems to reduce the current drawbacks and satisfy industry needs. This paper approaches and solves extremely challenging nonlinear analysis and control problems for highly nonlinear electromechanical dynamic systems without placing the problem studied into the scope of pure theoretical research. Our goal is to derive mathematical models, develop innovative design methods, synthesize novel nonlinear controllers, implement control algorithms. and perform experimental studies.

CCA-TuA4-3 10:40 CCA-939

Rotor Position Detection of a Switched Reluctance Motors Using FM Technique

Wang, Y. J.,
Sun, Y.Y.,
Huang, C.C.,
Tsai, M.C. Nat. Cheng Kung Univ.

Shaft position sensing is necessary in the switched reluctance (SR) motor in order to synchronize the phase excitation to the rotor position. In industrial applications, motor commutation often needs direct sensors to detect the rotor position. Being ¡Sensorless does not mean that the motor no longer requires rotor positioning; it means the position information is obtained indirectly, and not through a shaft sensor. According to the inductance characteristics of the SR motor, this paper adopts the linear frequency modulated (FM) principle and the output of the FM converter to get the rotor position signal. Experimental results verify the feasibility of the proposed method.

CCA-TuA4-4 11:00 CCA-945

A Practical Implementation of a Linear Induction Motor Drive Using New Generation DSP Controller

Tsai, Mi Ching,
Chen, Jeng Hu Nat. Cheng Kung Univ.

The concept of Plug & Play has become increasingly popular in consumer electronics because of the ease of use and low maintenance, it now appears possible to apply this concept to the motor drive design. New generations of DSP controllers, such as the Texas Instruments TMS320C240 ('C240) DSP controller, by integrating the high performance of a DSP core and the powerful on-chip peripherals of a microcontroller into a single-chip solution, have made this possible. This paper describes the practical implementation of a linear induction motor drive, which consists of power module and a single DSP controller, which will both reduce the cost and the complexity of the design. In order to save space and enable continuous operation, a linear induction motor has been specifically built for this study. Experimental results will be presented by a videotape in the conference.

CCA-TuA4-5 11:20 CCA-950

Transient Dynamics and Motion Control of Induction Motors

Lyshevski, Sergey E. Purdue Univ., Indianapolis

The need for innovative integrated methods in order to perform the comprehensive analysis and design of electric drives with induction motors has facilitated theoretical developments within the overall spectrum of control theory. Nonlinear analysis and modeling, identification and diagnostics, control and optimization, as well as other problems have to be studied. The system performance depends upon the validity of induction machine models used in design and optimization as well as upon control algorithms effectiveness, complexity and real-time implementation capabilities. In this paper, we develop complete mathematical models of three-phase induction machines in the machine (abc) and qd0 variables, synthesize control algorithms, and verify the theoretical developments.

CCA-TuA4-6 11:40 CCA-956

H-Infinity Design of a Robust Speed Controller for Induction Motors

Chiaverini, Stefano,
Figalli, Gennaro,
Fusco, Giuseppe Univ. degli Studi di Cassino

In this paper a speed controller for an induction motor is developed in the framework of H_{∞} theory design criteria. The proposed control law achieves convergence to zero of both speed and flux norm tracking errors and ensures robustness with respect to load torque disturbances and imperfect system modeling. Implementation of the controller requires full state measurement; this is exploited both to decouple the rotor speed and the flux norm dynamics via feedback linearization, and to close a static state-feedback loop at the new control inputs of the decoupled system. A simulation case study is finally reported to show the effectiveness of the proposed control scheme.

CCA-TuA4-7 12:00 CCA-962

On Robust Stability of Two Flux Observers for Induction Machines

Medvedev, Alexander Lulea Univ. of Tech.

This paper deals with stability properties of two known flux observers for induction machines. It is shown that an arbitrary fast convergence rate in one of the observers is achieved at the expense of its robustness against uncertainty in the rotor angular velocity. Another observer is proven to retain stability notwithstanding any error in the angular velocity measurements, but its estimation error convergence rate is limited by the rotor time constant.

CCA-TuA5 Hau

Ship Motions and Offshore Structures

CCA-TuA5-1 10:00 CCA-1096

Recent Development on Analysis and Control of Ship's Motions

Ohtsu, Kohei Tokyo Univ. of Mercantile Marine

This paper surveys recent developments in the field of analyzing methods of a ship's motions and its control at sea. The following items: (1) some models representing ship's motions, their identification and filtering method using actual data at sea, (2) control methods and their results in actual on-board experiments are emphasized.

CCA-TuA5-2 10:20 CCA-1104

Controlling Line Tension in Thruster Assisted Mooring Systems

Aamo, Ole Morten,
Fossen, Thor I. Norwegian Univ. of Sci. & Tech.

This paper addresses the potential for energy reduction obtained by using dynamic line tensioning in thruster assisted position mooring systems. Traditionally, mooring systems have been designed in such a way that thruster assistance has not been necessary under normal environmental conditions. However, as oil production moves into deeper waters, such over-dimensioned mooring systems are no longer feasible. Thus, new "hybrid" solutions must be developed, in which increased thruster action compensates for fewer, and lighter, anchor lines. In this paper, controlling the line tensions dynamically is suggested as an additional means of station keeping, and a control law is derived based on passivity. A model consisting of a rigid-body submodel for the vessel, and a finite element submodel for the mooring system is presented and used for simulations. The simulations show the performance of the proposed control system.

CCA-TuA5-3 10:40 CCA-1110

Thruster Assisted Position Mooring System for Turret Anchored FPSOs

Sorensen, Asgeir J. Norwegian Univ. of Sci. & Tech.
Strand, Jann Peter ABB Ind.
Fossen, Thor I. Norwegian Univ. of Sci. & Tech.

A thruster assisted position mooring system includes different control functions for station keeping and motions damping of the horizontal-plane motions. A new non-linear passivity-based state observer producing the thruster control actions has been

implemented and verified in full-scale tests. Even though sophisticated filtering and control techniques are applied in the high-level control systems, unforeseen load peaks caused by process disturbances acting on the local actuation system may challenge the power plant stability, if no proper precaution is taken. Both high and low level control aspects concerning integrated positioning and electrical propulsion system are addressed.

CCA-TuA5-4 11:00 CCA-1118

Development of Inverse LMI Method and its Applications to Dynamic Positioning System

Yamamoto, Ikuo,
Terada, Yuuzi Mitsubishi Heavy Ind.

In the paper, a new control design method based on the inverse LMI control algorithm is proposed and applied to a position keeping system of a floating vehicle. The LMI control algorithm is developed to cope with the step response command of controller firstly in the world. And also, the inverse LMI control algorithm is newly created for the user (designer) friendly style. The inverse LMI control design method is applied to the dynamic positioning system design of an offshore platform. LPV (Linear Parameter Varying)model for the offshore platform is derived by its nonlinear model, and the inverse LMI control designs successfully conducted. Effectiveness of the control design method is confirmed by numerical simulation. The method can cope with the nonlinear and robust control problems, and get the control output determined by the control constraint command easily.

CCA-TuA5-5 11:20 CCA-1768

Global Attitude/Position Regulation for Underwater Vehicles

Boskovic, Dejan M.,
Krstic, Miroslav Univ. of California, San Diego

In this paper a nonlinear controller is designed for a 6dof model of an unmanned underwater vehicle (UUV) which includes both the kinematics and the dynamics. It is shown how the use of a Lyapunov function consisting of a quadratic term in the velocity (both linear and angular), a quadratic term in the position and a logarithmic term in the attitude leads to a design of a control law that achieves global asymptotic stabilization to an arbitrary set point in position/attitude. The control law is made linearly bounded by avoiding cancellation of some of the quadratic nonlinearities in the model. No information about the inertia matrix, the damping, and the Coriolis/centripetal parameters is used in the controller, endowing it with a certain amount of parametric robustness. The control law is given in terms of the Modified Rodrigues parameters. An extensive simulation study shows that the proposed control law achieves excellent tracking for slowly changing trajectories, even though it is designed only for set point regulation. The nonlinear controller dramatically outperforms a linear controller.

CCA-TuA5-6 11:40 CCA-1761

Robustness Analysis of Accelerometry Using an Electrostatically Suspended Gyroscope

Fax, J. Alex California Inst. of Tech.
Hill, Daniel A. Boeing Elec. Systems & Missile Def.
Murray, Richard M. California Inst. of Tech.

The Electrostatically Suspended Gyroscope (ESG) is a two-axis inertial orientation sensor manufactured by Boeing and currently in use on U.S. Navy submarines. The additional ability of the ESG to act as an accelerometer is well known, but extraction of precision acceleration measurements from an ESG has not been achieved. The major obstacles to precision accelerometry are the nonlinear dynamics of the ESG rotor and parametric variation of the ESG electronics. In this paper, we derive a model for he ESG dynamics with an eye toward efficient representation of the uncertainties in the model. We represent the model uncertainties and nonlinearities in a framework amenable to μ-analysis and analyze ESG accelerometer precision using μ-analysis tools. Finally, we discuss the implementation of a digital ESG control architecture for use in ESG system identification and testing of suspension control and accelerometer algorithms.

CCA-TuA5-7 12:00 CCA-1791

Collision Avoidance Control of Ship with Genetic Algorithm

Ito, Masanori,
Zhang, Feifei,
Yoshida, Norimoto Tokyo Univ. of Mercantile Marine

Collision avoidance is one of the most important problems for ship navigation. Currently, shhips are usually equipped with ARPA systems, which processess radar information to announce caution when other ships are dangerously close. But it's only an annunciation system and the operator should watch carefully the situation, make judgement and control the ship. In this process, the criteria for judgement is so complex that a miss-judgement or miss-operation could result. In this paper a Genetic Algorithm (GA) based collision avoidance control system is presented.

CCA-TuA5-8 12:20 CCA-1785

PID Controller Optimization for Fin Roll Stabilization

Hickey, N.A. Univ. Edinburgh
Johnson, M.A.,
Katebi, M.R.,
Grimble, Michael J. Univ. of Strathclyde

A ship on the open sea, when subject to the motion of waves is a highly resonant dynamic system. The ship has a dynamic behavior similar to an inverted pendulum, where the magnitude of the swing or roll, is dependent upon the action of the waves on the ship. The frequency and magnitude of this motion are dependent on the natural frequency and damping factor of the ship. It is thus necessary for ships carrying passengers or weapon platforms that this undesirable motion be controlled.

CCA-TuA6 Lehua

Mobile Robot and Vehicle Control

CCA-TuA6-1 10:00 CCA-1003

Noncontact Hold and Transfer Control by a Magnetic Robot Hand Attached to a Mobile Robot with Two Independent Drive Wheels

Kojima, Hiroyuki,
Yuasa, Yoshitaka,
Kobayashi, Toshio Gunnma Univ.

In this paper, first, the structure of the trial production of the mechanical system of the noncontact hold and transfer control system consisting of a magnetic robot hand and a mobile robot with two independent drive wheels is expressed. Then, the state equation of the magnetic robot hand attached to the mobile robot is derived, and the robust noncontact hold control system with the magnetic levitation control is designed by use of the mixed sensitivity method based on the H_infi control theory. On the other hand, the disturbance observer for the mobile robot is designed using the equation of motion of the mobile robot, and the trajectory tracking control system of the mobile robot is constructed by use of the PD control and the disturbance observer. Furthermore, the experimental results concerning the noncontact hold and transfer control of a steel sphere are demonstrated, and the usefulness of the present noncontact hold and transfer control system with the magnetic robot hand attached to the mobile robot is confirmed.

CCA-TuA6-2 10:20 CCA-1009

A New Approach for Kalman Filtering on Mobile Robots in the Presence of Uncertainties

Larsen, Thomas D.,
Andersen, Nils A.,
Ravn, Ole Tech. Univ. of Denmark

In many practical Kalman filter applications, the quantity of most significance for the estimation error is the process noise matrix. When filters are stabilized or performance is sought improved, tuning of this matrix is the most common method. This tuning process cannot be done before the filter is implemented, as it is primarily made necessary by modelling errors. In this paper two different methods for modelling the process noise are described and evaluated; a traditional one based on Gaussian noise models and a new one based on propagating modelling uncertainties. It will be discussed which method to use and how to tune the filter to achieve the lowest estimation errors.

CCA-TuA6-3 10:40 CCA-1015

Robust Tracking and Regulation Control for Mobile Robots

Dixon, W.E.,
Dawson, D.M.,
Zergeroglu, E.,
Zhang, F. Clemson Univ.

This paper presents the design of a differentiable, robust tracking controller for a mobile robot system. The controller provides robustness with regard to parametric uncertainty and additive bounded disturbances in the dynamic model. Through the use of a dynamic oscillator and a Lyapunov-based stability analysis, we demonstrate that the position/orientation tracking error exponentially converges to a neighborhood about zero that can be made arbitrarily small (i.e., the controller ensures that the tracking error is globally uniformly ultimately bounded (GUUB)). In addition, we illustrate how the robust tracking controller can be reconfigured as a variable structure controller that ensures global exponential regulation to an arbitrary desired setpoint.

CCA-TuA6-4 11:00 CCA-1021

Design of Kalman Filters for Mobile Robots; Evaluation of the Kinematic and Odometric Approach

Larsen, Thomas D.,
Hansen, Karsten Lentfer,
Andersen, Nils A.,
Ravn, Ole Tech. Univ. of Denmark

Kalman filters have for a long time been widely used on mobile robots as a location estimator. Many different Kalman filter designs have been proposed, using models of various complexity. In this paper, two different design methods are evaluated and compared. Focus is put on the common setup where the mobile robot is equipped with a dual encoder system supported by some additional absolute measurements. A common filter type here, is the odometric filter where readings from the odometry system on the robot are used together with the geometry of the robot movement as a model of the robot. If additional kinematic assumptions are made, for instance regarding the velocity of the robot, an augmented model can be used instead. This kinematic filter has some advantages when used intelligently and it is shown how this type of filter can be used to suppress noise on encoder readings and velocity estimates. The Kalman filter normally consists of a time update followed by one or more data updates. However, it is shown that when using the kinematic filter, the encoder measurements should be fused prior to the time update for better performance.

CCA-TuA6-5 11:20 CCA-1027

Formation Control of Multiple Autonomous Vehicles

Kang, W. Naval Postgraduate School
Xi, N. Michigan State Univ.

This paper develops a general method of controller design for the formation-keeping of multiple autonomous vehicles. The purpose of the algorithm is to find controllers to keep multiple vehicles in a required formation, and to coordinate the vehicles in the presence of environmental change. Some useful coordination strategies such as movement with a leader, and simultaneous movement of formations are demonstrated by simulations.

CCA-TuA6-6 11:40 CCA-1033

Servo Control of Unstable-Wheeled System by Using Disturbance Torque Observer Compensation and Convex Optimization

Takemori, Fumiaki,
Iwata, Jun-ichi,
Okuyama, Yoshifumi Tottori Univ.

This paper presents the servo control for an unstable-wheeled system by using disturbance torque observer compensation. The validity of this control system is demonstrated through

experiments and a controller designed by convex optimization. We consider that unstable behaviour of the mono-wheeled system because of one supported point body is caused by the virtual disturbance torque. In the proposed disturbance observer, ordinary 2nd-order low pass filter for noise attenuation is insufficient to stabilize the whole wheeled system , so a more high order filter is designed by the H_infi loop shaping method from the view point of robust stability. Secondly, the servo controller for the closed loop system including such a disturbance observer is designed by the convex optimization algorithm in order to achieve multiple control specifications simultaneously

CACSD-TuM1 Koa
Design Methods

CACSD-TuM1-1 2:00 CACSD-328
Automatic PID Tuning: An Application of Unfalsified Control
Jun, Myungsoo,
Safonov, Michael G. Univ. of Southern California

In this paper, we give detailed procedures for using unfalsified control theory for real-time PID controller parameter tuning and adaptation. Related to the candidate-elimination algorithms of machine learning, our PID tuning technique does not need a plant model and makes PID gain selection possible by just using observed data. Simulation results are included.

CACSD-TuM1-3 2:40 CACSD-334
A Canonical Representation for Unfalsified Control in Truncated Spaces
Brugarolas, Paul B. California Inst. of Tech.
Safonov, Michael G. Univ. of Southern California

In this paper we present a canonical representation for truncated space unfalsified control. We show how it specializes to controller unfalsification and adaptive control problems. Moreover, we propose it to solve system identification problems. In addition, we analyze in detail the core issues of the truncated space unfalsified control theory, give a computational algorithm and practical considerations for its implementation.

CACSD-TuM1-4 3:00 CACSD-340
Design of Static Cascade Compensators Using Generalized Singular Values
Rotea, Mario A. Purdue Univ.

Cascade compensators are often used to direct the available control energy to a particular subset of plant modes whose dynamics is to be modified. In certain applications the cascade compensators can be taken to be simple frequency selective filters such as low-pass or band-pass filters. There are applications in which such simple solutions do not work. This paper describes a method to obtain cascade compensators when frequency selective filters do not suffice. The computations required to implement the results are rather simple and involve the calculation of the generalized singular value decomposition of a matrix pair constructed with frequency response data. When combined with robust methods for controller design, the results in this paper yield a simple and effective method for designing controllers that modify the dynamics associated with a specified subset of plant poles.

CACSD-TuM1-5 3:20 CACSD-346
Generalized Sampled and Hold Functions-Based Controllers Design for Uncertain Systems
Yu, Qi,
Er, Meng Joo,
Ni, M.L.,
Shen, L. Nanyang Tech. Univ.

In this paper, we design the Generalized Sampled and Hold Functions (GSHF)-based state-feedback controllers for the continuous-time systems with the norm-bounded time-varying rank-1 uncertainty. A sufficient stability condition for such sample-data control systems is then given by using a Riccati equation approach.

CACSD-TuM1-6 3:40 CACSD-351
H-Infinity Control of Linear Systems with Delayed Measurements
Shaked, Uri Tel-Aviv Univ.
de Souza, Carlos E. Lab. Nac. de Comp. Cient.

The problem of H-infinity control of linear, continuous, time-invariant systems with delayed measurements is considered. A frequency domain approach is adopted to find a dynamical output-feedback controller that processes the delayed measurements and achieves a prescribed performance level. The controller is derived by applying two recent H-infinity control methodologies, namely, H-infinity control based on delayed state measurements, and robust output-feedback H-infinity control using state-feedback methods.

CACSD-TuM2 Milo
CACSD Tools in Flight Control

CACSD-TuM2-1 2:00 CACSD-416
ICAD: An Appropriate CACSD Package for Aerospace Applications
Robertson, S.S.,
Leithead, W.E. Univ. of Strathclyde
O'Reilly, J. Univ. of Glasgow

An analysis and design method, referred to as ICAD, well suited for aerospace control design tasks is outlined. Embodied in a CACSD package, ICAD directly addresses the relevant issues of continuity, simplicity, transparency and flexibility in the modern aerospace MIMO context. Software requirements arising from ICAD are discussed, in particular, the model building and computational aspects. Some facets of the implementation within the CACSD package are illustrated and described.

CACSD-TuM2-2 2:20 CACSD-422
CONDUIT-Control Designer's Unified Interface
Levine, William S. Univ. of Maryland
Tischler, Mark B. Army/NASA ARC

CONDUIT is a computer software package. Its purpose is to assist engineers in the design of aircraft control systems. It is menu-driven, interactive, and based on previously developed

general software for optimization-based computer-aided design. CONDUIT is presently being used to assist in the design of stability and control augmentation systems at ten organizations.

CACSD-TuM2-3 2:40 CACSD-428

HAREM -HAndling Qualities Research and Evaluation Using MATLAB

Duda, Holger,
Duus, Gunnar German Aerospace Cen.

The analysis of aircraft handling qualities using numerical criteria is an important aspect during the development of modern aircraft. For this purpose and for the validation of new criteria DLR Institute of Flight Mechanics has developed a software tool which contains the most important handling qualities criteria and databases. The package is based on MATLAB, a widely used numeric computation and visualization software. HAREM features a central interface for an easy access to all criteria and databases, the possibility to evaluate several configurations with a single command as well as a convenient presentation and handling of the results. This paper contains a description of the concept and the application spectrum of HAREM as well as a short demonstration.

CACSD-TuM2-4 3:00 CACSD-433

Multi-Objective Design Assessment and Control Law Synthesis Tuning for Flight Control Development

Joos, Hans-Dieter DLR Oberpfaffenhofen
Finsterwalder, Reinhard Univ. of Bundeswehr

Flight control law design is a multi-variable control problem where various strict requirements from multiple disciplines have to be satisfied. This paper describes multi-objective control synthesis tuning and design assessment, with application to flight control design. The main feature of this methodology is that the various kinds of design objectives can be taken into account in their most natural form and design alternatives can be assessed most visibly with respect to given requirements. Multi-objective synthesis tuning by min-max parameter optimization allows interactive compromising in the set of what can be best-possibly achieved with a chosen control law structure.

CACSD-TuM2-5 3:20 CACSD-439

A Graphical User Interface for Flight Control Development

Finsterwalder, Reinhard Univ. of Bundeswehr
Joos, Hans-Dieter,
Varga, Andras DLR Oberpfaffenhofen

The FSA (First Shot Approach) Demonstrator of DLR and DASA/Airbus is a first prototype for an integrated multidisciplinary environment for flight control development. The FSA Demonstrator represents a state-of-the-art computational tool which facilitates the study of trade-off between competing specifications and performance metrics. It integrates an object-oriented modeling environment, a data and tool management system, general purpose system analysis, simulation and synthesis tools and an automatic multi-goal attainment optimization program. The FSA Demonstrator comes with a dedicated graphical user interface for problem setup and pushbutton program operation which allows easy setup and operation even by non-specialists. The main payoffs of the FSA are a significant reduction in the design cycle and an improved performance of handling qualities.

CACSD-TuM2-6 3:40 CACSD-445

Near-Optimal Trajectory Generation for Autonomous Aircraft Landing

Yakimenko, Oleg A.,
Kaminer, Isaac I. Naval Postgraduate School

This paper addresses the problem of real-time generation of near-optimal trajectories for air vehicle descent/landing on aircraft carriers in flight director assisted or automatic mode. The problem solved by parameterizing a certain class of near-optimal trajectories for a finite number of representative maneuvers. The parameterized set of solutions can then be used as zero-order approximations for real-time refinement of near optimal solutions corresponding to maneuvers not included in the initial parameter set.

CCA-TuM3 Mauka
Neuro-Fuzzy Control of Chemical Processes

CCA-TuM3-1 2:00 CCA-1044

An Expert Control Strategy Using Neural Networks for the Electrolytic Process in Zinc Hydrometallurgy

Wu, Min Central South Univ. of Tech.
Nakano, Michio Takushoku Univ.
She, Jin-Hua Tokyo Univ. of Engr.

The final step in zinc hydrometallurgy is the electrolytic process. The most important parameters to control the process are the concentrations of zinc and sulfuric acid in the electrolyte. This paper proposes an expert control strategy for determining and tracking the optimal concentrations, which uses neural networks, rule models and a single-loop control scheme. First, the process is described and the strategy that features an expert controller and three single-loop controllers is explained. Next, neural networks and rule models are constructed based on statistical data and empirical knowledge on the process. Then, the expert controller for determining the optimal concentrations is designed through a combination of the neural networks and rule models. The three single-loop controllers use the PI algorithm to track the optimal concentrations. Finally, the results of actual runs using the strategy are presented. They show that the strategy provides not only high-purity metallic zinc, but also significant economic benefits.

CCA-TuM3-2 2:20 CCA-1050

Neuro-Fuzzy Control of a Steam Boiler-Turbine Unit

Alturki, Fahd A.,
Abdennour, Adel Ben King Saud Univ.

Conceptually, Fuzzy Logic, which has drawn a great deal of attention recently, possesses the quality of simplicity. However, its early applications relied on trial and error in selecting either the fuzzy membership functions or the fuzzy rules. This made it depend rather too heavily on expert knowledge which may not always be available. Hence, a self-tuning or an adaptive Fuzzy Logic Controller (FLC) such as Adaptive Neuro-Fuzzy Logic Controller (ANFIS) removes this

stringent requirement. This paper demonstrates the application of ANFIS to a 160 MW nonlinear Multi-Input Multi-Output (MIMO) steam boiler-turbine unit. The space of operating conditions of the plant is partitioned into five regions. For each of the regions an optimal controller is designed. The resulting five linear controllers are used to train the ANFIS. Simulation results showed that the fuzzy controller closely reproduced the optimal performance in each of the design points and surpassed any single linear controller in these operating regions. These results also revealed the robustness of the FLC to parameter variations.

CCA-TuM3-3 2:40 CCA-1056

Prediction of Flooding in an Absorption Column Using Neural Networks

Parthasarathy, Sanjay Honeywell Tech. Cen.
Gowan, Hitesh Honeywell Hi-Spec Solutions
Indhar, Praveen Sasol Synthetic Fuels

This paper presents the results from a joint project between Honeywell Technology Center, Minneapolis, Honeywell Hi-Spec Solutions, South Africa and Sasol Synthetic Fuels, South Africa. The project aimed at predicting the occurrence of flooding in the absorption column of the Rectisol process at Sasol Synthetic Fuels. The prediction of flooding was an integral part of the overall Advanced Control Project on the Rectisol unit. The flooding predictor was used as a controlled variable (CV) in a multivariable controller with an objective function that maximizes the gas throughput. To this end, the prediction of flooding was critical for the success of the project. The technical problem was to first identify a measured variable or a set of variables that are good precursors to flooding. Once suitable precursors to flooding had been identified, a statistical flooding predictor was developed. Data from the Rectisol process corresponding to several different flooding scenarios was analyzed. Statistical techniques, such as correlation analysis, were applied to the data to identify appropriate flooding precursors. From this preliminary analysis and along with some process heuristics, the pressure drop across a section of the column was determined to be a good indicator of flooding. In addition, several other variables, directly measured or derived from measurements, were identified as possible precursors to flooding. Linear and nonlinear models (neural network models) were developed to predict the pressure drop across the section of the column using the variables identified to be good precursors to flooding. These models were implemented online on the distributed control system. Special flooding tests were conducted to evaluate the accuracy of the models. The results of the tests showed that the neural network differential pressure predictor was accurate. The linear differential pressure predictor, on the other hand, performed quite poorly. This indicated that there were sufficient nonlinear dynamical effects in the Rectisol process to warrant the use of a nonlinear model such as a neural network.

CCA-TuM3-5 3:20 CCA-1062

Comparative Study of Parametric and Structural Methodologies in Identification of an Experimental Nonlinear Process

Marchi, Pierre Alibert,
dos Santos Coelho, Leandro,
Coelho, Antonio A.R. Fed. Univ. of Santa Catarina

This paper presents a comparative study of parametric and structural identification methodologies when applied to the identification of an experimental nonlinear process. Several approaches for parametric identification are presented, such as: i) linear mathematical model obtained through recursive least-squares (RLS), ii) linear model with estimation algorithm using multi-step-ahead, iii) Hammerstein model, iv) Volterra model and, v) bilinear model. Two structural approaches for neural network configuration are used: i) multilayer perceptron, and vii) radial basis function. An experimental evaluation is performed on a fan-and-plate process which exhibits complex features. Main characteristics of each identification methodologies and experimental results are assessed and compared using performance indices and validation response curves.

CCA-TuM3-6 3:40 CCA-1068

Adaptive Neural Model Predictive Control of Chemical Process: An Empirical Study

Wang, Dianhui Dalian Maritime Univ.

This paper gives an empirical study in controlling a typical chemical processes: distillation column, where the equations governing the system are unknown. The neural networks are on-line trained to model the process at various operating points and then employed as nonlinear predictors for use in model predictive control. An explicit control laws are derived by using the Clark's GPC performance index and linearization technique. The experimental results show that the proposed neural control strategies have good practical potential for processes control.

CCA-TuM4 Makai

Electric Motors II

CCA-TuM4-2 2:20 CCA-1073

Sensorless Position Detection Using Neural Networks for the Control of Switched Reluctance Motors

Reay, Donald S.,
Williams, B.W. Heriot-Watt Univ.

For high performance position or torque control, or for many of the different possible approaches to torque ripple and acoustic noise reduction in a switched reluctance motor (SRM), position feedback is essential. However, optical position encoders add to the complexity and cost of SRMs, compromising some of their main advantages. This paper describes a novel method of sensorless position detection requiring no special converter or sensor circuitry, and which does not rely on accurate prior knowledge of the magnetic characteristics of the motor. The approach described is novel in two respects. Firstly, it does not rely on accurate prior knowledge of phase winding inductance but merely makes the assumption that it varies substantially as sin (Nr/theta), where Nr is the number of rotor poles and theta

is rotor angle. Secondly, the approach learns from previous good estimates of position and, once it has done so, makes use of this knowledge where performance of the basic estimation algorithm degrades (principally at low speeds of rotation). The technique has been investigated in simulation and a hardware implementation is under development.

CCA-TuM4-3 2:40 CCA-1078

Robust D-Stability of Generalized State-Space Systems with One Parameter Uncertainties

Fang, Chun-Hsiung,
Lu, Chun-Lin,
Hong, Lin,
Kau, Shih-Wei — Nat. Kaohsiung Inst. of Tech.
Lee, Li — Nat. Sun Yat-Sen Univ.

