MED99

Sessions

MA1
Optimal Control: $H_\infty/H_2/\ell_1$

Chair: *Rotstein, Héctor* — RAFAEL — ADA
Co-chair: *Bar-Gil, Aharon* — RAFAEL — ADA

A combined QFT/H_∞ Design Technique for TDOF Uncertain Feedback Systems

Sidi, Marcel — Center of Technological Education, Holon

Computation of ℓ_1 Optimal Controllers using H_2 Projections

Rotstein, Héctor — RAFAEL — ADA & Technion — IIT
Desages, Alfredo — Univ. Nacional del Sur

(J, J^0)-dissipative matrices and singular H_∞ control

Baramov, Lubomír — Univ. of Southampton

On the Existence of Nash Equilibrium Solution for Mixed H_2/H_∞ Control

Florentino, Helenice O. — UNESP, Botucatu
Sales, Roberto M. — USP, São Paulo

SVD H^∞ Controller Design for an Active Horizontal Spray Boom Suspension

Anthonis, Jan — K.U.Leuven
Ramon, Herman — K.U.Leuven

A Linear Matrix Inequality Approach towards H_∞ Control of Descriptor Systems

Rehm, Ansgar — Univ. of Stuttgart
Allgöwer, Frank — ETH Zürich

MA2
Discrete Events and Hybrid Systems

Chair: *Antsaklis, Panos J.* — Univ. of Notre Dame
Co-chair: *Colantonio, M. C.* — Imperial College

On Readily Available Supervisory Control Policies that Enforce Liveness in a Class of Completely Controlled Petri Nets

Sreenivas, Ramavarapu S. — Univ. of Illinois at Urbana-Ch.

Firing Sequences Estimation for Timed Petri Nets

Lefebvre, Dimitri — Univ. de Technologie de Belfort

Short and Long-term Scheduling in Semiconductor Manufacturing

Colantonio, M. C. — Imperial College
Papageorgiou, L. — University College London
Shah, N. — Imperial College

Hybrid Control of a Robotic Manufacturing System

Koutsoukos, Xenofon D. — Univ. of Notre Dame
Antsaklis, Panos J. — Univ. of Notre Dame

Discrete-Event State Equations and Petri Nets

Canuto, Enrico — Politecnico di Torino
Balduzzi, Fabio — Politecnico di Torino

Stabilizing a Linear System with Finite-State Hybrid Output Feedback

Liberzon, Daniel — Yale Univ.

MA3 (I)
Automotive Control and Energy Conversion Systems

Organizer: *Rizzo, Gianfranco* — Univ. of Salerno
Chair: *Rizzo, Gianfranco* — Univ. of Salerno
Co-chair: *Dambrosio, Lorenzo* — Polytechnic of Bari

Identification of Manifold Two-Phase Fuel Flow Model in a Spark Ignition Engine with Kalman Filter and Least Square Methods

Arsie, I. — Univ. di Salerno
Pianese, C. — Univ. di Salerno
Rizzo, Gianfranco — Univ. di Salerno

Optimal Idle Speed Control with Induction-to-Power Finite Delay for SI Engines

Glielmo, Luigi — Univ. di Napoli Federico II
Santini, Stefania — Univ. di Napoli Federico II
Serra, Gabriele — Magneti Marelli Engine Control Div.

Estimator-Based Adaptive Fuzzy Logic Control Technique for a Wind Turbine-Induction Generator System

Dadone, Andrea — Politecnico di Bari
Dambrosio, Lorenzo — Politecnico di Bari

Active Suspension Control of Ground Vehicle Heave and Pitch Motions

Campos, Javier — The Univ. of Texas at Arlington
Davis, Leo — Davis Technologies Int., Inc.
Lewis, Frank L. — The Univ. of Texas at Arlington
Ikenaga, Scott — The Univ. of Texas at Arlington
Evans, Mark — Davis Technologies Int., Inc.

An Object-Oriented Modular Simulation Model for Integrated Gasoline Engine and Automatic Transmission Control

Hong, Keum-Shik — Pusan National Univ.
Yang, Kyung-Jinn — Pusan National Univ.

A Comprehensive Model for ICE Oriented to the Electronic Control of the Injection

Anatone, Michele Univ. of L'Aquila
Carapellucci, Roberto Univ. of L'Aquila
Cipollone, Roberto Univ. of L'Aquila
Sciarretta, Antonio Univ. of L'Aquila

MA4
Linear Systems 1

Chair: *Yaniv, Oded* — Tel-Aviv Univ.
Co-chair: *Kaczorek, Tadeusz* — Warsaw Univ. of Technology

Stable Inversion of MIMO Linear Discrete Time Non-Minimum Phase Systems

George, Koshy — Delft Univ. of Technology
Verhaegen, Michel — Delft Univ. of Technology
Scherpen, Jacquelien M.A. — Delft Univ. of Technology

State Space and Internal Models in Discrete-time LQ Regulator Design

Gessing, Ryszard — Politechnika Śląska

Modified Internal Model Control for Unstable Systems

Yamada, Kou — Yamagata Univ.

The Wiener-Hopf Standard Control Problem: A Stable Fractional Approach

Xie, Li — Univ. of Posts and Telecom.
Xue, Dingyü — Northeastern Univ.

Reduction of Singular 2D Models to Equivalent Standard Models

Kaczorek, Tadeusz — Warsaw Univ. of Technology

Some New Results in Theory of Controllability

Bashirov, Agamirza — Eastern Mediterranean Univ.
Mahmudov, Nazim — Eastern Mediterranean Univ.

MA5
Adaptive Control 1

Chair: *Kosut, Robert* — SC Solutions Inc.
Co-chair: *Pait, Felipe M.* — Univ. de Sao Paulo

Iterative Adaptive (Unfalsified) Control
Kosut, Robert — SC Solutions Inc.

On the Design of Direct Adaptive Controllers
Pait, Felipe M. — Univ. de São Paulo

Tuning via Measurements of the Squared Error
Pait, Felipe M. — Univ. de São Paulo

Adaptive Generalized Predictive Control Subject to Input Constraints
Królikowski, Andrzej — Technical Univ. of Poznań

Decentralized Adaptive Controller with Zero Residual Tracking Errors
Mirkin, Boris M. — Academy of Sc. of Kyrgyz Republic

Advanced Adaptive Control for Complex Nonlinear Processes
Constantin, Nicolae — Univ. Politehnica of Bucharest
Dumitrache, Ion — Univ. Politehnica of Bucharest

MM1
Optimization Methods

Chair: *Rusnak, Ilan* — RAFAEL — ADA
Co-chair: *Guez, Allon* — Drexel Univ.

PI Controller Tuning via Multiobjective Optimization

Kookos, I. K. — Imperial College
Arvanitis, K. G. — National Tech. Univ. of Athens
Kalogeropoulos, G. — Univ. of Athens

Decomposition-Coordinated Optimization of Large-Scale Discrete Systems with Parallel-Sequential Coordinated Scheme

Lychenko, Nataly M. — Academy of Sc. of Kyrgyz Republic

Generalized PID Controller

Rusnak, Ilan — RAFAEL — ADA

Lagrange Problem for Non-Standard Nonlinear Singularly Perturbed Systems

Fridman, Emilia — Tel-Aviv Univ.

Optimization for Part Nesting and Layout Using a Distributed SPMD Architecture

Wetstein, Joseph P. — Drexel Univ.
Guez, Allon — Drexel Univ.

Computing Resources Dynamic Optimization of Digital Multichannel Control Systems

Frid, Arkadi I. — Ufa Aviation Technical Univ.
Enikeev, Adel K. — Ufa Aviation Technical Univ.
Novikov, Boris A. — Ufa Aviation Technical Univ.

MM2
Inteligent Control and Neural Networks

Chair: *Taylor, James H.* — Univ. of New Brunswick
Co-chair: *Anghelea, Marius* — Univ. of Gent

The Basic Ideas of Neural Predictive Control

Schnitman, Leizer — Aeronautics Inst. of Technology
Fontes, Adhemar de B. — Bahia Federal Univ.

A Rule-Based Neuro-Optimal Controller for Nonlinear MIMO Systems

Tuncay, Serhat — Middle East Technical Univ.
Leblebicioglu, Kemal — Middle East Technical Univ.
Ozgen, Canan — Middle East Technical Univ.
Halici, Ugur — Middle East Technical Univ.

Neural Network Based Softsensor for a Tubular Reactor

Anghelea, Marius — Univ. of Gent
Declercq, Filip — Univ. of Gent
De Keyser, Robin — Univ. of Gent
Decoster, Martin — EXXON Chemical Comp.

An Expert-Aided Implementation Interface for Industrial Process Control Systems

Taylor, James H. — Univ. of New Brunswick
Chan, Cheney — Univ. of New Brunswick

A Self-Organizing Neurocontroller for Vibration Suppression

Moshou, Dimitrios — K.U.Leuven
Anthonis, Jan — K.U.Leuven
Jancsók, Pál — K.U.Leuven
Ramon, Herman — K.U.Leuven

MM3
Control Applications

Chair: *Hong, Keum-Shik* — Pusan National Univ.
Co-chair: *Dayan, Yehoshua* — Technion — IIT

A New Modeling of the Macpherson Suspension System and its Optimal Pole-Placement Control

Hong, Keum-Shik — Pusan National Univ.
Jeon, Dong-Sub — Pusan National Univ.
Sohn, Hyun-Chull — Pusan National Univ.

A Numerical Algorithm for the Design of a Decentralized Controller for Open-Channel Networks

Seatzu, Carla — Univ. of Cagliari

Flight Control Design for a Missile: An Approximate Feedback Linearization Approach

Tsourdos, Antonios — Cranfield Univ.
Blumel, Anna L. — Cranfield Univ.
White, Brian A. — Cranfield Univ.

Robust Quasi NID Current and Flux Control of an Induction Motor for Position Control

van Duijnhoven, Marc — Eindhoven Technical Univ.
Błachuta, Marian J. — Silesian Technical Univ.

Contact Elimination in Mechanical Face Seals Using Active Control

Dayan, Joshua — Technion — IIT
Zou, Min — Seagate
Green, Itzhak — Georgia Tech

Design, Simulation & Control of a Segmented Reflector Test-bed

Morales, Mauricio — California State Univ., LA
Mirmirani, Majdedin — California State Univ., LA
Boussalis, Helen — California State Univ., LA

MM4
Linear Systems 2

Chair: *Kučera, Vladimír* — Trnka Lab. & ÚTIA
Co-chair: *Ferreira, Pedro M. G.* — PUC-Rio

Generalized Versions of Bode's Theorem

Gera, Amos E. — Elta

On a Conjecture and the Internal Model

Ferreira, Pedro M. G. — PUC-Rio

Reliable Computation of the Input-State-Output Relations in Autoregressive Representations of Multivariable Systems

Kraffer, Ferdinand — Inst. of Inf. Theory and Automation

The Suboptimal Tracking Problem in Linear Systems

Dostal, Petr — Technical Univ. Brno
Bobal, Vladimir — Technical Univ. Brno

Margins and Bandwidth Limitations of NMP SISO Feedback Systems

Sidi, Marcel — Center of Technological Education, Holon
Yaniv, Oded — Tel-Aviv Univ.

Reachability and Controllability of Positive Linear Systems with State Feedbacks

Kaczorek, Tadeusz — Warsaw Univ. of Technology

MM5 (I)
Nonlinear Systems Identification in Practice

Organizer: *Sjöberg, Jonas E.* — Chalmers Univ. of Technology
Chair: *Sjöberg, Jonas E.* — Chalmers Univ. of Technology
Co-chair: *Gutman, Per-Olof* — Technion — IIT

Adaptive Hybrid Physical/Neural Network Modeling and its Application to Greenhouse Climate Optimization

Linker, Raphael — Technion — IIT
Seginer, Ido — Technion — IIT
Gutman, Per-Olof — Technion — IIT

Initialization and Model Reduction for Wiener Model Identification

Hagenblad, Anna — Linköping Univ.

Nonlinear Identification of Automobile Vibration Dynamics

Westwick, David T. — Delft Univ. of Technology
George, Koshy — Delft Univ. of Technology
Verhaegen, Michel — Delft Univ. of Technology

Generalization: A Hidden Agenda in System Identification

Larsen, Jan — Technical Univ. of Denmark
Hansen, Lars Kai — Technical Univ. of Denmark

Nonlinear Identification of the Position Sled Dynamics of a CD Player

Sjöberg, Jonas E. — Chalmers Univ. of Technology
Gutman, Per-Olof — Technion — IIT

A Global Optimization Approach to Nonlinear System Identification

Tiano, A. — Univ. of Pavia
Pizzocchero, F. — Univ. of Pavia
Venini, P. — Univ. of Pavia

MP1
Flexible Structures

Chair: *Halevi, Yoram* — Technion — IIT
Co-chair: *Menini, Laura* — Univ. di Roma Tor Vergata

Design of a Multivariable Pole-Placement Controller for the Primary Mirror of the 10m Grantecan Telescope

Acosta, L. — La Laguna Univ.
Sigut, M. — La Laguna Univ.
Hamilton, A. — La Laguna Univ.
Méndez, J. A. — La Laguna Univ.
Marichal, G. N. — La Laguna Univ.
Moreno, L. — La Laguna Univ.