The robust D-stability problem for generalized state-space systems with uncertainties in the form of one-parameter family of matrices is investigated in this paper. Using algebra manipulation only, the maximal bounds of perturbations for simultaneously preserving the regularity, impulse-immunity, and D-stability are analytically derived. In this paper, two types of regions, conic sectors and open disks, which are frequently used in control system analysis and design are investigated. The results are also applied to solving the robust stability of a circuit with uncertain elements. This example demonstrates the superiority of the proposed approach to others existing in the literature.

CCA-TuM4-5 3:20 CCA-1084

An Improved Indirect Field Oriented Controller for the Induction Motor

Behal, A.,
Feemster, Matthew,
Dawson, D.M.,
Haste, D. — Clemson Univ.

In this paper, we illustrate how the standard indirect field oriented controller (IFOC) commonly used in current-fed induction motor drives can be modified to achieve global exponential rotor velocity/rotor flux tracking. The modifications to the IFOC scheme, which involve the injection of nonlinear terms into the current control input and the so-called desired rotor flux angle dynamics, facilitate the construction of a standard Lyapunov stability argument. The construction of a standard Lyapunov exponential stability argument allows one to easily design adaptive controllers to compensate for parametric uncertainty associated with the mechanical load.

CCA-TuM4-6 3:40 CCA-1090

Friction Compensation Strategy via Smooth Adaptive Dynamic Surface Control

Maulana, Aria Putra,
Ohmori, Hiromitsu,
Sano, Akira — Keio Univ.

This paper is dealing with the development of friction compensation scheme for positional set-point regulation at DC motor servomechanism via smooth adaptive dynamic surface control design. The control scheme is built through backstepping procedure in which the change of coordinate is interpreted as sliding surface design. No exact knowledge of the friction model is required for the design of the controller. The global asymptotic stability for positional set-point regulation is achieved using Lyapunov's direct method. Computer simulation and position servo experiment will be presented to confirm the capability of the proposed design.

CCA-TuM5 Hau
Control Applications in Aerospace Systems

CCA-TuM5-1 2:00 CCA-968

Orbit Determination by Means of Kalman Filter Using VLBI Data

Asai, Yoshihiko — Higashinippon Int. Univ.
Nishimura, Toshimitsu — Tokyo Engr. Univ.

In this paper, a new approach for the precise orbit determination technique, which is applicable to deep-space missions, is presented, instead of the conventional orbit determination system using RARR (Range and Range-Rate) data. In this approach, VLBI (Delta Very Long Baseline Interferometry) data are employed together with supplemental range data and are processed by the extended-Kalman-filter. This technique is applied to a typical Martian mission using simulation data and significant enhancement of precision in the orbit determination is demonstrated, compared to the conventional RARR method.

CCA-TuM5-2 2:20 CCA-973

New Method of Capturing Tumbling Object in Space and its Control Aspects

Nakasuka, Shinichi,
Fujiwara, Takeshi — Univ. of Tokyo

A novel capturing method of tumbling objects in non-gravitational field is proposed, aiming for the future on-orbit service missions such as capturing failed satellites or manned vehicle which loses control, or removing debris. The key technology for this capture is how to compensate for the difference of rotational motions between the chaser and the target at the moment of capture. Most conventional methods use manipulator movement for this objective while keeping the position and attitude of the chaser body constant, which limits the allowable rotational velocity and patterns of the tumbling motion of the target. In the proposed method, the chaser aligns its rotational motion with the target's one by appropriate control before capturing the target, which is expected to enlarge the allowable target rotational motion range. Technical issues to realize it are discussed and our approach to them are proposed, which is verified with some computer simulations and hardware experiments.

CCA-TuM5-3 2:40 CCA-979

Robust Attitude Controller Design of Linear Parameter Varying Spacecraft via Mu Synthesis and Gain Scheduling

Nagashio, Tomoyoki,
Kida, Takashi — Univ. of Electro-Communications

This paper studies three-axis attitude control problem of spacecraft which has slowly rotating flexible solar paddles. By the paddle rotation, the structure of dynamical coupling of the paddle vibration with the spacecraft attitude dynamics drastically changes. In order to control such a class of

spacecraft, we derive a parameter-varying modal equation and a generalized plant of descriptor form. Then, two stabilizing controllers, i.e., a fixed mu controller and a gain scheduled H_infi controller are designed. Based on some numerical studies for ETS-VI spacecraft model, their capabilities are shown and compared with each other.

CCA-TuM5-4 3:00 CCA-985

An Experimental Investigation of Active and Passive Control of Rotating Stall in Axial Compressors

Prasad, J.V.R.,
Neumeier, Y.,
Lal, M.,
Bae, S. H.,
Meehan, A. Georgia Inst. of Tech.

This paper presents results to date from on-going analytical and experimental investigations of passive and active control methods for suppression of stall in axial flow compressors. The passive control method involved inclusion of flow separators in the inlet and outlet ducts of the compressor. The active control methods investigated included bleed valve modulations, flow recirculation from plenum bleed to inlet of the compressor and fuel flow modulations. It was found that in contrast to theoretical expectations, the use of separators in the inlet and/or outlet ducts did not prevent the onset of rotating stall. However, it was found that with proper number of separators, the onset manner of the rotating stall was tempered. Experimental results to date indicate that it is possible to significantly suppress the onset of rotating stall through a combination of passive and active control schemes, and thus, extend the useful operational range of a compressor.

CCA-TuM5-5 3:20 CCA-991

Guidance Performance Analysis of Bank-To-Turn (BTT) Missiles

Lee, Jang Gyu Seoul Nat. Univ.
Han, Hyung Seok Kyungwon Univ.
Kim, Young Jim Seoul Nat. Univ.

Among the Bank-To-Turn (BTT) missile guidance methods, a prevalent method is to get the acceleration command and roll-angle command through a polar converting logic (PCL) from the acceleration commands generated by Skid-To-Turn (STT) missile guidance. In the design of a BTT missile guidance law using a PCL, the controllability of the system should be particularly considered in the terms of the stability of roll motion. In this paper, the problems found in the BTT missile guidance will be examined by applying a typical guidance law, i.e. proportional navigation (PN) guidance law, to a simple missile model. Then a biased proportional navigation (BPN) guidance law, which has an additional bias for angular constraints compared with PN, is introduced and applied to BTT missile guidance. The results from Monte-Carlo simulations for a 6 DOF missile model under several sensor noises show that BPN has better guidance performances for BTT missiles than the typical guidance law, PN.

CCA-TuM5-6 3:40 CCA-997

Automatic Approach and Landing for Propulsion Controlled Aircraft by H-Infinity Control

Ochi, Yoshimasa,
Kanai, Kimio Nat. Def. Acad.

This paper describes design of a flight control system for propulsion controlled aircraft (PCA), which are controlled using thrust only. Particularly, approach and landing phase is considered because it is the most critical one in flight control. The ILS-coupled automatic approach and landing flight control system is designed for a large transport aircraft, B-747 via H\ state-feedback control. In the design, the guidance and control loops are designed at a time, which makes it easy to optimize the whole system performance unlike one-by-one loop closure in classical control. The effectiveness of the control system is shown through computer simulation using a linear model of the B-747 aircraft in approach configuration.

CCA-TuM6 Lehua
Mobile Robot and its Control Architecture

CCA-TuM6-1 2:00 CCA-1123

A Control System for an Omnidirectional Mobile Robot

Paromtchik, I.E.,
Asama, Hajime,
Fujii, Teruo,
Endo, I. Inst. of Phys. and Chem. Res.

This paper deals with the development of a control system for an omnidirectional mobile robot. Our objective, overall control architecture and approach to motion generation are considered. The control system is implemented and tested on the omnidirectional mobile robot and the experimental results obtained are discussed. The operation of the control system is illustrated by a video on the remote control of the mobile robot and the visually-coupled motion of the two robots.

CCA-TuM6-2 2:20 CCA-1129

Decentralized Control of Mobile Robots in Coordination

Hirata, Yasuhisa,
Kosuge, Kazuhiro Tohoku Univ.
Asama, Hajime,
Kaetsu, Hayato,
Kawabata, Kuniaki Inst. of Phys. and Chem. Res.

We proposed a decentralized control algorithm of multiple robots handling a single object in coordination. The motion command of the object is given to one of the robots, referred to as a leader, and the other robots referred to as followers estimate the motion of the leader by themselves through the motion of the object and handle the object based on the estimated reference. In this paper, the proposed control algorithm is experimentally applied to three omni-directional mobile robots with three degrees of freedom of motion, and the results illustrate the validity of the proposed control algorithm.

CCA-TuM6-3 2:40 CCA-1135

Application of Non-Regressor Based Adaptive Control to Underwater Mobile Platform-Mounted Manipulator

Lee, Pan-Mook KRISO
Yuh, Junku Univ. of Hawaii

An underwater manipulator mounted on a mobile platform such as underwater vehicles is a multi-body dynamic system. The hydrodynamics of the manipulator mounted on the vehicle are poorly known and time-varying. Furthermore, its motion is disturbed by the vehicle motion. This paper presents a non-regressor based adaptive control scheme for the trajectory tracking of underwater mobile platform-mounted manipulators. The presented adaptive control system dose not require any information about the system. The adaptive control law estimates control gains defined by the combinations of the bounded constants of system parameter matrices. To evaluate the performance of the adaptive controller, computer simulation was performed with a two-link planar manipulator mounted on a one degree-of-freedom mobile platform. The effects of hydrodynamic forces acting on the manipulator are included.

CCA-TuM6-4 3:00 CCA-1779

Sensor Fusion Technique for Cable Following by Autonomous Underwater Vehicles

Balasuriya, Arjuna — Nanyang Tech. Univ.
Ura, Tamaki — Univ. of Tokyo

In this paper, a sensor fusion technique is proposed for Autonomous Underwater Vehicles (AUVs) to track underwater cables. The work presented here is an extension of the vision based cable tracking system proposed earlier. The focus of this paper is to solve the two practical problems encountered in vision based systems; namely 1) navigation of AUV when cable is invisible in the image, and 2) selection of the correct cable (interested feature) when there are many similar features appearing in the image. The proposed sensor fusion scheme uses deadreckoning position uncertainty with a 2D position model of the cable to predict the region of interest iin the image. Experiment results presented in this paper shows that the proposed method solveds the above mentioned practical problems.

CCA-TuM6-5 3:20 CCA-1141

Mobile Robot Teleoperation Using Local Storages

Kawabata, Kuniaki,
Ishikawa, Tatsuya,
Asama, Hajime,
Endo, Isao — Inst. of Phys. and Chem. Res.

In this paper, we propose a teleoperation system with Intelligent Data Carriers (IDCs). An IDC is a device that turns the working environment to an agent. By using IDCs for teleoperation system, the required sensing ability of the robot can be reduced because the robot can take the information about its working environment from IDCs that are placed in the remote site. This implies the effectiveness of an implicit collaboration among the operator, the robot and the environment. We have the experiments using real network and systems.

CACSD-TuP1 Koa
Optimization-Based CACSD

CACSD-TuP1-1 4:20 CACSD-357

DirectSD -A Toolbox for Direct Design of SD Systems

Polyakov, K. Yu,
Rosenvasser, Ye.N. — State Univ. of Ocean Tech.
Lampe, Bernhard P. — Univ. of Rostock

A new Matlab toolbox DirectSD for analysis and direct synthesis of sampled-data (SD) systems in continuous time is presented. The design methods used in the toolbox are based on a new theoretical base, the main part of which is the parametric transfer function concept, which makes it possible to investigate SD systems in continuous time in the frequency domain. The toolbox includes macros for analysis and direct H_2- and H_inf-optimization of SISO SD systems under deterministic and stochastic disturbances.

CACSD-TuP1-2 4:40 CACSD-363

Computation of Time Optimal Controls by Gradient Matching

Szymkat, Maciej,
Korytowski, A.,
Turnau, A. — St. Staszic Tech. Univ.

Time optimal control of nonlinear systems is considered. To find the optimal horizon, a sequence of fixed-horizon problems of minimizing an auxiliary cost functional is solved by gradient methods, with the use of adjoint trajectories. Due to the gradient matching the optimization procedure for every fixed horizon is convergent to a (local) minimum in control space. Basically, the control switching times are decision variables. The proposed computational methods of search for optimal horizon are based on an estimation-continuation strategy. The approach proved effective in the case of a cart-pendulum system.

CACSD-TuP1-4 5:20 CACSD-369

Direct Collocation and Nonlinear Programming for Optimal Control Problem Using an Enhanced Transcribing Scheme

Hu, G.S.,
Ong, Chong-Jin,
Teo, C.L. — Nat. Univ. of Singapore

In this paper, an enhanced transcribing scheme is proposed for solving optimal control problems using direct collocation and nonlinear programming. This new scheme is based on the standard method of direct collocation that converts an optimal control problem into a nonlinear programming problem via simultaneous state and control discretization. When compared with the standard method, the enhanced scheme has the advantage of higher solution accuracy with minimal additional computational effort. It is particularly suited for systems with states that are related to each other in a special form. For such systems, the ensuing nonlinear programming problem has the same number of constraints as those using standard method. Numerical results on several optimal control problems using the enhanced scheme are presented, together with comparisons with the results obtained from standard scheme.

CACSD-TuP1-6 6:00 CACSD-375

Reliability-Directed Computer-Aided Design System

Abramov, Oleg V.,
Katueva, Y.V. Inst. for Autom. and Control Processes
Lazarev, G.I. Vladivostok State Univ.
Suponya, A.A. Inst. for Autom. and Control Processes

A theoretical approach and applied techniques for designing analogues engineering devices and systems with due account of random variations in system parameters and reliability specifications are considered. For solving this problem a so-called operational/parametric approach is used. This approach is based on the computer-aided simulation of system capability and availability, parameter deviations and techniques of optimal parametric synthesis in terms of reliability criteria. Special attention is paid to algorithms that reduce the labor content of parameters optimization problems. For seeking a numerical solution of the parametric design problem a computer-aided reliability-oriented design system is proposed.

CACSD-TuP2 Milo
MaTX/RtMaTX: A Freeware for Integrated CACSD

CACSD-TuP2-1 4:20 CACSD-451

MaTX/RtMaTX: A Freeware for Integrated CACSD

Koga, Masanobu Tokyo Inst. of Tech.

The purpose of this paper is to give an overview of a cost-efficient integrated CACSD environment MATX/RTMATX. The software supports not only the analysis of control systems , and the design of controllers, but also the real-time implementation of controllers. MATX/RTMATX is distributed as a free software and is used in many universities and several companies mainly in Japan. This session focuses on the applications in some fields, such as robot motion control, visual simulation, mathematical and modeling with symbolic manipulation, economics, and education in control engineering.

CACSD-TuP2-2 4:40 CACSD-457

Robot Motion Control by MaTX/RtMaTX

Yamakita, Masaki Tokyo Inst. of Tech.

MaTX/RtMaTX is a simple real-time computer language for computer simulations and real-time control applications. The language's monitor was developed using the C and assembly language. An advantage of this language is its efficient handling of matrix operations such as wedge products, contraction operators, and Lie brackets. The presented examples show that MaTX/RtMaTX is a convenient language for implementation of several control algorithms with matrix operations.

CACSD-TuP2-3 5:00 CACSD-462

Modeling and Simulation of Mechanical Systems - Combination of a Symbolic Computation Tool and MaTX

Hoshino, Tasuku,
Furuta, Katsuhisa Tokyo Inst. of Tech.

This paper illustrates an efficient way of modeling mechanical systems and performing the numerical simulation, by combinationally using symbolic and numerical computation tools. Since deriving the model and its minimal representation involves symbolic manipulations of equations, it must be handled by the symbolic computation tool. On the other hand, the simulation task requires numerical evaluations of the same object repeatedly; it can be efficiently processed by the numerical tool, especially when the values of objects are immediately available. The key point is how to export the symbolic objects easily into the numerical environment. The authors try to automatically generate source codes of the objects for the numerical tool, and join two environments on the source level. The stabilization of the spherical pendulum is served as an example, and its modeling and the simulation using Mathematica/MaTX are included.

CACSD-TuP2-4 5:20 CACSD-468

VRSC: Visual Robotic Simulation and Control with MaTX/RtMaTX

Nonaka, Kenichiro Musashi Inst. of Tech.

A three dimensional graphic library, a graphic user interface library and its structure mode for MaTX/RtMaTX on Win32 are introduced. They are developed for the following purpose: to provide a visual and interactive man-machine interface for MaTX/RtMaTX, to give the 3 dimensional graphics for visually grasping the state of the dynamical system, and to unify the plant information including dynamics and appearance. A control system based on these libraries for existing 3DOF manipulator is presented, in which action commands are presented as a menu of window, and the current posture of the manipulator is displayed as a 3 dimensional figure while dynamical simulation or a real-time control is executed.

CACSD-TuP2-5 5:40 CACSD-474

MaTX for IO -Extension of MaTX for Economic Input-Output Analysis

Tsukui, Makiko Tokyo Int. Univ.

Economic input-output analysis is regarded as one of the popular method for empirical analysis of economic phenomena, especially such analysis of interdependence of industries. In this field, it is necessary to use some computer software with following features; 1) ability of large scale computation of matrices, 2) easy modification by programming, 3) various library functions for input-output analysis, 4) acceptability of various formats of data, 5) good user interface. In this study, we shall try to develop MaTX for IO to satisfy these features.

CACSD-TuP2-6 6:00 CACSD-480

MaTX Aided Control Education

Hatakeyama, Shoshiro,
Pan, Yaodong Tokyo Denki Univ.

This paper presents how MaTX is used to aid the education of Classical and Modern Control Theory in a lecture named System Engineering Practice for third year students at Department of Computers and System Engineering, College of Science and Engineering, Tokyo Denki University, Japan.

CCA-TuP3 Mauka

Control Applications in Flows and Turbomachines

CCA-TuP3-1 4:20 CCA-1146

Adaptive Detection of Instabilities and Nonlinear Analysis of a Reduced-Order Model for Flutter and Rotating Stall in Turbomachinery

Copeland, G. Scott — United Tech. Res. Cen.
Kevrekidis, Ioannis G. — Princeton Univ.
Rico-Martinez, Ramiro — Inst. Tecnologico de Celaya

In this effort system parameters are adaptively varied to identify bifurcations from equilibrium in simulations of a reduced-order model for turbomachinery aeromechanics. An element of the adaptive process is identification of a low-order locally nonlinear discrete-time map from the observables. The nonlinear behavior of the system in the neighborhood of the bifurcation is then estimated from the identified system.

CCA-TuP3-3 5:00 CCA-1151

Low-Dimensional Models for Active Control of Flow Separation

Narayanan, Satish,
Khibnik, Alexander I.,
Jacobson, Clas — United Tech. Res. Cen.
Kevrekedis, Y. — Princeton Univ.
Rico-Martinez, Ramiro — Inst. Tecnologico de Celaya
Lust, K. — Cornell Univ.

We study the spatiotemporal dynamics of flow separation in a planar diffuser to extract reduced-order models that may be used to guide active separation control. Proper orthogonal decomposition of numerical simulation data revealed organized dynamics of the large-scale separated structures. This result, combined with the observation (in simulations as well as laboratory experiments) of limit cycle/quasiperiodic dynamics and spatial symmetry breaking, suggests an underlying low-dimensional dynamical system. Galerkin-based and neural network-based modeling of the POD modal coefficients lead to (parameter dependent) low-dimensional models of separation dynamics. The use of such models for active separation control appears promising.

CCA-TuP3-4 5:20 CCA-730

Nonlinear Control Design for Rotating Stall with Magnetic Bearing Actuators

Wang, Yong — California Inst. of Tech.
Paduano, James D. — Massachusetts Inst. of Tech.
Murray, Richard M. — California Inst. of Tech.

Rotating stall is one type of aerodynamic instability limiting the performance of aeroengines. A set of magnetic bearings supporting the compressor rotor is a potential actuator for active control of rotating stall. Based on a first-principles model we show that using this type of actuation, the first harmonic mode of rotating stall is linearly controllable, but the zeroth and the second harmonic modes are linearly uncontrollable. For systems with a stable zeroth (surge) mode, we give an explicit procedure for designing feedback laws such that the Hopf bifurcation of the second mode stall inception is supercritical. We also investigate the effects of magnitude saturation on the size of the region of attraction. We demonstrate the theoretical results by numerical simulations of a model for a transonic compressor at the NASA Glenn Research Center.

CCA-TuP3-5 5:40 CCA-1157

On the Design of Feedback Controllers for a Convecting Fluid Flow via Reduced Order Modeling

Burns, John A.,
King, Belinda B. — Virginia Pol. Inst. and State Univ.
Rubio, Diana — North Carolina State Univ.

In this paper, we study the effect of model reduction strategies for actuator design and control of a thermal convection loop. The problem concerns flow through a thin pipe in which the Boussinesq approximation of Newtonian viscous flows is assumed.

CCA-TuP4 Makai

Applications of Adaptive Control for Systems with Nonsmooth Nonlinearities

CCA-TuP4-1 4:20 CCA-1163

Backlash Compensation in Nonlinear Systems Using Dynamic Inversion by Neural Networks

Selmic, Rastko R.,
Lewis, Frank L. — Univ. of Texas at Arlington

A dynamic inversion compensation scheme is presented for backlash. The compensator uses the backstepping technique with neural networks (NN) for inverting the backlash nonlinearity in the feedforward path. The technique provides a general procedure for using NN to determine the dynamic preinverse of an invertible dynamical system. A tuning algorithm is presented for the NN backlash compensator which yields a stable closed-loop system.

CCA-TuP4-2 4:40 CCA-1169

Tracking Control in the Presence of Nonlinear Dynamic Frictional Effects: Robot Extension

Feemster, Matthew,
Dawson, D.M.,
Behal, A.,
Dixon, W.E. — Clemson Univ.

In this paper, we extend the observer/control strategies previously published in [Vedagarbha 1997] to an n-link, serially connected, direct drive, rigid link, revolute robot operating in the presence of nonlinear, friction effects modeled by the Lu-Gre model. In addition, we also present a new adaptive control technique for compensating for the nonlinear parameterizable Stribeck effects. Specifically, an adaptive observer/controller scheme is developed which contains a feedforward approximation of the Stribeck effects. This feedforward approximation is used in a composite controller/observer strategy which forces the average square integral of the position tracking error to an arbitrarily small value.

CCA-TuP4-3 5:00 CCA-1175

Adaptive Friction Compensation of Servo Mechanisms

Ge, S.S.,
Lee, T.H.,
Ren, S.X. — Nat. Univ. of Singapore

In this paper, adaptive friction compensation is investigated using both model-based and neural network (non-model-based) parameterization techniques. Intensive computer simulations are carried out to show the effectiveness of the proposed control techniques, and to illustrate the effects of certain system parameters on the performance of the closed-loop system.

CCA-TuP4-4 5:20 CCA-1181

Adaptive One-Step-Ahead Control with Input Amplitude, Rate, and Acceleration Constraints

Cheng, J. John,
Wang, Yi-Ming Nat. Chung Cheng Univ.

This paper considers tracking control design for uncertain linear SISO stable processes with input amplitude, rate, as well as acceleration constraints. A self-tuning adaptive control was developed. Its underlying control designs carried out via one-step ahead optimal control while its parameter update is obtained through the least-square projection algorithm. It is shown that, under a sufficient condition, the proposed adaptive control is globally convergent in the sense that the adaptive control asymptotically matches the constrained one-step-ahead optimal control which assumed system parameters are available. Computer simulation of the velocity tracking performance of a DC motor with input voltage amplitude, rate, and acceleration constraints are provided to illustrates the effectiveness of the proposed adaptive control.

CCA-TuP4-5 5:40 CCA-1187

Transient Stability Enhancement of Power Systems by Robust Adaptive Control with Saturation Constraint

Zhang, Ying,
Wen, Changyun,
Soh, Yeng Chai Nanyang Tech. Univ.

This paper proposes a backstepping technique for designing discrete-time adaptive excitation controller to enhance the transient stability of power systems under large sudden faults. This approach can be applied directly on nonlinear model of power system and it allows for abrupt changes in the power system parameters caused by three phase short circuit faults. It is shown that the proposed excitation controller can enhance transient stability when the power system suffers large sudden faults. The robustness of the power system under the proposed excitation controller is established in the presence of time-varying parametric uncertainties, unmodeled dynamics and external disturbances. Both theoretical analysis and simulation results are presented to show the effectiveness of the proposed controller.

CCA-TuP4-6 6:00 CCA-1193

Adaptive Estimation of Magnetic Bearing Parameters

Baloh, Michael,
Tao, Gang,
Allaire, Paul Univ. of Virginia

As magnetic bearing applications become more complicated, the need for accurate models of the controlled bearing systems becomes more important. Ordinarily, accurate models are obtained by first levitating and then performing system identification. The method for measuring the actuator properties often involves lengthy tests that are performed manually. This paper presents the initial research into using adaptive estimation to identify unknown parameters and disturbances for a simple one-dimensional magnetic bearing system. Analysis of the plant and construction of an estimator are presented with simulation results that show the estimator performance. Lastly, a more general model with hysteresis is parameterized and estimated.

CCA-TuP5 Hau
Flight Control III

CCA-TuP5-1 4:20 CCA-1199

A Study of Longitudinal Flight Maneuvers for the CTOL Aircraft Model

Al-Hiddabi, Saif A.,
McClamroch, N. Harris Univ. of Michigan

We study several flight control problems for a conventional aircraft take off and landing (CTOL) flight control model, a simplified model for aircraft longitudinal flight dynamics. In particular, we study the execution of a maneuver for which the aircraft is intended to follow a path in a vertical plane corresponding to specified change in altitude. We formulate the problem as a nonlinear tracking control problem. Controllers are developed for two cases: a non-aggressive maneuver, corresponding to a large altitude change. We demonstrate the need to develop a controller that includes feedforward terms in order to achieve aggressive maneuvering. Our approach throughout is to make use of nonlinear control theory, which is complicated by the non-minimum phase characteristics of the CTOL model.

CCA-TuP5-2 4:40 CCA-1205

LPV Controller Design for ALFLEX by Using LMI

Ando, Yoshinori,
Tsuge, Hidetaka,
Suzuki, Masayuki Nagoya Univ.

In this paper, we consider the LPV systems. The LPV controller with varying parameters are proposed. This controller is less conservative than H-infinity controllers. We reveal the condition to be able to design the LPV controller. Next we apply the LPV controller to the ALFLEX longitudinal motion control in running on ground. By simulation we confirm the utility of the proposed method to stabilization. Also we check the property for the disturbance rejection.

CCA-TuP5-3 5:00 CCA-1211

Formation Flying Control of Multiple Spacecraft via Graphs, Matrix Inequalities, and Switching

Mesbahi, Mehran,
Hadaegh, F.Y. California Inst. of Tech.

Ideas from elementary graph theory and linear matrix inequalities are combined with logic-based switching to shed light on the various control strategies which are feasible in the leader-following framework for the formation flying of multiple spacecraft.

CCA-TuP5-4 5:20 CCA-1217

Motion Control of Highly-Maneuverable Aircraft

Lyshevski, Sergey E.,
Dunipace, Kenneth R. Purdue Univ., Indianapolis
Colgren, Richard D. Lockheed Martin Skunk Works

This paper approaches and solves a spectrum of problems in the motion control of highly maneuverable aircraft. In particular, analysis and identification, as well as optimization and control of advanced aircraft are researched to attain the specified flying and handling qualities (agility and maneuverability, controllability and other pilotage quantities), guarantee survivability, damage adaptation and recovery, improve mission effectiveness, etc. This paper reports a new completely automated setup to perform real-time identification and control with failure accommodation. Innovative identification and design methods are applied. It is shown that the required aircraft performance through the specified operational envelope at various attitudes, including high-angle-of -attack regimes, can be achieved through real-time nonlinear analysis, identification, and control reconfiguration. An example is studied to demonstrate the practical use of the analytical and numerical results. In particular, the feasibility and viability of the identification and design methods developed, as well as the computational effectiveness and numerical stability of the algorithms, are illustrated. It is documented that the decision making process can be performed in real-time.

CCA-TuP5-5 5:40 CCA-1223

The Frequency-Domain Heterogeneous Control Mixer Module Method for Control Reconfiguration

Zhenyu, Yang,
Huazhang, Shao,
Zongji, Chen Beijing Univ.

In order to meet the control reconfiguration requirements within a limited frequency range for the fault tolerant control system, a numerical frequency range for the fault tolerant control systems, a numerical frequency-domain control mixer module method is developed in this paper, and the sufficient condition for the existence of a real mixer matrix is obtained basing on the proper frequency samplings. Furthermore, the heterogeneous control approach [6] is employed to deal with the non-smooth transition problem during the control mixer switches. Finally, a practical self-repairing flight control system is utilized to test our methods.

CCA-TuP5-6 6:00 CCA-1229

High-Performance Direct-Drive Flight Actuators: Advanced Technology Demonstration

Lyshevski, Sergey E. Purdue Univ., Indianapolis

In this paper, a new concept in design of fly-by-wire actuator systems is developed to be implemented in advanced flight vehicles. To attain the specified vehicle performance (agility and maneuverability, controllability, flying and handling qualities), highly reliable flight actuators are needed to be deployed. To satisfy severe requirements on weight and size , efficiency and torque density, steady-state and dynamic characteristics, ruggedness and reliability, survivability and maintenance, novel flight actuator systems are developed using high-performance stepper motors with advanced power electronics controlled by microprocessors. It is illustrated that the desired performance and integrity are guaranteed. Weight and size are decreased, reliability and survivability are increased, by using the advanced actuator technology reported. Permanent magnet stepper motors can be directly attached to control surfaces, and redundancy needed is achieved. This solution enhances the reliability by eliminating geartrains and ensures compact, highly integrated assembling compared with the existing actuators. Permanent-magnet stepper motors are needed to be controlled. A new design method is reported to design control laws, and the Lyapunov stability theory is used to prove the robust stability and tracking as well as to find the feedback coefficients. It is illustrated that innovative control algorithms are designed based upon the electric machinery features to maximize the electromagnetic torque developed. Experiments have been performed to illustrate the effectiveness and feasibility of direct-drive actuator technology.

CCA-TuP6 Lehua
Inverted Pendulum Control

CCA-TuP6-1 4:20 CCA-1235

Robust Control of a Triple Inverted Pendulum

Tsachouridis, Vassilios A. Univ. of Leicester

The design and implementation of a robust computer control system for balancing and improving the steady state performance of a triple inverted pendulum-cart system is considered. The controller is based on discrete-time theory. An integrator is used to eliminate the effects of small constant sensor offsets and rail inclinations. Disturbance attenuation and relative stability characteristics are studied via frequency response analysis. Frequency response simulations and experimental results are reported.

CCA-TuP6-2 4:40 CCA-1241

Multivariable Adaptive Model Output Following Control System Based on Backstepping Strategy and its Application to Parallel Inverted Pendulums

Takahashi, Masanori Ariake Nat. College of Tech.
Mizumoto, Ikuro,
Iwai, Zenta,
Kohzawa, Ryuichi Kumamoto Univ.

In this paper, we propose a design method of an output feedback--based adaptive model output following control system based on backstepping strategy for MIMO plants. It is shown that the proposed adaptive control system has robustness with regard to output--dependent disturbances. Further, the proposed adaptive control method is applied to the parallel inverted pendulums with output--dependent disturbances and the effectiveness of the control system is confirmed through experiments.

CCA-TuP6-3 5:00 CCA-1249

Time Optimal Control for the Pendulum-Cart System in Real-Time

Turnau, A.,
Korytowski, A.,
Szymkat, M. St. Staszic Tech. Univ.

An experiment in practical implementation of simulated time-optimal control in a laboratory cart-pendulum system is described. The simulation results are compared with two types of measured trajectories of the real system: generated by an implementation of the time-optimal control, and generated by a rule-based algorithm. The technologies of rapid prototyping, real-time simulation and hardware-in-the-loop simulation are used for direct synthesis of control algorithms. The feasibility of construction of time-optimal controller in the real system has been pointed out.

CCA-TuP6-4 5:20 CCA-1255

Swing Up of an Inverted Pendulum by Simulator-Based Foresight Control

Uchida, Motomiki,
Nakano, K. Fukuoka Inst. of Tech.

One of the typical nonlinear system is a pendulum. Cause of difficulties of controlling a pendulum is miss-matching of number between inputs and outputs, that is to say, single input and double outputs. The feature of a pendulum is nonlinear as to angle and linear as to cart position. Another point is that state equations do not have terms of position of a cart. In addition, the angle of a pendulum must satisfy the dynamic equation at horizontal line. In order to swing up a pendulum of these properties, first, we define a reference angle of a pendulum which satisfies the dynamic equation at horizontal line. After the pendulum goes up around upright word, when the pendulum system becomes a linear time-invariant system, we define the ideal curves of both angle and position which will converge to the origin. The angle of the pendulum is controlled by SFC (Simulator based Foresight Control) all the way which can be applicable for a non-affine nonlinear systems.

CCA-TuP6-5 5:40 CCA-1260

Dynamic Model Based Friction Compensation on the Furuta Pendulum

Gafvert, Magnus Lund Inst. of Tech

The Furuta pendulum is used to evaluate a friction compensator based on the dynamic LuGre friction model. The effect of friction compensation is very well illustrated by reduction of limit cycles when stabilizing the pendulum. The observer based LuGre friction compensator is compared with classical Coulomb and Stiction compensator schemes. Existing analysis of the LuGre observer is extended to observer based friction compensation in general linear state feedback control of linear time invariant systems where friction enters the system at the input. In particular this observer based friction compensation is applicable on the pendulum. The performance of the LuGre compensator was found to be similar to that of the Stiction compensator. Important differences is the smooth control signal obtained from the LuGre observer, and that it uses less prior information.

CCA-TuP6-6 6:00 CCA-1266

Adaptive Robust Stabilization of a Class of Nonlinear Systems with Partially Known Uncertainties

Wu, Hansheng Hiroshima Prefectural Univ.

The problem of robust stabilization of nonlinear systems with partially known uncertainties is considered. A class of continuous adaptive robust state feedback controllers with simpler structure is proposed. It is shown that the resulting closed-loop nonlinear systems with uncertainties are stable in the sense of uniform ultimate boundednesss. In contrast with some results presented in the control literature, the proposed adaptive law for updating the estimate values of the unknown parameters is continuous, and the existence of the solutions to the resulting closed-loop systems in the usual sense can well be guaranteed. Moreover, due to the continuity of state feedback controller and adaptive law, the proposed adaptive robust state feedback controllers is easily implemented in practical robust control problems. Finally, an illustrative example is given to demonstrate the utilization of the results.

CACSD-WA1 Koa

CACSD-WA1-1 10:00 CACSD-486

Performance Indices in Evolutionary CACSD Automation with Application to Batch PID Generation

Feng, Wenyuan,
Li, Yun Univ. of Glasgow

This paper addresses the issue of transforming CACSD to 'Computer-Automated Control System Design', the fundamental step towards which is to devise simple performance indices that can reflect all time and frequency-domain requirements under constraints. The merit and selectivity of five commonly used indices are hence analyzed and assessed against design specifications, together with five new indices proposed. It is shown that these indices can offer selectivity for damping ratios ranging from 0.5 to 1.0 (and extending to the infinity) for the overall closed-loop system. Using the ITAE index, evolutionary computation is applied to enable batch PID design automation. This leads to multiple optimal controllers for various time-constant ratios, satisfying both time and frequency domain requirements, including robust stability and low maximum sensitivity.

CACSD-WA1-2 10:20 CACSD-492

Genetic Algorithm Enabled Computer-Automated Design of QFT Control Systems

Chen, Wen-Hua,
Ballance, Donald J.,
Feng, Wenyuan,
Li, Yun Univ. of Glasgow

This paper first reviews existing Quantitative Feedback Theory (QFT) based design techniques and difficulties that a designer encounters. Based on this analysis and taking into account practical constraints, an evolutionary computation enabled automatic design procedure is developed. It can be employed to provide an initial controller quickly on which to base manual loop-shaping and refinements, or be used to further tune existing controllers or start from scratch. A design example against a MATLAB QFT Toolbox benchmark problem shows that this methodology not only automates loop-shaping but also improves design quality and, most usefully, improves the quality with a reduced order controller. The entire design is targeted towards global optimization, including the prefilter selection.

CACSD-WA1-3 10:40 CACSD-498

Control System Design Automation with Robust Tracking Thumbprint Performance Using a Multi-Objective Evolutionary Algorithm

Tan, K.C.,
Lee, T.H.,
Khor, E.F. Nat. Univ. of Singapore

This paper develops a multi-objective evolutionary based methodology for control system design automation of robust tracking thumbprint performances in QFT. Unlike conventional two-stage design approach, the technique is capable of evolving both nominal controller and pre-filter concurrently without the need of QFT bound computation and manual loop-shaping procedure. It is shown that the method can easily accommodate practical soft/hard constraints and allows engineers to examine the different design trade-offs. Validation upon a benchmark QFT. This paper develops a multi-objective evolutionary based methodology for control system design automation of robust tracking thumbprint performances in QFT. Unlike conventional two-stage design approach, the technique is capable of evolving both nominal controller and pre-filter concurrently without the need of QFT bound computation and manual loop-shaping procedure. It is shown that the method can easily accommodate practical soft/hard constraints and allows engineers to examine the different design trade-offs. Validation upon a benchmark QFT design problem illustrates the usefulness of the proposed methodology.

CACSD-WA1-4 11:00 CACSD-504

Population-Diversity Based Genetic Algorithm for Fuzzy Control of Synchronous Generators

Wen, J.Y.,
Wu, Q.H.,
Shimmin, D.W.,
Turner, D.R. Univ. of Liverpool
Cheng, S.J. Huazhong Univ. of Sci. & Tech.

This paper proposes a method to design an optimal fuzzy controller (OFC) for excitation control of synchronous generators. The design is based on optimizing a number of parameters involved in the fuzzy and defuzzification process directly. A population diversity based genetic algorithm (PDGA) is derived to solve this multi-parameter optimization problem. The new method has been used to design an optimal fuzzy excitation controller for synchronous generator, satisfactory results are obtained.

CACSD-WA1-5 11:20 CACSD-510

Parameter Identification of an Induction Machine Using Genetic Algorithms

Huang, K.S. Guangdong Univ. of Tech.
Kent, W.,
Wu, Q.H.,
Turner, D.R. Univ. of Liverpool

This paper applies genetic algorithms (GAS) to the problem of parameter identification of induction machines. For the purpose of variable speed application, the motor's general mathematical model based upon Kron's voltage equations has been employed to estimate the parameters, and the motor's start-up performance has been used as the measurement during the identification process. Results with different measurement noises and different measured performances are presented. For comparison, the results of a simple random search (SRS) method under the same condition are also given. The results show that the performance of the GA is much better than that of the SRS technique. It is concluded that the GA is a powerful tool for parameter identification.

CACSD-WA1-6 11:40 CACSD-516

Lotka-Volterra Machine for a General Model of Complex Biological Systems

Hirafuji, Masayuki,
Tanaka, Kei,
Hagan, Scott Nat. Agric. Res. Cen.

It has been proven that the generalized Lotka-Volterra equations can express arbitrary continuous functions if there are sufficient hidden nodes that are not assigned by observational data. We show that the generalized Lotka-Volterra equations encompass a description of the same structure as do artificial neural networks. Since the equations can be used as a universal modeling framework, we named the computational models of the equations Lotka-Volterra Machines (LVMs). We developed a software tool (Java applet) to construct LVMs and identified unknown parameters in the LVM using a genetic algorithm. It is demonstrated that the LVM can model the growth of organs in a plant and the tool can identify the parameters of the LVM although it may have more than 20 unknown parameters, and that the resulting LVM can correctly forecast the dynamics of organs. Originally the Lotka-Volterra equation was proposed to model ecosystems. We show that the LVM can be transformed into the equations for a hypercycle, a model of chemical processes essential to life. Therefore the LVM has the ability to represent the dynamics at almost all levels of hierarchical structure in complex biological systems. We developed a large LVM simulator (Java applet) to simulate a much larger LVM. Large LVMs on the order of hundreds of nodes show a different character from that of small LVMs. Specific aspects of the character of huge LVMs are discussed from examples of simulations. We propose a self-organizing mechanism according to which a sufficient number of nodes, interconnected by diverse weights in a huge LVM, can maintain their order against fluctuations coming from all other nodes.

CACSD-WA2 Milo

Systems Engineering Methods for Powertrain Control Development

CACSD-WA2-1 10:00 CACSD-557

Using Modern Design Tools to Integrate the Systems Engineering and Software Engineering Processes

Holway, Paul,
Michaels, Larry,
Quinn, Stan,
Santos, Craig MathWorks, Inc.

The traditional method for designing systems that contain embedded computers involves the use of requirements analysis tools that capture the overall requirements for the system, and then permit the flow down of those requirements

into specifications for the various subsystems. At the end of the process is a specification for the embedded code. This method works well, but the overhead it entails is burdensome and lends to a long design cycle. The engineers that start the process will get a design that works, but it is likely to be an inexact representation of what they had in mind. Furthermore, the excessive time spent in the writing of specs, translating the documentation into understandable form, and gaining insight into the system is time that can not be used to optimize the design. The process could be vastly improved were an executable specification available. Such an approach is available from The Mathworks.

CACSD-WA2-2 10:20 CACSD-563

A Modeling Environment for Production Powertrain Controller Development

Sivashankar, N.,
Butts, K. Ford Res. Lab.

Automotive companies are increasingly using computer model based product development processes. The usage of models in powertrain embedded control systems development is the main focus of this paper. The scope and the types of models that are used in different steps vary across the development process. However, it is desirable to have an integrated modeling environment and a general model architecture throughout the process for optimal resource utilization. This paper describes a multi-user flexible modeling environment that satisfies such a need. The concept is demonstrated with an example. The resources required to develop and maintain the environment are also discussed.

CACSD-WA2-3 10:40 CACSD-569

Implementation Details and Test Results for a Transient Engine Dynamometer and Hardware-In-The-Loop Vehicle Model

Babbitt, Guy R.,
Moskwa, John J. Univ. of Wisconsin-Madison

A state-of-the-art transient dynamometer engine test system has been developed in the Powertrain Control Research Laboratory (PCRL) at the University of Wisconsin-Madison. This system includes a hydrostatic dynamometer capable of excitation in excess of 300Hz, integrated with a controller running the dynamic driveline equations in real time to calculate the instantaneous engine loads during transients. This hardware-in-the-loop (HIL) virtual engine loading system can be a powerful tool for use in engine and powertrain research, as well as control and diagnostic algorithm development and validation. This paper describes the system and presents experimental open loop and closed loop HIL data from the transient dynamometer system that represents the virtual vehicle.

CACSD-WA2-4 11:00 CACSD-575

Production Intent Rapid Prototyping

Erkkinen, Tom J. Applied Dynamics Int.

A new generation of MCUs are either in use or are being strongly considered for the next generation of automotive powertrain controllers. Silicon vendors are aggressively developing system-on-a-chip architectures to significantly increase compute performance without a correspondingly large increase in manufacturing cost. The lack of a system bus with easily accessible ports poses a major problem within the instrumentation and calibration community. Standards are starting to emerge to address this, such as NEXUS. However, the ripple effect of this on other portions of the development cycle such as rapid prototyping of embedded controllers (RPC) is not yet known and is a major concern. Traditionally, rapid prototyping has used a shared memory approach that either replaced the main memory or provided a window into certain memory segments. Instead of accessing the standard ROM, the CPU would actually access a separate memory module that was linked to the Rapid Prototyping system. However, all CPU interactions would occur on the system bus and involve similar access times. With the new RISC processors, the CPU accesses the on-chip ROM much faster than the off-chip shared memory. Thus the question facing the rapid prototyping community is, Will it be possible to do accurate, well-instrumented, closed-loop rapid prototyping with the new thirty-two bit RISC chipsets as is presently being done? Answers to this question, identification of challenges faced, and opportunities provided for RPC with next-generation processors are discussed herein.

CACSD-WA2-5 11:20 CACSD-581

Symbolic Verification of Executable Control Specifications

Banphawatthanarak, Chonlawit,
Krogh, Bruce H. Carnegie Mellon Univ.
Butts, Ken Ford Res. Lab.

Recently, new CACSD tools have appeared that make it possible to create executable specifications for embedded control systems. Stateflow tm is a MATLAB/Simulink toolbox that supports the development of executable specifications for discrete-state functions. It also supports general flowcharting of program functions. This paper describes a MATLAB program, sf2smv 2.0, that generates input for a symbolic model checking program, SMV2, to verify properties of Stateflow tm diagrams in Simulink. The SMV modules are constructed to reflect precisely the execution semantics in the simulation of Stateflow diagrams. This extends previous work that created verification files that reflected an idealized version of the Stateflow semantics. This paper describes how the principal stateflow execution rules are translated into SMV modules. Examples are used to illustrate the transformation procedures and their application to verify properties of executable specifications for control features in automotive powertrain control applications.

CACSD-WA2-6 11:40 CACSD-587

Automated Test of ECUs in a Hardware-In-The-Loop Simulation Environment

Boot, Rolf AUDI AG
Richert, Jobst,
Schuette, Herbert dSpace GmbH
Ruekgauer, Andreas dSpace Inc.

This paper describes the application of real-time simulation tools and how automation techniques can be used during the development process of modern automotive electronic control units (ECUs) in order to effectively meet the demands placed by the increasing complexity of the software and the resulting

intricate ECU tests. During the past few years, the software for engine ECUs in particular has shown an almost exponential growth in range and complexity, since they must fulfill the customers' demands for comfort as well as the government's requirements on emissions reduction and on-board diagnosis (OBD-I and OBD-II). In addition, the number of control loops within engine control systems is increasing, which means that the proper test of ECU operation requires that all control loops are in place and closed. Hardware-in-the-loop (HIL) simulation along with Test Automation (TA) is increasingly important for the efficient integration of production type engine ECUs. With more and more manufacturers relying on independent suppliers, the need for automatically testing black box systems, including closed-loop and open-loop functions, self-diagnoses, failure memory management and the triggering of failure lamps, becomes paramount. Since malfunctions in these areas cause a high recall potential for vehicle manufacturers, especially when they are discovered by the customer first, they must be avoided by all means. A contemporary engine ECU has more than 150 error bits. Assuming three minutes per diagnosis test for only one operating point (such as cold or warm engine, idle speed, partial or full load), and new software revisions to be tested every two weeks, it becomes apparent that this complexity cannot be met anymore without automation.

CCA-WA3 Mauka

Chemical and Biological Processes

CCA-WA3-1 10:00 CCA-1272

Implementing Supervisory Control for Chemical Batch Process

Akesson, K.,
Fabian, Martin Chalmers Univ. of Tech.

In chemical batch control applications the specification of how to produce a batch is called a recipe. When several recipes execute concurrently within a plant there is a possibility for circular wait between recipes utilizing shared resources. A circular wait might lead to the loss of an entire batch; this is costly and should therefore be avoided. This work describes the implementation of a discrete-event supervisor aimed to prevent a batch processing system from running into circular waits by restricting resource allocations. The supervisor interacts with SattLine, a commercial control system for flexible production systems, which in turn executes the batch recipes. The supervisor consists of two parts, (1) generation of a circular wait free specification, and (2) an execution part that restricts the behavior of the control system such that the specification is fulfilled.

CCA-WA3-2 10:20 CCA-1278

Transition Control of Paper-Making Processes: Paper Grade Change

Murphy, Timothy F.,
Chen, Shih-Chin ABB Ind. Sys., Inc.

Grade change on a paper machine is a transition from one set of operating conditions to another. During the transition, without proper coordination and control, the entire process could have radical fluctuations and produce significant amounts of off-spec paper or even cause sheet break. The production loss and the efforts to recycle off-spec waste are very costly. To address the issue, this paper formulates the dynamic models of paper-making processes and presents an effective control of grade change transitions. The method has been applied several hundreds of paper machines. A real application example is included here to demonstrate the actual performance of the described approach.

CCA-WA3-3 10:40 CCA-1284

A Simple Method for Oscillation Diagnosis in Process Control Loops

Horch, Alexander Royal Inst. of Tech.

A simple method for the diagnosis of oscillations in process control loops is presented. The new method is based on the cross-correlation between control variable and loop output and it is shown to correctly diagnose the two most important reasons for oscillations in control loops in the process industry, namely external oscillating disturbances and static friction (stiction) in control valves.

CCA-WA3-4 11:00 CCA-1290

Blood Glucose Regulation: An Output Feedback Approach

Femat, Ricardo,
Ruiz-Velazquez, E. UASLP

Diabetes mellitus is a disease that afflicts many people. Here , an output feedback for blood glucose regulation is presented. To this end, the glucose regulation problem is seen as an output tracking problem. In this way, the proposed controller leads the glucose level from diabetic to normal behavior. The resulting controller contains two parts: (I) A state estimator and (II) a linearizing-like control law. The proposed controller yields smooth control actions. Numerical simulations show that the controller is able to reject load disturbances.

CCA-WA3-5 11:20 CCA-1294

A Control Relevant Dynamic Model of Grate Sintering

Martinsen, Frode,
Foss, Bjarne A.,
Johansen, Tor Arne Norwegian Univ. of Sci. & Tech.

In this paper a control relevant nonlinear dynamic model of grate sintering is presented. The model is designed for control purposes for use in future model predictive control (MPC) strategies. A multi-model approach is utilized where the model is represented as a convex combination of locally affine models. The model performance is compared to global models listed in the literature by simulations and by comparison to industrial plant data.

CCA-WA3-6 11:40 CCA-1300

Optimized Modeling of the Intra Myocardial Coronary Circulation.

Hirayama, H. Asahikawa medical college
Okizaki, A. Asahikawa Medical College
Okita, T. Shizuoka Univ.
Nishimura, T. Ohita Univ.

We propose an optimized model of coronary circulation for evaluating patho-physiological hemodynamical changes in the intra myocardial blood flow. The model consisted of an

equivalent electrical circuit comprised of epicardial, sub epicardial, the middle layer and the sub endocardial regions. The cost function consisted of squares of the temporal and static changes in perfusion pressures, intra myocardial arterial and venous flow rates and control inputs. We could simulate reported experimental data for coronary arterial and venous flows.

CCA-WA3-7 12:00 CCA-1306

Adaptive Control of Peristaltic Pumps During Continuous Venovenous Hemofiltration

Morales, Efrain O.,
Polycarpou, Marios,
Hemasilpin, Nat,
Bissler, John J. Univ. of Cincinnati

Continuous venovenous hemofiltration (CVVH) is a lifesaving renal replacement therapy used in clinical intensive care settings. Patients undergoing a life threatening illness often develop renal failure, and CVVH performs the blood filtering process while the kidneys recover. The open-loop fluid flow induced by the peristaltic pumps utilized in CVVH cannot provide the fluid balance accuracy necessary to treat neonates. This paper presents a hierarchical control architecture for CVVH. The control methodology uses a direct adaptive control scheme for the peristaltic pumps and a supervisory control algorithm for high-level decisions on the safe operation of the system. Adaptive control of the pumps results in improved accuracy of fluid flow, while the supervisory controller provides greater autonomy and reduces the burden on clinical personnel. The performance of the proposed hierarchical controller is illustrated by experiments on a hemofiltration machine using a simulated patient.

CCA-WA4 Makai
System Identification and Signal Modeling

CCA-WA4-1 10:00 CCA-1312

System Identification of Anti-Vibration Units in Semiconductor Exposure Apparatus

Kato, H.,
Wakui, S. Canon Inc.
Mayama, T. Canon, Inc.
Toukairin, A.,
Takanashi, H.,
Adachi, S. Utsunomiya Univ.

In this paper, system identification of semiconductor exposure apparatus is discussed. It has a multi-degrees-of-freedom mechanism which includes anti-vibration units for microvibration control. A dynamical model of the mechanism is necessary in order to design the microvibration controller. The model is practically constructed in a short time using subspace method. Identification results are evaluated through experimental data in comparison with conventional frequency response method.

CCA-WA4-2 10:20 CCA-1318

Scale Transform Approach for Impulse Responses Identification

Zhang, Jiangang,
Zhang, Jie,
Mao, Jianqin Beijing Univ.

It is well known that noise is very difficult to deal with in system identification. Based on multiresolution analysis and wavelets, scale transform approach for impulse response identification is proposed in this paper. Impulse response function is expressed with the expansion of orthonormal scale function, orthonormal scale transform is exerted on signal, and least squares are used for parameter identification. Simulation results give a description of the advantages of this approach.

CCA-WA4-3 10:40 CCA-1324

The Application of Parameter Identification Methods with Competing Systems to Model a Human Interface Device

Repperger, D.W. Air Force Res. Lab.
Phillips, C.A. Wright State Univ.
Krier, M. Air Force Res. Lab.
Long, L.,
Taylor, S. Wright State Univ.

Identification methods are applied to experimental data (hand motion) from a design study on a human interface system. The internal model of the Kalman Filter employed for the state estimation implicitly utilizes two competing systems (involving an agonist and an antagonist human muscle actuator). The parameters are obtained by minimizing the sums of the squares of the output error residuals, which are tested for whiteness. A particular state variable formulation is developed which satisfies the appropriate identifiability conditions. The competing systems utilized were linear second-order, and this technique is a generalization of a methodology applied in pharmacological studies in which competing systems interact to produce a parsimonious parameter representation of a process.

CCA-WA4-4 11:00 CCA-1330

Detection of the Fundamental Frequency in Noisy Enviroment for Speech Enhancement of a Hearing AID

Yanagisawa, Koichi,
Tanaka, Kyoko,
Yamaura, Itsuo Shinshu Univ.

This paper describes a method for noise-proof detection of a fundamental frequency of the voice in noisy environment. The noise reduction techniques have been required in the development of a hearing aid, because noise makes intelligibility of hearing awfully inferior. In various methods of the noise reduction, the fundamental frequency is often a significant parameter, but it is difficult to extract the accurate frequency from the noisy voice. In order to utilize a comb filter method for the noise reduction, a new method detecting the fundamental frequency is developed by using a property of continuity in the fundamental frequency and a power spectrum envelope (PSE) of the human voice. The continuity of the PSE is utilized for determining the most reliable frequency. A gross pitch error (GPE) is reduced by the determination. Besides the frequency used for the comb filter is obtained from a linear predicting frequency and the latest fundamental frequency

from the noisy voice, so as to suppress fluctuation of the frequency that degrades filtered voice. The procedure improves a fine pitch error (FPE) within 5%. The results of the evaluation showed that the present method proved to be superior to a traditional cepstrum method in the GPE and the FPE. We conclude that the proposed frequency detection method is available for the noise reduction in the comb filter method.

CCA-WA4-6 11:40 CCA-1336

Selection and Performance of Probabilistic Tables Used in Non-Model Based Signal Prediction

Zeceña, Juan Carlos Cordova,
Yaz, Edwin E. Univ. of Arkansas

Conditional probabilistic tables are used as a means to estimate the future value of a signal when little if any knowledge on the system that gives rise to the signal is available. The size of the probabilistic table, namely its dimension and the quantization employed, determines its ability to distinguish between very similar actual conditions on the signal, and therefore, when correctly selected, enables accurate predictions to take place. In this paper, the maximum number of point intersections within an appropriate time window that the signal induces on a zero slope line forms the basis of an heuristic rule for the selection of the dimension of the probabilistic table. The performance of tables with smaller and larger than necessary dimensions are compared against each other and also against two other prediction schemes which involve linear observers and a zero-order hold to be explained.

CCA-WA4-7 12:00 CCA-1342

Analysis of Alfa-Beta-Gamma Filters

Tenne, Dirk State Univ. of New York at Buffalo
Singh, Tarunraj State Univ. of New York

This paper discusses in detail the alpha-beta-gamma filter which is a sampled data target tracker which can asymptotically track a constant acceleration target. The alpha-beta-gamma filter is analyzed by determining the bounds on the alpha-beta-gamma parameters for stability. A closed form equation for the mean square response of the system to white noise is derived to characterize its ability to filter noise.

CCA-WA5 Hau
Control Problems in Heavy-Duty Vehicles

CCA-WA5-1 10:00 CCA-1348

Longitudinal and Lateral Control of Heavy-Duty Trucks for Automated Vehicle Following in Mixed Traffic: Experimental Results from the CHAUFFEUR Project

Fritz, Hans DaimlerChrysler AG

Longitudinal and lateral control of heavy duty trucks for vehicle following is presented . A manually driven leading truck is followed at a very small distance by another truck automatically. No additional road infra structure is necessary. For longitudinal and lateral control, information about the relative position of the leading and following truck is determined by an onboard image processing system, Additionally, a vehicle t vehicle communication system gives information about the state of the leading truck. Longitudinal control has a two layered structure. In the inner control loop, a model based nonlinear acceleration controller linearizes the essential nonlinearities of the drive train. Based on this linearization, the outer control loop (a linear state space controller) controls a small and safe distance to the leading truck. Lateral control is done by an electronic tow bar approach where the rear truck follows the same track as the leading truck. Practical results with two 40 ton semitrailer trucks are given.

CCA-WA5-2 10:20 CCA-1353

Speed Control Experiments with an Automated Heavy Vehicle

Tan, Yaolong,
Robotis, Andreas,
Kanellakopoulos, Ioannis UCLA

This paper presents experimental results of the first-stage implementation of a new generation of longitudinal controllers for commercial heavy vehicles. The experimental vehicle used is a Class-8 18-wheel tractor-trailer combination vehicle, equipped with electronic throttle, brake, and steering actuators, and the corresponding sensors for automated operation. In the first stage of the experiments we tested two of our speed control algorithms: fixed-gain PID and PIQ controllers. The verification of our theoretical predictions by the experimental results provides the basis for investigating further control performance improvement with more advanced controllers.

CCA-WA5-3 10:40 CCA-1359

Automated Lane Guidance of Commercial Vehicles

Tomizuka, M.,
Tai, M.,
Wang, J-Y.,
Hingwe, P. Univ. of California, Berkeley

This paper is concerned with automated lane guidance of heavy vehicles in the context of Automated Highway Systems (AHS). Emphasis is on tractor-semitrailer combinations. Vehicle models are formulated in both the vehicle coordinate frame and the road coordinate frame. The model in the latter frame is appropriate for dynamical analysis and controller design since the lateral error is measured relative to the road. The vehicle speed and the look-ahead distance, i.e. the location of lateral error sensor relative to the tractor's center of gravity, significantly affect the open loop dynamics from the front wheel steering angle to the lateral error. This aspect is studied by linear analysis. Two classes of lateral controllers are presented: one class is designed based on linear H¥ loop shaping methods and the other is based on nonlinear robust control and adaptive control. Simulation results are presented to verify the linear and nonlinear designs.