Application of a Classical PD Regulator to the Control of a Flexible Planar Closed Chain Linkage

Gasparetto, Alessandro — Univ. of Udine
Miani, Stefano — Univ. of Udine

Control of Flexible Structures Using Models with Dead Time

Raskin, Natalya — Technion — IIT
Halevi, Yoram — Technion — IIT

Balanced Realization of Flexible Structures with General Damping: A Power Series Approach

Halevi, Yoram — Technion — IIT

Computation in closed form of the equations of motion for a flexible beam with lumped masses and rotational inertias

Menini, Laura — Univ. di Roma Tor Vergata
Tornambè, Antonio — Univ. di Roma Tre
Zaccarian, Luca — Univ. di Roma Tor Vergata

MP2
Fault Detection

Chair: *Speyer, Jason L.* — Univ. of California, LA

Improved Observer for Sensor Fault Diagnosis of a Power Plant

Simani, Silvio — Univ. di Ferrara
Fantuzzi, Cesare — Univ. di Ferrara
Beghelli, Sergio — Univ. di Ferrara

Residual-Sensitive Fault Detection Filter

Chen, Robert H. — Univ. of California, LA
Speyer, Jason L. — Univ. of California, LA

Catastrophic Failure Evaluation

Macdonald, John M. — Los Alamos National Lab.
Nekimken, Howard — Los Alamos National Lab.
Picard, Rick — Los Alamos National Lab.
Olson, Keith — Los Alamos National Lab.
Bates, Adam — Los Alamos National Lab.
Ortiz, Augustine — Los Alamos National Lab.

MP3 (I)
Target Tracking

Organizer: *Bar-Shalom, Yaakov* — Univ. of Connecticut
Chair: *Bar-Shalom, Yaakov* — Univ. of Connecticut
Co-chair: *Madan, Rabi* — ONR, Arlington

Nonlinear Filters with Virtual Measurements

Daum, Frederick E. — Raytheon Co.

System Level Performance of Radar Waveforms

Niu, Ruixin — Univ. of Connecticut
Willett, Peter — Univ. of Connecticut
Bar-Shalom, Yaakov — Univ. of Connecticut

A Radar Power Multiplier Algorithm for Acquisition of Low Observable Ballistic Missiles Using an ESA Radar

Sivananthan, Sivaloganathan — ARCON Corp.
Kirubarajan, Thiagalingam — Univ. of Connecticut
Bar-Shalom, Yaakov — Univ. of Connecticut

Trajectory and Launch Point Estimation for Ballistic Missiles from Boost Phase LOS Measurements

Li, Yicong — Comverse Network Systems
Kirubarajan, Thiagalingam — Univ. of Connecticut
Bar-Shalom, Yaakov — Univ. of Connecticut

Artificial Neural Network Embedded Kalman Filter Bearing Only Passive Target Tracking

Surendra Rao, Alladi — Naval Sc. and Technological Lab.

MP5
Adaptive Control 2

Chair: *Feuer, Arie* — Technion — IIT
Co-chair: *Arvanitis, K. G.* — National Tech. Univ. of Athens

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Adaptive Pole Placement Control of Linear Systems Using Periodic Multirate-Input Controllers

Arvanitis, K. G. — National Tech. Univ. of Athens
Kalogeropoulos, G. — Univ. of Athens

Development of a Self-Tuning PID Controller Based on Neural Network for Nonlinear Systems

Han, Woo-yong — Jeonju Technical College
Han, Jin-wook — Chonbuk National Univ.
Lee, Chang-goo — Chonbuk National Univ.

Multi-Drug Infusion Control Using a Robust Direct Adaptive Controller for Plants with Time Delays

Ozcelik, Selahattin — Texas A&M Univ.–Kingsville
Palerm, Cesar C. — Rensselaer Polytechnic Inst.
Kaufman, Howard — Rensselaer Polytechnic Inst.

Indirect Adaptive Control of Drug Infusion for a Circulatory System Model

Achuthan, G. — Rensselaer Polytechnic Inst.
Alekseyenko, Y. — Rensselaer Polytechnic Inst.
Ishihara, A. — Rensselaer Polytechnic Inst.
Kaufman, Howard — Rensselaer Polytechnic Inst.

Optimal Adaptive Control of Uncertain Stochastic Discrete Linear Systems

Rusnak, Ilan — RAFAEL — ADA

TA1
Sampled-Data Systems

Chair: *Palmor, Zalman J.* — Technion — IIT
Co-chair: *Weller, Steve* — Univ. of Newcastle

Improved Wiener-Hopf Method for H^2-Design of Sampled-Data Systems

Lampe, Bernhard P. — Univ. of Rostock
Rosenwasser, Yephim N. — St.Petersburg U. Ocean Techn.

H^∞ Design of Generalized Sampling and Hold Functions with Waveform Constraints

Kahane, Allan C. — Technion — IIT
Mirkin, Leonid — Technion — IIT
Palmor, Zalman J. — Technion — IIT

Sampling Zeros and Robust Sampled-Data Control Design

Weller, Steven — Univ. of Newcastle

Self-Tuning PID Controller Using δ-Model Identification

Bobal, Vladimir — Technical Univ. Brno
Dostal, Petr — Technical Univ. Brno
Sysel, Martin — Technical Univ. Brno

TA2 (I)
Recent Innovations in Process Control

Organizer: *Lewin, Daniel R.* — Technion — IIT
Chair: *Ogunnaike, Babatunde A.* — E.I. DuPont de Nemours
Co-chair: *Lewin, Daniel R.* — Technion — IIT

Multiple Model Control of a Pilot Distillation Column

Rodriguez, Julio A. — Sydney Univ.
Goodwin, Graham C. — Univ. of Newcastle
Romagnoli, Jose A. ("Cacho") — Sydney Univ.

Online Outlier Detection and Removal

Menold, Patrick H. — ETH Zürich
Pearson, Ronald K. — ETH Zürich
Allgöwer, Frank — ETH Zürich

Identification for Control Purposes by Relay Techniques: Achievable Performance versus Complexity

Marchetti, G. — Univ. di Pisa
Scali, Claudio — Univ. di Pisa

Algorithmic Internal Model Control of Unstable Systems

Berber, Ridvan — Univ. of Ankara
Brosilow, Coleman — Case Western Reserve Univ.

Robust Stability Analysis of Nonlinear Processes Using Empirical State Affine Models and LMI's

Budman, Hector — Univ. of Waterloo
Knapp, Timothy — Univ. of Waterloo

Model Predictive Control of a Continuous Granulation Process

Adetayo, Anthony A. — DuPont Central R&D
Pottmann, Martin — DuPont Dacron
Ogunnaike, Babatunde A. — DuPont Central R&D
Ennis, Brian J. — E&G Associates

TA3
Stability and Stabilization

Chair: *Keel, L. H.* — Tennessee State Univ.
Co-chair: *Johansson, Mikael* — Lund Inst. of Technology

Analytic Conditions for Stabilizability

Keel, L. H. — Tennessee State Univ.
Bhattacharyya, S. P. — Texas A&M Univ.

Stability of Dynamical Systems with Parameter Perturbations

Liberzon, Mark R. — Moscow State Aviation Techn. Univ.

BIBO Stability of NARX Models

Dzieliński, Andrzej — Warsaw Univ. of Technology

Improving Efficiency in the Computation of Piecewise Quadratic Lyapunov Functions

Johansson, Mikael — Lund Inst. of Technology
Ghulchak, Andrey — Lund Inst. of Technology
Rantzer, Anders — Lund Inst. of Technology

Practical Stability of Synchronized Chaotic Attractors and its Control

Kapitaniak, Tomasz — Technical Univ. of Lodz
Czolczynski, Krzysztof — Technical Univ. of Lodz
Brindley, John — Univ. of Leeds

Remarks on Open-Loop Stabilizability of Linear Infinite-Dimensional Time-Varying Discrete-Time Systems

Przyłuski, K. Maciej — Polish Academy of Sc.

TA4
Nonlinear Systems 1

Chair: *Fradkov, Alexander L.* — Russian Acad. of Sc.
Co-chair: *Krasnosel'skii, Alexander M.* — Russian Acad. of Sc.

On Oscillations in Resonant Equations with Complex Nonlinearities

Krasnosel'skii, Alexander M. — Russian Academy of Sc.

Feedback Resonance in 1-DOF and 2-DOF Nonlinear Oscillators

Fradkov, Alexander L. — Russian Academy of Sc.
Andrievsky, Boris R. — Russian Academy of Sc.

Input-Output Models for a Class of Nonlinear Systems: Questions and Answers

Kotta, Ülle — Tallinn Technical Univ.

Aspects of Traction Control

Friedland, Bernard — New Jersey Inst. of Technology

Energy Control of Hamiltonian Systems under Disturbances

Polushin, Ilya G. — Russian Academy of Sc.
Fradkov, Alexander L. — Russian Academy of Sc.

Nonlinear Systems Admitting Hybrid Feedback Control Stabilization

Litsyn, Elena — The Weizmann Instit. of Sc.
Nepomnyashchikh, Yurii V. — Perm State Univ.
Ponosov, Arcady — Inst. for Matematiske Fag

TA5
Filtering

Chair: *Colaneri, Patrizio* — Politecnico di Milano
Co-chair: *Yaesh, I.* — Taas Israel Industries

Robust H_∞ Filtering of Stationary Discrete-Time Linear Systems with Stochastic Uncertainties

Gershon, E. — Tel-Aviv Univ.
Shaked, Uri — Tel-Aviv Univ.
Yaesh, I. — Taas Israel Industries

The J-Spectral Interactor Matrix in the Discrete-Time Singular H_∞ Filtering Problem

Colaneri, Patrizio — Politecnico di Milano
Maroni, Massimo — Politecnico di Milano

Kalman Bucy Filtering for Singular Output-Noise Covariance

Carravetta, Francesco — CNR-IASI
Germani, Alfredo — L'Aquila Univ.
Manes, Costanzo — L'Aquila Univ.

On the Feasibility and Convergence of H_∞ Multistep Predictors

Maroni, Massimo — Politecnico di Milano
Bolzern, Paolo — Politecnico di Milano

Nonlinear Observers for a Class of Differential Delay Systems

Aggoune, Woihida — Univ. Henri Poincaré, INRIA CONGE
Darouach, Mohamed — Univ. Henri Poincaré

TM1 (I)
Control of Distributed Parameter Systems

Organizer: *Reich, Simeon* — Technion — IIT
Organizer: *Demetriou, Michael A.* — Worcester Poly. Inst.
Chair: *Demetriou, Michael A.* — Worcester Poly. Inst.
Co-chair: *Reich, Simeon* — Technion — IIT

Boundary Control of the Korteweg–de Vries–Burgers Equation: Further Results on Stabilization and Numerical Demonstration

Balogh, Andras — Univ. of California, San Diego
Krstic, Miroslav — Univ. of California, San Diego

Finite Horizon H_∞ Control of Systems with State Delays

Fridman, Emilia — Tel-Aviv Univ.
Shaked, Uri — Tel-Aviv Univ.

Numerical Criterion for Stabilizing Steady State Solutions of the Navier-Stokes Equations

Titi, Edriss S. — Univ. of California, Irvine
Cao, Chongsheng — Univ. of California, Irvine
Kevrekidis, Yannis — Univ. of California, Irvine

Lax-Phillips Scattering and Well-Posed Linear Systems

Staffans, Olof J. — Åbo Akademi Univ.

Identification and Adaptive Control of Some Stochastic Distributed Parameter Systems

Pasik-Duncan, Bozenna — Univ. of Kansas

TM2 (I)
Integration of Process Design and Process Control

Organizer: *Lewin, Daniel R.* — Technion — IIT
Chair: *Lewin, Daniel R.* — Technion — IIT
Co-chair: *Ogunnaike, Babatunde A.* — E.I. DuPont de Nemours

Interaction of Design and Control

Lewin, Daniel R. — Technion — IIT

Simultaneous Process Design and Process Control: Application to Complex Separation Systems

Ross, Roderick — Imperial College
Bansal, Vikrant — Imperial College
Perkins, John D. — Imperial College
Pistikopoulos, Efstratios N. — Imperial College

Process Design with Complex Nonlinearities

Seider, Warren D. — Univ. of Pennsylvania

Towards Integration of Controllability into Plant Design

Jørgensen, S. Bay — Technical Univ. of Denmark
Gani, R. — Technical Univ. of Denmark
Andersen, T. R. — Technical Univ. of Denmark

Controllability and Resiliency Analysis for a Heat-Integrated C3-Splitter

Solovyev, Boris M. — Technion — IIT
Lewin, Daniel R. — Technion — IIT

On the Generation of the Most Promising Control Structure for Large Dimensional Systems

Kookos, I. K. — Imperial College
Arvanitis, K. G. — National Tech. Univ. of Athens
Kalogeropoulos, G. — Univ. of Athens

TM3 (I)
Advances to Meet the Missile Guidance Challenge at the Verge of the New Millennium

Organizer: *Shinar, Josef* — Technion — IIT
Organizer: *Ben-Asher, Josef Z.* — Technion — IIT
Organizer: *Gurfil, Pini* — RAFAEL — ADA
Chair: *Davidovitz, Avraham* — RAFAEL — ADA

Integrated Design of Agile Missile Guidance and Control Systems

Menon, P. K. — Optimal Synthesis Inc.
Ohlmeyer, E. J. — Naval Surface Warfare Center

Optimal Guidance with Time Delay for Continuous Time Systems

Gitizadeh, R. — Taas Israel Industries
Yaesh, I. — Taas Israel Industries
Ben-Asher, Josef Z. — Technion — IIT

Optimal Guidance Laws with Uncertain Time-of-Flight

Rusnak, Ilan — RAFAEL — ADA

Design of Non-Saturating Guidance Systems

Gurfil, Pini — RAFAEL — ADA
Jodorkovsky, Mario — RAFAEL — ADA
Guelman, Moshe — Technion — IIT

Robust Missile Guidance Law against Highly Maneuvering Targets

Shinar, Josef — Technion — IIT
Shima, Tal — Technion — IIT

TM4
Nonlinear Systems 2

Chair: *Friedland, Bernard* — New Jersey Inst. of Technology
Co-chair: *Kotta, Ülle* — Tallin Technical Univ.

From Physical Realizations to Nonlinear Stability, Passivity and Optimality

Margaliot, Michael — Tel-Aviv Univ.
Langholz, Gideon — Tel-Aviv Univ.