CCA-WA5-4 11:00 CCA-1365

Modeling and Robust Control of Power Steering System of Heavy Vehicles for AHS

Hingwe, P.,
Tai, M.,
Tomizuka, M. Univ. of California, Berkeley

This paper is concerned with the modeling and control of steering system as a subsystem of lateral control architecture

of heavy vehicles for the Automated Highway Systems. A steering system retrofitted with an actuator is considered. The input and output of the steering system are the reference steering angle command to the actuator and the actual steering angle of the front wheel respectively. Open loop experimental data is fitted to a second order linear model. A linear loop-shaping controller has been designed and experimentally verified. It has also been successfully used as an inner-loop controller of the vehicle lateral control system in the open and closed loop experiments of the heavy vehicle system.

CCA-WA5-5 11:20 CCA-1371

Stability Analysis via Passivity of the Lateral Actuator Dynamics of a Heavy Vehicle

Canudas de Wit, Carlos,
Claeys, Xavier — Lab. d'Autom. de Grenoble
Bechart, Hubert — Renault Dir. de la Recherche

The paper presents a model and a control law for the steering actuator used in heavy duty vehicles. A stability analysis has been conducted using passivity properties of the hydraulic system. These results are pertaining to applications where new automatic vehicle features (i.e. lateral control) are to be designed.

CCA-WA5-6 11:40 CCA-1377

Stability Issues for Vehicle Platooning in Automated Highway Systems

Canudas de Wit, Carlos,
Brogliato, Bernard — Lab. d'Autom. de Grenoble

This paper discusses notions and definitions pertinent to the stability of systems operating in platoon structures. This paper reviews some of the existing stability definitions (i.e. string stability), and discusses how the available platoon information and separation policies influences the stability results. It turns out that some of these notions and control policies do not suffice to ensure safety (collision avoidance) of the platoon. This is illustrated via simulation examples showing that there exists, in general, a non empty set of initial condition that results in a colliding situation. This set being not necessarily small. In connection with this, we propose a new way to formulate the platooning problem aiming at solving some of these difficulties.

CCA-WA6 Lehua
Mechatronics I

CCA-WA6-1 10:00 CCA-1383

Global Stabilization of Centrifugal Compressors via Stability-Based Switching Controllers

Leonessa, Alexander,
Haddad, Wassim M.,
Li, Hua — Georgia Inst. of Tech.

In this paper we develop a globally stabilizing stability-based switching controller strategy for a three-state lumped parameter centrifugal compressor surge model. The proposed model involves pressure and mass flow compression system dynamics as well as spool dynamics to account for the influence of speed transients on the compression surge dynamics. The proposed nonlinear switching controller architecture involves throttle and compressor torque regulation and is directly applicable to compression systems with actuator amplitude and rate saturation constraints.

CCA-WA6-2 10:20 CCA-1389

A Chaos Model via Relay Feedback

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

The generation of chaos by a linear system with nonlinear feedback has been studied by many researchers. In this paper, a chaotic system using Relay as nonlinear feedback element is presented. The system is easily analyzed by means of the describing function approach, which gives parameter condition leading to chaotic motion[5][6]. By the bilinear transformation, the proposed system is also shown to be transformed into Brockett proposed chaotic system with piecewise-linear feedback element[7].

CCA-WA6-3 10:40 CCA-1394

Binary Excitation Based System Identification for Precision Ballscrew Table

Huang, Pai-Yi,
Chen, Yung-Yaw — Nat. Taiwan Univ.

Mechanical devices usually come with undesirable nonlinearities such as frictions, backlashes and saturation. Under the assumption of linear systems, the commonly seen identification schemes utilize sinusoidal excitation signals for parameter identifications. However, the data for identification are unavoidably distorted by the fore-mentioned nonlinearities and the identification result is not satisfactory. In this paper, a method based on binary excitation signals is proposed. The method does not suffer from the problem of nonlinear distortions in signal shape and is able to determine the bias term for asymmetric frictions such that an accurate model can be derived. A 0.01 micrometer high precision ballscrew table with asymmetric frictions is utilized as a test plant for this approach. The result proves to be very successful.

CCA-WA6-4 11:00 CCA-1400

Special-Purpose Devices Using Techniques of Discontinuous Control and Setting Adjustment (DC & SA) in Control Applications

Mkrtchian, Vardan,
Hovakimyan, Aramais,
Hunanyan, Armen,
Kchachaturyan, Tigran — State Engr. Univ. of Armenia

This paper deals with special-Purpose Devices Using Techniques of Discontinuous Control and Setting Adjustment (DC&SA) in Control Applications. DC&SA are result of a synthesis of two independent concepts of control: The sliding Mode and Optimal Rating. This paper is aimed not only at stating and developing the results obtained in the sphere of discontinuous system design, but also at presenting these results in close correlation with the basic concepts, problems and methods of theoretical aspects of present day control theory. The discontinuity of control results in a discontinuity part of the differential equations describing the system motions. If such discontinuities are deliberately introduced on

certain surfaces in the system state space. then motions in a sliding mode may occur in the system. To improve efficiency of practical implementation long-period fiber Bragg GRatigs, used as sensors, are regarded as electronic elements having a discontinuity switching mode where the sliding modes are the basic motions. Implementation of this approach implies the knowledge of the conditions of the occurrence of sliding modes for which purpose a sliding mode indicator has been developed. The state vector of the system is unknown. In this connection we designed spatial observer who uses measurements as basic data, and it will help to identify the state vector of the system.

CCA-WA6-5 11:20 CCA-1406

Modeling of Actuator Systems Using Multilayer Electrostrictive Materials

Lee, Fu-Shin Huafan Univ.

A general model for fuel injection valves using multilayer electrostrictive materials actuators is established. Based upon finite element approach, the model describes the dynamic behaviors of the multilayer electrostrictive actuators and correlates with dynamics of other lumped-parameter components to form overall system state equations for the fuel injector. Simulations are performed for the system using LiF, RbI, and NaF electrostrictive materials with different number of layers to form the actuators.

CCA-WA6-6 11:40 CCA-1412

Proposal of a Parallel Supporting Damper with Tendon and Robust Control System Design

Kimura, Junso Hiroshima Univ.
Harada, Shigeru Mitsubishi Heavy Ind.
Saeki, Masami Hiroshima Univ.

In this paper, a new type damper is proposed. It is based on the Tendon control and is constructed using parallel supporting mechanism, by which this damper has some effective features. One of them is the effect of dynamic absorber. And some control system is designed for the structure with this proposed damper. It aims at the improvement of vibration property, the guarantee of robust stability and the low sensitivity property for disturbance. Some simulation results show the good performance of it.

CACSD-WM1 Koa
Intelligent CACSD

CACSD-WM1-1 2:00 CACSD-522

A Formal Approach to Reactive System Design: Unmanned Aerial Vehicle Flight Management System Design Example

Koo, T. John,
Sinopoli, Bruno,
Sangiovanni-Vincentelli, Alberto,
Sastry, Shankar Univ. of California, Berkeley

This paper presents a formal methodology for the design, implementation and validation of reactive systems. The methodology has been applied to the design of a Flight Management Systems (FMS) for a model helicopter in the BEAR project[9]. POLIS[2], a model sign tool developed at the University of California at Berkeley, is extensively used. The automation of the design problem and the validation techniques provided by this tool allow to shorten prototyping time and to prove the correctness of the properties of the system. Automatic code generation guarantees error free implementation, which is fundamental in safety critical applications. Simulation of the entire design is performed using Ptolemy, a hierarchical heterogeneous simulation environment.

CACSD-WM1-2 2:20 CACSD-528

Software-Enabled Control for Intelligent UAVs

Schrage, Daniel P.,
Vachtsevanos, George Georgia Inst. of Tech.

The emerging era of Uninhabited Aerial Vehicles (UAVs) demands software architectures capable of distributed computing, plug-and-play of control algorithms, rapid real-time algorithm switching and on-line reconfiguration and customization of algorithms. An Open Control Platform (OCP) that enables such capabilities is required. Under the DARPA Software Enabled Control (SEC) program Georgia Tech is teamed with The Boeing Company to develop advances in SEC technologies, as well as to provide a mid-level OCP. The objective of this project is to develop SEC methods for complex dynamic systems with the application focus on intelligent UAVs. The technology will be demonstrated on a small Vertical Takeoff and Landing (VTOL) UAV, the Yamaha R-50/RMAX helicopter. This paper and presentation will present an overview of the project.

CACSD-WM1-3 2:40 CACSD-533

Fuzzy-Neural Control with Application to a Heating System

Mesbah, Samy,
Pang, Grantham Univ. of Hong Kong

In this paper, a fuzzy-neuro approach will be presented for the design of bang-bang control system. A description of the architecture will be given. The multi-layered structure of the controller is essentially a neural network which resembles a fuzzy rule-based system. The robustness issue of an application to a heating system will also be described.

CACSD-WM1-4 3:00 CACSD-539

The SAL Interpreter for Large-Scale Optimization in Distributed Control Systems

Bailey-Kellogg, Christopher Dartmouth College
Zhao, Feng Xerox Palo Alto Res. Cen.

Many sensor-rich control systems interact with spatially distributed physical environments. This paper describes the Spatial Aggregation Language (SAL) interpreter, a programming environment to support data interpretation and control tasks for distributed physical systems. SAL provides a set of powerful, abstract components to represent and exploit spatial structures in distributed physical data at multiple levels of abstraction. The programming environment supports rapid prototyping of application programs and interactive manipulation of spatial structures. In comparison with existing tools, the SAL environment is centered on geometric and topological representations that encode and utilize domain-specific knowledge, such as metrics, adjacency relations, and

equivalence predicates. We illustrate the use of SAL in decentralized control design for thermal regulation.

CACSD-WM1-5 3:20 CACSD-545

Tools and Techniques for Evaluating Control Architecture

James, John R. J.R. James Associates
McClain, Richard Lockhead Martin Adv. Tech. Lab.

Conceiving, designing, and constructing computer-controlled systems require adequate models of system components. One has to determine which components are independent of others as well as the nature of interdependencies among components. The arrangement of relationships among dependent and independent components determines the system architecture. Modifying the behavior of a network of components comprising a system architecture is the central task of control engineering. Classical design approaches focus on single- and multivariable components whose dynamical models are independent of each other. However, interest in discrete-event dynamical systems and the growth of hybrid systems tools and techniques require us to evaluate event-based components as well as components whose models include discrete logic and continuously evolving variables. The mixed-signal issues of hybrid systems' analytical problems have repeatedly occurred in artificial intelligence as the pixel-to-predicate problem for vision understanding and the sensor-to-shooter problem for military applications. This paper describes an independent research and development (IRAD) project at Lockheed Martin Advanced Technology Laboratories. The project developed an approach to evaluate alternative architectures that control large-scale, networked systems whose components may or may not be independent and whose activities are distributed in time and space. We overview the approach and discuss how it can evaluate alternative architectures for control of large-scale, distributed systems and for analysis of approaches for recovery from various system failure modes.

CACSD-WM1-6 3:40 CACSD-551

A Learning Algorithm for Recurrent Neural Networks and its Application to Nonlinear Identification

Yamamoto, Yoshihiro Tottori Univ.
Nikiforuk, Peter N. Univ. of Saskatchewan

A new learning algorithm is presented for a supervised learning of recurrent neural networks without using a gradient method. First, fictitious teacher signals for the outputs of each hidden unit are algebraically determined by an error back propagation (EBP) method. Then, the weight parameters are determined by using an exponentially weighted least squares (EWLS) method. This is called EBP-EWLS algorithm which is an extension of the algorithm for a multi-layered neural network. The algorithm is applied for identification of a nonlinear system to present an effectiveness of the proposed method and a new idea for nonlinear identification

CACSD-WM2 Milo
Applications of CACSD

CACSD-WM2-1 2:00 CACSD-624

SCADA in Hydropower Plants

Mavrin, Mario,
Koroman, V.,
Borovic, B. Brodarski Inst.

For the purpose of improving the supervisory control in a hydropower plant, the SCADA application was built in during the general overhaul of the hydropower plant Miljacka on the river Krka in Croatia. The lowest level of the execution of the controlling algorithms was on the SIEMENS PLCs S7-400. The SCADA application is the top of the supervisory control structure. The controlling application was made in the form of enclosed logical parts of the process displayed on individual control panels used for supervisory control. The communication of the SCADA application with the PLCs is realized by the communication server Applicom PC 2000 ETH, using SINEC H1 (Industrial Ethernet) protocol via fiber optics.

CACSD-WM2-2 2:20 CACSD-595

Experience with a MATLAB Toolbox for Multiple-Control Coordination in Large Power Systems

Kamwa, I. Inst. de Recherche d'Hydro-Quebec
Henniche, A. Laval Univ.
Gerin-Lajoie, L.,
Lefebvre, D. TransEnergie, Hydro-Quebec

Despite the significant progress observed during the nineties, computer-aided control system design in large power systems remains in its infancy, especially when due account is to be given to wide-area interactions. Furthermore, the recent catastrophic breakups in the WSCC have increased concern about better robustness and enhanced coordination of multiple-system damping controllers so as to maximize the reliability benefits of large-scale control. This paper reports on our experience with a toolbox specifically developed to fulfill these needs. It significantly alleviates the burden of tuning many damping controllers simultaneously, considering several practical factors such as the large size of actual bulk power systems, the complicated information pattern involved in multiple-control scenarios and the effective use of flexible controller architecture to achieve robustness. The toolbox is an attempt by Hydro-Quebec to apply to its many routine and advanced control problems the more rigorous model-based design approach so familiar to a control system engineer but so difficult to apply on a bulk power system without a supporting computer-aided environment.

CACSD-WM2-3 2:40 CACSD-602

Computer-Aided Design of Sliding Mode Control of Permanent Magnet Synchronous Motor

Golea, Amar Biskra Univ.
Golea, Noureddine O.E.B. Univ.
Kadjoudj, Med. Batna Univ.
Benounnes, N. Biskra Univ.

This paper deals with a methodology for Computer-Aided Design (CAD) of sliding mode speed control of Permanent Magnet Synchronous Motor (PMSM) the drive system is built

around several components that have their own technology and multiple time-scales: electrical machine, power semiconductors and control circuits from the firing sequences to the different regulators. By using digital simulation as a reliable way, a methodology for CAD has been implemented to test the different dynamics of the drive system. In this paper the sliding mode control is applied in all regulation loops from speed regulation until the minimization of harmonics introduced by the line converter.

CACSD-WM2-4 3:00 CACSD-607

Design of Longitudinal Variable Structure Flight Control System for the F-18 Aircraft Model with Parameter Perturbations

Jafarov, Elbrous M.,
Tasaltin, Ramazan Istanbul Tech. Univ.

In this paper a new variable structure control law for uncertain MIMO systems is investigated. The conditions for the existence of a sliding mode is derived. The asymptotic stability in large of the VSS is studied by using Lyapunov V-function method. By these conditions successfully designed the longitudinal position and tracking variable structure control systems for the F-18 aircraft MIMO model with parameter perturbations. Longitudinal dynamics of F-18 aircraft with parameter perturbations is considered. Finally simulation results for VSS with chattering and free of chattering cases are presented to show the effectiveness of the design methods.

CACSD-WM2-5 3:20 CACSD-613

Estimation of Temperature Profiles of Slabs in a Reheat Furnace by Using the Kalman Filter

Wick, Hans-Joachim Consultant-Autom.
Koester, Friedhelm Hoesch Spundwand u. Profil GmbH

The application of modern systems theory has opened the way for solving complicated measuring problems. Thus, variables which are not directly measurable can be reconstructed from easily measurable variables by using Kalman Filtering[1]. The center temperature of a slab in a reheat furnace which is not directly measurable can be estimated from the measured surface temperature of the observed slab. Improved estimation of slab center temperatures would be valuable as part of a computer control system for a steel reheat furnace.

CACSD-WM2-6 3:40 CACSD-618

Conception of Researcher's Environment for CACSD Gamma-1PC

Mikhailova, L.S.,
Alexandrov, A.G.,
Vnukow, A.V.,
Isakov, R.V.,
Ryazantchev, R.P. Moscow State Inst. of Steel and Alloys

GAMMA-1PC is a computer-aided control system design (CACSD) tools for controllers algorithms synthesis of multivariable plants. It intends for engineers-developers of real control system. It consists of an USER-ENV environment for an user (a set of directives that provide design of control system on the base of some technical indices) and tools for modernization and increase of directive quantity by a researcher (the languages for building of directive user interface and calculation part). For researcher's convenience in framework of CACSD GAMMA-1PC researcher's environment was developed. It does not require a knowledge of special researcher's languages It provides the block-diagram input of a new directive and automatic translation it into the software for user interface and calculation part of directive. Researcher's environment includes a modules library (a set of ready modules for directive creation), an editor for building a block-diagram of directive with these modules and a translator of block-diagram into the program in researcher's languages.

CCA-WM3 Mauka
Fault Detection and Isolation in Dynamical Systems

CCA-WM3-1 2:00 CCA-1424

Robust Nonlinear Fault Diagnosis: Application to Robotic Systems

Trunov, Alexander,
Polycarpou, Marios Univ. of Cincinnati

Fault detection, diagnosis, and accommodation play an important role in the operation of autonomous robotic systems. Incipient faults in the actuators, sensors or in the dynamics of a robotic manipulator can lead to deterioration in performance and unsafe operating conditions. This paper presents a robust nonlinear fault diagnosis scheme for detecting and approximating faults occurring in a class of nonlinear multi-input multi-output systems. The proposed approach utilizes on-line approximators and adaptive nonlinear filtering techniques to obtain estimates of the fault functions. Performance of the nonlinear fault diagnosis scheme is analyzed by investigating its robustness and fault sensitivity properties in the presence of slowly developing or abrupt faults. A simulation example is presented to illustrate the ability of the fault diagnosis scheme to detect faults in a single link robotic manipulator with a revolute elastic joint.

CCA-WM3-2 2:20 CCA-1430

Diagnostic Reasoning Based on Means-End Models: Experiences and Future Prospects

Larsson, Jan Eric Lund Inst. of Tech.

Multilevel Flow Models (MFM) are graphical models of goals and functions of technical systems. MFM was invented by Morten Lund at the Technical University of Denmark and several new algorithms and implementations have been contributed by the group headed by Jan Eric Larsson at Lund Institute of Technology. MFM provides a good basis for computer-based supervision and diagnosis, especially in real-time applications, were fast execution and guaranteed worst-case response times are essential. The expressive power of MFM is similar to that of rule-based expert systems, while the explicit representation of means-end knowledge and the graphical nature of the models make the knowledge engineering effort less and the execution efficiency higher than that of standard expert systems. The paper gives an overview of existing MFM algorithms, and different MFM projects which have been performed or are currently in progress.

CCA-WM3-3 2:40 CCA-1755

Fault Diagnosis of the IFAC Benchmark Problem with a Model-Based Recurrent Neural Network

Gan, Chengyu,
Danai, Kourosh Univ. of Massachusetts

The paper demonstrates the utility of a model-based recurrent neural network (MBRNN) in fault diagnosis. The MBRNN can be formatted according to a state-space model. Therefore, it can use model-based fault detection and isolation (FDI) solutions as a starting point, and improve them via training by adapting them to plant nonlinearities. In this paper, the application of MBRNN to the IFAC Benchmark Problem is explored and its performance is compared with 'black box' neural network solutions. For this problem, the MBRNN is formulated according to the Eigen-Structure Assignment (ESA) residual generator. The results indicate that the MBRNN provides better results than 'black box' neural networks, and that with training it improves the results from the ESA residual generator.

CCA-WM3-4 3:00 CCA-1436

Optimal Auxiliary Input for Fault Detection of Systems with Model Uncertainty

Hatanaka, Toshiharu,
Uosaki, Katsuji Tottori Univ.

Introduction of an auxiliary input is known to be useful to detect the system fault quickly without affecting the original system behaviour in normal mode. Such as auxiliary input is designed to enlarge the distance measured by the Kullback discrimination information measure between the system models corresponding of the normal and the fault modes. However, in practice, the designer hardly knows that exact models. Hence, the optimal auxiliary input should be designed for the case of the system models with uncertainty. Here, the auxiliary input is designed to maximize the distance for the worst combination of system models. Numerical simulation results indicate the applicability of the proposed auxiliary input in fault detection.

CCA-WM3-5 3:20 CCA-1442

Detection of Abrupt Changes in Modal Characteristics of a Vibrating Structure -A Case Study

Popescu, Theodor Res. Inst. for Inf., Bucharest

The problem of change detection in the poles of signals having unknown time varying zeroes is addressed. It is used, instead of the test statistics based upon the standard likelihood ratio approach, which is of no help in this case because of the unknown zeroes, a test statistics based on an identification method (instrumental variables), which is known to decouple the AR and MA coefficients of the model. The procedure has been used for change detection in modal characteristics of a single degree of freedom oscillator and of a vibrating structure, a multi-story reinforced concrete building, subject to a strong seismic motion.

CCA-WM4 Makai
Network and Discrete Event Systems

CCA-WM4-1 2:00 CCA-1448

Asymptotic Behavior of Networked Control Systems

Walsh, Gregory C. Univ. of Maryland
Beldiman, Octavian,
Bushnell, Linda Duke Univ.

The defining characteristic of a networked control system (NCS) is having a feedback loop that passes through a local area computer network. This paper considers nonlinear systems controlled in this manner, and demonstrates that for sufficiently high transmission rates, the network may be considered transparent. Three methods of scheduling data packets are compared: a static scheduler (token ring) the Try-Once-discard (maximum error first) scheduler with continuous priority levels and the Try-Once-Discard scheduler with discrete priority levels. The third method is of particular interest when only a small number of bits are available for collision resolution. Asymptotic stability is guaranteed in the first two cases, and ultimate uniform boundedness in the third. In the final section, simulations demonstrate the theoretical results. The contributions of this paper are two-fold: First, it extends the earlier results on NCS to nonlinear systems, and second, it allows for finite word-length message identifiers.

CCA-WM4-2 2:20 CCA-1454

Impact of Flow Control on Quality of Service Driven Packet Scheduling Disciplines

Hayes, David A.,
Rumsewicz, Michael Royal Melbourne Inst. of Tech.
Andrew, Lachlan L. H. Univ. of Melbourne

In this paper we investigate the interaction between window based flow control and a recently proposed packet scheduling discipline designed for real-time services. The scheduling discipline, called the Dual Queue discipline, has been shown to provide greater flexibility than other scheduling disciplines such as fair queuing. However, its performance on non real-time services has not been previously investigated. We show that the Dual Queue's performance for non real-time services is again better than that of alternative approaches, which indicates that it will perform well in an environment of mixed real-time and non real-time traffic, such as the current internet.

CCA-WM4-3 2:40 CCA-1460

Development of State Space Model and Study of Performance Characteristics of Digital Based Excitation Control System ST4B with Single Machine Connected to Infinite Bus

Rangnekar, Saroj M. A. College of Tech.

Digital based Excitation Control Systems (ECSs) with microprocessors or PCs are coming up very fast and replacing analog controllers for excitation. The ECS model ST4B is a fast responding digital based ECS, incorporating proportional integral controls, recently proposed by IEEE. Detailed state space model of ST4B with a single machine connected to infinite bus (SMIB) has been developed to provide a complete description and a thorough insight of the model. SMIB has been modelled in terms of K-constants arrived at based on a

detailed analysis by the author[1]. The chosen significant parameters of ECS, voltage regulator gains Kpr and Kir and time constant Ta have been varied over a wide range and time response and frequency response characteristics have been derived through simulation and computation using specially developed programs along with the software package Matlab-Simulink, and the best values of the parameters arrived at. As Kpr and Kir increase up to an optimum value, the time responses improve and for higher values of gains the responses tend to become uneven and oscillatory.

CCA-WM4-4 3:00 CCA-1466

Admission Control by MDP Theory: A Single-Sample-Path-Based Approach

Wang, Junjie Univ. of Maryland

The theory of Markov Decision Process (MDP) has been widely applied to the networking management such as routing and admission control. However, the traditional MDP approach is mainly hindered by prohibitive computational complexity. The performance potential theory offers an efficient solution to alleviate such difficulties in infinite-horizon MDP problems. The concept potential leads to some important properties that allow it to be measured on a single sample path, thereby adapting to the dynamic characteristics in realistic applications such as high speed networks. In this paper, we investigate the application of single-sample-path-based potential theory to the admission control in the network with multiple classes of traffic. Optimal policies under different traffic characteristics are obtained with a fast convergence. Some simple and efficient algorithms are developed for online implementation.

CCA-WM4-5 3:20 CCA-1472

Deadlock Detection and Controller Synthesis for Production Systems Using Partial Order Techniques

Hellgren, Anders,
Fabian, Martin,
Lennartson, Bengt Chalmers Univ. of Tech.

Discrete event systems can be used to model the behaviour of production systems. The supervisory control theory is a suitable tool for synthesizing controllers that coordinate the resource utilization of concurrent products in the production system. Due to the combinatorial state space explosion, computations become intractable for most real life systems. To alleviate this problem, methods that do not enumerate the entire state space are needed. One method that has proven valuable for the verification of concurrent systems is based on partial order principles. For a certain class of production systems it is shown how such ideas may be used to synthesize non-blocking discrete event controllers.

CCA-WM4-6 3:40 CCA-1478

Optimization in Markov Decision Problems with Transition-Dependent Cost Functions

Wang, Junjie Univ. of Maryland
Cao, Xi-Ren Hong Kong Univ. of Sci. & Tech.

The traditional MDP deals with the cost function which only depends on the state and the corresponding action. In the real world, however, there are many applications where the cost incurred depends on the particular transition as well, which makes the traditional MDP solution infeasible for these problems. In this paper, we apply the performance potential theory as an optimization tool for MDP. In particular, the notion of the expanded Markov chain is introduced to map this problem to a general form. Both computation-based and sample-path-based algorithms are developed for potential derivation. We address ourselves to the complexity-reduction techniques. Finally, we apply these techniques to the Join the Shortest Queue application, which is a significant component in the analysis of communication system.

CCA-WM5 Hau
Vehicle Suspensions

CCA-WM5-1 2:00 CCA-1484

Modeling and Identification of the Vehicle Suspension Characteristics Using Local Linear Model Trees

Halfmann, Christoph,
Nelles, O.,
Holzmann, H. Darmstadt Univ. of Tech.

In this paper an automotive MacPherson suspension unit is identified and modeled using a radial basis function network with local linear weighting functions (LOLIMOT). The output of the network represents the nonlinear force characteristic of the spring-and-damper unit in dependency of the measured spring travels at the front axle and the corresponding spring travel velocities. The network parameters are interpreted physically by comparing the five local linear models identified with the network to a physical second-order model of the wheel suspension unit. Implemented in an overall vehicle model the network or its look-up table representation represents an adaptable model of the nonlinear vehicle suspension characteristics.

CCA-WM5-2 2:20 CCA-1490

Neuro-Fuzzy Based Modeling of Vehicle Suspension System

Nazaruddin, Yul Y. Bandung Inst. of Tech.
Yamakita, Masaki Tokyo Inst. of Tech.

An alternative approach to identify suspension system models using neuro-fuzzy technique is presented in this paper. Structure and design scheme based on this approach will be briefly discussed, which includes an adaptive network employed as a building block, and the back-propagation gradient method as well as least square estimator as a hybrid learning rule. The objective is to represent the suspension dynamics by a set of fuzzy rules representation. By using this approach, the nonlinear characteristics of the suspension system can also be accommodated. Experimental evaluation of the proposed technique has been conducted using an input-output data collected from a running test vehicle. Observations by comparing the model responses with the actual output measurements revealed that satisfactory model matching were obtained which means that the models have captured the real basic features of the vehicle suspension dynamic characteristics.

CCA-WM5-3 2:40 CCA-1496

Bilinear Disturbance-Accommodating Optimal Control of Semi-Active Suspension for Automobiles

Yoshida, Kazuo,
Okamoto, Bunta Keio Univ.

The design of suspension is very important for ride-comfort on automobiles. A lot of active and semi-active suspensions have been studied. In recent years, the car with active or semi-active suspension has been put into practice. Since the active suspension needs large power and space, a semi-active suspension have recently received attention. In this study, the bilinear disturbance accommodating control theory is established and it is applied to the semi-active control of suspension for automobiles. In this study, a 1/2 body model with 4-DOF is used. By applying the proposed bilinear disturbance accommodating optimal control to the semi-active suspension, its performance is investigated in the simulation. As a result, it showed better performance than the passive control with respect to the vertical acceleration and the pitch angular acceleration of car body which give influence on ride-comfort for automobiles.

CCA-WM5-4 3:00 CCA-1734

Adaptive Nonlinear Control of Repulsive Maglev Suspension Systems

Huang, Chao-Ming,
Chen, Min-Shin,
Yen, Jia-Yush Nat. Taiwan Univ.