Nonlinear State Estimation for Rigid Body Motion with Low-Pass Sensors

Rehbinder, Henrik — KTH, Sweden
Hu, Xiaoming — KTH, Sweden

Control Systems with Actuator Saturation and Bifurcations at Infinity

Ponce, Enrique — Univ. Sevilla
Aracil, Javier — Univ. Sevilla
Pagano, Daniel — Univ. Federal de Santa Catarina

An Antiwindup Control Using μ-Synthesis

Lu, E. — Univ. Bordeaux I
Bergeon, B. — Univ. Bordeaux I
Ygorra, S. — Univ. Bordeaux I

A High Gain Observer for Robust State Feedback Controller

Uçar, Ahmet — Firat Univ.

On the Role of Invariance in the Theory of Systems and Control — An Intelligible Introduction for the Beginners

Shima, Masasuke — Hokkaido Univ.

TM5
Identification 1

Chair: *Pachter, Meir* — Air Force Inst. of Technology
Co-chair: *Ninness, Brett* — Univ. of Newcastle

A Directional Forgetting Algorithm Based on the Decomposition of the Information Matrix

Cao, Liyu — Carleton Univ.
Schwartz, Howard M. — Carleton Univ.

A Parameter Estimation Method for a Special Class of Systems of Ordinary Differential Equations

Seatzu, Carla — Univ. of Cagliari

An Algorithm for Control System Loop Gain Identification

Pachter, Meir — Air Force Inst. of Technology

Real-Time Identification Using a Classical Nonlinear Optimization Algorithm and the Flatness Properties of a System: Application to an Intensity/Pressure Converter

Sanchez, Augustin — National Inst. Appl. Sc., Toulouse
Mahout, Vincent — National Inst. Appl. Sc., Toulouse

Stopping of Algorithms and Faults Detection in Kalman Filter Application

Hajiyev, Chingiz — Istanbul Technical Univ.

Estimation Variance is not Model Structure Independent

Ninness, Brett — Univ. of Newcastle
Hjalmarsson, Håkan — Royal Inst. of Technolgy
Gustafsson, Fredrik — Linköping Univ.

TP1 (I)
Dynamical Models

Organizer: *Reich, Simeon* — Technion — IIT
Organizer: *Demetriou, Michael A.* — Worcester Poly. Inst.
Chair: *Ackleh, Azmy S.* — Univ. of Southwestern Louisiana
Co-chair: *Fridman, Emilia* — Tel-Aviv Univ.

Stability, Euler Approximations of Dynamical Systems and Fixed Point Iterations

Farkhi, Elza — Tel-Aviv Univ.

Asymptotic Behavior of Infinite Products of Order-Preserving Mappings in Banach Space

Reich, Simeon — Technion — IIT
Zaslavski, Alexander J. — Technion — IIT

Exponential Stabilization of Vibrating Systems by Collocated Feedback

Weiss, George — Imperial College
Curtain, Ruth F. — Univ. of Groningen

A Composite Semigroup for the Infinite-Dimensional Differential Sylvester Equation

Emirsajlow, Zbigniew — Technical Univ. of Szczecin

Input-Output Stability of Systems Governed by Nonlinear Second Order Evolution Equations in Hilbert Spaces

Gil', Michael I. — Ben-Gurion Univ.

TP2
Process Control

Chair: *Dumont, Guy A.* — Univ. of British Columbia
Co-chair: *Oisiovici, Ronia M.* — Univ. Estadual de Campinas

Wood Chip Refiner Control

Ismail, Ahmed A. — Univ. of British Columbia
Dumont, Guy A. — Univ. of British Columbia

Automatic Tuning of the Window Size in the Box Car Backslope Data Compression Algorithm

Pettersson, Jens — Royal Inst. of Technology
Gutman, Per-Olof — Technion — IIT

Experimental Tests of Digital Filters for Control of a Pilot-Scale Batch Distillation Column

Oisiovici, Ronia M. — Univ. Estadual de Campinas
Cruz, Sandra L. — Univ. Estadual de Campinas
Pereira, João A. F. R. — Univ. Estadual de Campinas

A Linear Time-Varying State-Space Model of Batch Distillation Columns for Control Applications

Oisiovici, Ronia M. — Univ. Estadual de Campinas
Cruz, Sandra L. — Univ. Estadual de Campinas

Neuro-Fuzzy Modeling in Petrochemical Industry

Bucolo, Maide — Univ. di Catania
Graziani, Salvatore — Univ. di Catania
Fortuna, Luigi — Univ. di Catania
Sinatra, Mario — ERG Petroli Siracusa

TP3
Aerospace Control

Chair: *Ben-Asher, Josef Z.* — Technion — IIT
Co-chair: *Idan, Moshe* — Technion — IIT

An Integrated Algorithm for Path Planning and Flight Controller Scheduling for Autonomous Helicopters

Egerstedt, Magnus — Royal Inst. of Technology
Koo, T. K. John — Univ. of California, Berkeley
Hoffmann, Frank — Univ. of California, Berkeley
Sastry, Shankar — Univ. of California, Berkeley

Actuator Design for Aircraft Robustness Versus Category II PIO

Amato, Francesco — Univ. of Naples
Iervolino, Raffaele — Univ. of Naples
Scala, Stefano — Italian Aerospace Research Centre
Verde, Leopoldo — Italian Aerospace Research Centre

On Algorithms for Attitude Estimation Using GPS

Bar-Itzhack, Itzhack Y. — Technion — IIT
Nadler, Assaf — Technion — IIT

TP4
Time Delay Systems

Chair: *Mirkin, Leonid* — Technion — IIT
Co-chair: *Yaniv, Oded* — Tel-Aviv Univ.

Every Stabilizing Dead-Time Controller has an Observer-Predictor-Based Structure

Mirkin, Leonid — Technion — IIT
Raskin, Natalya — Technion — IIT

The Structure at Infinity of Linear Delay Systems and the Row-by-Row Decoupling Problem

Rabah, Rabah — Inst. de Rech. en Cyb. de Nantes
Malabre, Michel — Inst. de Rech. en Cyb. de Nantes

Stabilization of Singularly Perturbed Linearly Systems with Delay and Saturating Control

Ionita, Achim — National Inst. of Aerospace Res.
Dragan, Vasile — Romanian Academy

Near Optimal PLL Design for Decision Feedback Carrier and Timing Recovery

Yaniv, Oded — Tel-Aviv Univ.
Raphaeli, Dan — Tel-Aviv Univ.

TP5
Identification 2

Chair: *Balakrishnan, S. N.* — Univ. of Missouri-Rolla
Co-chair: *Nagurka, Mark* — Marquette Univ.

Modelling and Identification of a High Temperature Short Time Pasteurization Process Including Delays

Alastruey, Carlos F. — Public Univ. of Navarra
De la Sen, Manuel — Univ. of the Basque Country
Garcia-Sanz, Mario — Public Univ. of Navarra

Parameter Identification In Nonlineaer Systems Using Hopfield Neural Networks

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

Optimal Combination of Identification and Control for Bounded-Noise ARX Systems

Królikowski, Andrzej — Technical Univ. of Poznań

Closed-loop model-free subspace-based LQG-design

Favoreel, Wouter — Katholieke Univ. Leuven
De Moor, Bart — Katholieke Univ. Leuven
Gevers, Michel — Univ. Catholique de Louvain
Van Overschee, Peter — Katholieke Univ. Leuven

Measurement of Impedance Characteristics of Computer Keyboard Keys

Nagurka, Mark — Marquette Univ.
Marklin, Richard — Marquette Univ.

WA1 (I)
Optimal Control

Organizer: *Reich, Simeon* — Technion — IIT
Organizer: *Demetriou, Michael A.* — Worcester Poly. Inst.
Chair: *Malanowski, Kazimierz* — Polish Academy of Sc.
Co-chair: *Ackleh, Azmy S.* — Univ. Southwestern Louisiana

Structure of Optimal Solutions of Infinite Dimensional Control Problems

Zaslavski, Alexander J. — Technion — IIT

Lipschitz Stability of Solutions to Parametric Optimal Control for Parabolic Equations

Malanowski, Kazimierz — Polish Academy of Sc.
Tröltzsch, Fredi — Technische Univ. Chemnitz-Zwickau

Optimal Control of Differential Inclusions Involving Partial Differential Operators

Ioffe, Alexander — Technion — IIT

On the Existence of Optimal Strategies for Multichain Markov Decision Processes

Leizarowitz, Arie — Technion — IIT

Feedback Control for Descriptor Systems

Kurina, Galina A. — Voronezh State Forestry Academy

WA2
Manufacturing

Chair: *Fatikow, Sergej* — Univ. of Karlsruhe
Co-chair: *Dahan, Marc* — Inst. de Productique, Besancon

Optimal Design of Transfer Lines and Multiposition Machines

Dolgui, Alexandre — Univ. of Technology of Troyes
Guschinsky, Nikolai N. — Academy of Sc. of Belarus
Levin, Genrikh M. — Academy of Sc. of Belarus

Conrol Architecture of a Flexible Microrobot-Based Microassembly Station

Fatikow, Sergej — Univ. of Karlsruhe
Seyfried, J. — Univ. of Karlsruhe

The Relationship between Planning and Production Activities in Process Industries

Jovan, Vladimir — Jozef Stefan Inst.

Strategies for Integrating Preparation and Realisation — The Case of Product Models

Larsen, Michael Holm — The Technical Univ. of Denmark
Kirkby, Phillip — The Technical Univ. of Denmark
Vesterager, Johan — The Technical Univ. of Denmark

Aided Decision and Authentication of Lamellated Wood Frameworks

Imberdis, Claude — Inst. de productique, Besançon
Gendreau, Dominique — IUFM de Franche Comté
Dahan, Marc — Inst. de productique, Besançon

WA3
Robotics 1

Chair: *Ailon, Amit* — Ben-Gurion Univ.
Co-chair: *Michalska, Hannah* — McGill Univ.

An Estimate to the Energy Function of a Rigid Robot with a Stabilizing PD Controller

Ailon, Amit — Ben-Gurion Univ.
Gil', Michael I. — Ben-Gurion Univ.

Hierarchical Fuzzy Behavior-Based Control of a Multi-Agent Robotic System

Berman, Sigal — Ben-Gurion Univ.
de Oliveira, Marco A. A. — The Univ. of New Mexico
Edan, Yael — Ben-Gurion Univ.
Jamshidi, Mohammad — The Univ. of New Mexico

Geometric and System Decomposition Techniques in Application to Control of a Mobile Robot with Trailer

Michalska, Hannah — McGill Univ.

Following a Path of Varying Curvature as an Output Regulation Problem

Altafini, Claudio — Royal Inst. of Technology

On Enhancing GJK Algorithm for Distance Computation Between Convex Polyhedra: Comparison of Improvements

Shiang, Shen-Po — National Taiwan Univ.
Chien, Yu-ren — National Taiwan Univ.
Liu, Jing-Sin — Academia Sinica

WA4
Robust Control

Chair: *Zeheb, Ezra* — Technion — IIT
Co-chair: *Rodríguez-Palacios, Alejandro* — Cenidet

Links Between Robust and Quadratic Stability of Uncertain Discrete-Time Polynomials

Henrion, Didier — LAAS-CNRS, Toulouse
Šebek, Michael — Trnka Lab. & ÚTIA
Kučera, Vladimír — Trnka Lab. & ÚTIA

Development of the Modal Regulator Design Method for a Plant with Interval Parameters

Smagina, Yelena — Israel
Brewer, Irina — USA

Robust Stability Condition for the System with Feedback Connected Uncertainty and Uncertain Number of Unstable Poles

Yamada, Kou — Yamagata Univ.

Real and Complex Stability Radii in Automatic Load-Frequency Control Systems via LQG/LTR and LMI

Terra, Marco H. — Univ. of São Paulo
Masca, Gregõria M. T. — Univ. of São Paulo

Robust Control for a Class of Linear Infinite Dimensional Systems with Multiplicative Disturbances

Rodríguez-Palacios, Alejandro — Cenidet
Fernández-Anaya, Guillermo — UIA

About Some Interconnection Between LTR and RPIS

de Larminat, Philippe — Inst. de Rech. en Cyb. de Nantes
Lebret, Guy — Inst. de Rech. en Cyb. de Nantes
Puren, Sophie — Ing. Pour Signaux et Systèmes

WA5
Signal and Image Processing

Chair: *Shimkin, Nachum* — Technion — IIT

A Novel Architecture for Digital Pulse Height Analysis with Application to Radiation Spectroscopy

Elhanany, Itamar — Nuclear Research Center Negev
Jacobi, Shimshon — Nuclear Research Center Negev
Kahane, Michael — Nuclear Research Center Negev
Marcus, Eli — Nuclear Research Center Negev
Tirosh, Dan — Nuclear Research Center Negev
Barak, Dov — Nuclear Research Center Negev

Real-Time Adaptive Filtering for Nonstationary Image Restoration Using Gaussian Input

Abilov, Abdulriza — Ankara Univ.
Tuzunalp, Onder — Ankara Univ.
Telatar, Ziya — Ankara Univ.

The Edge Point Detection Problem in Image Sequences: Definition and Comparative Evaluation of Some 3D Edge Detecting Schemes

Jetto, L. — Univ. of Ancona
Orlando, G. — Univ. of Ancona
Sanfilippo, A. — Univ. of Ancona

WM1 (I)
Parameter Estimation

Organizer: *Reich, Simeon* — Technion — IIT
Organizer: *Demetriou, Michael A.* — Worcester Poly. Inst.
Chair: *Reich, Simeon* — Technion — IIT
Co-chair: *Demetriou, Michael A.* — Worcester Poly. Inst.

Model-Based Detection Observer of Component Failures for Distributed Parameter Systems

Demetriou, Michael A. — Worcester Polytechnic Instit.