Magnetic levitation systems have recently become the focus of many research interests not only because they are most suitable for high precision engineering applications but also due to the fact that they represent a difficult challenge to control engineers. As a result, most previous studies have focused on the control stabilization problem. In this paper, we address the issue of performance with respect to uncertainty in order to achieve a desired rigidity. The proposed controller is an adaptive backstepping controller. The adaptive backstepping controller provides system stability under model uncertainty, and achieves the desired servo performance. The experiments show that the proposed control achieves a superior behavior than other control.

CCA-WM5-5 3:20 CCA-1502

Active Suspension Control Using a Novel Strut and Active Filtered Feedback: Design and Implementation

Ikenaga, S.,
Lewis, Frank L.,
Davis, L.,
Campos, J.,
Evans, M.,
Scully, S. Univ. of Texas, Arlington

An active suspension control approach is designed for a quarter-vehicle suspension system using a filtered feedback control scheme and a novel compressible fluid suspension system. Analysis of feedback for the mechanical subsystem shows that motions of the sprung mass above and below the wheel frequency can be mitigated using skyhook damping plus active filtering of spring and damping coefficients. The frequency-dependent filtering is accomplished through an outer control loop that generates the target strut force, plus an inner force control loop. Performance of the active suspension control is demonstrated in simulations.

CCA-WM5-6 3:40 CCA-1509

Active Vibration Isolation by Adaptive Control

Shaw, Jinsiang Huafan Univ.

In this paper an adaptive controller known as the self-tuning regulator (STR) is employed for actively controlling an actuator for vibration isolation. Numerical simulations of the developed STR for active vibration isolation of a simple mass-spring-damper system of two-degree-of-freedom subject to external disturbances are carried out. Experimental studies of vibration isolation by using magnetostrictive actuator with Terfenol-D rod are also presented. Both studies demonstrate the validity and effectiveness of the STR for active vibration isolation when the system is disturbed by a pure harmonic, two-modes harmonic, random, or even band-limited white noise excitation. In addition, the results are shown to be superior in terms of faster convergence and more vibration attenuation to those obtained by using previously developed adaptive plant disturbance canceler.

CCA-WM6 Lehua
Control Integrity in Adverse Operating Conditions

CCA-WM6-1 2:00 CCA-1515

A Virtual Closed Loop Remedy for Temporary Sensor Failures

Suh, Jon,
Bajpai, Gaurav,
Chang, B.C. Drexel Univ.

Digital system upsets can occur as a result of electrical transients induced by electro-magnetic fields[5][7]. One possible upset is the irrecoverable loss of sensor data due to noisy readings or data changes in the input circuitry. The control system may not perform adequately when faced with such modes of failure. The present paper focuses on a technique in which a virtual closed loop is used to overcome these modes of failure. The advantage of using this technique is confirmed by results from a DC motor control system set-up in electromagnetic environments.

CCA-WM6-2 2:20 CCA-1519

Characterization of a Recoverable Flight Control Computer System

Malekpour, Mahyar,
Torres, Wilfredo NASA Langley Res. Cen.

The design and development of a Closed-Loop System to study and evaluates the performance of the Honeywell Recoverable Computer System (RCS) in electromagnetic environments (EME) is presented. The development of a Windows-based software package to handle the time-critical communication of data and commands between the RCS and flight simulation code in real-time, while meeting the stringent hard deadlines is also submitted. The performance results of the RCS and characteristics of its upset recovery scheme while exercising flight control laws under ideal conditions as well as in the presence of electromagnetic fields are also discussed.

CCA-WM6-3 2:40 CCA-1797

Stochastic Perturbation Analysis of Computer Control Systems Subject to Electromagnetic Disturbances

Gray, W. Steven,
Gonzalez, Oscar,
Dogan, Mustafa Old Dominion Univ.

High intensity electromagnetic radiation has been demonstrated to be a source of computer upsets in commercially available digital flight control systems. Thus there is a strong need to investigate its effect on stability and performance. In [3]-[5], electromagnetic disturbances were modeled with a continuous-time Markovian exosystem generating disturbance events. To analyze the effect of these disturbances, the radiated system was modeled as a discrete-time jump linear system with an appropriate set of transition probability rates. The linear systems in this model were all deterministic, hence this method rendered a worst-case stability analysis. In this paper, the technique is generalized by allowing stochastic perturbations to be randomly introduced by the exosystem model. A preliminary stability theory is developed, and an example is presented to compare stability boundaries for radiation parameters using this model against the worst-case scenario.

CCA-WM6-4 3:00 CCA-1525

Detecting Controller Malfunctions in Electromagnetic Environments: Part I: Modeling and Estimation of Nominal System Function

Weinstein, Bernice NASA Langley Res. Cen.

A strategy for detecting control law calculation errors in critical flight control computers during laboratory validation testing is presented. This paper addresses Part I of the detection strategy which involves the use of modeling of the aircraft control laws and the design of Kalman filters to predict the correct control commands. Part II of the strategy which involves the use of the predicted control commands to detect control command errors is presented in the companion paper.

CCA-WM6-5 3:20 CCA-1531

Detecting Controller Malfunctions in Electromagnetic Environments: Part II-Design & Analysis of the Detector

Belcastro, Celeste NASA Langley Res. Cen.

Verifying the integrity of control computers in adverse operating environments is a key issue in the development, validation, certification and operation of critical control systems. Future commercial aircraft will necessitate flight-critical systems with high reliability requirements for stability augmentation, flutter suppression, and guidance and control. Operational integrity of such systems in adverse environments must be validated, This paper considers the problem of applying dynamic detection techniques to monitoring the integrity of fault tolerant control computers in critical applications. Specifically, this paper considers the detection of malfunctions in an aircraft flight control computer (FCC) that is subjected to electromagnetic environment (EME) disturbances during laboratory testing. A dynamic monitoring strategy is presented and demonstrated for the FCC from glideslope engaged until flare under clear air turbulence conditions using a detailed simulation of the B737 Autoland. The performance of the monitoring system is analyzed.

CCA-WM6-6 3:40 CCA-1538

Adaptive Estimation and Accommodation of Loss of Control Effectiveness Using a Lyapunov Method

Wu, N. Eva Binghamton Univ.

A Lyapunov approach is used to design regulators for systems subject to loss of control effectiveness. Control effectiveness factors are used to quantify faults entering control systems through actuators. An adaptive Kalman filtering algorithm is used to estimate the state as well as the amount of reduction of control effectiveness in a closed-loop setting. The state estimate is fed back to achieve the steady state regulation, while the control effectiveness estimate is used for the on-line tuning of the control law. The resulting regulator is guaranteed to be stable when the estimation error is sufficiently small. An aircraft longitudinal model is used to demonstrate the use of the Lyapunov method.

CCA-WP1 Koa
CAD & Monitoring

CCA-WP1-1 4:20 CCA-1543

Development of nD Control System Toolbox for Use with MATLAB

Xu, Li Asahi Univ.
Yamada, Minoru Gifu Nat. College of Tech.
Saito, Osami Chiba Univ.

The purpose of this paper is to describe some main aspects on the development of an integrated CAD Toolbox for nD system theory, named nD Control System Toolbox, for use with the software product MATLAB and the associated Extended Symbolic Math Toolbox. The developed toolbox consists of several functional packages that provide various basic tools and facilities for both numerical and symbolic manipulations required in analysis and synthesis of 2D control systems such as stability test, factor coprime factorizations and solution of various linear matrix equations, etc., which usually involve very complicated procedures.

CCA-WP1-2 4:40 CCA-1549

An Attribute Graph Grammar for Signal Flow Graphs

Adachi, Yoshihiro,
Kobayashi, Suguru,
Tsuchida, Kensei Toyo Univ.
Yaku, Takeo Nihon Univ.

A signal flow graph grammar has been developed that generates signal flow graphs by means of subgraph rewriting. It includes some context-sensitive productions and is very concise. An attribute signal flow graph grammar has also been formalized as an extended grammar of the signal flow graph grammar, in order to formally define and evaluate a variety of information accompanying signal flow graphs. As a specific example of the attribute signal flow graph grammar, we formalized the attributes and semantic rules to extract the relationships of the signals running in signal flow graphs. A parser-evaluator that we have implemented on the basis of the formalized grammar evaluates the attribute values while it parses a diagram in a bottom-up parallel manner. This attribute signal flow graph grammar is expected to become the theoretical and practical foundation for supporting

computerized system analysis and design by using signal flow graphs.

CCA-WP1-3 5:00 CCA-1555

A Tool for Rapid System Identification

Wallen, Anders Lund Inst. of Tech

This paper presents an interactive tool for rapid system identification. It is based on analysis of step responses. The graphical user interface lets the user manipulate the step response for a given model structure directly, and perform a least squares fit to data. A few standard model structures as well as static input non-linearities are handled.

CCA-WP1-4 5:20 CCA-1561

Identification Tool for Chemical Processes

Tani, Shigeyuki,
Takahashi, Shinsuke,
Sekozawa, Teruji Hitachi Ltd.

Model Predictive Control technology which evaluates production costs is being watched in the field of process-control. Now we have developed the control package for the advanced control of chemical processes, and at the same time we developed an identification tool for making predictive process models. Current tools have problems such as, we can't make high-precision models without efficient identification techniques, and it is not effective for specialized cases of chemical processes. So we developed the identification tool by constructing a GUI and reducing the need for the engineering support by constructing new functions which are for chemical processes cases.

CCA-WP1-5 5:40 CCA-1567

An Effective Neuro-Fuzzy Paradigm for Machinery Condition Health Monitoring

Yen, Gary,
Meesad, Phayung Oklahoma State Univ.

A new learning algorithm suitable for pattern classification in machine condition health monitoring based on fuzzy neural networks called an Incremental Learning Fuzzy Neuron Network (ILFN) has been developed. The ILFN, using Gaussian neurons to represent the distributions of the input space, is an on-line, one-pass, and incremental learning algorithm. The network is a self-organized classifier with the ability to adaptively learn new information without forgetting old knowledge. To prove the concept, the simulations have been performed with the vibration data known as Westland vibration data set. Furthermore, the classification performance of the network has been tested on other benchmark data sets, such as, the Fisher's Iris data, and a vowel data set. For the generalization capability, comparison studies among other well-known classifiers were performed and the ILFN was found competitive with or even superior to many existing classifiers. Additionally, the ILFN uses far less training time than conventional classifiers.

CCA-WP1-6 6:00 CCA-1573

Wavelet Packet Feature Extraction for Vibration Monitoring

Yen, Gary,
Lin, Kuo-Chung Oklahoma State Univ.

Condition monitoring of dynamic systems based on vibration signatures has generally relied upon Fourier based analysis as a means of translating vibration signals in time domain into the frequency domain. However, Fourier analysis provided a poor representation of signals well localized in time. In this case, it is difficult to detect and identify the signal pattern from their expansion coefficients because the information is diluted across the whole basis. The wavelet packet transform is introduced as an alternative means of extracting time-frequency information from vibration signature. Moreover, with the aid of statistical based feature selection criteria, a lot of feature components containing little discriminant information could be discarded resulting in a feature subset with reduced number of parameters. This significantly reduces the long training time that is often associated with neural network classifier and increases the generalization ability of the neural network classifier.

CCA-WP2 Milo
Intelligent Building Control

CCA-WP2-1 4:20 CCA-1579

Development of Air-Conditioning Control Algorithm for Building Energy-Saving

Yamada, Fumio,
Yonezawa, Kenzo,
Sugawara, Susumu,
Nishimura, Nobutaka Toshiba Corp.

In office buildings, the requirement is that the room air-conditioning control system has to provide a comfortable thermal feeling for the working people. While energy saving may sometime conflict with comfort, it is possible to eliminate the wasteful use of energy associated its overuse without prejudice to comfort. The basic concept is that the target set values for the room temperature should be changed dynamically so as to suit the constantly changing room environment. This paper shows that the well-known comfort index PMV is useful to air-conditioning control systems aimed at both energy-saving and comfort.

CCA-WP2-2 4:40 CCA-1585

The Open Protocol Standard for Computerized Building System: BACnet

Haakenstad, Larry K. Alerton Tech., Inc.

BACnet is the term commonly used to refer to the ANSI/ASHRAE standard 135-1995, adopted and supported by the American National Standards Institute (ANSI) and the American Society of Heating Refrigeration and Air-conditioning Engineers (ASHRAE). BACnet stands for Building Automation and Control Network. BACnet is a true,non-propietary open protocol communication standard conceived by a consortium of building management, system users and manufacturers. It identifies all the rules for system components to share data with each other, how this is done, the communications media that can be used and how information from components is to be interpreted.

CCA-WP2-4 5:20 CCA-1744

Creating Better Business Outcomes through Enterprise Integration with Advanced Building Control Solutions

Miller, Daniel T. Honeywell H&BC Solutions & Services

This paper explores that benefits of integration of building control solutions with enterprise level applications and how underlying technologies and industry standards are used to improve facility management decision making. The discussion will also focus on how building control solutions providers like Honeywell Inc. are addressing a facilities' total information access and control needs to make higher order integration a competitive advantage in creating better business outcomes.

CCA-WP2-6 6:00 CCA-1591

Dynamic Zoning Based Supervisory Control for Elevators

So, Albert T.P.,
Yu, Janson K.L. City Univ. of Hong Kong
Chan, W.L. Hong Kong Pol. Univ.

Zoning is one conventional way to make an existing elevator system adapt to different traffic patterns. However, zoning is generally either fixed permanently or static based on time scheduling where the floors being grouped into zones are predetermined during the design stage. In this paper, a new concept is introduced that can provide the feature of dynamic zoning for a elevator system based on the real time traffic patterns. The objectives are to achieve maximum handling capacity of the system and minimum waiting/travelling time for passengers during up-peak and down-peak traffic conditions. Two new algorithms, namely Uniform RTT and Demand Matching, have been developed for intelligent control. Information related to real time zoning can be delivered to passengers by LED display boards installed at each landing above the landing doors. A computer simulation based on a software package on market, Elevator 2.0 has revealed that the two new algorithms can improve the passenger waiting/travelling time under the two major traffic conditions. The original concept of dynamic zoning was published in an elevator journal[1].

CCA-WP3 Mauka

Control of Communication Networks

CCA-WP3-2 4:40 CCA-1597

Multi-Attribute Learning Mechanism for Network Control and Management

Inoue, Akiya,
Yamamoto, Hisao NTT Service Integration Lab.

This paper presents a learning mechanism to extract a action pattern under various network conditions. A multi-attribute learning mechanism has the ability to indicate the success probability of each action pattern under given network conditions. Not only observed network information but also qualitative factors can be used in this mechanism. It is an effective way to support decision-making to take multiple factors including probabilistic or uncertain factors. A dynamic routing scheme employing this mechanism and performance evaluation are shown as an application example.

CCA-WP3-3 5:00 CCA-1603

Stability Analysis of Window-Based Flow Control Mechanism in TCP/IP Networks

Ohsaki, Hiroyuki,
Murata, Masayuki,
Ushio, Toshimitsu,
Miyahara, Hideo Osaka Univ.

Recently, a new version of the TCP mechanism, called TCP Vegas, is proposed, and has potential to achieve better performance than current mechanisms such as TCP Tahoe and Reno. This paper considers a window-based flow control mechanism based on a slightly modified congestion avoidance mechanism of TCP Vegas, and introduces its mathematical model described by a nonlinear difference equation. We calculate its fixed point, and a stability condition of the fixed point is derived.

CCA-WP3-4 5:20 CCA-1607

Towards Efficient Call Admission Control for State-Dependent Routing in Multirate Networks

Ahlfors, Ulf,
Korner, Ulf,
Pioro, Michal Lund Inst. of Tech.

In this paper we consider a link serving multiple service classes. We evaluate the properties of the link admission control policies that are obtained from an efficient scheme proposed by Krishnan and Hubner. The Krishnan and Hubner approach suggests efficient calculations of state-dependent routing criteria for multi-rate networks through state-space aggregation. Through simple examples we show that it is possible that the approximations made in the approach might lead to degraded performance, instead of the expected improvement. We outline and discuss a possible extension to the Krishnan and Hubner approach in an effort to address the problem.

CCA-WP3-5 5:40 CCA-1614

Load Balancing and Control for Distributed World Wide Web Servers

Castro, Maurice,
Dwyer, Michael,
Rumsewicz, Michael Royal Melbourne Inst. of Tech.

In this paper we describe an admission control and load balancing scheme for multicomputer World Wide Web servers. The scheme consists of a Frontend admission control function which regulates requests sent to Backend web server using periodic load measurements passed from the Backends to the Frontends. The aims of scheme are two-fold: to ensure that traffic offered to Backends can be serviced promptly and to make full use of the Backend capacity. We describe simulation results and an Erlang based implementation of the scheme. It is shown that the algorithm is trivial to implement, has negligible computational complexity, and provides effective load balancing and control. The scheme has now been implemented in the eddie open source project, an Ericcson sponsored effort aimed at delivering commercial grade, quality of service driven web server solutions.

CCA-WP3-6 6:00 CCA-1620

Distributed Web Caching Using Hash-Based Query Caching Method

Asaka, Takuya Waseda Univ.
Miwa, Hiroyoshi NTT Service Integration Lab.
Tanaka, Yoshiaki Waseda Univ.

Distributed Web caching allows multiple clients to quickly access a pool of popular Web pages. Conventional distributed Web caching schemes, e.g., the Internet cache protocol and hash routing, require the sending of many query messages among cache servers and/or impose a large load on the cache servers when they are widely dispersed. To overcome these problems. we propose a hash-based query caching method using both a hash function and a query caching method. This method can find cached objects among several cache servers by using only one query message. Compared to conventional methods, this method reduces cache server overhead, object retrieval latency and loads to the network.

CCA-WP4 Makai
Manufacturing Systems

CCA-WP4-1 4:20 CCA-1626

Robust Output High-Gain Feedback Controllers for the Atomic Force Microscope under High Data Sampling Rate

Hsu, Su-Hau,
Fu, Li-Chen Nat. Taiwan Univ.

This paper proposed a robust output feedback controller of an atomic force microscope (AFM) device for the purpose of high rate date sampling. The AFM device is modeled as a cantilever-sample system in which the interactive forces between the cantilever and the sample consists of a long range attractive force and short range repulsive force. By using the feedback linearization and the singular perturbation technique, an output high-gain feedback controller is designed such that the cantilever tip can track the surface of the sample at a high rate of date sampling even though the topology of the surface is arbitrary and not given a priori. By adopting the controller developed here, the signals to be measured are the deflection of the cantilever. Finally a computer simulation is provided to demonstrate the effectiveness of the proposed cantilever.

CCA-WP4-2 4:40 CCA-1632

Simulation-Based Planning and Control of Production Fractals

Sihn, Wilfried,
Lickefett, M.,
Pirron, Joerg Fraunhofer Inst. For Manufac.

In order to increase their competitiveness, companies optimize their manufacturing processes by adapting structures to the requirements of technology and market. On the other hand, they try to fulfil specific requirements by extreme customer orientation and manufacturing on demand. This leads to new organizational structures and manufacturing systems. Appropriate organization forms, such as the fractal company, are distinguished by high flexibility, rapid adaptability and exploitation of human potentials. However, these manufacturing companies also require appropriate PPC-systems (Production Planning and Control system) or, rather, new methods of PPC. In addition to high planning reliability, these systems have to ensure high flexibility, distributed processes of planning and decision-making, general orientation towards common goals, and an information flow that conforms to the requirements. The most important elements of such a PPC-system are long-range analysis of the production structure, medium- and long-range planning for the entire production area, short- and medium-range coordination among production fractals and short-range shop-control inside the fractals. At the Fraunhofer Institute for Manufacturing Engineering and Automation, simulation-based systems are being developed to support the planning and control of such organization forms within production. The user is put into the position of planning job orders reliably and optimizing production, concerning cost and schedule reliability, by making use of the advantages of decentralized structures.

CCA-WP4-3 5:00 CCA-1636

Model Based Predictive Control in RTP Semiconductor Manufacturing

De Keyser, Robin Univ. of Gent
Donald, III, James ASM America Inc.

Temperature control in single-wafer semiconductor reactors has become a hot topic. The interest in the subject illustrates the fact that the temperature measurement and control issues are far from trivial. This is due to the reactor design which is inherently non-isothermal, to the principal difficulties in measuring wafer temperature (or film thickness) in real-time and to the typically large interaction present between zones in radiantly heated systems. CVD-RTP (Chemical Vapor Deposition - Rapid Thermal Processing) reactors offer a challenge to control engineers in that the control of temperature uniformity over the wafer surface is of utmost importance for the next generation of processing equipment. This paper presents a solution based on the methodology of MBPC (Model Based Predictive Control).

CCA-WP4-4 5:20 CCA-1642

Development of a Robot Holon Using an Open Modular Controller

Schnell, Jakob,
Andersen, Soren,
Langer, Gilad,
Sorensen, Christian Tech. Univ. of Denmark

Holonic Manufacturing Systems (HMS) has during the last period presented itself as an advantageous theoretical foundation for the problems that arise in controlling agile manufacturing systems. Previous research, at the Department, has demonstrated how modern shop floor control systems can be developed based on standard architectures for cell-control supported by engineering concepts and enabling technologies. In continuation to this research new concepts and theories for shop floor control are investigated. Ongoing research on HMS has resulted in development of the Holonic Multicell Control System (HoMuCS) architecture and methodology for implementing a HMS. This paper specifically reviews the development of a Robot Holon based on an open controller in the context of the HoMuCS architecture. The paper will describe the results and research work that was involved in

developing a robot holon for a physical robot. The robot holon was implemented on a existing robot at the department which was upgraded by removing its native control system and replacing it with a new PC-based open controller. The development of the robot holon builds on the notion that a robot holon will be able to perform both processing tasks and material handling tasks. Based on that an attempt to draw up a robot-architecture in the HoMuCS that can easily be reconfigured for these types of tasks. The research results gave a further specification of the HoMuCS architecture by extending it with the special robot holon type.

CCA-WP4-5 5:40 CCA-1648

Applying a Neural Network to the Adaptive Control for JIT Production Systems

Takahashi, Katsuhiko,
Nakamura, Nobuto Hiroshima Univ.

By applying a NN (neural network), this paper proposes an adaptive control system for the two types of JIT (Just-in-Time) production systems with unstable changes in demand. In the proposed system, a multi-layered NN is applied to detecting the pattern change in the time series data on demand, and the detected pattern change is utilized for adjusting the buffer size in the JIT production systems. The performance of the proposed system is investigated and compared with that of the previous system by simulation experiments.

CCA-WP4-6 6:00 CCA-1654

Control of Liquid Slosh in an Industrial Packaging Machine

Grundelius, Mattias,
Bernhardsson, Bo Lund Inst. of Tech.

Linear movement of open containers containing liquid is considered. The design is based on a simple linearized slosh model. An open-loop acceleration trajectory is calculated using optimal control techniques. The calculated acceleration profiles are evaluated using experiments with a laser-based sensor and recordings by a video camera. The performance is better than previous ad-hoc controllers.

CCA-WP5 Hau
Nonlinear and Gain Scheduled Vehicles Control

CCA-WP5-1 4:20 CCA-1660

Technical Challenges in the Development of Vehicle Stability Control System

Tseng, H.E. Ford Motor Co.
Madau, D.,
Ashrafi, B. Visteon Autom. Systems
Brown, T. Ford Motor Co.
Recker, D. Visteon Autom. Systems

This paper addresses realistic subjects encountered in the challenge of achieving technology improvement in a vehicle stability control system. They include driver intent recognition, control development philosophy, vehicle side slip estimation, and road bank angle estimation.

CCA-WP5-2 4:40 CCA-1667

Tracking Control of Vehicles Using Nonlinear Model

Kobayashi, Tomoaki Univ. of Tsukuba
Ohtsuka, Toshiyuki Osaka Univ.

This paper studies automatic operation of vehicles aiming at making the position and the attitude angle of four-wheeled vehicles follow target trajectories. A control theory which enables tracking of various routes is described by using a model which allows variable velocity. In this case the model is expressed as a nonlinear system. Since analytical evaluation of the performance is difficult for a nonlinear system, the control performance is evaluated through numerical simulations. This research focuses on two points: examination of the model with variable velocity, and evaluation of the control theory to follow a target trajectory controlling velocity of a vehicle.

CCA-WP5-3 5:00 CCA-1673

Trajectory Control of an Articulated Vehicle with Tripe Trailers

Tanaka, Kazuo,
Taniguchi, Tadanari Univ. of Electro-Communications
Wang, Hua O. Duke Univ.

This paper presents backing up control for a vehicle with triple trailers. In particular, we consider constraints on input and output and disturbance rejection that are incorporated in the LMI conditions. In application to the truck with triple trailers setup, we utilize these LMI conditions to explicitly avoid the saturation of the steering angle and the jack-knife phenomenon in the control design. The simulation and experimental results demonstrate that the controller effectively achieves the backing up control of the vehicle with triple trailers while avoiding the saturation of the actuator and jack-knife phenomenon. Moreover, the feedback controller guarantees the stability and performance even for disturbance.

CCA-WP5-4 5:20 CCA-1679

Robust Stabilization of the Vehicle Dynamics by Gain-Scheduled H-Infinity Control

Ono, Eiichi Toyota Central R & D Labs.
Hosoe, Shigeyuki Nagoya Univ.
Asano, Katsuhiro,
Sugai, Masaru,
Doi, Shun'ichi Toyota Central R & D Labs.

Controller synthesis for protecting the vehicle from spin is described as a robust stabilization problem against perturbations of rear cornering force. The controller is designed by gain-scheduled H-infinity control theory so that the closed-loop system satisfies an H-infinity norm condition guaranteeing the stability of the vehicle. The controller adjusts the braking force distribution to the right and the left wheels. The result has been tested by executing experiment. The experimental results showed that the designed controller can robustly stabilizes the vehicle and protects it from spin under the presence of large perturbations of rear cornering force.

CCA-WP5-5 5:40 CCA-1686

Parallel Parking Car-Like Robot Using Fuzzy Gain Scheduling

Lian, Kuang-Yow,
Chiu, Chian-Song,
Chiang, Tung-Sheng Chung-Yuan Christian Univ.

In this study, a fuzzy gain scheduling controller is proposed to parallel park the car-like robot. At first, a fuzzy sliding mode controller (FSMC) embedded by driving experience is developed to locally track a most typical path for the parallel parking. In order to extend the controlled region, several typical paths are formed and can be pieced together to constitute a complete parking path in a large region. Then, a fuzzy gain scheduler with knowledge-based structure is proposed to decide the best parking path and to generate the proper control gains.

CCA-WP5-6 6:00 CCA-1692

Stop & Go Controller for Adaptive Cruise Control

Persson, Mikael Lund Inst. of Tech.
Botling, Fredrik,
Hesslow, Erik Volvo Tech. Dev. Co.
Johansson, Rolf Lund Inst. of Tech.

In the field of vehicle control, conventional cruise control systems have been available on the market for many years. During the last years, modern cars include more and more electronic systems. These systems are often governed by a computer or a network of computers programmed with powerful software. One of those new services is Adaptive Cruise control (ACC) (or Autonomous Intelligent Cruise control (AICC), which extends the conventional cruise control system to include automated car following when the receding car is driving at a lower speed than the desired set-speed. The focus of ACC has mainly been directed towards high-speed highway application, but to improve the comfort to the driver also low-speed situations must be considered. This paper presents an ACC system that is capable of car following in low-speed situations, e.g. in suburban areas, as well as in high-speed situations. The system is implemented in a test car and the result is evaluated.

CCA-WP6 Lehua
Mechatronics II

CCA-WP6-1 4:20 CCA-1698

Gain-Scheduled Control of a System with Input Constraint by Suppression of Input Derivatives

Nishimura, Hidekazu,
Takagi, Kiyoshi,
Yamamoto, Kohei Chiba Univ.

The purpose of this study is to design a gain-scheduled feedback compensator for a system constrained on the input. Description of the input saturation by the hyperbolic tangential function transfers the system description to a form of a linear parameter-dependent system. This formulation allows applying the gain-scheduling control synthesis via linear matrix inequalities (LMI). In order to avoid the windup phenomena caused by input limitation suppression of the input derivatives is employed. While the input derivatives could not be taken into account in the previous studies because of using the discontinuous functions as the input limitations, in this study it is available to take account of the input derivatives in the controller design. This means that the designed controller includes integrators and constructs a type-one control system. Consideration of input derivatives may mitigate sudden change of the input even if there is no feedback loop of error between input and output of the nonlinear function. Simulation results show usefulness of the proposed design method.

CCA-WP6-2 4:40 CCA-1704

Active Distance Stabilization of Large Bodies with Picometer Repeatability

Canuto, Enrico,
Donati, Francesco Pol. di Torino
Bertinetto, Fabrizio,
Mana, Giovanni Ist. Metrolog. Gustavo Colonnetti
Bisi, Marco,
Cesare, Stefano,
Pepe, Stefano Alenia Aerospazio

The paper presents control design and results of a leading experiment in the distance stabilization of large bodies, emulating optical mirrors, with picometer repeatability. The experiment, called COSI (Control Optics Structure Interaction), was funded by the European Space Agency (ESA) in view of future space telescopes needing picoradian precision over time scales>1s. Distance stabilization is achieved by actively controlling the optical length of Fabry-Perot cavities in the vacuum. The first experiments stabilized three 0.5m distances between two 7kg plates with a residual control error better than 3pm (1o), in presence of severe environment noise and artificial micrometer distance variations, thus fully demonstrating feasibility of COSI concept and technology

CCA-WP6-3 5:00 CCA-1710

A Supervisory Fuzzy Neural Network Controller for Slider-Crank Mechanism

Lin, Faa-Jeng,
Fung, Rong-Fong,
Lin, Hsin-Hai,
Hong, Chih-Ming Chung Yuan Christian Univ.