Parameter Estimation Problem for a Nonlinear Parabolic Equation with a Singular Nonlocal Diffusion Term

Ackleh, Azmy S. — Univ. of Southwestern Louisiana

Parameter Identification in a Nonautononous Nonlinear Volterra Integral Equation

Ackleh, Azmy S. — Univ. Southwestern Louisiana
Aizicovici, Sergiu — Ohio Univ.
Ferdinand, Robert R. — East Central Univ.
Reich, Simeon — Technion — IIT

Adaptive Control of a Time-Varying Parabolic System: Averaging Analysis

Hong, Keum-Shik — Pusan National Univ.
Solo, Victor — Macquarie Univ.
Bentsman, Joseph — Univ. of Illinois at Urbana

Approximation of High-Order Lumped Systems by using Non-Integer Order Transfer Functions

Fortuna, Luigi — Univ. di Catania
Graziani, Salvatore — Univ. di Catania
Muscato, Giovanni — Univ. di Catania
Nunnari, Giuseppe — Univ. di Catania
Porto, Domenico — Univ. di Catania

WM2
Fuzzy Logic Methods
Chair: *Jamshidi, Mohammad* The Univ. of New Mexico

Closed-Loop Robust Controllers with Fuzzy Gain Scheduling for FNS Assisted Walking of Paraplegics

Moulin, Mark Technion — IIT
Inbar, Gideon F. Technion — IIT

Mathematical Formulation of Fuzzy Cognitive Maps

Stylios, Chrysostomos D. Univ. of Patras
Groumpos, Peter P. Univ. of Patras

An Outline for a Universal Logic System: A Logic System in Eight Truth Values

Heald, Graeme RMIT Univ.

Using Soft Computing Methodologies for Multistage Supervisory Control of Complex Systems

Stylios, Chrysostomos D. Univ. of Patras
Christova, Nikolinka Univ. of Patras
Groumpos, Peter P. Univ. of Patras

WM3
Robotics 2

Chair: *Berman, Nadav* — Ben-Gurion Univ.
Co-chair: *Schwartz, Howard* — Carleton Univ.

Variable Structure Control with Varying Bounds of Robot Manipulators

Nigrowsky, Pierre M. B. — Brunel Univ.
Turner, Peter J. — Brunel Univ.

An MRAC Output Feedback Controller for Robot Manipulators

Schwartz, Howard M. — Carleton Univ.

Basic Fairing Principles of Fiberglass Pits and Patches

Oliver, Glen C. — Univ. of Texas at Arlington
Shiakolas, Panayiotis S. — Univ. of Texas at Arlington
Lawley, Tommy J. — Univ. of Texas at Arlington

RobSurf: A Near Real Time OLP System for Robotic Surface Finishing

Shiakolas, Panayiotis S. — Univ. of Texas at Arlington
Labalo, Dragan — Univ. of Texas at Arlington
Fitzgerald, J. Mick — Univ. of Texas at Arlington

Adaptive Nonlinear Visual Servoing Using Lyapunov-Based Design

Conticelli, Fabio — Scuola Superiore Sant'Anna
Allotta, Benedetto — Scuola Superiore Sant'Anna

On the Inclusion of Robot Dynamics in Visual Servoing Systems

Conticelli, Fabio — Scuola Superiore Sant'Anna
Allotta, Benedetto — Scuola Superiore Sant'Anna

WM4 (I)
Sliding Mode Control

Organizer: *Zinober, Alan S. I.* — The Univ. of Sheffield
Chair: *Zinober, Alan S. I.* — The Univ. of Sheffield

Partial Lipschitz Nonlinear Sliding Mode Observers

Koshkouei, Ali J. — Univ. of Sheffield
Zinober, Alan S. I. — Univ. of Sheffield

Dynamical Adaptive First and Second Order Sliding Mode Control of Nonlinear Non-Triangular Uncertain Systems

Zinober, Alan S. I. — Univ. of Sheffield
Scarratt, Julie C. — Univ. of Sheffield
Ferrara, Antonella — Univ. of Pavia
Giacomini, Luisa — Aston Univ.
Rios-Bolívar, Miguel — Univ. de Los Andes

Adaptive Sliding Backstepping Control of Nonlinear Semi-Strict Feedback Form Systems

Koshkouei, Ali J. — Univ. of Sheffield
Zinober, Alan S. I. — Univ. of Sheffield

A Feedforward-Feedback Interpretation of a Sliding Mode Control Law

Monsees, Govert — Delft Univ. of Technology
George, Koshy — Delft Univ. of Technology
Scherpen, Jacquelien M.A. — Delft Univ. of Technology
Verhaegen, Michel — Delft Univ. of Technology

Nonminimum Phase Output Tracking via Sliding Mode Control: Stable System Center Technique

Shkolnikov, Ilya A. — The Univ. of Alabama in Huntsville
Shtessel, Yuri B. — The Univ. of Alabama in Huntsville

2-Sliding Mode with Adaptation

Bartolini, Giorgio — Univ. of Cagliary
Levant, Arie — Inst. for Industrial Mathematics
Pisano, Alessandro — Univ. of Cagliary
Usai, Elio — Univ. of Cagliary

WM5
Computer Networks and Queing Systems
Chair: *Shimkin, Nachum* Technion — IIT

The Optimal Markov Strategy for Access in ISDNs with Reserves of Channels

Melikov, Agassy Z. International American Univ.
Deniz, Dervis Z. Eastern Mediterranean Univ.

Tbit/sec Switching Scheme for ATM/WDM High-Speed Computer Networks

Elhanany, Itamar Ben-Gurion Univ.
Sadot, Dan Ben-Gurion Univ.

Grid-based ATM Switch Architecture: A New Fault-Tolerant Space-Division Switch Fabric Architecture

Laskaridis, Haralampos S. Aristotle Univ. of Thessaloniki
Veglis, Andreas A. Aristotle Univ. of Thessaloniki
Papadimitriou, Georgios I. Aristotle Univ. of Thessaloniki
Pomportsis, Andreas S. Aristotle Univ. of Thessaloniki

MED99

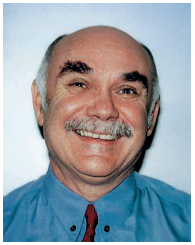
Abstracts

Plenary Session I

Identification and Robust Control: Bridging the Gap

Graham C. Goodwin, The University of Newcastle

The topics of Identification and Robust Control have a rich history and have reached a level of considerable maturity. However, a major difficulty is that the two fields have evolved along different lines and now have many incompatibilities. The aim of this paper is to raise awareness to this problem for researchers. We suggest that alternative formulations may be desirable in both fields to obtain a satisfactory match. One possible line of attack on the problem is proposed together with illustrations showing the potential merits in gaining a better understanding of this problem.



Graham C. Goodwin was born in Broken Hill, Australia in 1945. He obtained a B.Sc. (Physics), B.E. (Electrical Engineering), and Ph.D. from the University of New South Wales. From 1970 until 1974 he was a lecturer in the Department of Computing and Control, Imperial College, London. Since 1974 he has been with the Department of Electrical and Computer Engineering, The University of Newcastle, Australia. He is the co-author of seven books: *Control Theory* (Oliver and Boyd, 1970), *Dynamic System Identification* (Academic Press, 1977), *Adaptive Filtering, Prediction and Control* (Prentice Hall, 1984), *Digital Control and Estimation* (Prentice Hall, 1989), *Sampling in Digital Signal Processing and Control* (Birkhäuser, 1996), *Fundamental Limitations in Filtering and Control* (Springer, 1997), *Control System Design* (Prentice Hall, 1999), as well as several hundred technical papers.

Graham Goodwin is the recipient of several international prizes including a best paper award by *IEEE Trans. Automatic Control*, and best engineering text book award from the International Federation of Automatic Control. He is currently Professor of Electrical Engineering and Director of the Centre for Integrated Dynamics and Control at the University of Newcastle. Graham Goodwin is a Fellow of IEEE; an Honorary Fellow of Institute of Engineers, Australia; a Fellow of the Australian Academy of Science; a Fellow of the Australian Academy of Technology, Science and Engineering; and a member of International Statistical Institute.

Plenary Session II

Control of Hybrid Systems and Some Applications

Michael Heymann, Technion — IIT

Hybrid systems, in which discrete and continuous behaviors coexist and interact, have been receiving increasing attention in recent years both in the control theory community and in the computer science community. While from the control theory viewpoint, hybrid systems are dynamical systems endowed with discontinuities and discrete changes, from the computer science viewpoint, hybrid systems are viewed as discrete systems endowed with dynamic timing constraints. These two viewpoints led to very different research agendas.

The present talk will review some of the main issues associated with analysis and control of a class of hybrid systems called hybrid machines so as to satisfy safety and liveness specifications. Several real-life practical applications of hybrid systems theory will be discussed.

Michael Heymann received the B.Sc. and M.Sc. degrees from the Technion, Haifa, Israel, in 1960 and 1962, respectively, and the Ph.D. degree from the University of Oklahoma, Norman, in 1965, all in Chemical Engineering.
During 1965–1966 he was on the Faculty of the University of Oklahoma. From 1966 to 1968 he was with Mobil Research and Development Corporation, engaged in research in control and systems theory. From 1968 to 1970 he was with the Ben-Gurion University of the Negev, Beer-Sheva, where he established and headed the department of Chemical Engineering. Since 1970 he has been with the Technion where he is currently Professor in the Department of Computer Science and Director of the Center for Intelligent Systems which he also founded. He is holder of the Carl Fechheimer Chair in Electrical Engineering. He has previously been with the Department of Electrical Engineering and with the department of Applied Mathematics of which he was Chairman during 1972–1973. He held visiting positions at various institutes, including the University of Toronto, the University of Florida, the University of Eindhoven, Concordia University, CSIR, Yale University, the University of Bremen and the University of Newcastle. Since 1983 he has been associated with NASA Ames Research Center, where he has spent many summers as well as the years 1983–1984, 1988–1989, 1995–1996 as an NRC-Senior Research Associate and more recently as a Jan-Jose-State University visiting Scientist.
His research covered topics in the areas of linear system theory, differential games, optimization, and adaptive control. His current interests are chiefly in the areas of discrete-event control, hybrid systems, the theory of concurrent processes and their applications.
He has been on the editorial boards of the *SIAM Journal of Control and Optimization* and *Systems & Control Letters*.

Plenary Session III

Optimization over Linear Matrix Inequalities

Stephen Boyd, Stanford University

The recent development of efficient interior-point algorithms for convex optimization problems involving linear matrix inequalities (LMIs) has spurred research in a wide variety of application fields, including control system analysis and synthesis, combinatorial optimization, circuit design, structural optimization, experiment design, and geometrical problems involving ellipsoidal bounding and approximation.

In the first part of the talk, I will describe the basic problems, semidefinite programming (SDP) and determinant maximization, discuss their basic properties, and give a brief description of interior-point methods for their solution. In the second half of the talk I will survey applications from several areas.

Stephen Boyd received the A.B. degree in Mathematics, from Harvard University in 1980, and the Ph.D. in Electrical Engineering and Computer Science from the University of California, Berkeley, in 1985. In 1985 he joined the Electrical Engineering Department at Stanford University, where he is now Professor and Director of the Information Systems Laboratory. His interests include computer-aided control system design, and convex programming applications in control, signal processing, and circuits.

Plenary Session IV

Target Tracking and Data Fusion: How to Get the Most Out of Your Sensors

Yaakov Bar-Shalom, University of Connecticut

This talk describes the evolution of the technology of tracking objects of interest (targets) in a cluttered environment using remote sensors. Approaches for handling target maneuvers (unpredictable motion) and false measurements (clutter) are discussed. Advanced ("intelligent") techniques with moderate complexity are described. The emphasis is on algorithms which model the environment and the scenarios of interest in a realistic manner and have the ability to track low observable (LO) targets. The various architectures of information processing for multisensor data fusion are discussed. Applications are presented from Air Traffic Control (data fusion from 5 FAA/JSS radars for 800 targets) and underwater surveillance for a LO target.

Yaakov Bar-Shalom was born on May 11, 1941. He received the B.S. and M.S. degrees from the Technion — Israel Institute of Technology in 1963 and 1967 and the Ph.D. degree from Princeton University in 1970, all in electrical engineering. From 1970 to 1976 he was with Systems Control, Inc., Palo Alto, California. Currently he is Professor of Electrical and Systems Engineering and Director of the ESP Lab (Estimation and Signal Processing) at the University of Connecticut. His research interests are in estimation theory and stochastic adaptive control and has published over 220 papers in these areas. In view of the causality principle between the given name of a person (in this case, "(he) will track," in the modern version of the original language of the Bible) and the profession of this person, his interests have focused on tracking. His other interests are stochastic control of vertical airfoils and of pairs of inclined foot supports on crystals. He co-authored the monograph *Tracking and Data Association* (Academic Press, 1988), the graduate text *Estimation and Tracking: Principles, Techniques and Software* (Artech House, 1993), the text *Multitarget-Multisensor Tracking: Principles and Techniques* (YBS Publishing, 1995), and edited the books *Multitarget-Multisensor Tracking: Applications and Advances* (Artech House, Vol. I 1990; Vol. II 1992). He has been elected Fellow of IEEE for "contributions to the theory of stochastic systems and of multitarget tracking." He has been consulting to numerous companies, and originated the series of Multitarget-Multisensor Tracking short courses offered via UCLA Extension, at Government Laboratories, private companies and overseas. He has also developed the commercially available interactive software packages MULTIDAT™ for automatic track formation and tracking of maneuvering or splitting targets in clutter, PASSDAT™ for data association from multiple passive sensors, BEARDAT™ for target localization from bearing and frequency measurements in clutter, IMDAT™ for image segmentation and target centroid tracking and FUSEDAT™ for fusion of possibly heterogeneous multisensor data for tracking. During 1976 and 1977 he served as Associate Editor of the *IEEE Transactions on Automatic Control* and from 1978 to 1981 as Associate Editor of *Automatica*. He was Program Chairman of the 1982 American Control Conference, General Chairman of the 1985 ACC, and Co-Chairman of the 1989 IEEE International Conference on Control and Applications. During 1983–87 he served as Chairman of the Conference Activities Board of the IEEE Control Systems Society and during 1987–89 was a member of the Board of Governors of the IEEE CSS. In 1987 he received the IEEE CSS Distinguished Member Award. Since 1995 he is a Distinguished Lecturer of the IEEE AESS. He is co-recipient of the M. Barry Carlton Award for the best paper in the *IEEE Transactions on Aerospace and Electronic Systems* in 1995.