A supervisory fuzzy neural network (FNN)controller is proposed to control a nonlinear slider-crank mechanism in this study. The control system is composed of a permanent magnet (PM) synchronous servo motor drive coupled with a slider-crank mechanism and a supervisory FNN position controller. The supervisory FNN controller comprises a sliding mode FNN controller and a supervisory controller. The sliding mode FNN controller combines the advantages of the sliding node control with robust characteristics and the FNN with On-line learning ability. The supervisory controller is designed to stabilize the system states around a defined bound region. The theoretical and stability analyses of the supervisory FNN controller are discussed in detail. Simulation and experimental results are provided to show that the proposed control system is robust with regard to plant parameter variations and external load disturbances.

CCA-WP6-4 5:20 CCA-1716

Model Reference Adaptive Control with Multi-Rate Type Neural Network for Electro-Pneumatic Servo System

Tanaka, Kanya — Yamaguchi Univ.
Yamada, Yuji — Kure Inst. Nat. College
Satoh, Taiji,
Uchibori, Akihiko — Yamaguchi Univ.
Uchikado, Shigeru — Tokyo Denki Univ.

In this paper, we propose a design scheme which combines a model reference adaptive control with a neural network (NN) for the electro-pneumatic servo system. In this design scheme, we adopt a multi-rate type NN in which an update-time of weights is selected as multiple of a sampling-time. The effectiveness of the proposed design scheme is confirmed by experiments using the existent electro-pneumatic servo system.

CCA-WP6-5 5:40 CCA-1722

Improved Control of Pneumatic Lumber Handling Systems

Wang, Xiaochun George,
Kim, Chris — Integrated Manufac. Tech. Inst.

Though pneumatic systems are used for many applications. The control of such systems present major challenge because of nonlinearity caused by friction and the nonlinear volume-pressure relation in pneumatics. This paper presents the results on modeling, estimation and control of a heavy industrial pneumatic log handling machine. It is shown that a modified self-tuning generalized predictive control can achieve much improved performance over the control schemes.

CCA-WP6-6 6:00 CCA-1728

Robust Compensators Design for Existing Control Systems

Yari, A. R.,
Eisaka, T. — Kitami Inst. of Tech.

We propose some simple methods for designing attachable robust compensators that improve the robustness and decrease the sensitivity of attached control systems. Concerning with the practical design method of Robust Model Matching (RMM), we propose linear-time-invariant (LTI) attachable robust compensators for LTI control systems with some structured and unstructured disturbances. First, a generalized approach to the standard RMM is proposed. Then, a new configuration for RMM that separates the robust compensator from the existing controller is proposed. We also examine the efficiency of the proposed method by a laboratory experiment.

CCA-ThA1 Koa
Flexible Structures

CCA-ThA1-1 10:00 CCA-291

Compensator Design for the ALFA Adaptive Optics System

Looze, Douglas P.,
Beker, Orhan — Univ. of Massachusetts
Kaspar, Markus,
Hippler, Stephan — Max Planck Inst. fur Astronom.e

This paper presents and compares compensator designs for the ALFA adaptive optics system.

CCA-ThA1-2 10:20 CCA-297

Vibration Suppression Control of Flexible Robot Arm with CMS Modeling and Output Feedback Sliding Mode Controller

Kobayashi, Nobuyuki,
Inoue, Kengo — Aoyama Gakuin Univ.

A reduced order output feedback control algorithm based on a low order modeling methodology for suppressing the vibration and obtaining the high speed, high precision positioning of the flexible robot arm is proposed and discussed. The proposed low order modeling methodology gives no modal truncation error and makes it possible to vary the mode shapes of the link according to the change of the boundary conditions due to the feedback gains and the payload at the tip of the arm. Furthermore, this methodology can take into account not only the flexibility of links but also the flexibility of joints. The reduced order output feedback control algorithm is designed by the combination of sliding mode controller and suboptimal output feedback controller so as to achieve both the damping of the system vibration and the stabilization at the same time. The results of numerical simulation and of experiment for a two-link robot arm model prove that the proposed modeling methodology is able to describe the dynamic behaviors of the arm, and the controller designed applying the suboptimal output feedback sliding mode control is able to control the arm quite well.

CCA-ThA1-3 10:40 CCA-303

Fault-Tolerant Decentralized Control for Large Space Structures

Kobayashi, Yohji — Kobe City College of Tech.
Ikeda, Masao — Osaka Univ.
Fujisaki, Yasumasa — Kobe Univ.

This paper considers position and attitude control of large space structures composed of a number of subsystems which are interconnected by springs and dampers. A decentralized control law of dynamic displacement feedback compatible with subsystems is applied under the assumption that sensors and actuators are collocated. The overall closed-loop system is robustly stable against perturbations in mass, damping, and stiffness if rigid modes of each subsystem are controllable and observable. The objective of this paper is to derive conditions under which stability of the overall system is preserved even when some local controllers fail. The conditions are expressed in terms of the stiffness (or damping) matrices and interconnection location matrices of the subsystems whose local controllers fail.

CCA-ThA1-4 11:00 CCA-309

Vibration Suppression Control of Flexible Arms by Using Sliding Mode Method

Chen, Xinkai — Tokyo Denki Univ.
Guo, Shuxiang — Kagawa Univ.
Fukuda, Toshio — Nagoya Univ.

In this paper, we consider the vibration suppression control of flexible arms by using sliding mode method. The vibration motion of the flexible arm has infinite number of modes. The

higher order modes of the flexible arm are considered as the disturbances. Since the payload mass is usually unknown, the model uncertainties usually exist. The sliding surface is designed such that the dynamics on the surface is stable under the sliding mode control. The robustness of sliding mode control is effectively employed to compensate the model uncertainties and the disturbances. For different payloads, experimental results show that the robustness of the proposed method is superior to that of the traditional pole-placement methods.

CCA-ThA1-5 11:20 CCA-315

Fuzzy Logic Control of a Moving Flexible Manipulator

Chen, Chong,
Yin, Yican Middle Tennessee State Univ.

Flexible manipulators provide significant advantages over commonly used rigid robots, such as high operation speed and high power efficiency. However, the controller design for these manipulators is very complicated because of the nonlinear vibration dynamics. In this paper, a rule-based scheme for implementing a fuzzy logic controller to drive a flexible manipulator is proposed. The phase portrait plane has been adopted to build the rules based on mathematical reasoning rather than the conventional trial and error method, which is dependent on the operator's experience. In order to improve the performance of the fuzzy logic controller, an adjustable weight parameter has been introduced t build the control table. A set of variable width triangular membership functions is used to improve the resolution of the controller . The effectiveness of the control law has been demonstrated with numerical simulation

CCA-ThA1-6 11:40 CCA-321

Structural Design for Reduced-Order H-Infinity Controller

Hiramoto, Kazuhiko,
Doki, Hitoshi,
Obinata, Goro Akita Univ.

We consider an integrated design problem of structural and control systems. Using reduced-order H_∞ controller design method proposed by Mustafa and Glover, we formulate the integrated design as a simultaneous design of the structural design parameter and the reduced order H_∞ controller. The formulated problem does not need to take an iterative procedure (controller synthesis and structural modification) which is employed in most integrated design.

CCA-ThA2a Milo
Scaled Control Equipment

CCA-ThA2a-1 10:00 CCA-327

A Scaled Testbed for Vehicle Control: The IRS

Brennan, S.,
Alleyne, A. Univ. of Illinois, Urbana-Champaign

This paper presents a novel testbed for vehicle control experiments: The Illinois Roadway Simulator (IRS). This is a scaled roadway suitable for easily visualizing preliminary vehicle control studies. The concept of the IRS is given along with the details of its design and construction. A review of vehicle dynamics gives the standard Bicycle Model for linear operating conditions. The parameters of the model are then obtained for representative IRS vehicles. The resulting vehicle dynamics are then compared with dynamics of full-scale vehicles for dynamic similitude. The dynamic similitude comparison is the key to gaining confidence in the scaled testbed as an accurate representation of actual vehicles. A series of experimental verifications are used to match the identified vehicle dynamics to the responses predicted by the standard vehicle model with some additional augmentations.

CCA-ThA2a-2 10:20 CCA-333

The University of Toronto RC Helicopter: A Test Bed for Nonlinear Control

Bortoff, Scott A. Univ. of Toronto

Model helicopters are becoming increasingly popular as benchmark systems for control theory and as platforms for aerial robotics. As benchmark systems, an important question to ask is: How do results for model helicopters scale to the full-size version? After presenting a description of a typical laboratory-scale helicopter system, we discusses some of the key differences between model and full-sized helicopters. We also discuss some of the fundamental issues of scale, including efficiency as the helicopter becomes very small or very large.

CCA-ThA2a-3 10:40 CCA-339

Implications of Control-Structure Interaction in the Scaled Structural Control System Testing

Dyke, Shirley J.,
Jansen, Laura M. Washington Univ.

Experimental testing is an important step in the verification of control strategies. In the case of civil engineering structural control systems, small scale testing is commonly used to demonstrate key concepts and methods. Large or full scale testing is expensive and only a handful of facilities exist in the world. Thus some researchers have considered experimental techniques which focus on the control device itself, and emulate the behavior of the structure with a simulator. The concern is that these techniques do not account for the interaction between the control device and the structure. This issue will be examined herein. In a numerical example, the behaviour of the control device when tested independently will be compared to that of the device when it is used to control a structure.

CCA-ThA2a-4 11:00 CCA-345

A Testbed for Nonlinear Flight Control Techniques: The Caltech Ducted Fan

Milam, Mark,
Murray, Richard M. California Inst. of Tech.

This paper considers the fundamental design and modeling of the Caltech ducted fan. The Caltech ducted fan is a scaled model of the longitudinal axis of a flight vehicle. The purpose of the ducted fan is the research and development of new nonlinear flight guidance and control techniques for Uninhabited Combat Aerial Vehicles. It is shown that critical design relations must be satisfied in order that the ducted fan's longitudinal dynamics behave similar to those of an flight vehicle. Preliminary flight test results illustrate the flying qualities of the ducted fan.

CCA-ThA2b Milo

Chemical Process Control

CCA-ThA2b-6 11:40 CCA-352

Plantwide Control Design and Analysis of a Continuous Polymerization Process Using Optimal Control Methods

Robinson, Derek L.,
Schnelle, Phillip D. E.I. DuPont de Nemours & Co.
McAvoy, Thomas Univ. of Maryland

An optimal control based algorithm, using a linear quadratic state-feedback regulator (LQR) on a linear model, has been developed which identifies viable proportional-integral with feedforward (PI/FF) control strategies. In this approach, two matrices, SFB and SFF, are calculated from the linear state space matrices and the optimal control gain. The SFB and SFF reveal the respective dominant feedback and ratio/feedforward paths of a system. Three screening and four performance heuristics have been developed to interpret these matrices to reveal the dominant control pathways of a system. Information gained from these matrices is used to formulate PI/FF control architecture (s). These architectures are tested on a fixed dynamic simulation to judge their performance. A continuous polymerization process was used as test case to evaluate the results of the optimal control based algorithm and to test the heuristics presented here. The algorithm identified weak manipulated variables and eliminated them from the list of degrees of freedom. It also identified viable potential control architectures that were tested with the fixed dynamic simulations. The algorithm provided information on each candidate architecture's simplicity and degree of decoupled, feedback-path dominance. These results, for each case, were confirmed through simulations

CCA-ThA2b-7 12:00 CCA-359

Automatic Detection of Excessively Oscillatory Feedback Control Loops

Miao, Tina,
Seborg, Dale E. Univ. of California, Santa Barbara

A statistically-based approach is proposed t detect excessively oscillatory feedback control loops. The technique is simple and requires only normal operating data. The effectiveness and widespread applicability of the new approach are demonstrated in several experimental applications, including an industrial distillation column.

CCA-ThA3 Mauka

Control of Chemical Processes II

CCA-ThA3-1 10:00 CCA-365

Design of a Decentralized Output Feedback Control Law by Solving a Linear Least Squares Problem

Seatzu, Carla Univ. of Cagliari

In this paper we study the output feedback control problem using a decentralized dynamic feedback control scheme. We propose a numerical procedure which consists in the evaluation of the decentralized feedback gains such that the closed-loop behaviour of the decentralized system approaches, in the least squares sense, the evolution of a target centralized closed-loop plant. In this way, the synthesis problem reduces to the identification of a set of unknown parameters in a linear system of ordinary differential equations. Since also the time derivatives of the target states can be computed, the solution can be determined by solving a linear least squares problem, where no difficulty due to local minima and good initial estimate occur.

CCA-ThA3-2 10:20 CCA-371

Pressure Feedback Reduced-Order Dynamic Compensation for Axial Flow Compression Systems

Haddad, Wassim M.,
Corrado, Joseph R,
Leonessa, Alexander Georgia Inst. of Tech.

In this paper we develop linear, fixed-order (i.e., full- and reduced-order) pressure rise feedback dynamic compensators for axial flow compressors. Unlike the nonlinear static controllers proposed in the literature possessing gain at all frequencies, the proposed dynamic compensators explicitly account for compressor performance versus sensor accuracy, compressor performance versus processor throughput, and compressor performance versus disturbance rejection. Furthermore, the proposed controller is predicated on \emph{only} pressure rise measurements, providing a considerable simplification in the sensing architecture over the bifurcation-based and backstepping controllers proposed in the literature.

CCA-ThA3-3 10:40 CCA-377

Bifurcation Control of Rayleigh-Benard Convection

Chen, Dong,
Wang, Hua O.,
Howle, Laurens E. Duke Univ.

Bifurcation control deals with the modification of the bifurcation characteristics of a parameterized nonlinear system by a judiciously designed control input. In this paper, we investigate the problem of active control of Rayleigh-Benard convection (RBC) via a bifurcation control approach. Active control of Rayleigh-Benard convection is a problem of importance to both theoretical research and industrial applications. Several forms of bifurcation control laws are designed based on the mathematical analysis of the governing partial differential equations for RBC. Simulations as well as experimental studies have been carried out to validate the control designs. A composite bifurcation control law combining a linear control law and a cubic control law is found to be most effective and flexible for this problem.

CCA-ThA3-4 11:00 CCA-383

Rapid Process Recipe Optimization for Batch Thermal Reactors

Erickson, Mark A.,
Shah, S.,
Gudmundsson, T.,
Pandey, P. Voyan Tech.

This paper describes a method for rapidly optimizing the uniformity of thin films deposited or grown on semiconductor wafers in batch thermal reactors. The method allows process recipes to be automatically optimized in as few as two process runs. Challenges associated with optimizing process recipes to

yield uniform final film thickness on all wafers processed in each batch are presented, and the uniformity problem is formulated as a run-to-run control problem. A solution to this problem is presented that includes a run-to-run process model, an estimator, and a controller. This solution has been implemented in a software package that is used by engineers in the field to optimize process recipes. Measured results are presented from the optimization of two different process recipes.

CCA-ThA3-5 11:20 CCA-391

Towards Delta Domain in Predictive Control-An Application to the Space Crystal Furnace TITUS

Ebert, Wolfram Humboldt-Univ. of Berlin

A new formulation of predictive control which uses a closely to the continuous time plant related delta description is given. Starting with the derivation of an end-point state weighted generalized predictive controller a polynomial controller representation is given and the theoretical value of the endpoint state weighting matrix is derived. The robustness with respect to additive plant/model mismatch is involved by the Hinf analysis. The Space Crystal Furnace TITUS is modeled using strongly coupled symmetric composite systems. A final simulation underlines the improved accuracy of the temperature gradient.

CCA-ThA3-6 11:40 CCA-397

Operation and Control of a Semibatch Reactive Distillation Column

Fernholz, Gregor,
Wang, Wei,
Engell, Sebastian,
Fougner, Kajsa,
Bredehoft, Jan-Peter Univ. of Dortmund

Reactive distillation integrates reaction and separation into one apparatus and offers the possibility to over-come restrictions given by chemical and phase equilibria. The batch and semibatch modes permit a more flexible operation compared to the continuous case especially for multi product plants. Here the heterogeneously catalyzed esterification of methanol and acetic acid in a reactive distillation column which is operated in semibatch mode is investigated. The solution of a minimum batch time problem de-fines the optimal trajectory of the process. The task of feed-back control is to track this trajectory in the presence of disturbances and model uncertainties. Due to the nonlinear plant behaviour, robustness properties have to be taken into consideration in the design. The nonlinearity of the system is considered as an uncertainty of the linear nominal model in the optimal operating region. A robust controller is de-signed using a combination of a loop shaping procedure and frequency response approximation. The linear closed-loop system is stable for the nominal model as well as for the models containing uncertainties. The controller also shows good tracking performance when used with the nonlinear model.

CCA-ThA3-7 12:00 CCA-403

Robust LQ Optimal Controller Designing for Refining Process

Xue, Anke,
Lu, Yingquan,
Sun, Youxian Zhejiang Univ.

This paper presents a synthetic design procedure of robust LQ optimal controller for refining process, including modeling and robust optimal system designing. The paper discusses three major topics: mathematical modeling of the process with large uncertainty, determination of a synthetic performance index for optimizing the process, and design of the robust optimal control system with robust guaranteed stability. This research is a part of preliminary results of the real refining process optimal control system implemented in Minfeng Paper Mill, Zhejiang Province. Simulation test results show that the proposed modeling and control algorithms are efficient and practicable.

CCA-ThA4 Makai
Fuzzy & Neural Network

CCA-ThA4-1 10:00 CCA-409

Adjustment Rule Generation for Static Systems

Kiji, Junichi Toshiba Corp.

In many industrial fields, there are still difficulties in adjusting parameters of nonlinear systems. In order to cope with the difficulties, this paper proposes that adjustment should be divided into choosing appropriate parameters, calculating the amount of modification of the chosen parameters, and dealing with nonlinear phenomena. An adjustment rule which describes how to choose appropriate parameter in every situation is generated by using characteristics of influences of parameters. The calculation of the modification is carried out on trial just before the chosen parameter is really modified for adjustment. Nonlinear phenomena during adjustment can be categorized into vibration and inert-zone, and they should be evaded by extra treatments prepared beforehand. In addition, a sufficient condition for convergence to the desired state is explained in the case that the characteristics of the objected system are known. Finally, an example shows that the proposed method is applicable to unknown nonlinear static system

CCA-ThA4-2 10:20 CCA-415

New Robust and Optimal Designs for Takagi-Sugeno Fuzzy Control Systems

Tanaka, Kazuo,
Hori, Tsuyoshi Univ. of Electro-Communications
Wang, Hua O. Duke Univ.

This paper presents a new robust and optimal fuzzy control. The optimal fuzzy controller is designed by solving the minimization problem that minimizes the upper bound of a given quadratic performance index. Next, robust stability conditions for a class of uncertain fuzzy systems are derived. The robust fuzzy controller is designed so as to maximize the norm of the uncertain blocks in a Takagi-Sugeno fuzzy model. More importantly, the control problem that simultaneously considers both the optimal fuzzy controller design and the

robust fuzzy controller design is defined and is efficiently solved via convex optimization techniques based on LMIs

CCA-ThA4-3 10:40 CCA-421

Fuzzy-Logic-Based Guidance Law Design for Missile Systems

Lin, Chih-Min,
Mon, Yi-Jen Yuan-Ze Univ.

This paper presents the design of fuzzy-logic-based command to line-of-sight (CLOS) guidance law. In this presented design, the fuzzy inference rules are constructed in terms of polar coordinate parameters and their fuzzy associated memories (FAM) are trained by adaptive-network-based fuzzy inference system (ANFIS). An on-line tuning algorithm is also proposed to adjust the FAM based on the missile attitude to eradicate the coupling effect. Simulation results demonstrate that the proposed fuzzy-logic-based CLAS guidance law can achieve satisfactory performance with small miss-distance.

CCA-ThA4-4 11:00 CCA-427

Neural Network Assisted Control Loop Tuner

Wojsznis, Willy K.,
Blevins, Terry L.,
Thiele, Dirk Fisher-Rosemount Systems

This article explores the application of non-linear tuning rules estimators to a known relay-oscillation tuner. Two approaches were tested. One uses non-linear functions to approximate the desirable controller parameters. The other incorporates Neural Network for computing process model and controller parameters. As a basis for computation, the Ultimate Gain, Ultimate Period, and Process Dead Time are defined during the tuning experiment. Neural Network is trained in simulation using these process parameters as inputs and known process model parameters and desired PID controller tuning parameters as outputs. The PID tuning parameters are defined from the simulation process model using IMC or Lambda tuning rules. This concept was implemented in a scalable industrial control system. Simulation test results show a vast improvement in model identification and control loop performance as compared to previous relay-oscillation based tuning approaches.

CCA-ThA4-5 11:20 CCA-432

FEP Learning Algorithm: Application to Direct Self-Learning Control

Mendil, Boubekeur Univ. of Bejaia
Benmahammed, Khier Univ. of Setif

One significant problem with neural control is that of credit assignment, that is, how should errors in the plant output be used to modify the controller, since the plant is interposed between the controller output and the scored output. While the controller takes as inputs the plant outputs, then we can propagate forward the error through the controller network, and then we update its weights. This is the basic principle of the FeedForward Error Propagation (FEP) learning algorithm developed in this paper. This new algorithm does not need a second network (e.g. a critic network or a forward model) to train the controller. This avoid the extra network uncertainty and greatly simplifies the computation complexity and, thus, makes it suitable for on line learning. Here, the FEP algorithm is used to design a direct self-learning control system. The inverted pendulum control problem is used to state the performance of the proposed algorithm with respect to that of backpropagation learning algorithm. Simulation results have showed that the FEP-based controller performance is better since it stabilizes the pole in the desired state during shorter periods of time. This can be explained by the efficiency of FEP in the error calculations and, in the other hand, by the forward model uncertainty of indirect self-learning. Furthermore, the FEP-based controller training is much faster.

CCA-ThA4-6 11:40 CCA-1749

Model-Based Recurrent Neural Network for Modeling Nonlinear Dynamic Systems

Gan, Chengyu,
Danai, Kourosh Univ. of Massachusetts

A model-based recurrent neural network (MBRNN) is introduced for modeling nonlinear dynamic systems. The topology of MBRNN as well as its initial weights are defined according to the linearized state-space model of the plant. As such, the MBRNN has the ability to incorporate the analytical knowledge of the plant in its formulation. With its original topology intact, the MBRNN can then be trained to represent the plant nonlinearities through modifying its nodes' activation functions, which consist of contours of Gaussian radial basis functions (RBFs). Training involves adjusting the weights of the RBFs so as to modify the contours representing the activation functions. The performance of the MBRNN is demonstrated via several examples. The results indicate that it requires much shorter training than needed by ordinary recurrent networks. This training efficiency is attributed to the MBRNN's fixed topology, which is independent of training.

CCA-ThA4-7 12:00 CCA-436

Feedforward IIR Active Noise Control Using Genetic Algorithm

Kim, Jong Boo Induk Inst. of Tech.
Lee, Tae Pyo Hyundai Motors Co.
Yim, Kook Hyun Taesan Precision co.

This paper presents an active noise control (ANC) algorithm using genetic algorithm with infinite impulse response (IIR) filter structure. Stochastic gradient algorithms such as least mean square (LMS) algorithm are conventionally used for their simplicity and stability. But these algorithms have disadvantages of local minimum and large eigenvalue disparity of input signal's autocorrelation matrix. To solve those problems, several researches have been made to adaptive filtering schemes based on genetic algorithm. But their application is limited to the system that is able to know desired signal directly. In general active noise and vibration control systems are not be able to sense desired signal directly, so they have some difficulties or problems such that learning sample set is proportional to population size. Proposed active controller is composed of genetic controllers that can learn by one sample set per one generation. This structure can be properly applied to active control system. Computer simulations show that proposed genetic structured IIR active controller has more optimal result to feedforward active noise control systems.

CCA-ThA5 Hau

Control of Automotive Systems

CCA-ThA5-1 10:00 CCA-442

Force Tracking Control for Active Suspensions-Theory and Experiments

Chantranuwathana, Supavut,
Peng, Huei Univ. of Michigan

This paper presents experimental results of a force-tracking controller for a quarter-car active suspension system. In a previous publication (Chantranuwathana and Peng 1999), an active suspension architecture was presented. The overall active suspension system was decomposed into two loops. At the main loop, the desired force signal is calculated by using a standard LQ design process. The Adaptive Robust Control design technique is then used to design the force controller such that the desired force signal is achieved in a robust manner when actuator or other plant uncertainties are present. Experimental results of the proposed ARC force-tracking algorithm are reported in this paper. It was found that force-tracking of up to 5Hz can be reliably achieved.

CCA-ThA5-2 10:20 CCA-448

Modeling, Performance Analysis and Control Design of a Hybrid Sport-Utility Vehicle

Brahma, Avra,
Glenn, Bradley,
Guezennec, Yann,
Miller, Troy,
Rizzoni, Giorgio,
Washington, Gregory Ohio State Univ.

This paper proposes a unified power flow approach to the modeling of hybrid electric vehicles, resulting in a highly scalable and reconfigurable modeling tool. Furthermore, this simulation tool is used in conjunction with a fuzzy logic, rule-based controller to optimize the energy efficiency through the control of the power flows of a parallel HEV configuration. Finally, this modeling and control approach is applied to the design and optimization of a hybrid electric sport-utility vehicle. The results show that this modeling approach provides the required modeling flexibility, and that the model and the control strategy based on this power flow approach can be optimized to yield significant fuel economy gains.

CCA-ThA5-3 10:40 CCA-454

Improving Turbocharged Diesel Engine Operation with Turbo Power Assist System

Kolmanovsky, Ilya Ford Res. Lab.
Stefanopoulou, A.G. Univ. of California, Santa Barbara
Powell, B.K. Ford Res. Lab.

The paper investigates improvements in the turbocharged diesel engine transient response that can be attained when a turbocharger power assist system, consisting, for example, of an electric motor and a battery, is coupled to the turbocharger shaft. The method of investigation relies on formulating and solving numerically an appropriate minimum time optimal control problem. Comparison with a conventional turbocharged diesel engine response reveals the mechanism by which acceleration improvements are attained while maintaining high fuel efficiency and equivalent smoke emission levels. A feedback controller that generates responses qualitatively similar to the optimal ones is also described.

CCA-ThA5-4 11:00 CCA-460

In-Cylinder Measurement for Engine Cold Start Control

Tunestal, Per,
Wilcutts, Mark,
Lee, Albert T.,
Hedrick, J. Karl Univ. of California, Berkeley

We examine the use of in-cylinder measurements for engine control, with emphasis on emissions control during cold start. First, the cold start emissions control problem is described. An overview of previous research in the area of in-cylinder measurements for control is presented, including sensors for pressure and other quantities. Next, analysis of cylinder pressure is described. Lastly, a cold start engine test stand, and preliminary experimental tests of cylinder pressure measurement and real-time processing are presented.

CCA-ThA5-5 11:20 CCA-465

Multivariable Controller Structure in a Variable Cam Timing Engine with Electronic Throttle and Torque Feedback

Hsieh, Stephen C.,
Freudenberg, James S. Univ. of Michigan
Stefanopoulou, Anna G. Univ. of California, Santa Barbara

By adding an electronic throttle and a torque sensor to an engine equipped with variable cam timing, it is potentially possible to vary cam phasing to improve emissions and fuel economy while preserving the torque response of a conventional non-VCT engine. To do so effectively, however, requires the use of multivariable control. A controller consisting of decentralized individual control loops will not yield satisfactory performance because such a controller cannot compensate for system interactions. Yet, a fully multivariable controller may not prove necessary in order to achieve the desired performance. In this paper, we design linear multivariable controllers at a number of operating points and simplify the resulting controllers by eliminating cross-coupling terms that do not affect the closed loop response. Doing so provides insight useful in tuning controller parameters.

CCA-ThA5-6 11:40 CCA-471

Modeling and Control of Gasoline Direct Injection Stratified Charge (DISC) Engines

Sun, Jing,
Kolmanovsky, Ilya,
Brehob, Diana,
Cook, Jeffrey A.,
Buckland, Julie,
Haghgooie, Mo Ford Res. Lab.

In this paper, we present a phenomenological nonlinear dynamic model for direct injection stratified charge (DISC) gasoline engines and discuss several key control problems for this advanced technology powertrain. The model is developed and validated using dynamometer engine mapping data obtained from a 4-cylinder DISC engine. It captures the static behavior of the key components of a DISC engine, such as the torque and emissions generation and volumetric efficiency, as

well as the essential dynamics for the intake manifold and engine rotational inertia. It is shown that the multi-mode operation of a DISC engine dictates a hybrid model structure and also requires a coordinated multivariable control strategy to achieve expected performance.

CCA-ThA6 Lehua
Robotics

CCA-ThA6-1 10:00 CCA-478

Passive Walking Robot QUARTET

Osuka, Koichi Kyoto Univ.
Fujitani, Tatsuya,
Ono, Toshiro Osaka Pref. Univ.