Plenary Session V

Deep Space Control Challenges of the New Millennium

David S. Bayard, Jet Propulsion Laboratory

The exploration of deep space presents a variety of significant control challenges. Long communication delays coupled with challenging new science objectives require high levels of system autonomy and increasingly demanding pointing and control capabilities. Historically, missions based on the use of a large single spacecraft have been successful and popular since the early days of NASA. However, these large spacecraft missions are currently being displaced by more frequent and more focused missions based on the use of smaller and less expensive spacecraft designs. This trend drives the need to design smart software and good algorithms which together with the miniaturization of control components will improve performance while replacing the heavier and more expensive hardware used in the past.

NASA's future space exploration will also include mission types that have never been attempted before, posing significant challenges to the underlying control system. This includes controlled landing on small bodies (e.g., asteroids and comets), sample return missions (where samples are brought back from other planets), robotic exploration of planetary surfaces (e.g., intelligent rovers), high precision formation flying, and deep space optical interferometry,

While the control of planetary spacecraft for traditional flyby and orbiter missions are based on well-understood methodologies, control approaches for many future missions will be fundamentally different. This paradigm shift will require completely new control system development approaches, system architectures, and much greater levels of system autonomy to meet expected performance in the presence of significant environmental disturbances, and plant uncertainties. This paper will trace the motivation for these changes and will layout the approach taken to meet the new challenges. Emerging missions will be used to explain and illustrate the need for these changes.

Dr. **David S. Bayard** is a Senior Research Scientist at the Jet Propulsion Laboratory, California Institute of Technology. He received the B.A. degree in mathematics and chemistry from Queens College of the City University of New York in 1977, and the M.S. and Ph.D. degrees in electrical engineering from the State University of New York at Stony Brook in 1979 and 1984, respectively. During the period 1980–1983 he served as an industrial consultant to Norden Systems, General Instruments, and Comtech Laboratories, involved in adaptive filtering for radar tracking systems, nonlinear system identification, and optimal adaptive control for countermeasures. In 1984, he served on the faculty at SUNY Stony Brook as a Visiting Professor, and in 1985 joined the Guidance and Control section of the Jet Propulsion Laboratory.
Dr. Bayard is currently a Guidance and Control Research Group Leader at JPL. He has been the technical lead for research in the identification and control of large flexible structures, adaptive control of robotic manipulators, attitude estimation and control for miniature spacecraft, adaptive vibration control, nonlinear estimation for robotic ballons, development of Mars precision landing technology, reconfigurable control design for the Space Infra-Red Telescope Facility (SIRTF), and the application of modern estimation and control techniques to numerous emerging spacecraft and planetary missions. Dr. Bayard's research interests include adaptive control, signal processing, system identification, dynamic programming and optimization, stochastic control, and optimal experiment design, and he has published over 100 journal and conference papers in these areas. In 1996 he received the NASA Exceptional Service Medal for fundamental contributions to autonomous spacecraft control systems. Dr. Bayard is a member of IEEE, SIAM, AIAA, Phi Beta Kappa and Beta Delta Chi.

Presentation by representative of the European Commission

Control Systems and European R&D Programmes: Past Experiences and New Challenges

Dr.-Ing. *Alkis Konstantellos*

In this presentation two topics are addressed: *(a)* the content and results of the last four European R&D Framework programmes since 1984 and the spectrum of control systems applications funded and *(b)* the 5th R&D Framework Programme (1999–2002) which was launched in February 1999 and the mechanisms and opportunities for collaborative research.

Up to now, although there has not been an obvious central area for control systems, the European Union programmes have supported a significant number of related research projects, working groups, trials and take up actions affecting vital parts of the production and services innovation processes. These have addressed *(a)* either generic and advanced control algorithms, architectures and systems including safety critical and complexity issues or *(b)* sectoral applications (primarily in automotive/aerospace, process including batch, semiconductor and electronics industries). Other projects dealt with controls combined with decision, concurrent engineering, visualization, simulation and industrial communications from design through operations to the integration and management of controls with instrumentation and business systems (MES and higher levels).

The new EU R&D programmes and in particular the Information Society Technologies programme (IST) are user-driven with specific support for radical innovation and high risk ideas. IST is an integrated 3.6 Bi EURO programme, running for 4 years and encompassing the previous programmes ESPRIT(IT), TELEMATICS and ACTS (telecomms).

Based on experience with the technological developments of the last few years and a set of strategic objectives, the IST programme is designed along four focused "key actions," two additional activities and flexible cross-programme topics:

I: Systems and services for the citizen (e.g., transport, health care, environment and administration);

II: New methods of work and e-commerce;

III: Multimedia content and tools;

IV: Essential technologies and infrastructures (IT and comms);

FET: Future and emerging technologies;

RN: Research networking;

CAP: Cross-programme actions.

Within this context several new challenges could be posed to control systems developers and users in this programme, e.g.: *1)* encourage the creation of revolutionary control methods and facilitate implementation of affordable and dependable solutions, *2)* stimulate a response to expected new and promising paradigms from/to other disciplines such as quantum computing and communications, information ecosystems and nanotechnologies, *3)* create synergies between the ubiquitous control domains and

related enabling technologies such as real time systems, next generation instrumentation, fast interfaces and active networks as well as interactions with user industries, *4)* enhance micro and macro level collaborations and awareness among interested parties and *5)* conduct market and socio-economic analyses and impact assessments of control systems research and related projects.

The new R&D programmes of the European Union and in particular the IST programme provide a broad portfolio of themes and could facilitate the exploition of the rich ideas of the control systems and automation communities.

A combined QFT/H_∞ Design Technique for TDOF Uncertain Feedback Systems

Marcel Sidi Center of Technological Education, Holon

Summary: The present paper presents a way to incorporate QFT principles to the H^∞ control design technique to solve the TDOF Feedback Problem with Highly Uncertain Plants. The proposed design procedure is illustrated with SISO and MIMO design examples for highly uncertain plants.

Keywords: QFT, H^∞, uncertain plant, sensitivity.

Computation of ℓ_1 Optimal Controllers using H_2 Projections

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Summary: Although the ℓ_1 or peak-to-peak norm can be used to capture a number of desirable closed-loop specifications, few practical applications of the criterion have been reported to date. Arguably, the single main reason for this is that, unlike the situation with the close H_2 and H_∞ relatives, efficient numerical algorithms for ℓ_1 are still not available. The purpose of the present paper is to present an algorithm for computing sub-optimal ℓ_1 controllers using sequential H_2 projections. As opposed to previous approaches, the algorithm does not use interpolations constraints nor attempts to solve an infinite optimization problem via finite approximation. Instead, sequential projections onto convex sets are performed to decide whether a given sub-optimal ℓ_1-norm level can be achieved or not. The present algorithm has several key advantages over previous methods:

1. At each stage, a finite optimization problem must be solved. This finite dimensionality is not due to truncation but results from the *exact* application of the algorithm.
2. The finite optimization problems are H_2 projections and can be solved efficiently.
3. The approach does not rely on interpolation constraints. The same algorithm that works for the simplest version of the ℓ_1 problem (e.g., 1-block, SISO), can be modified in a straightforward manner to yield a solution to the general linear time-invariant case (e.g., 4-block, MIMO).

(J, J^0)-dissipative matrices and singular H_∞ control

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Summary: This paper deals with a class of H_∞ control problems where the transfer matrix from the external input to the measured output is invertible on the imaginary axis including infinity whil e there is no assumption about the infinite and/or imaginary-axis zeros of the transfer matrix from the control input to the penalized output. Our approach is based on the chain-scattering representation and a newly proposed (J, J^0)-dissipative factorization extending thus the well-known approach of H. Kimura, while preserving its simplicity. We provide also a characterization o f the set of controllers solving the given problem.

Keywords: Singular H_∞ control, (J, J^0)-dissipative matrices, controller parametrization, chain-scattering representation.

On the Existence of Nash Equilibrium Solution for Mixed H_2/H_∞ Control

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Summary: The aim of this work is the application of the game theory in mixed H_2/H_∞ control problems, using convex optimization. We use the formulation of the mixed H_2/H_∞ control problem as a Nonzero-Sum NASH Game, where the two pay-off functions are associated with two players, which represent the H_2 and H_∞ criteria. We show that the necessary and sufficient conditions for the existence of a NASH equilibrium solution are related to the existence of a global optimal solution to a convex optimization problem. The plant is assumed linear and time-invariant and the resulting controller is a state-feedback law.

Keywords: Nash Game, H_2/H_∞ Control, Convex Optimization.

SVD H^{∞} Controller Design for an Active Horizontal Spray Boom Suspension

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Herman Ramon K.U.Leuven

Summary: An active suspension, acting as a band stop filter, to reduce the horizontal motions of an agricultural spray boom, is designed. Because the translational and the rotational behaviour of the system can be separated, a super optimal SVD H^{∞} controller is achieved by two single SISO designs. Black box frequency domain identification methods render continuous models. Accelerometer drift, performance and robustness issues are tackled. The final active horizontal suspension is validated on a commercial available spray boom.

Keywords: SVD H^{∞} controller, black box frequency domain identification, active suspension, spray boom.

A Linear Matrix Inequality Approach towards H_∞ Control of Descriptor Systems

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Summary: In this paper H_∞ control of high index and non-regular linear descriptor systems is addressed. Based on a generalization of the bounded real lemma (BRL) to index one systems, all controllers solving the H_∞ control problem can be characterized via biaffine matrix inequalities (BMIs). These inequalities imply a certain structure of candidate matrix solutions. Making use of this structure, standard linear algebra tools can be used in order to show the equivalence of the BMI synthesis conditions to a numerically appealing characterization of the solution of the H_∞ control problem via linear matrix inequalities (LMIs). We also address the computation of full- and reduced order controllers.

Keywords: State-space H_∞-control, singular systems, Linear Matrix Inequalities.

On Readily Available Supervisory Control Policies that Enforce Liveness in a Class of Completely Controlled Petri Nets

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Summary: A *Petri Net* (PN) is said to be *live* if it is possible to fire any transition from every reachable marking, although not necessarily immediately. Under appropriate conditions, a non-live PN can be made live via supervision. Under this paradigm an external-agent, the supervisor, prevents the firing of certain transitions at each reachable marking so as to enforce liveness. A PN is said to be completely controllable if the supervisor can prevent the firing of any transition. Testing the existence of a supervisory policy that enforces *liveness* in a completely controlled Petri net can be computationally expensive. In this paper we present a new class of PNs for which there is a readily available supervisory policy that enforces liveness. This observation obviates the aforementioned test for the specific class of PNs introduced in this paper.

Keywords: DEDS, supervisory control, Petri nets, liveness.

Firing Sequences Estimation for Timed Petri Nets

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Summary: This work deals with the firing sequences estimation for transitions - timed Petri nets by measurement of the places marking. Firing durations are unknown, but supposed not to be null. In fact, the Petri net marking is measured, on line, with a sampling period Dt small enough such that each transition is fired, at the most, one time during Dt. The estimation problem has exact and approximated solutions that are described. Sufficient conditions are given on the accuracy of the marking measurement, such that the estimation of the firing sequences is an exact one. If the estimation provides several solutions, the Petri net is completed in order to give a unique solution.

Keywords: Timed Petri nets, manufacturing systems, estimation, firing sequences, Moore-Penrose inverse.

Short and Long-term Scheduling in Semiconductor Manufacturing

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N. Shah Imperial College

Summary: This paper addresses the scheduling problem in semiconductor manufacturing. A two level hierarchical structure is considered to take into account different horizons in the decision making process. Long-term planning is solved by means of an ℓ_1-norm Model Predictive Controller which gives the release policy to a short-term controller. The latter is based on a State-Task-Network representation of the batch recipe and provides the detailed operation of the fab.

Keywords: Semiconductor fabs, discrete-events, planning, scheduling, optimization.

Hybrid Control of a Robotic Manufacturing System

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Summary: In this paper, a new approach for control of hybrid systems is introduced and illustrated using a robotic manufacturing system. Hybrid systems, which are used to model the physical process, and their controllers are viewed as system components of an intelligent control framework and they are modeled as set-dynamical systems. The central concept studied in hybrid system modeling is quasideterminism and it is used to address the problems that arise because of the nondeterministic nature of the discrete approximations of the continuous dynamics. Decision algorithms are derived based on supervisory control of discrete-event systems described by Petri nets. The notions of abstraction and multirate time scales play an important role in the design of decision algorithms to supervise the operation of the system.

Keywords: Hybrid control systems, quasideterminism, Petri nets.

Discrete-Event State Equations and Petri Nets

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Summary: In this paper we present a novel formulation for the modeling and control of discrete event dynamic systems. This original approach leads to a discrete-event state equations formulation satisfying Kalman axioms, where the state is defined as the sequence of potential events (enabled transitions in terms of Petri net language) forced by the occurrence of state events (free evolution) or by arbitrary input events (forced evolution). The proposed formulation is considered to be very general and appropriate to any discrete event systems. This conviction is supported by the analysis performed by comparing discrete-event state equations with classical discrete-event models like untimed and timed Petri nets, finite-state timed and untimed automata. We show that all these models can be formulated as a sub-class of the discrete-event state equations.

Keywords: State equations, discrete-event, Petri Nets, Automata.

Stabilizing a Linear System with Finite-State Hybrid Output Feedback

Daniel Liberzon Yale Univ.

Summary: The purpose of this short note is to establish and explore a link between the problem of stabilizing a linear system using finite-state hybrid output feedback and the problem of finding a stabilizing switching sequence for a switched linear system with unstable individual matrices, each of which separately has recently received attention in the literature.

Keywords: Switched linear system, finite-state hybrid output feedback.