In this paper, passive walking of the eight-legged robot Quartet that has simple straight legs, and is also constrained to have two degrees of freedom for the simplicity of its motion, is described. It is known that a legged robot can continue to walk down a slight slope steadily without any actuation if appropriate initial conditions are given . Since no control input except for gravitational torque is applied to the robot, more natural gaits compared with those of conventional actuated walking robots are expected. In walking simulation, bifurcation that occurs along with the increase of slope angle and finally leads to chaotic gait is discussed. In walking experiment, some kind of trajectory stability can be observed.

CCA-ThA6-2 10:20 CCA-484

Walking of a Biped Robot with Passive Ankle Joints

Yi, Keon Young Kwangwoon Univ.

This paper deals with a walking of a biped robot which has ankle joints without motor. Ankle joints have been built using springs and mechanical constraints, which gives a flexibility of joint within a certain range and a stiffness beyond the range. The biped with passive ankles proposed here gives a good contact between its sole and the ground and makes foot landing soft. As a result, installing force sensors for measuring the center of gravity of the biped becomes easier. Weight and cost of legs are also reduced. As the cost of the advantages, however, the control problem becomes more difficult because the torque of the ankle joint to put the biped in a desired walking gait cannot be provided from the passive ankle joint. To solve this problem, we proposed a dynamic gait modification method by adjusting the position of a hip joint. Experimental results with the minor modification of the SD-2 robot in the Ohio State University are given to show the validity of the proposed controller.

CCA-ThA6-3 10:40 CCA-490

Biologically Inspired Adaptive Dynamic Walking of the Quadruped on Irregular Terrain

Fukuoka, Yasuhiro,
Nakamura, Hiroyuki,
Kimura, Hiroshi Univ. of Electro-Communications

In the present study we attempt to induce a quadruped robot to walk dynamically on irregular terrain by using a neural system model. In this paper, in order to realize walking on irregular terrain, we propose the biologically-inspired control method consisting of four levels, those are, ‘‘adaptive control using a muscle stiffness model”, ‘‘adaptive control based on vestibular sensation”, ‘‘parameters adjustment based on somatic sensation and reflexes coordination based on vestibular sensation”, and ”motion switching based on visual information”. As results of basic experiments of each level, we show that a robot can walk on a single bump and up a slope by using such adaptive control method. We also show that the functions as a lower controller in the Drew’s physiological model for leg control mechanism based on visual information are satisfied by a CPG characterized by mutual entrainment with a musculo-skeletal system, automatic interpolation, and self stabilization. These findings suggest a simple method for producing autonomous adaptive dynamic walking on terrain of high degree irregularity.

CCA-ThA6-4 11:00 CCA-496

Analysis and Design of Running Robots in Touchdown Phase

Ikeda, Takayuki,
Iwatani, Yasushi,
Suse, Koichi,
Mita, Tsutomu Tokyo Inst. of Tech.

In order to create a running and jumping quadruped robot composed of all articular joints, we have developed a mono-leg robot which simulates the landing and lift-off motions of kangaroos. From the photograph data of the gait motion of a kangaroo, time responses of four fundamental variables are approximated by solutions of second or first order differential equations. Then we proposed a control strategy of the robot which realizes these differential equations as controlled constraints. Experimental results show that a running mono-leg robot is produced which has a smooth jumping gaits.

CCA-ThA6-5 11:20 CCA-502

Control and Analysis of the Gait of Snake Robots

Prautsch, P.,
Mita, T. Tokyo Inst. of Tech.

The snake’s interesting gait enables them to climb a hill or wind up a tree to climb it up. Hirose has long investigated the motion of snakes and made several snake robots. He also showed that the trace of the snake body draws the so called serpenoid curve. However, the control of the position of the snake head was shown t0 be difficult. Here, as the first report of our research outcome, we will show a dynamical position control of the snake robot and discuss the effect of constraining the trace of the head to a serpemoid curve.

CCA-ThA6-6 11:40 CCA-508

Dynamic Modeling of Flexure Jointed Hexapods for Control Purposes

McInroy, John E. Univ. of Wyoming

A number of researchers have been investigating the use of Stewart platforms (or hexapods) for precision applications. This paper presents a new dynamic model suitable for control of flexure jointed hexapods. Novel contributions include: (1) Base acceleration inputs are included; (2) The dynamic model is experimentally verified; (3) The model is developed so that it is suitable for control, and (4) a decoupled force control is derived.

CCA-ThM1 Koa

Vibration Control and Input Shaping

CCA-ThM1-1 2:00 CCA-514

Estimation and Control of Vibrations of Circular Saws

Wang, Xiaochun G.,
Xi, Fengfeng Jeff,
Li, Daming,
Qin, Zhong Integrated Manufac. Tech. Inst.

Vibration control has been identified by wood products industry as one of the key technologies for increasing wood recovery in wood machining. This paper presents results of a research project for active vibration control of circular saws using magnetic actuators. An active control system is developed to increase wood recovery by reducing saw blade vibration. For on-line estimation and control of vibration characteristics, a state-space model is developed based on the finite element model analysis and experimental measurement. The characteristics of different vibration modes is estimated on-line by a Kalman filter based state estimator. A state feedback controller design is then implemented on-line and good damping results have been achieved. Keywords: Vibration Control, State Estimation, Mode Based Control, Kalman Filter.

CCA-ThM1-2 2:20 CCA-521

New Simple Adaptive Control Subject to Disturbances and Application to Torsional Vibrational Suppression

Mine, M.,
Date, K.,
Ohmori, Hiromitsu,
Sano, Akira Keio Univ.
Todaka, Yujui,
Nishida, Hideyuki Fuji Electric. Co.

The present paper proposes a new simple adaptive control scheme taking account of disturbances for a non-ASPR system and investigates the global stability of the obtained adaptive algorithm. Two schemes for rejecting disturbance effects are discussed from feedback and adaptive feedforward points of view. The validity of the proposed algorithm is examined in numerical simulation and experimental study in which the adaptive torsional vibration control of an induction motor connected with a load by a flexible shaft can be achieved in the presence of torque disturbance without using any sensor for the load.

CCA-ThM1-3 2:40 CCA-527

Control of Elevator Having Parametric Vibration Using LPV Control Method

Rijanto, Estiko,
Muramatsu, Takashi,
Tagawa, Yasutaka Tokyo Univ. of Agric. and Tech.

In this paper a control system for elevator vibration reduction is designed incorporating a new feature i.e. parameter variation in the elevator's dynamics. In a high speed elevator the vibration is not only caused by irregularity or unshape of the guide-rail but also by parameter variable vibration due to the deflection of the guide-rail. In order to obtain a better control system for elevator vibration reduction a new method which incorporates the parameter variation dynamics is required. Firstly in this paper a dynamical model of an elevator is formulated, by assuming that at high speed vertical movement the stiffness of the guide rail varies against the elevator vertical position. Second, a controller is designed with the main objective to reduce vibration caused by any external force. When it is stationary the controller works in reducing vibration due to the shock when a passenger gets in to or get out of the elevator, and when it is moving up and down the controller reduces vibration caused by irregularity or unshape of the guide-rail and by parameter variation. Finally the performance of the designed controller is evaluated through computer simulation. Since an output feedback controller is designed only horizontal acceleration of the elevator cabin is needed for feedback signal. The vertical position is measured to be used in calculating the stiffness of the guide-rail. Simulation results show that the designed controller enhances significantly the performance of the elevator.

CCA-ThM1-4 3:00 CCA-533

Vibration Reduction with Specified-Swing Input Shapers

Singhose, William Georgia Inst. of Tech.
Mills, Bart,
Seering, Warren Massachusetts Inst. of Tech.

Residual vibration of flexible structures can be greatly reduced by generating specially-shaped command signals. Input shaping is a type of command generation scheme that is implemented by convolving a sequence of impulses with any desired system command. The resulting shaped input is used as the reference command. Many types of useful impulse sequences have been proposed. Most of these have contained only positively valued impulses. However, when some of the impulses are allowed to have negative amplitudes, the system rise time can be improved. The improved rise time comes with the potential drawback of actuator saturation. New types of impulse sequences containing negative impulses are proposed. These sequences allow the designer to specify the swing in amplitude between successive impulses. This in turn allows the actuator effort to be controlled.

CCA-ThM1-5 3:20 CCA-539

Input Shaper Design for Double-Pendulum Planar Gantry Cranes

Kenison, Michael,
Singhose, William Georgia Inst. of Tech.

Manipulating payloads with gantry cranes can be difficult given the inherent system flexibility. In fact, the payload cannot move until some deflection occurs in the support cable, thereby generating a horizontal force. Gantry crane dynamics can often be effectively modeled as a single linear flexible mode. However, if the crane is equipped with a large-mass hook and the payload is sufficiently light, then the dynamics can become complicated by double-pendulum effects. This paper presents a method for determining the contribution of the second pendulum mode to the overall dynamic response. Furthermore, an input shaping scheme is developed to reduce residual oscillations. This control method utilizes the double-pendulum dynamics to determine the parameters of the input shaping algorithm.

CCA-ThM1-6 3:40 CCA-545

Limiting Excitation of Unmodeled High Modes with Negative Input Shapers

Singhose, William,
Grosser, Karen Georgia Inst. of Tech.

Vibration of flexible structures can be greatly reduced by using properly shaped reference commands. Input shaping is a command generation scheme that filters the reference command in real time by convolving it with a sequence of impulses, called the input shaper. The resulting shaped command has a slower rise time than the unfiltered command. The rise time is increased by the time duration of the input shaper, so it is desirable to keep the duration as short as possible. To achieve very short durations, the shaper must contain negatively valued impulses. The improved rise time of negative input shapers comes with the potential drawbacks of actuator saturation, increased sensitivity to modeling errors, and excitation of unmodeled high modes. A method for controlling the potential excitation of unmodeled high modes is presented. Characteristics of the impulse sequence as a function of the limitation on high-mode excitation are presented. Simulations of a linear system with unmodeled high modes are used to demonstrate the important features of this approach.

CCA-ThM2 Milo
Robust and Nonlinear Control of Magnetic Bearings

CCA-ThM2-1 2:00 CCA-551

Magnetic Suspension and Vibration Control of Beams for Non-Contact Processing

Trumper, David L.,
Weng, Ming-chih,
Ritter, Robert J. Massachusetts Inst. of Tech.

This paper presents an integrated approach to magnetic suspension of a tubular beam for non-contact processing. We describe non-contact sensors and actuators, structure modelling/identification, and control methods for such systems. We have also designed an experiment that uses 8 sensors and 8 actuators to suspend a 3 m long, 6.35 mm diameter steel tube. Results from this experiment are presented herein. To facilitate the experiment, we designed a novel two-dimensional position sensor by utilizing the concept of an x-y variable differential transformer. We also designed two types of actuators that apply magnetic force on the tube in two axes. The system dynamics are modelled theoretically, and identified experimentally from within the closed-loop system. In order to control the system under varying boundary conditions, we propose a slow roll-up lead compensator. We also introduce sensor interpolation and sensor averaging methods to make the control loop more robust. Our proposed ideas are verified in the experimental results.

CCA-ThM2-2 2:20 CCA-743

Sliding Mode Nonlinear Control of Magnetic Bearings

Torres, Mauricio C.N.R.S.
Sira-Ramirez, Hebertt CINVESTAV-IPN
Escobar, Gerardo C.N.R.S.

This note presents a sliding mode controller for the robust stabilization of a magnetic bearing system. The approach avoids the need of premagnetization currents frequently used to linearize the system model. It utilizes two sliding manifolds achieving desired dynamics and complementarity of coil currents. Two differents controller has been designed. The second one takes account of discrete inputs as is the case in electronic power amplifiers. Simulations are presented to show the effectiveness and robustness of the designed feedback sliding mode controller.

CCA-ThM2-3 2:40 CCA-558

Uncertain Model and Mu-Synthesis of a Magnetic Bearing

Namerikawa, Toru,
Fujita, Masayuki Kanazawa Univ.

This paper deals with modeling, uncertain structure and Mu-synthesis of magnetic bearings. The dynamics of magnetic bearing systems are characterized by their instability and complex dynamics of rotor and electromagnets, hence they should have a robustness for stability and performance against model uncertainties. First we derive a nominal mathematical model of the plant under some assumption, then consider the gap between the real physical system and the obtained nominal design model. This gap has complex structure which is expressed by the structured uncertainties that includes linearization error, parametric uncertainties, unmodeled dynamics, and gyroscopic effect. Then we set the interconnection structure which contains the above structurally represented uncertainties. Next we design a robust controller which achieves robust performance condition using the structured singular value Mu. Finally, we evaluate the proposed interconnection structure and verify robustness of stability and performance of the designed Mu controller by several numerical simulations.

CCA-ThM2-4 3:00 CCA-564

Low-Order Mu-Synthesis Controller Design for a Large Boiler Feed Pump Equipped with Active Magnetic Bearings

Losch, Florian,
Gähler, Conrad Int. Cen. for Magnetic Bearings
Herzog, Raoul MECOS Traxler

In this paper, the robust controller design for a 3 MW boiler feed pump is presented. The dynamics of this pump are discussed, and a systematic way for transforming the robustness and performance requirements to the mu-synthesis setting is described. As the core of the paper, a new theorem for determining suitable uncertainty weighting functions for MIMO-problems is presented and applied to the AMB pump. The controller designed on this basis proves to meet the specifications.

CCA-ThM2-5 3:20 CCA-570

Mu-Control of a High Speed Spindle Thrust Magnetic Bearing

Fittro, Roger L. Aston Univ.
Knospe, Carl R. Univ. of Virginia

Experimental results demonstrate that mu synthesis provides an excellent tool for increasing the dynamic stiffness of thrust magnetic thrust bearings. Accurate system modeling and

appropriate uncertainty descriptions are critical to obtaining such results and are described in detail. Both complex mu and mixed mu synthesis were used to design controllers. The performance of the mu controllers is compared to that of an optimized PID controller. The dynamic stiffness of the spindle's thrust axis was increased by a factor of two over that obtained with optimized PID control.

CCA-ThM2-6 3:40 CCA-576

Adaptive Unbalance Vibration Control of Magnetic Bearing System Using Frequency Estimation for Multiple Periodic Disturbances with Noise

Nonami, Kenzo,
Liu, Zi-he Chiba Univ.

In this study, we focus on the error of estimated frequency of disturbance and present a new adaptive frequency tracking and new modification law after examining relation between the error of frequency and output level in detail. We also develop a multiple frequency estimation algorithm, which is insensitive to observation noise and prove the asymptotic stability for adaptive nonlinear algorithm and adaptive frequency tracking method theoretically. The results of simulation show that when estimated frequency by difference equation method approach to the true value, then the output error converges to zero (or equilibrium point) asymptotically. This corresponds to the asymptotic stability condition. The effectiveness of this method and the theoretical proof are verified by simulation. The experimental results show that the proposed algorithm is effective for achieving unbalance vibration suppression.

CCA-ThM3 Mauka
Process Control

CCA-ThM3-1 2:00 CCA-582

Adaptive Fuzzy Temperature Control for Hydronic Heating Systems

Haissig, Christine M. Honeywell Tech. Cen.

This paper describes an innovative adaptive fuzzy control (AFC) algorithm for regulating the room temperature in a hydronic heating system. The hydronic heating system consists of a boiler that provides central heating water to a radiator or radiators in a home or apartment. Room temperature is regulated with a motor that drives a variable-position valve on each radiator that controls the flow of hot water through the radiator. The AFC automatically learns the steady-state radiator valve positions for five operating set points and uses this information in a fuzzy controller that commands the radiator valve position. Laboratory tests under typical operating conditions show that the AFC simultaneously improves the control quality while reducing the battery consumption when compared with a conventional proportional-integral (PI) feedback controller. For a 70-hour laboratory test with typical operating set points, the control quality increased 32% while the estimated battery consumption decreased 36%. The AFC's memory and processing requirements are suitable for embedded microprocessors, so it is a realistic replacement for a conventional PID algorithm.

CCA-ThM3-2 2:20 CCA-589

Auto-Tuning PID Using Loop Shaping Ideas

Gaikwad, Sujit,
Dash, Sachi,
Stein, Gunter Honeywell Tech. Cen.

In this paper we present a direct approach for auto-tuning PID controllers. The approach is based on loop-shaping principles. Auto-tuning is accomplished under closed-loop system excitation without fitting a model of the system. The tuning procedure recursively adapts PID parameters to achieve a target loop-shape. In simulation testing the procedure works very well for systems with integrators, dead-time, lead dynamics, inverse response, sensor noise and colored noise disturbances. Here we present an example of a first order plant with delay operating under a colored noise disturbance.

CCA-ThM3-3 2:40 CCA-1740

Exapilot, Operational Efficiency Increase Support Package

Kobayashi, Yasunori,
Takatsu, Haruo Yokogawa Electric Corp.

Manual operations in steady state and unusual operations of plants are mostly conducted by operators and the quality of these operations suffers from fluctuation due to the variance in those operators' skill, which remains since long a bottleneck for the increase in the operational efficiency. Here at Yokogawa Electric Corporation, we have developed Exapilot Operational Efficiency Increase Support Package running on DOS/V Windows NT4.0 for: minimization of the number of DCS operations, saving direct and indirect resources, succession to skilled operators' expertise and improvement in safety. This tool increases the operational efficiency by semi-automating and homogenizing those operations through the systemization of skilled operators' expertise. The remarkable feature of Exapilot is operational Efficiency Increase Cycle. Also in this package, a user application program is provided in a flowchart format that can be used as an online-SOP (standard operational procedures) at hand.

CCA-ThM3-4 3:00 CCA-594

A Comparison of Identification-Based Performance Bounds for Robust Process Control

Adusumilli, S. Arizona State Univ.
Dash, Sachi Honeywell Tech. Cen.
Rivera, D.E.,
Tsakalis, K. Arizona State Univ.

This paper compares three different uncertainty estimation techniques in terms of predicting a priori performance bounds on the closed-loop system. A major benefit of computing the performance bounds is they expedite the controller implementation process, which is a critical component in the acceptance of the control system by the process operators. A key ingredient in computing these bounds is uncertainty estimation. The three methods evaluated are the Coprime Factor Uncertainty Method, Zhu's Asymptotic Method, and Bayard's Frequency-Domain Method. We compare the performance bounds obtained by applying these uncertainty estimation procedures on a paper machine control case study.

CCA-ThM3-5 3:20 CCA-600

An Optimizing Control for District Heating and Cooling Plant

Murai, Masahiko,
Sakamoto, Yoshiyuki,
Shinozaki, Tsutomu Toshiba Corp.

We present an optimizing control method for electric district heating and cooling (DHC) plants. The purpose of the method is to minimize the operating cost of the plants. The optimization models are constructed by input-output properties of the components into mixed 0-1 linear programming problem. The advanced feature of the method is to be able to handle 1) double-bundle heat pumps, 2) thermal storage tanks, and 3) peak-cut strategy. The numerical example shows that the optimization result based on the method gives appropriate schedule for DHC plant operations.

CCA-ThM3-6 3:40 CCA-605

Impacts of Enterprise Wide Supply-Chain Management Techniques on Process Control

Tjoa, I. Bhieng,
Raman, Ramesh MC Res. & Innovation Cen.
Itou, Toshiaki,
Fujita, Kaoru,
Natori, Yukikazu Mitsubishi Chem. Corp.

In an effort to continuously improving business productivity, companies are adopting new practices towards a continuous optimization of the total enterprise in the areas of business processes, supply chain and plant life cycle. This trend is supported with the enabling technology for integrated enterprise systems, such as Enterprise Resource Planning (ERP) and Supply Chain Management (SCM) systems. With an ERP system, various types of information can be accessed in one system which allows us to do work flow reengineering more effectively. The accessibility of information from the lower layer (process automation/control) system such as process data to the upper layer (enterprise) system such as business data is critical for establishing an effective SCM system. This system plays a critical role for linking the enterprise and the control sitemaps in optimizing the enterprise performance. In a chemical industry, the range of feasible operation regions that is set for the SCM system to find the best operation policy will indirectly depend on the ability of the process control system to perform in the range of operation regions. One of the requirements for an efficient production network is the ability to adopt changes in production operations with greater flexibility. This requirement will put a challenge on the process control technology. Meeting this requirement will allow for greater feasible operation regions set in the SCM study. Here, we discuss the potential impacts of a new trend in enterprise wide SCM practices on process control system in a chemical plant operation.

CCA-ThM4 Makai
Power Systems Control I

CCA-ThM4-1 2:00 CCA-609

Nonlinear Control of Non-Minimum Phase Systems: Application to the Voltage and Speed Regulation of Power Systems

Okou, Aime Francis,
Akhrif, Ouassima,
Dessaint, Louis-A. École de Tech. Superieure

A novel control scheme for nonlinear multi-input multi-output (MIMO) systems which have unstable zero dynamics is presented. The proposed approach consists of a state-feedback controller which simultaneously achieves the input-output linearization of the nonlinear system and stabilizes the internal dynamics using a Lyapunov-based scheme. The approach is used to design a nonlinear MIMO voltage and speed regulator for a single machine infinite bus power system.

CCA-ThM4-2 2:20 CCA-616

Robust Load Frequency Controller in a Deregulated Environment: A Mu-Synthesis Approach

Bevrani, Hassan West Regional Electric Co.

An approach based on mu-synthesis tools is proposed for the design of robust load frequency controller for electric power system in deregulated environment. In this paper, we consider the system (area) as a collection of independent generation, transmission and distribution companies and Connections between this area and the rest of the system are taken as disturbances. An example is given to illustrate the proposed approach. The resulting controller is shown to minimize the effect of disturbances and achieve acceptable frequency regulation.

CCA-ThM4-3 2:40 CCA-622

Fuzzy Logic in Voltage and Reactive Power Control in Power Systems

Ekel, P.Ya.,
Terra, L.D.B.,
Junges, M.F.D. Catholic Univ. of Minas Gerais
de Oliveira, F.J.A.,
Kowaltschuck, R.,
Taguti, T.Y. Parana State Energy Co.

This paper presents results of research aimed at improving efficiency of coordinated on-line control of system voltage and reactive power on the basis of developing models, methods, and a control system, integrating traditional numerical techniques with fuzzy logic technology. An approach associated with experimental design is considered to construct diverse types of sensitivity indices, which serve as the basis for multi-attribute evaluating efficiency of control actions and , therefore, for forming rules included in knowledge base. Questions of the construction and tuning of linguistic variables as well as rational implementation of fuzzy logic procedures are discussed.

CCA-ThM4-4 3:00 CCA-628

Stability Analysis of the International Space Station Electrical Power System

Ly, J.H.,
Truong, C. Aerospace Corp.

Two novel and efficient approaches to analyze the stability robustness at the interface between source and loads of a direct current (dc) distributed power system subject to loads that are turned on/off arbitrarily and operating at heavy/light power modes are presented. The first is a rule based algorithm using the Nyquist stability criterion. The second is based on the multivariable stability margin theory. Each of these two approaches provide a different perspective of the dynamic behavior of the system. The first provides classical gain and phase margin. The second addresses the robustness of the system under simultaneous variations in the loadings. Analysis of the stability of the Flight 5A configuration of the International Space Station Electrical Power System (ISS EPS) using the Nyquist criterion is presented.

CCA-ThM4-5 3:20 CCA-634

Robust Control of Gas Generator in a 1.5 MW Gas Turbine Engine

Gomma, H. W.,
Owens, David H. Univ. of Exeter

This paper describes the robust control design of a gas generator engine. A non-linear model of the engine has been developed with in Simulink (1) from details previously presented in reference (2). State space Hinfi control designs are performed using a linearized model to represent the key components in the single loop control configuration. The performance criteria are specified in terms of stability margins, bandwidth and desired response of the engine to large step input. The engine is subject to constraints on its manipulated variable (i.e. the throttle valve angle) which cause integral wind up. The Hinfi design is simplified to a classical proportional-integral (PI) controller. To take a full advantage of the design a techniques so called Utilize Saturation Feedback is used to reduce the effect of the integral windup. The results show that the PI control produces results similar to Hinfi at low speeds but that Hinfi gives better robustness and performance at higher speeds. Non linear simulations with parameter changes support the conclusion that the design is robust.

CCA-ThM4-6 3:40 CCA-640

Unsupervised Neural Network for Fault Detection and Classification in Dynamic Systems

Pei, Xiaoqin,
Chowdhury, Fahmida N. Univ. of Southwestern Louisiana

In this paper, we present recent results of using a Kohonen neural network to detect and classify faults occurring in a dynamic system. The measured outputs from the system are first used in a Kalman filter to generate residual vectors that serve as fault indicators. The idea is that as the residuals are generated they are sent one-by-one to the Kohonen network, both the Kalman filter and the Kohonen network operating on-line in real time. The Kohonen network detects and categorizes the fault, since the residual vectors serve as signatures for different types of faults. The Kohonen network starts with a few pre-designated categories, each category representing a fault type. As more and more residual vectors become available, the Kohonen network opens new categories for residuals that do not have a good enough match with any of the existing categories. The concept is illustrated by an application example that uses actual fault data commercially recorded by the utilities in Texas.

CCA-ThM5 Hau
ABS and Adaptive Control

CCA-ThM5-2 2:20 CCA-646

Adaptive Fuzzy Logic Control of an Anti-Locking Braking System

Kokes, Guy,
Singh, Tarunraj SUNY at Buffalo

Over the last few decades digital computer technology has matured to the point that the engineering world has witnessed a revolution in the way in which mathematical problems are solved. Problems too complex to be solved analytically can now be solved in a feasible manner, by employing a computer system which emulates the human learning and decision-making process. Areas such as neural networks, expert systems, and fuzzy logic systems implement ‘‘human-like’’ capabilities. This work focuses on the design of Adaptive Fuzzy Logic Control of an anti-lock braking system. This controller will never know the exact plant model, but will know input-output relations of the plant (training data). The controller will initially employ a priori training data to control the braking system, but will continue to train on-line while continuously updating confidence parameters and placement of fuzzy sets by employing optimization algorithms. Old data will be slowly forgotten while up-to-date training data are acquired. Thus, changes in road conditions or in the plant itself will be learned.

CCA-ThM5-3 2:40 CCA-652

Hardware-In-The Loop Simulator for ABS/TCS

Lee, Jae-Cheon Keimyung Univ.
Suh, Myung-Won Sung-Kyun-Kwan Univ.

The prevalence of microprocessor-based controllers in automotive systems has greatly increased the need for simulators to validate and test control systems over their full range of operation. This paper introduces PC-based HIL (hardware in the loop) RTS (Real time simulator) for ABS (Anti-Lock Braking system) and TCS (Traction Control System.) The analyses of the commercial ECU (Electronic control Units) and components for ABS/TCS were successfully accomplished by utilizing the HIL simulator in this study. Furthermore, it is expected that the simulator could contribute to developing more advanced vehicle dynamics control systems.

CCA-ThM5-4 3:00 CCA-658

Design of a State Control for a Solid-Coupled Magnetic Levitation Transport System

Groning, Ingolf,
Zickermann, Richard,
Henneberger, Gerhard Aachen Inst. of Tech.

This paper deals with the development and construction of a state control for a solid-coupled magnetic levitation transport

system. It carries a transportation vehicle with a linear homopolar motor. Both systems are supplied by contactless energy transmission. The bearing magnet only needs a simple and cheap track for levitation and guidance. The state control enables the use of a single sided bearing magnet.

CCA-ThM5-5 3:20 CCA-662

Road Friction Estimation Using Adaptive Observer with Periodical Sigma-Modification

Nishira, Hikaru Univ. of Tokyo
Kawabe, Taketoshi Nissan Motor Co.
Shin, Seiichi Univ. of Tokyo

We propose here an adaptive observer for estimation of a road friction coefficient, which is important for vehicle control. The observer needs driving torque and wheel speeds of driven and non-driven wheels as inputs. The road friction coefficient is assumed to be represented by a product of a known function and an unknown parameter to be estimated by an adaptive law. It is shown that non-robust adaptive law can get the true value, if there are no disturbance. However, it diverges when disturbances are added. Periodical σ-modification is proposed here as a robust adaptive law. The estimation robustness against disturbances can be improved with the law. Numerical simulation results are presented to show the effectiveness of the law.

CCA-ThM5-6 CCA-

In the field of vehicle control, conventional cruise control systems have been available on the market for many years. During the last years, modern cars include more and more electronic systems. These systems are often governed by a computer or a network of computers programmed with powerful software. One of those new services is Adaptive Cruise Control (ACC), which extends the conventional cruise control system to include automated car following when the preceding car is driving at a lower speed than the desired set-speed. The focus of ACC has mainly been directed towards high-speed highway application, but to improve the comfort to the driver also low-speed situations must be considered. This paper presents an ACC system that is capable of car following in low-speed situations, e.g. in suburban areas, as well as in high-speed situations. The system is implemented in a test car and the result is evaluated.

CCA-ThM6 Lehua
Robot Control

CCA-ThM6-1 2:00 CCA-668

An Experimental Facility for Nonlinear Robot Control

van Beek, Bert Oce-Tech. B.V.
de Jager, Bram Eindhoven Univ. of Tech.

An experimental facility for evaluating robot controllers is discussed. Highlighted are the motivation for the need of such a system, its design, modeling, construction, and general use. A recently proposed globally stable PID type controller and a passivity based computed torque controller were implemented and some preliminary experimental results are presented. They illustrate the usefulness of this facility.

CCA-ThM6-2 2:20 CCA-674

IMC Design with Limiting Properties of LQR and its Application to Trajectory Tracking Control

Suzuki, R.,
Doi, M.,
Kobayashi, N.,
Furuya, S. Kanazawa Inst. of Tech.

In this paper, a control method for trajectory tracking control is discussed. The control method is derived by the internal model control (IMC) and limiting properties of LQ control. Then the proposed control is applied to trajectory tracking for a two links robot manipulator. Experimental results show that the proposed method is effective on robot trajectory control.

CCA-ThM6-3 2:40 CCA-680

Unfalsified Direct Adaptive Control of a Two-Link Robot Arm

Tsao, Tung-Ching Spectrum Astro, Inc
Safonov, Michael G. Univ. of Southern California

This paper describes an application of unfalsified control theory to the design of an adaptive controller for a nonlinear robot manipulator. A nonlinear ‘computed torque’ control structure is employed. Four parameters representing unknown masses, inertias and other dynamical coefficients are adaptively adjusted in real-time using an linear programming technique to optimally satisfy control-law unfalsification conditions. Simulations show that the method yields significantly more precise and rapid parameter adjustments than conventional continuous parameter update rules, especially when the manipulator arm is subject to sudden random changes in mass or load properties.

CCA-ThM6-4 3:00 CCA-687

Design of Nonlinear Tracking Controllers for Robots

Lyshevski, Sergey E.,
Sinha, A.S.C.,
Rizkalla, Maher Purdue Univ., Indianapolis

This paper reports an innovative synthesis procedure to design nonlinear tracking control algorithms for robotic manipulators. The nonlinear mathematical model is used. It is shown that the offered controller ensures robust tracking and stability. Analytical and numerical studies are performed to design a nonlinear controller and to analyze the manipulator dynamics. An example is given to illustrate the method reported. In particular, the transient dynamics and tracking performance are studied for a two-link robot.

CCA-ThM6-5 3:20 CCA-693

RD500 Manipulator Force Controller Design: A Multiobjective Approach

Folcher, Jean-Pierre École Nat. Superieure de Tech. Avan.
Andriot, Claude Commisariat a l'Energie Atomique

The force control of robot manipulator RD500 is presented. Then, a multiobjective robust controller synthesis approach for LTI systems subject to a passive perturbation is proposed. Finally, the design of a single-joint of the manipulator is performed and numerical experiments demonstrate the effectiveness of the proposed multiobjective approach.

CCA-ThM6-6 3:40 CCA-699

Performance Improvement of Direct Gradient Descent Control for General Nonlinear Systems

Shimizu, K.,
Otsuka, K. Keio Univ.

This paper is concerned with Direct Gradient Descent Control (DGDC) of general nonlinear systems. DGDC manipulates control inputs directly so as to decrease a performance function like the squared error, based on the gradients of the performance function and the steepest descent method. We propose several methods to improve performances of DGDC. Convergence speed and asymptotically stability of DGDC are improved by two approaches. The first one is to consider time derivative of the performance function. Namely, to improve the convergence, we modify the DGDC by decreasing both the performance function and its time derivative. The second one is to introduce a new artificial control vector and to consider the extended controller for DGDC such that two kinds of performance function are decreased. Our simulation results with the modified DGDC showed very good performances for various plants.

CCA-ThP1 Koa
Motion and Vibration Control via Command Shaping

CCA-ThP1-1 4:20 CCA-707

Benchmarking Optimal Control Strategies for Flexible Systems

Reynolds, Michael C.,
Meckl, Peter H. Purdue Univ.

With so many command shaping methods available, there is a need for benchmarking so that the contributions and performance of a particular input can be assessed. This paper develops a closed-form solution for the move plus settling time of a rigid body input when applied to a flexible system with damping. The rigid body solution creates an upper and lower bound on most feasible solutions for systems with actuator constraints. This paper describes the usefulness and importance of benchmarking using the rigid body solution as well as other inputs.

CCA-ThP1-2 4:40 CCA-713

An Expert System for the Design of Input Shapers

French, Lila Massachusetts Inst. of Tech.
Singhose, William Georgia Inst. of Tech.
Seering, Warren Massachusetts Inst. of Tech.

Input shaping is a command generation technique that reduces vibration by convolving a sequence of impulses, known as the input shaper, with any desired system command. The success of the approach depends on the characteristics of the input shaper. Numerous shapers have been proposed, each with unique properties. The selection of an input shaper for any given system has generally relied to some degree on the knowledge of an expert. An expert system has been developed in an attempt to capture the expertise involved in input shaper design. Furthermore, the design of the input shaper can be refined if the system response is fed back into the expert system.

CCA-ThP1-3 5:00 CCA-719

Comparison of Command Shaping Controllers for Suppressing Payload Sway in a Rotary Boom Crane

Lewis, Derek Seagate Tech.
Parker, Gordon G. Michigan Tech. Univ.
Driessen, Brian,
Robinett, Rush D. Sandia Nat. Lab.

This paper presents the simulation results for two variations on a basic command shaping filter designed to reduce operator induced pendulation in a rotary boom crane. The crane model and the basic command shaper design are based on a previous paper [1], which consists of a fixed vertical support, a boom capable of rotating about the vertical and elevating with respect to the horizontal, and a lift-line of variable length which sways about the boom tip in a spherical pendulum. The command shaper adapts to changes in the crane configuration and notches out the pendulation frequency, reducing pendulation. The two alternate designs contain additional time-varying elements to improve anti-sway performance. Command shaper stability is studied via conditions for slowly time-varying systems developed by Charles Desoer [2]. Stability is evaluated for the analytic models and verified with numerical simulation results.

CCA-ThP1-4 5:20 CCA-1774

Command Shaping Boom Crane Control System with Nonlinear Inputs

Parker, Gordon G. Michigan Tech. Univ.
Groom, Kenneth,
Hurtado, Johnny,
Robinett, Rush D. Sandia Nat. Lab.
Leban, Frank Naval Surface Warfare Cen.

This paper presents the application of a command shaping control method for suppressing payload swing caused by operator commanded maneuvers, in rotary, ship-based, boom cranes. The crane configuration investigated, consists of a payload mass that swings on the end of a spherical pendulum of varying lift-line length (hoisting). The lift-line is attached to a boom capable of elevation (luffing) and rotation about a vertical axis (slewing). Positioning of the payload is accomplished through luff, slew and hoist commands issued in real-time by an operator, Payload oscillation is excited by a nonlinear combination of the operator's inputs. It is shown that linear filters are sufficient under certain conditions. The command shaping strategy, consisting of a time-varying filter, reduces payload oscillation by 18 dB in experiments using the 1/16th scale Navy Crane Testbed at Sandia National Laboratories.

CCA-ThP1-5 5:40 CCA-725

Achieving Fast Motions in Semiconductor Manufacturing Machinery

Meckl, Peter H. Purdue Univ.
Umemoto, Kazunobu NEC Corp.

Many manufacturing devices must execute motions as quickly as possible to achieve profitable high-volume production. This paper develops shaped torque inputs that minimize move time while avoiding overshoot and oscillation. These inputs are applied to an actual semiconductor manufacturing machine, utilizing both feedforward and feedback strategies for

minimizing the degree of vibration generated during fast motions.

CCA-ThP2 Milo
Control of Magnetic Bearings and Steppers

CCA-ThP2-2 4:40 CCA-737
Elimination of Imbalance Vibrations in Magnetic Bearing Systems Using Discrete-Time Gain-Scheduled Q-Parameterization Controllers
Mohamed, Abdelfatah,
Hassan, Ikbal M.M.,
Hashem, Adel M.K. Assiut Univ.

In this paper we propose a method to eliminate the imbalance vibrations in magnetic bearing systems using discrete-time gain-scheduled Q-parameterization controllers. Imbalance in rotating machines generates variable frequencies sinusoidal disturbance forces that cause the vibrations. Since the frequency of vibrations equals the rotational speed, the free parameter Q of the Q-parameterization controllers is scheduled as a function of the rotational speed to achieve rejection of the imbalance sinusoidal disturbance forces at all operating speeds. First we present a mathematical model for the magnetic bearing in state space from which includes the effect of imbalance. Second, we explain the discrete-time Q-parameterization controller design for the magnetic bearing to achieve robust stability and rejection of the variable frequencies sinusoidal disturbance forces. The free parameter Q is assumed to be a second order proper stable transfer function whose denominator parameters are fixed and the numerator parameters are scheduled as second order polynomial functions of the rotational speed such that rejection of the imbalance sinusoidal disturbance is achieved. Finally several simulation results are presented. The results showed that elimination of the imbalance vibrations are achieved at all operating speeds, moreover robust stability is also achieved.

CCA-ThP2-4 5:20 CCA-749
Direct Closed-Loop Identification of Magnetic Suspension System
Sun, Lianming,
Ohmori, Hiromitsu,
Sano, Akira Keio Univ.

A new direct closed-loop identification method only using the plant input/output data acquired through an output inter-sampling scheme is presented in this paper. By taking the faster sampling of the system output than the control interval, we can clarify that the inter-sampled plant model can also be described by a SIMO model structure, which can provide the identifiability of the closed-loop. One of the advantages is that the proposed identification method using the inter-sampled output observations can remove the ordinary restrictive identifiability condition, and it is not required that the reference input holds the persistently exciting (PE) property. Its effectiveness is demonstrated through an experimental study using a magnetic suspension system.

CCA-ThP2-5 5:40 CCA-755
Nonlinear Output Feedback Control for Stepper Motors: A Robust Adaptive Approach
Melkote, Hemant,
Khorrami, Farshad Pol. Univ.

Nonlinear adaptive output feedback control of stepper motors is considered in this paper. Utilizing the phase currents as inputs, an adaptive controller is derived for permanent magnet (PM) and variable reluctance (VR) stepper motors that achieves robustness to parametric and dynamic uncertainties such as friction, load torque or cogging torque in the motor dynamics. The controller utilizes only the rotor position for feedback and achieves global uniform boundedness of the tracking error. The design methodology is based on our earlier work on robust adaptive control of nonlinear systems. The stability of the system is proved through Lyapunov techniques. Simulation results are depicted to illustrate the performance of the controller.

CCA-ThP3 Mauka
Control of Semiconductor Manufacturing Processes

CCA-ThP3-1 4:20 CCA-761
Control of a III-V Epitaxial MOCVD Process Using Ultraviolet Absorption Concentration Monitoring
Gaffney Flynn, Monique S. Litton Guid. & Cont. Sys.
Smith, Roy,
Abraham, Patrick,
DenBaars, Steven P. Univ. of California, Santa Barbara

Metalorganic chemical vapor deposition (MOCVD) is a promising technology for the growth of epitaxial semiconductors. It has traditionally lacked real-time growth monitoring and control, which limits the precise reproducibility needed for high performance devices. Two complementary control approaches are investigated experimentally. The first is a feedforward disturbance rejection strategy using ultrasonic concentration measurements to reject source gas bubbler disturbances. The second is a feedback system using an ultraviolet (UV) absorption sensor for real-time monitoring of reaction chamber gas concentrations. Post-growth X-ray analysis of InP/GaInAs superlattice test devices is used to evaluate control system performance.

CCA-ThP3-2 4:40 CCA-767
Piloting Epitaxy through Ellipsometric Feedback
Warnick, Sean C.,
Dahleh, Munther A. Massachusetts Inst. of Tech.

This research explores the synthesis of feedback controllers for gas-source molecular beam epitaxy, and related processes, using spectroscopic ellipsometry as a sensor technology. The objective in these processes is to deposit a spatially uniform film that has certain properties with respect to thickness. We approach this objective of synchronizing film properties with thickness as a relaxation of tracking with a natural separation in the feedback design. This paper surveys some of the key issues associated with the modeling, tracking, and synchronization of this system. Simulations indicate previously ungrowable structures, such as quaternary films with arbitrary graded compositions, can be realized..

CCA-ThP3-3 5:00 CCA-773

Real-Time Estimation of Patterned Wafer Parameters Using In-Situ Spectroscopic Ellipsometry

Galarza, Cecilia G.,
Khargonekar, Pramod P.,
Terry, Jr, Fred L. Univ. of Michigan

We analyze the problem of real-time thickness estimation for patterned wafers during an etching process using in situ spectroscopic ellipsometry. For that, a two-stage estimation algorithm is proposed. The first stage is an automatic model calibration algorithm that uses the data collected during an initial interval. The second stage is a nonlinear state estimation system designed for the tuned model. We study the sensitivity of this estimation strategy to variations in the wafer parameters and the process conditions

CCA-ThP3-4 5:20 CCA-779

Real-Time Plasma Etch Control Using In-Situ Sensors and Neural Networks

Stokes, David,
May, Gary S. Georgia Inst. of Tech.

Consistent demands on semiconductor manufacturers to produce circuits with increased density and complexity have made stringent process control an issue of growing importance in the industry. Recent work has shown that neural networks offer great promise in modeling complex fabrication processes such as reactive ion etching (RIE). Motivated by these results, this paper explores the use of neural networks for real-time, model-based feedback control of RIE. This objective is accomplished in part by constructing a predictive model for the system, which can be inverted (or approximately inverted) to achieve the desired control. The efficacy of this approach is demonstrated using experimental data from a SiO2 etch process to simulate real-time control of etch rate, uniformity, selectivity, and anisotropy. In addition, using a residual gas analysis system as a sensor, the approach is further demonstrated using actual experimental data acquired during the etch of a GaAs/AlGaAs metal-semiconductor-metal structure. In the latter case, real-time control of the etch rate of the constituent materials is investigated.

CCA-ThP3-5 5:40 CCA-784

Micro-Sensor Arrays for Calibration, Control, and Monitoring of Semiconductor Manufacturing Processes

Fisher, Darin,
Freed, Mason,
Spanos, Costas,
Poolla, Kameshwar Univ. of California, Berkeley

In this paper we first motivate the use of autonomous micro-sensor arrays for use in semiconductor manufacturing. Following this, we discuss three critical issues that must be addressed in order to realize our goal of building these micro-sensor arrays. We then describe our on-going development efforts of fabricating spatially resolved etch-rate and temperature sensors.

CCA-ThP3-6 6:00 CCA-789

Interprocess Run-To-Run Feedforward Control for Wafer Patterning

Wagner, Aaron B. Univ. of Michigan
Ruegsegger, Steven M. IBM
Freudenberg, James S.,
Grimard, Dennis S. Univ. of Michigan

We consider run-to-run feedforward control from lithography to etch in wafer patterning. Under feedforward control, measured deviations in photoresist line width are corrected automatically by adjustment of etch bias. Two potential problems with feedforward control are listed: (1) the possibility of feeding measurement noise forward exists and could result in increased final CD variability, and (2) it may be difficult to adjust etch bias without disturbing other important etch characteristics. First, a controller design that addresses concern (1) is considered. Models of the lithography and measurement errors along with minimum mean square error estimation are employed to reduce the chances of acting on erroneous measurements. Building on the first, a second controller is then designed to address concern (2). The controller selects a recipe from a pre-qualified set rather than making arbitrary etch adjustments. It is assumed the recipes in the set provide a means for adjusting etch bias while guaranteeing acceptable results for other characteristics. Both controllers are simulated using industrial data.

CCA-ThP4 Makai
Power Systems Control II

CCA-ThP4-1 4:20 CCA-796

Emulating Large, Time Varying Rotary Power Loads At Low Cost

McInroy, John E.,
Legowski, S.F.,
Morris, C.M.,
Muknahallipatna, S.,
Bershinsky, V. Univ. of Wyoming

A high performance, high power dynamometer system is proposed. By using a field controlled DC generator (rather than a DC motor) 10-200 HP, high bandwidth loads can be accurately emulated. The implementation is both economical to build and to operate. Because power loads are sometimes needed (for instance, they are required when testing motor efficiency), the approach emulates power loads, rather than the commonly emulated torque loads. By emphasizing only the pertinent dynamics, a simplified model appropriate for control is found, but the model is still nonlinear and parameter dependent. A linearizing control which also measures parameter changes without the need for specialized instruments is proposed. The control applies to machines which maintain nearly a constant velocity over large loads, so it is appropriate for induction motors, synchronous motors, etc. Experimental tests using both standardized motor efficiency trajectories and power measurements from an oilfield pumpjack confirm the system's ability to respond as quickly and as accurately as the best methods previously proposed, but at a fraction of the implementation and operational costs.

CCA-ThP4-2 4:40 CCA-802

Robust Controller Design for Simultaneous Control of Throttle Pressure and Megawatt Output in a Power Plant Unit

Zhao, Haipeng — Univ. of Illinois at Urbana-Champagn
Li, Wei — Univ. of Illinois, Urbana-Champaign
Taft, Cyrus — EPRI I&C Cen.
Bentsman, Joseph — Univ. of Illinois, Urbana-Champaign

This paper presents an application of H_infinity and mu-synthesis controller design methods to a coal-fired power generation unit and compares the closed loop performance and robustness of H_infty and mu-synthesis control laws with those of an H_2 control law. All three controller synthesis procedures are applied to a two-input two-output plant model which has time delay, differential part, colored noise output disturbance, and sensor noise disturbance. Application of the procedures to the model shows that when the shape of the closed loop control signals of all three designs is closely matched, in the low frequency range the mu-synthesis and H_infinity control laws have robustness much better than that of H_2 control law, while providing adequate robustness in the high frequency range. H_infinity control law gives the best performance, and H_2 - the worst of the three designs, exhibiting the largest overshoot. The balancing procedure permits significant reduction of the order of the controllers without degradation in performance and robustness. The comparative evaluation of three designs shows that in power plant control problem H_infinity and mu-synthesis designs provide much more consistent and convenient performance/robustness trade-off than H_2 design.

CCA-ThP4-3 5:00 CCA-808

Nonlinear and Linear Robust Control of Switching Power Converters

Bevrani, Hassan — West Regional Electric Co.
Abrishamchian, M.,
Sarari-shad, N. — K.N. Toosi Univ. of Tech.

Switching power converters are nonlinear and time variant systems. The classical controller design for a switching power converter based on the linear model derived by one of conventional modeling methods. However, the parameter and load variations and input unregulated voltage are not taken into consideration simultaneously in a controller design. In this paper, we use input-output feedback linearization technique for nonlinear control issue, and Kharitonov, H_infi and mu-synthesis techniques for robust control issue to design of nonlinear and linear robust controllers to access both satisfactory stability and satisfactory performance, even in case of uncertainties and disturbances, for typical fifth-order DC-DC switching power converter. The stability and performance of the converter and the effectiveness of the proposed controllers are demonstrated by some simulated results. Making use of simulation results, varies comparisons between these controllers and a variety of other controllers are then made, exhibiting the high efficiency of these methods compared to conventional methods.

CCA-ThP4-4 5:20 CCA-814

Nonlinear Variable Speed Control of Wind Turbines

Song, Y.D.,
Dhinakaran, B. — North Carolina A&T State Univ.

While variable speed operation of wind turbines has several advantages, it poses difficult challenges to the design of control system. The purpose of this work is to present a nonlinear variable speed control method for wind turbines. This method is based on the regulation of excitation winding voltage of the generator. Based on both mechanical and electrical dynamics, a nonlinear control algorithm is derived which is able to achieve smooth and asymptotic rotor speed tracking. The effectiveness of the method is verified via computer simulation with varying operating conditions.

CCA-ThP4-5 5:40 CCA-820

Reduced-Order Estimation of Power System Harmonics Using Set Theory

Andreou, Spyros,
Yaz, Edwin E.,
Olejniczak, Kraig J. — Univ. of Arkansas
Yaz, Yvonne Iike — Centenary College

In this work, we consider state estimation of harmonic signals with time-varying magnitudes. Presence of such signals has been increasing in electric power systems due to the increased use of power electronics circuits possessing nonlinear voltage vs. current characteristics. In this work, harmonic signals are modelled using ellipsoidal set-theoretic methods and an optimal reduced-order estimator, which has one-half the dimension of the state vector, is introduced for predicting the unknown time-varying harmonic magnitudes. The optimality is in the sense of minimizing both the sum of the lengths of the principal axes and the volume of the ellipsoid for estimation error. This new estimator is compared with a full-order set-theoretic estimator in an example where each frequency component has a randomly changing magnitude.

CCA-ThP4-6 6:00 CCA-826

Optimization-Based Tuning and Coordination of Flexible Damping Controllers for Bulk Power Systems

Kamwa, I. — Inst. de Recherche d'Hydro-Quebec
Trudel, G.,
Lefebvre, D. — TransEnergie, Hydro-Quebec

This paper proposes a simultaneous tuning approach for power system damping controllers which seems better able than current SISO-based methods to cope with the foreseeable increase in system complexity and adverse interactions. To tackle the most difficult situations, the retained control architecture comprises several degrees-of-freedom in terms of dynamic feedback loops, each consisting of a high-order differential filter. The tuning of these flexible controllers is then performed by minimizing a selective modal performance index in the parameter space. Adding stability and robustness constraints greatly improves the engineering significance of the resulting design. Three examples adapted from the literature are used for illustration: a robust power system stabilizer (PSS) for a single-machine infinite-bus system with multiple operating points, a thyristor-controlled series capacitor (TCSC) controller for a large power system, and a coordinated

design of multiple PSSs for a two-area/four-machine test system.

CCA-ThP5 Hau
Automotive Control

CCA-ThP5-1 4:20 CCA-833
Optimization of Complex Powertrain Systems for Fuel Economy and Emissions
Kolmanovsky, Ilya,
van Nieuwstadt, Michiel,
Sun, Jing Ford Res. Lab.

Stringent emission regulations combined with customer demands for improved fuel economy and performance have forced the automotive industry to consider more advanced powertrain configurations than standard port-fuel injected gasoline engines. Modern state-of-the-art powertrain systems may combine several power sources (internal combustion engines, electric motors, fuel cells, etc.) and various exhaust after treatment devices (catalytic converters, lean NOx traps, particulate filters, etc.) in addition to conventional engine subsystems such as turbochargers and exhaust gas recirculation. The determination of the way in which these systems need be operated to meet driver's torque demand, performance and fuel economy expectations while satisfying federal emission regulations is a complex and a multiobjective optimal control problem. This paper reviews some of the approaches to this problem in the context of two case studies.

CCA-ThP5-2 4:40 CCA-840
Diesel-Electric Drivetrains for Hybrid-Electric Vehicles: New Challenging Problems in Multivariable Analysis and Control
Lyshevski, Sergey E. Purdue Univ., Indianapolis

Our goal is to develop a complete mathematical model to perform nonlinear analysis and design for multivariable diesel-electric drivetrains. l This allows one to study energy conversion needed to perform sophisticated analysis of hybrid-electric vehicle performance (driveability and controllability, maneuverability and agility), efficiency, fuel economy and exhaust emission, etc. The full spectrum of the physical phenomena of interconnected energy conversion processes in diesel and electric machines are studied in the contest of multivariable nonlinear analysis, optimization and control. Using a set of differential equations derived, which maps the steady-state and dynamic behaviour of high-performance diesel-electric powertrains, an optimal energy management system is designed and tested.

CCA-ThP5-3 5:00 CCA-846
Automation Concept for a New Dynamical Engine Test Stand
Schmidt, Martin,
Kessel, Jens-Achim Darmstadt Univ. of Tech.

Dynamical Engine Test Stands are an important tool for the development and optimization of internal combustion (IC) engines. This paper deals with the automation concept for a new dynamical engine test stand considering the graphical user interface, the hard- and software structure, the simulation models for vehicle and driver, and the modes of operation.

CCA-ThP5-4 5:20 CCA-852
Intake Oxygen Concentration Estimation for DI Diesel Engines
Diop, Sette Lab. des Signaux & Systemes
Moraal, Paul E. Ford Motor Co.
Kolmanovsky, Ilya,
van Nieuwstadt, Michiel Ford Res. Lab.

In order to reduce emissions and improve performance of internal combustion engines, it is desirable to know the oxygen concentration of the gas inducted into the engine so that the appropriate amount of fuel can be injected. This is especially true for diesel engines in which up to 50% of the exhaust gas is recirculated back into the engine. This work presents an estimation algorithm for the oxygen concentration in the intake manifold of a turbocharged diesel engine. The only quantities needed for the estimation scheme are boost pressure, fueling rate, engine speed, and EGR valve lift, all of which are generally known to the engine control unit. This estimator is a first order linear dynamic model (with time varying coefficients) and asymptotically stable. Due to the unobservability of the oxygen concentration model, the speed of convergence of the estimation scheme is fixed by engine parameters, but is as fast as the phenomenon of mixing of the exhaust gas recirculated with the air in the intake manifold. Simulation studies show the effectiveness of the proposed estimator.

CCA-ThP5-5 5:40 CCA-858
Nonlinear Analysis and Control of Turbocharged Diesels
Lyshevski, Sergey E.,
Sinha, A.S.C. Purdue Univ., Indianapolis
Seger, J.P. Cummins Engine Co., Inc.

The major objectives of this paper are to analyze and model, control and optimize advanced diesels with optimal electronic fuel systems in order to improve fuel economy and reduce emission, guarantee the desired performance and increase service life, etc. Using a nonlinear mathematical model developed, a spectrum of problems in nonlinear analysis, control, and optimization are solved. In particular, using a complete mathematical model, the torque production features are studied. To inject the fuel into the cylinders, advanced fuel systems should be used to guarantee a spectrum of requirements to optimize the diesel performance. Thorough analytical results are performed, and novel control algorithms are designed and tested.

CCA-ThP6 Lehua
Robot Manipulators

CCA-ThP6-1 4:20 CCA-863
Lyapunov Recursive Design of Robust Tracking Control with L2-Gain Performance for Electrically-Driven Robot Manipulators
Ishii, Chiharu Ashikaga Inst. of Tech.
Shen, Tielong Sophia Univ.
Qu, Zhihua Univ. of Central Florida

This paper develops a new Lyapunov recursive design for the tracking control problem of rigid-link electrically-driven robot manipulators with uncertainty. The novelty is in the strategy to construct such a Lyapunov function recursively that ensures not only stability of a tracking error system but also an L2-gain constraint for the tracking performance. First, torque level control input to achieve tracking control is applied for manipulator loop, and filtered tracking error system is derived. The penalty signal for tracking error between the outputs of the manipulator and desired trajectories is introduced and the tracking performance is evaluated by L2-gain from torque level disturbance signal to the penalty signal. Finally, voltage level control law is designed recursively such that the closed-loop error system is globally stable in the sense of uniform ultimate bounded stability with the L2-gain less than any given small level. Simulation works were carried out for tracking control of a two-link electrically-driven manipulator. The results show the effectiveness of the proposed control scheme.

CCA-ThP6-2 4:40 CCA-869

Decentralized Control of Cooperative Manipulators Based on Virtual Force Transmission Algorithm

Itoh, Masanao,
Murakami, Toshiyuki,
Ohnishi, Kouhei Keio Univ.

This paper describes a novel approach to control the cooperative manipulators in the grasping motion. In this method, first, the grasping force and accelerating force are calculated at the end-effectors. Then the impedance controller is adopted to calculate the force. Second, the force is resolved from tip to base link so that the rotational force is changed into the torque and the others are given to the next joint. This means that the force is transmitted among joints step by step, and the desired tasks are realized asymptotically. Final, the work space observer is adopted so that the error is corrected in the tip motion response. Using this method, it is possible to realize decentralized control of plural and cooperative manipulators and the control structure is simplified. The proposed method is confirmed by several simulations and experiments.

CCA-ThP6-3 5:00 CCA-875

Robust Adaptive Friction Compensation for Tracking Control of Robots

Tomei, Patrizio Univ. of Roma

The tracing problem is considered for robot manipulators with unknown parameters and dynamic friction, in the presence of bounded disturbances and /or modeling uncertainties. We design a robust adaptive control algorithm which guarantees arbitrary disturbance attenuation. If the disturbances belong to L2, asymptotic tracking is also achieved.

CCA-ThP6-4 5:20 CCA-881

Robust Output Feedback Control of Robot Manipulators Using High-Gain Observer

Shin, Eui Seok,
Lee, Kang Woong Hankuk Aviation Univ.

In this paper, we design a robust output feedback controller for trajectory control of n-link robot manipulators with bounded parametric uncertainties. The state feedback controller with integral control improves tracking error due to limit of the robust feedback gains and use of continuous control input for chattering rejection. High-gain observer is used to estimate joint velocities. We show that the stability of the state feedback control system is asymptotically stable and the output feedback controller recovers the performance achieved under the state feedback controller. The performance of the proposed method is demonstrated by simulation on a 2-link robot manipulator.

CCA-ThP6-5 5:40 CCA-887

An Approach to Robust Hierarchical Impedance Control in Redundant Manipulator

Ishii, Kunihiko,
Fujimoto, Yasutaka,
Murakami, Toshiyuki,
Ohnishi, Kouhei Keio Univ.

In case the sophisticated use of robots is considered, it is preferable that the robot has intelligent and flexible abilities according to the environmental variation. Also the easy expansion of the system structure is required. Then the conventional centralized approaches are strictly limited to construct the controller because the system expansion is difficult without the complicated calculation and procedure. To improve the above issue, this paper proposes a hierarchical structure of the controller based on virtual impedance. The validity of the proposed strategy is confirmed by several numerical results.