Identification of Manifold Two-Phase Fuel Flow Model in a Spark Ignition Engine with Kalman Filter and Least Square Methods

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Summary: In this paper the identification of the two-phase fuel flow model in the intake manifold for a spark ignition engine is approached. The dynamic model is part of an integrated system of models with hierarchical structure, ranging from phenomenological to neural network approaches, for the analysis and the optimal design of engine control strategies in automotive engines, which is actually in use by a major automotive supplier. Two different techniques for the estimation of model parameters are compared: (i) a classical least square method and (ii) the Kalman filtering approach. The former approach requires a set of off-line identifications performed through the generation of air-fuel ratio transients for each engine operating condition. Model parameters are then identified via inverse modelling approach using non linear least square techniques and stored in a look-up table in the ECU. The second technique consists in the design of a non-linear observer based on an extended Kalman filter. This latter approach can be applicable in on-line operations in order to estimate both states and parameters of the dynamical model. The study has been performed on a set of 35 air-fuel ratio dynamic transients generated on a dynamic test bench for a spark ignition Alfa Romeo 1.4 litres with 4 cylinders, equipped with a IAW multi-point ECS. A train of square waves have been imposed on the nominal injection time pulse width in order to generate the air-fuel ratio strength excursions.

Both techniques allow to predict the observed values with good accuracy, consistently with the physical processes occurring in the region interested by the fuel injection. The results obtained from the two techniques are discussed and compared, and the emerging advantages of the Kalman filtering approach are shown.

Optimal Idle Speed Control with Induction-to-Power Finite Delay for SI Engines

Luigi Glielmo Univ. di Napoli Federico II
Stefania Santini Univ. di Napoli Federico II
Gabriele Serra Magneti Marelli Engine Control Div.

Summary: We present an idle-speed controller designed through an optimal LQ technique taking into account during the design phase the presence of a finite time delay between variations in the manifold pressure and in the produced torque. Effectiveness of the scheme and its robustness to underestimation of the delay are shown through computer simulations.

Keywords: Internal combustion engine control, idle speed control, time delay systems, optimal control, LQ control.

Estimator-Based Adaptive Fuzzy Logic Control Technique for a Wind Turbine-Induction Generator System

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Lorenzo Dambrosio Politecnico di Bari

Summary: The control of a wind power plant, operating as an isolated power source, is analyzed. The plant consists of a wind turbine and a three-phase induction electric generator, connected by means of a gear box. The mathematical models of the wind turbine and of the electrical generator are indicated. The use of an Estimator-based Adaptive Fuzzy Logic control technique to govern the system is proposed. The results of a control test case are shown in order to demonstrate the reliability of the proposed control technique.

Keywords: Control, fuzzy, adaptive, wind, system.

Active Suspension Control of Ground Vehicle Heave and Pitch Motions

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Leo Davis — Davis Technologies Int., Inc.
Frank L. Lewis — The Univ. of Texas at Arlington
Scott Ikenaga — The Univ. of Texas at Arlington
Mark Evans — Davis Technologies Int., Inc.

Summary: Ride quality depends of a combination of vertical displacement (heave) and angular displacement (pitch). Road irregularities are the main factor affecting ride comfort. Suspension elements between the road wheels and the vehicle body generate vertical forces which excite both heave and pitch motions. An active controller design based on time-scale separation and an "input decoupling transformation" is given. It is shown to give better performance that conventional passive suspension control.

Keywords: Active suspension control, heave and pitch control, skyhook damping control, time-scale separation, input decoupling transformation.

An Object-Oriented Modular Simulation Model for Integrated Gasoline Engine and Automatic Transmission Control

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Summary: In this paper a computer simulation model for control system design of gasoline engines with an automatic transmission is presented. A modular programming approach has been pursued, and MATLAB/SIMULINK has been utilized as a programming environment. Engine/transmission systems are analyzed in the object-oriented fashion. Thus, easy construction of various computer models by assembling various objects is possible. An object in this paper represents a physical part, an equation, or an algorithm. The top level in the powertrain model consists of three classes: an engine, a transmission, and a driveline. Each class is designed to perform by itself. The construction procedure of a typical powertrain model together with supplementary explanation is demonstrated. It is expected that the whole program and individual class constructed in this paper are useful for the automotive engineers who design a new engine/transmission system and/or modify an existing system.

Keywords: MATLAB/SIMULINK, gasoline engine, automatic transmission, object-oriented model.

A Comprehensive Model for ICE Oriented to the Electronic Control of the Injection

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Summary: The electronic control of spark ignition port injected engines requires simulation tools able to predict online the relevant dynamics concurring to the mixture formation, mainly during engine transients.

A comprehensive mathematical model, specifically conceived for this application, is presented in this paper. The model is based on a time-dependent physically consistent description of the main processes. The most peculiar aspect is the integration between the description of the air and exhaust gas dynamics inside the manifolds and the model for the fuel dynamics in liquid and vapour phases. The gas model describes the pressure wave propagation in the ducts in a lumped-parameter way; the fuel model adopts a quasi-lagrangian two-dimensional approach for the spray and a zero-dimensional representation for the fuel puddles. The overall model, which has a modular structure, also accounts for the other relevant processes occurring in the engine, such as combustion, heat transfer, pollutants formation, shaft dynamics, etc.

The model has been applied on a one-cylinder, electronically injected, research engine (AVL 540), that is under testing by the authors. The results obtained for the air and exhaust dynamics point out the accuracy of the model when compared with the more complex and resource-consuming method of characteristics. The model has been then applied to build the steady air maps of the engine and to characterize the parameters of an universally adopted fuel dynamics model (X-τ) at different operating conditions.

Keywords: Internal combustion engines, electronic control, modeling.

Stable Inversion of MIMO Linear Discrete Time Non-Minimum Phase Systems

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Summary: A novel technique to achieve output tracking via stable inversion of non-minimum phase linear systems is presented wherein the desired signal is obtained from field measurements, and hence corrupted by noise. The earlier approach to stable inversion does not take into account the noise in the system. The unknown input decoupled observer approach is applicable only to minimum phase systems. Moreover, the unobservable states are inadequately constructed resulting in inferior output tracking in the presence of noise. In this paper we extend this procedure to non-minimum phase systems. We present the novel Stable Dynamic model Inversion (SDI) approach which is applicable to non-minimum phase systems, and takes into account the presence of noise in target time histories.

Keywords: Discrete time systems, model inversion, output tracking.

State Space and Internal Models in Discrete-time LQ Regulator Design

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Summary: Discrete-time state space model, denoted by $\mathcal{I}$, is proposed for direct implementation of the discrete-time linear-quadratic regulator (DLQR) in the case when not all the state components but only the output of the plant is available, or using other words, when not a state feedback but output feedback is implemented. It is shown that for the proposed state, the DLQR problem solution determines the dynamic regulator with output feedback. In connection with this the order of the closed loop system is increased with respect to the case when the DLQR with state feedback is applied. It is shown that the CL system with dynamic DLQR and output feedback implements solution of the optimal DLQ problem with state feedback for the augmented state space model, denoted by $\mathcal{II}$. It is also shown that the DLQR problem solution for the model $\mathcal{II}$ and appropriately chosen performance index gives partially prescribed pole placement of the closed-loop system. The case of non zero both the set point and disturbance is considered by using an appropriate internal model corrector. Including this corrector to the augmented plant the considered case is transformed to usual DLQR stabilisation problem with zero set point. Using the proposed state determination and internal model approach, the modified DLQR design technique, giving a partially prescribed pole placement, is described. Finally, the method is illustrated in an example.

Keywords: Linear-quadratic regulator, discrete-time systems, state space models, internal models, system design.

Modified Internal Model Control for Unstable Systems

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Summary: In the present paper, we propose a modified Internal Model Control systems that is implemented for unstable plants. This modification is simple and natural. Some characteristics of modified Internal Model Control such as stability, robust stability and so on are clarified.

The Wiener-Hopf Standard Control Problem: A Stable Fractional Approach

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Summary: In this paper, we present the solution to the standard Wiener-Hopf control problem with the quadratic cost. The solution presented here is based on the stable, rational and proper fractional representation theory and spectral factorizations, and in particular the controller class is proper. Three cases of the external signal are considered. Under a set of assumptions, the minimum and finite costs are given. Meanwhile controllers are also parameterized in terms of an arbitrary stable, real rational, and strictly proper matrix $Z(s)$.

Keywords: The standard control problem, Wiener-Hopf optimization design, stable fractional representation.

Reduction of Singular 2D Models to Equivalent Standard Models

Tadeusz Kaczorek Warsaw Univ. of Technology

Summary: A new extended Roesser type model is introduced. It is shown that:

1. Any singular 2D general model (1) with can be reduced to the model (6) (or (6')));
2. Regular singular 2D model (9) can be reduced to standard extended Roesser type model (11),

Sufficient conditions are established under which a singular 2D general model (1) can be reduced to standard models of the form (28) or (35).

Keywords: Extended Roesser model, singular 2D model, reduction, sufficient conditions.

Some New Results in Theory of Controllability

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Summary: The new necessary and sufficient conditions, formulated in terms of convergence of a certain sequence of operators involving the resolvent of the negative of the controllability operator, are found for deterministic linear stationary control systems to be completely and approximately controllable, respectively. These conditions are applied to study the S_T-controllability (that is a property of attaining for the time T an arbitrarily small neighborhood of each point in the state space with a probability arbitrarily near to one) and the C_T-controllability (that is the S_T-controllability fortified with some uniformity) of stochastic systems. It is shown that a partially observable linear stationary control system with an additive Gaussian white noise disturbance is S_T-controllable (C_T-controllable) for each $T > 0$ if and only if its deterministic part is approximately (completely) controllable for each time $T > 0$.

Keywords: Controllability, stochastic controllability, linear systems.

Iterative Adaptive (Unfalsified) Control

Robert Kosut SC Solutions Inc.

Summary: Uncertainty model unfalsification is reviewed. Based on the concept of unfalsification, an iterative direct (unfalsified) adaptive control scheme is proposed which may alleviate some of the difficulties of iterative adaptation, e.g., convergence.

On the Design of Direct Adaptive Controllers

Felipe M. Pait Univ. de São Paulo

Summary: Direct adaptive control systems without the familiar reference models is considered. A framework for design using quadratic cost functions is presented, and corresponding error equations are derived using ideas from linear-quadratic optimal control.

Keywords: Adaptive control, direct control, Linear-Quadratic optimal control.

Tuning via Measurements of the Squared Error

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Summary: Given data x, we wish to adjust a parameter vector $p(t)$ so as to minimize $z(t) = x^p - y$ as best we can in some norm sense. If y (or equivalently z) were available, we might choose as our cost function the integral of z^2 and minimize it using standard least-squares algorithms. We consider the case when neither y nor z are available; rather, at each instant we are able to choose $p(t)$ and measure $z^2(t)$, that is to say, z's magnitude but not its sign.

Keywords: Adaptive control, parameter estimation, direct control.

Adaptive Generalized Predictive Control Subject to Input Constraints

Andrzej Królikowski Technical Univ. of Poznań

Summary: Generalized predictive control (GPC) problem of ARIMAX/ARMAX system in the pres-ence of input constraints and parametric uncertainty is considered. An adaptive controller is implemented in an indirect way, and the considered constraints imposed on the control signal are of the rate, amplitude and energy type. A simulation comparative study of the adap-tive control system behavior is given with respect to the design parameters and constraints. Additionally, two one-step controllers are compared by means of simulations.

Keywords: Generalized predictive control, adaptive control, input constraints.

Decentralized Adaptive Controller with Zero Residual Tracking Errors

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Summary: In this paper we develop a unified approach to the solution of the adaptive decentralized tracking problem. First we propose a decentralized information setup of control with reference model coordination, which allows to use coordinating information about reference signals of the other subsystems in all local control laws. This setup guarantees zero residual tracking errors for unmodeled interconnections and the local dynamics. We proposed a modified local adaptive control scheme with an additional delayed signal, which improves the transient performance. We use our new setup for the decentralized adaptive control of hybrid systems in which the control parameters are updated at discrete instants.

Keywords: Adaptive decentralized control, large-scale systems, model coordination.

Advanced Adaptive Control for Complex Nonlinear Processes

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Ion Dumitrache Univ. Politehnica of Bucharest

Summary: Adaptive techniques based on neural-networks are investigated in an application to the identification and subsequent on-line control of a process exhibiting nonlinearities and typical disturbances. The method proposed consists of a novel identification technique based on extended memory adaptation (EMA) and an efficient implementation of the predictive control based on a nonlinear programming method. A forced circulation evaporator was chosen as a realistic nonlinear case study for the techniques discussed in the paper.

Keywords: Adaptive control, nonlinear models, on-line control, neural networks.

PI Controller Tuning via Multiobjective Optimization

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Summary: A great number of PID controller tuning methods is now available to the designer of process control systems. Most of them are based on the satisfaction of single design objectives, such as the decay ratio, phase and gain margins, resonant peak and frequency, overshoot and certain error integral criteria. However, these methods have several shortcomings that stem from the fact that all degrees of freedom, namely the controller adjustable parameters, are consumed in order to satisfy a single objective. It is widely recognized that the solutions of numerous design problems, in various branches of engineering, are incomplete because they fail to take into account all the important characteristics of the particular problem. Controller design problems are among them. The problem that the controller designer faces is the simultaneous satisfaction of several criteria that are posed either on the time or on the frequency domain. In this respect, in this paper, a new method for tuning PI and PID controllers for models commonly used in process control, is presented. The proposed method is based on the satisfaction of more than one control design objectives. The design objectives are the satisfaction of certain phase and gain margin, the maximization of the resonant frequency and the minimization of a weighted integral of squared error. In solving the multiobjective optimization problem obtained, a simplified goal attainment formulation is proposed. The usefulness of the proposed method is demonstrated through simulation examples and a comparison with well known tuning formulas is also provided. The proposed method gives satisfactory results for models such as integrator plus delay time and first order plus delay time models. Furthermore, the method is shown to give acceptable tunings even in the extreme cases where the delay time is the dominant feature of the system under study. Thus, the proposed method is applicable in a wide range of controller design problems commonly encountered in process control giving satisfactory results.

Keywords: PID controllers, process control, tuning rules, multiobjective optimization, goal attainment method.

Decomposition-Coordinated Optimization of Large-Scale Discrete Systems with Parallel-Sequential Coordinated Scheme

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Summary: Hierarchical algorithms are developed for optimal control of interconnected discrete dynamic large-scale systems with control and state constraints. Synthesis of algorithms based on goal function adaptation in a specially formulated intermediate equivalent optimization problem in three (or two) levels. New algorithms are used iterative parallel-sequential coordination scheme which take in to account information about subsystem states in the calculation coordinated parameters. One feature of this is that fixing state and control prediction trajectories are not common for all subsystems but update for them. This algorithms have shown computational benefits.

Keywords: Optimal control, large-scale interconnected systems, decomposition-coordinated methods.

Generalized PID Controller

Ilan Rusnak RAFAEL — ADA

Summary: The PI, PD and PID controllers are widely used and successfully applied controllers to many applications. Their successful application, good performance, easiness of tuning are sufficient rational for their use, although their structure is justified by heuristics. In this paper by the use of optimal control theory we formulate a tracking problem and show those cases when their solution gives the PI, PD and PID controllers, thus avoiding heuristics and giving a systematic approach to explanation for their excellent performance. It is shown that the PI controller is optimal for a first order system, the PID controller is optimal for a 2nd order systems with no zero. The reference trajectory is generated by a system identical to the plant. Then the same approach, that led to the PI and PID controller, is applied to a general linear, strictly proper system and a generalized PID controller is derived. Such controller is called here PIDn-1 controller. As an example, a generalized PID controller for a DC motor with one flexible mode is presented.

Keywords: PID controller, optimal control

Lagrange Problem for Non-Standard Nonlinear Singularly Perturbed Systems

Emilia Fridman Tel-Aviv Univ.

Summary: We study the infinite horizon optimal control problem for an affine singularly perturbed system, which is nonlinear not only in the slow variable (as in the standard case), but also in the fast variable. We construct an ϵ-independent composite controller by solving a slow partial differential equation, that corresponds to the reduced Hamiltonian system, and by solving a fast partial differential equation. The composite controller solves the local Lagrange problem for all small enough ϵ. It solves also the corresponding problem for the descriptor system. We obtain an asymptotic approximation of the optimal controller, optimal trajectory and of the solution to Hamilton-Jacobi equation.

Keywords: Singular perturbations, nonlinear optimal control, descriptor systems.

Optimization for Part Nesting and Layout Using a Distributed SPMD Architecture

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Summary: There is a need to perform highly complex real-time optimization during manufacturing to solve the problem of maximizing the yield of production while minimizing the cost of materials. Although traditional linear and non-linear programming approaches have dealt with these problems, some problems are too complex and result in a combinatorial explosion for those methods. We are interested in developing a solution to the leather nesting task, an NP-hard problem. We feel the best solution to a large and complex problem such as this is to attempt to model the behavior that is already evident in nature. There are many examples in nature providing an optimal packing or nesting of items. Our algorithm will offer a better solution to problems of this class by presenting a controlled trade-off between computation time and regional optimality of the solution. Our goal is to develop an algorithmic scheme that will yield the best possible solution to this combinatorial optimization problem using a hierarchical approach to object determination and placing, an intelligent controller, and parallel executed simple local decision rules based on nearest neighbor parameters which achieve results that are competitive with or better than the results of a human nester, and to aid in manufacturing. In our SPMD model, each object to be placed will be a separate process in a parallel computing architecture, and will consider the parameters (location, orientation) of its nearest neighbors (other parts in the vicinity) to make translocation and re-orientation decisions. We intend to show that the fusion of existing algorithms and the establishment of uniform and 'simple' local decision rules will more quickly yield to a better optimum for the entire system. The algorithms developed in this study are applicable to a large class of optimization problems.

Computing Resources Dynamic Optimization of Digital Multichannel Control Systems

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Boris A. Novikov Ufa Aviation Technical Univ.

Summary: The new view on digital multichannel control systems design is considered. The suggested method provides an optimal reallocation of calculating resources according to quality criterion including its sensitivity to sampling period variations and the risk degree of inspected coordinate approaching to critical value. Reallocation of calculating resources is based on the results of pre-calculated response surface which represents the solution of the system of non-linear equations by the Lagrange undetermined multipliers method.

Keywords: Dynamic optimisation, calculating resources, reallocation.

The Basic Ideas of Neural Predictive Control

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Summary: This paper presents the application of predictive control techniques using Artificial Neural Nets (ANN). The idea is illustrate the structure of the predictive controller and the optimization functions that is usually used to update the control action, then apply the ANN technique. The ANN equations and its gradient equations are developed. Based on the ANN capacity to predict, on a optimization function and on a rule to update the control action, NPC (Neural Predictive Control) algorithms are developed and applied to control the selected plant. The paper also proposes an intelligent adaptability to ponder control action as function of dominant pole displacement.

Keywords: Predictive control, neural nets, nonlinear systems.

A Rule-Based Neuro-Optimal Controller for Nonlinear MIMO Systems

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Canan Ozgen Middle East Technical Univ.
Ugur Halici Middle East Technical Univ.

Summary: In this study, we propose a new method to control multi-input multi-output (MIMO) systems optimally. The method is based on a rule-base derived optimally, which is then interpolated by neural networks. The idea is originally based on the knowledge-based artificial neural networks (KBANN) which perform interpolation in the rule space of an expert system.

Keywords: Optimal control, neural networks, rules based systems, interpolation.

Neural Network Based Softsensor for a Tubular Reactor

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Summary: The paper deals with the mathematical modeling of a high pressure jacketed tubular reactor and the development of a neural network based softsensor for estimating the polymer (low density polyethylene) quality at the exit of a tubular reactor. This is of a great practical importance as the measurement of the polymer quality (given by the weight average degree of polymerization) is essentially needed for designing any control algorithm that regulates the end-use properties of the polymer. The reactor model consists of differential equations written as function of the dimensionless reactor length. The rates of formation of various species in the reactor are described by the kinetics of free radical polymerization. The method of moments is used for describing the polymer molecular properties. The chain transfer to solvent process and the coolant flow through the reactor jacket are taken into account. The reactor mixture speed is assumed constant, the inlet pressure and the pulse valve effects are not included in the model. The reactor model is simulated, compared with results obtained by other authors and resembles the behavior of a healthy tubular reactor. The general property of the reactors in the chemical industry is that they are highly nonlinear. Moreover, important variables (such as the weight average degree of polymerization) can not be measured directly and on-line. An alternative is to use a softsensor measurement. The softsensor is an artificial intelligence instrument and belongs to the class of inferential measurement techniques. The paper develops the general concept of the softsensor and applies it to the problem of estimating the polymer quality. A tubular reactor with one injection of initiator, with a preheater section and coolant flow is considered. The process information easily measurable and directly available for building the softsensor consists of the temperature profile, the coolant flow temperature and the solvent concentration. As softsensor structure a feedforward neural network with one hidden layer is employed. Neural networks have strong nonlinear function approximation capabilities and are widely used for modeling of nonlinear processes. The data for the neural networks training/validation is obtained by integrating the reactor model for different initial conditions. The neural networks inputs consist of directly measurable process variables and process characteristics (such as the area under the temperature profile peak, the peak location). The solvent concentration proves to be an important input for the softsensor and improves significantly the softsensor approximation property.

Keywords: Mathematical modeling, tubular reactor, polymerization, neural network, softsensor.

An Expert-Aided Implementation Interface for Industrial Process Control Systems

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Summary: We present the design and implementation of a new expert-system "front end" or *Design Advisor for Implementing Systems* (DAIS) for use in conjunction with a commercial digital control system environment, e.g., the Elsag Bailey INFI 90 System. The objective of DAIS is to make it substantially easier for applications engineers to make effective use of the broad spectrum of capabilities of this and similar hardware and software systems for industrial controls implementation. This concept is of quite general applicability for industrial controls environments.

Keywords: Computer-aided control engineering, expert-aided controls implementation, controls design advisor.

A Self-Organizing Neurocontroller for Vibration Suppression

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Herman Ramon K.U.Leuven

Summary: The Self-Organizing Map Neural Network is used in a supervised way to represent a sensor-actuator mapping. The learning of the controller assumes no prior information, but only reward/failure signals that are produced by an evaluation criterion. The evaluation criterion used is based on the low-pass filtering of the gradient of a reward function and the local storing of the filtered gradient value. The control method is tested in vibration isolation of a flexible spray boom used in agriculture for pesticide application. The Neural Network learns to stabilise the boom on-line without any prior information and with a very high performance.

Keywords: Neural networks, self-organizing systems, active vehicle suspension, agriculture.

A New Modeling of the Macpherson Suspension System and its Optimal Pole-Placement Control

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Summary: In this paper a new model and an optimal pole-placement control for the Macpherson suspension system are investigated. The focus in this new modeling is the rotational motion of the unsprung mass. The two generalized coordinates selected in this new model are the vertical displacement of the sprung mass and the angular displacement of the control arm. The vertical acceleration of the sprung mass is measured, while the angular displacement of the control arm is estimated. It is shown that the conventional model is a special case of this new model since the transfer function of this new model coincides with that of the conventional one if the lower support point of the damper is located at the mass center of the unsprung mass. It is also shown that the resonance frequencies of this new model agree better with the experimental results. Therefore, this new model is more general in the sense that it provides an extra degree of freedom in determining a plant model for control system design. An optimal pole-placement control which combines the LQ control and the pole-placement technique is investigated using this new model. The control law derived for an active suspension system is applied to the system with a semi-active damper, and the performance degradation with a semi-active actuator is evaluated. Simulations are provided.

Keywords: Suspension, control arm, frequency response, optimal control, pole-placement.

A Numerical Algorithm for the Design of a Decentralized Controller for Open-Channel Networks

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Summary: In this paper we propose the design of a decentralized constant-volume control law for open-channel networks. The decentralized controller enables us to maintain the stored volumes in the different reaches practically constant, even with variations in users withdrawals, by acting only on the upstream gate of the reach whose volume variation is detected.

Control law is designed by solving a linear least squares problem in the frequency domain. The numerical algorithm adopted allows us to impose the desired structure to the feedback gain matrix by means of the optimization of the controller parameters. It makes the closed-loop transfer function approach a target function as closely as possible over a specified frequency range.

Keywords: Open-channels, decentralized control, structured feedback control law, linear least squares problem.

Flight Control Design for a Missile: An Approximate Feedback Linearization Approach

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Summary: Input-output approximate linearisation of a non-linear sixth order system has been studied. A method for controlling the non-linear system that is i/o linearisable is examined that retains the order and the relative degree of the system in the linearisation process, hence producing a linearised system with no internal or zero dynamics. Desired tracking performance for lateral accelerations and roll rate of the missile is achieved by using a non-linear control law that has been derived by selecting the lateral velocities and roll rate as the linearisation outputs. Simulation results are shown that exercise the final design and show that the linearisation and controller design are satisfactory.

Keywords: Non-linear multivariable control, feedback linearisation, trajectory control, missile system.

Robust Quasi NID Current and Flux Control of an Induction Motor for Position Control

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Summary: In the paper, a new control design method called Dynamic Contraction method is applied to the flux and quadrature current robust control of an induction motor operated using the field orientation principle. The resulting input-output decoupled and linearized drive is then used for time-optimal position control. Two control structures providing a practically time-optimal control are presented and compared.

Keywords: Dynamic Contraction Method, field oriented control, time optimal control.

Contact Elimination in Mechanical Face Seals Using Active Control

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Summary: Wear and failure of mechanical seals may be critical in certain application and should be avoided. Large relative misalignment between the seal faces may cause intermittent contact and the increased friction eventually can bring failure. Adjustment of seal clearance is probably the most readily implemented method, of reducing the relative misalignment in order to eliminate seal face contact, during seal operation. This method is demonstrated with the aid of a noncontacting flexibly mounted rotor (FMR) mechanical face seal test rig employing a cascade control scheme. Eddy current proximity probes measure the seal clearance directly. The inner loop controls the clearance, maintaining a desired gap through adjusting the air pressure in the rotor chamber of the seal. When contact is detected the outer loop adjusts the desired clearance according to variance differences in the probes signals. These differences in variance have been found to be a reliable quantitative indication for such contacts. They are complimentary to other more qualitative phenomenological indications, and provide the controlled variable data for the outer loop. Experiments are conducted to test and verify the control scheme and strategy. Analysis and results both show that, for the seal under investigation and contrary to intuition, reducing seal clearance can eliminate contact.

Keywords: Mechanical face seal, contact elimination, active control.

Design, Simulation & Control of a Segmented Reflector Test-bed

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Summary: Segmented reflectors are one of the best practical choices for future astrophysical missions. Because it lacks the dimensional stability provided by a monolithic primary mirror, a segmented reflector requires an active control system in order to make the reflecting surface have comparable optical performance. This paper describes a control oriented test-bed developed at the Control and Structures Research Laboratory (CSRL) at California State University, Los Angeles (CSULA). The CSRL test-bed is a 2.4 m focal length Cassegrain configuration telescope consisting of a 2.66 m actively controlled segmented primary and an active secondary. The primary consists of six hexagonal panels surrounding a fixed central panel and supported by a light-weight flexible truss structure. The project has been funded by NASA to study the complex dynamic behavior of large segmented optical systems.

Keywords: Control, structures, segmented reflector, test-bed.

Generalized Versions of Bode's Theorem

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Summary: The fundamental theorem of Bode states that the integral over all frequencies of the natural log of the magnitude of the sensitivity function vanishes. This was seen to be true for an open-loop stable function with the difference between the degrees of the numerator and denominator at least 2. Extensions of the theorem have been carried out *(1)* to unstable open-loop systems *(2)* to eliminate the limitation that the difference between numerator and denumerator must be greater than 1. A generalized version of Bode's theorem to include weighted sensitivity integrals is presented. The theorem is also extended to include transfer functions with time delay. Some examples are provided to show its utility.

Keywords: Bode's theorem, sensitivity integral, weighted sensitivity, time-delay systems.

On a Conjecture and the Internal Model

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Summary: In the robust tracking problem with two-output plants it is shown that if the plant is unstable, the mumerators corresponding to the two outputs cannot be unrelated. However, if the plant is stable, the two parts of the plant can be unrelated and, in fact, the compensator which solves the problem incorporates an inverse internal model of the exogenous signal.

Keywords: Tracking, two-output plants, inverse internal model, robustness, stability.

Reliable Computation of the Input-State-Output Relations in Autoregressive Representations of Multivariable Systems

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Summary: Input-state-output analysis of systems with external variables on equal footing is pursued through a numerical algorithm for processing a set of linear differential equations in the form of an autoregressive representation. Instead of resorting to the computation of elementary polynomial operations, numerically robust routines from numerical linear algebra are used to compute an implicit state-space realization in the form of a minimal driving variable representation. The representation is used to detect candidate inputs among the external variables. The algorithm is based on polynomial matrix to state space conversions leading to application of well-proven methods of numerical linear algebra such as Gram-Schmidt orthonormalization, Householder transformations, and the singular value decomposition.

Keywords: Subspace methods, numerical methods, linear systems.

The Suboptimal Tracking Problem in Linear Systems

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Summary: The contribution is focused on control system design for the purposes of suboptimal LQ tracking in continuous-time SISO linear systems. The proposed method is based on the polynomial approach. The presented procedures are proposed for a class of references frequently used in practice. The resulting controller is obtained via the solution of a polynomial Diophantine equation with the right side given by spectral factorization. The theoretical results are tested on an illustrative example.

Keywords: LQ tracking, polynomial approach, spectral factorization, Diophantine equation.

Margins and Bandwidth Limitations of NMP SISO Feedback Systems

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Summary: Equations and graphs in order to evaluate the limitations and tradeoff between extreme cross over frequencies and gain and phase margins of an important class of open loop non minimum-phase transfer functions, as a function of the right half plane zeros or poles, are given.

Keywords: Feedback, non minimum phase, bandwidth limitations, margins, SISO.

Reachability and Controllability of Positive Linear Systems with State Feedbacks

Tadeusz Kaczorek Warsaw Univ. of Technology

Summary: It is shown that the reachability and controllability of positive linear systems is not invariant under the state-feedbacks.

Keywords: Controllability, invariance, positive linear system, reachability, state-feedback.

Adaptive Hybrid Physical/Neural Network Modeling and its Application to Greenhouse Climate Optimization

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Summary: This paper focuses on adaptive modeling of non-linear systems which operate in slowly changing environments. Due to an inability to control the environment, a large amount of data spanning the whole feasible input space can not be collected over a reasonably short period of time. As a result, modeling such systems with neural networks, which usually have poor extrapolation properties, might lead to poor results. In order to avoid these poor extrapolations, hybrid physical/neural network models are used. Such models are formed by the combination, in parallel, of a physical model (approximately valid over the whole space), and a radial basis function (RBF) network, which provides localized predictions only where training data are available.

In this paper, the hybrid modeling approach is extended by adapting the RBF network on-line, so that the region over which the network is valid grows over time. In order to simplify the RBF training, the centers are located on a fixed rectangular grid: if necessary, a new center is added at the grid point closest to the new datapoint. This approach also allows for keeping the RBF width constant and equal for all the centers.

The problem of discarding some of the data, so that the database does not become prohibitively large, is also addressed. In order to avoid 'forgetting' previously modeled regions of the space, datapoints are not discarded based solely on their 'age'. Rather, the number of datapoints near each center is limited, and when this limit is reached, the oldest datapoint associated with that center is discarded.

Greenhouse climate modeling, and its use for climate optimization, is presented as an illustration of the method.

Keywords: Hybrid modeling, adaptation, greenhouse, radial basis function.

Initialization and Model Reduction for Wiener Model Identification

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Summary: The identification of nonlinear systems by the minimization of a prediction error criterion suffers from the problem of local minima. To get a reliable estimate we need good initial values for the parameters. In this paper we discuss the class of nonlinear Wiener models, consisting of a linear dynamic system followed by a static nonlinearity. By selecting a parameterization where the parameters enter linearly in the error, we can obtain an initial estimate of the model via linear regression. An example shows that this approach may be preferential to trying to estimate the linear system directly form input-output data, if the input is not Gaussian. We discuss some of the user's choices and how the linear regression initial estimate can be converted to a desired model structure to use in the prediction error criterion minimization. The method is also applied to experimental data.

Keywords: System identification, Wiener models, nonlinear systems, local minima.

Nonlinear Identification of Automobile Vibration Dynamics

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Summary: The identification of nonlinear state-space systems from input-output measurements is considered. The system is separated into a linear state-space system with a static nonlinearity, driven by the state and input, in feedback. Initially, the contribution from the nonlinearity is treated as an unknown system input driving an otherwise linear plant. A neural network is then used to model the feedback nonlinearity. A realistic simulation of a nonlinear automobile suspension is used to demonstrate the application of the identification algorithm.

Keywords: State-space models, subspace methods, stable inversion, nonlinear system identification, neural networks.

Generalization: A Hidden Agenda in System Identification

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Summary: This paper concerns the importance of the generalization concept in system identification.

Typically system identification is carried out by adapting parameters so as to minimize a criterion or cost function on a limited set of noisy training data samples obtained from the underlying potentially nonlinear system. However, there is always the hidden agenda that the model should perform well, not only on the training set, but also on the future samples. Invoking the generalization concept provides a handle on the model bias/variance trade off as well as model predictions. In this context, we define generalization performance as the expected performance on future data.

We discuss how the generalization concept can be formulated for nonlinear stationary, as well as non-stationary systems using flexible models such as neural networks. Further, various methods for assessing the generalization performance is mentioned, and finally, it is demonstrated how the generalization performance actively can be used as a tool for optimizing the model structure.

The suggested framework is demonstrated on simple system identification problems.

The paper can be downloaded via: http://eivind.imm.dtu.dk/staff/jlarsen/pubs or ftp://eivind.imm.dtu.dk/dist/1999/larsen.med99.ps.gz

Keywords: Generalization error, non-stationary systems, nonlinear system identification.

Nonlinear Identification of the Position Sled Dynamics of a CD Player

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Summary: This contribution concerns the identification of the dynamics of a sled carrying the optics housing of a CD player. The memory access time of the CD player depends, among other factors, on the settling time of the sled after a step change. This contribution focuses on the oscillations at the end of a step response. Measured closed-loop data are used to identify different types of black-box models of the sled dynamic. First linear models are concerned, and then different types of nonlinear models. The different types of models are compared and discussed. Due to poor excitation of the plant, some conclusions are uncertain. However, it is clear that the nonlinear models give better simulation performance on validation data than the linear ones. Also, the oscillations at the end of a step response seem to be controller induced. Therefore, it seems appropriate to use different models, and then also different controllers, at different parts of a step response.

Keywords: Nonlinear system identification, nonlinear systems, estimation, modeling.

A Global Optimization Approach to Nonlinear System Identification

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Summary: This paper addresses the identification problem for nonlinear multivariable dynamical systems. A novel identification method is presented, which is based on a suitable modification of Simulated Annealing Algorithm. This method allows to formulate and solve numerically the related minimization problem by using an efficient random search minimization approach. The main features of the proposed identification method are illustrated through its application to a case study, which consists of the simulated hysteretic model of a vibrating civil structure under seismic excitation. The results show that the proposed identification method is quite efficient in comparison with other conventional identification methods.

Design of a Multivariable Pole-Placement Controller for the Primary Mirror of the 10m Grantecan Telescope

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Summary: In the design of a telescope the most important specification is to obtain a quality in the images as high as possible. The Gran Telescopio Canarias (GTC) has got a 10m diameter primary mirror, which is segmented in 36 hexagonal pieces. This paper presents a multivariable controller for the primary mirror based on a local-global strategy. This means that the command sent to the segments will have a local contribution (using information of the own segment) and a global contribution (using information of the whole mirror). The goal of the control process is to keep the 36 segments which form the primary mirror always on a paraboloidal surface. The controller design process has been fundamental to know in detail the system dynamics features in the sense of symmetries and the coupling existing in the primary mirror of the GTC. The requirements about the sampling frecuencies have also been studied. This work is the result of a collaboration between the GRANTECAN, S.A. Company and the Group of Computers and Control of Department of Applied Physics of La Laguna University.

Application of a Classical PD Regulator to the Control of a Flexible Planar Closed Chain Linkage

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Stefano Miani Univ. of Udine

Summary: This paper presents an approach to the control of a flexible planar closed-chain linkage. A very accurate dynamic model of the system is briefly summarized. Such a model is then employed to test a classical PD regulator in simulation to control a flexible planar four-bar linkage. The chosen PD control is described, and the most significant results of the simulation are presented and discussed.

Keywords: Flexible mechanism, four-bar linkage, PD control, simulation.

Control of Flexible Structures Using Models with Dead Time

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Yoram Halevi Technion — IIT

Summary: A new method for modeling and control of noncollocated flexible structures is proposed. The first step is modeling the controlled structure by a reduced order model including a delay between actuator excitation and the noncollocated sensor measurement, caused by the finite wave propagation velocity. A fixed order control scheme for compensating the response delay is then used. In addition, a new design methodology for the controller gain matrices, such that the residual dynamics is suppressed and the spillover effects are reduced, is suggested.

Keywords: Flexible structures, vibration control, order reduction, dead time, spillover suppression.

Balanced Realization of Flexible Structures with General Damping: A Power Series Approach

Yoram Halevi Technion — IIT

Summary: A method of approximating the balanced realization for lightly damped flexible structures is presented. The damped system is treated as a perturbation from the undamped system, and the controllability and observability gramians, as well as the balancing transformation are given as a power series in the perturbation scaling factor. The approximation utilizes the special structure of the system i.e. the positive definitness of the inertia, damping and stiffness matrices, and the fact that the damping is small., to obtain closed form expressions for the series coefficient matrices. These expressions lead to interesting structural properties, which are discussed and related to physical properties of vibrating systems. The results can be obtained at any level of accuracy by appropriate truncation of the series.

Keywords: Order reduction, balanced realization, flexible structures.

Computation in closed form of the equations of motion for a flexible beam with lumped masses and rotational inertias

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Antonio Tornambè Univ. di Roma Tre
Luca Zaccarian Univ. di Roma Tor Vergata

Summary: This paper is concerned with the problem of modelling flexible structures in which the effects of distributed elasticity and of both distributed and lumped masses are to be taken into account. The eigenvalue-eigenfunction problem, which constitutes the exact model of the free vibrations of the structure, is given for the general case of a flexible beam having lumped masses and rotational inertiae placed along its length. The proposed method is applied to a simple case study: a clamped beam with a rigid body attached to its free end.

Keywords: Flexible structures, Lagrangian techniques.

Improved Observer for Sensor Fault Diagnosis of a Power Plant

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Sergio Beghelli Univ. di Ferrara

Summary: The paper focuses on the problem of the derivation of a suitable mathematical description of a power plant for diagnostic purpose, by using equation error models. The diagnostic tool obtained has been tested on real data acquired from the 120MW power plant of Pont sur Sambre.

Keywords: Fault detection and diagnosis, analytical redundancy, model-based approach, unknown input observer, equation error model.

Residual-Sensitive Fault Detection Filter

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Summary: A fault detection and identification algorithm, called the residual-sensitive fault detection filter, is presented. The objective of the filter is to monitor certain faults called target faults and block other faults which are called nuisance faults. This filter is derived from solving a min-max problem which makes the residual sensitive to the target fault, but insensitive to the nuisance faults. It is shown that this filter approximates the properties of the classical fault detection filter such that in the limit where the weighting on the nuisance faults is zero, the residual-sensitive fault detection filter is equivalent to the unknown input observer and there exists a reduced-order filter. Fault detection filter designs can be obtained for both linear time-invariant and time-varying systems.

Keywords: Fault detection and identification, worst case design, robust fault detection filter, analytical redundancy.

Catastrophic Failure Evaluation

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Summary: The random events of catastrophic failures impacting process control systems and networks are the topic of this paper. In an unpredictable catastrophic event such as a lighting strike, power outage, or failures only affecting certain portions of the overall system, how is the integrity of a system determined? This investigation includes overall the system impact on random catastrophic failures. System scenarios are evaluated with a method for determining impacts on these systems. Criticality Values and a composite System Criticality Value are introduced. A system vulnerability value is derived and investigated. A suggestion for mapping this methodology onto a network is encouraged.

Keywords: System criticality value, criticality values, process control, catastrophic failures, redundancy.

Nonlinear Filters with Virtual Measurements

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Summary: The method of virtual measurements will be described for designing nonlinear filters. This filter theory is based on the exponential family of probability densities, and it generalizes the Kalman filter and the Benes filter. In some important applications the performance of the new filter is vastly superior to the extended Kalman filter (EKF). Unlike the EKF, the new theory does not use linearization. This theory can be used to design exact nonlinear filters as well as approximate nonlinear filters. The new theory uses "virtual measurements" to avoid the problem of solving a system of nonlinear partial differential equations, and replaces it with the problem of solving two linear PDEs off-line, analogous to the Hopf-Cole transformation. The basic mathematical tool is a relatively new theory called "finite sums decomposition," developed by F. Neuman.

System Level Performance of Radar Waveforms

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Summary: It is well known that different radar signal waveforms produce very different resolution cells. These affect fine measurement error, gross measurement error through spurious sidelobe "pop-ups," and miss probability, and hence yield different tracking performance. In a recent paper, sonar waveform selection was explored via the hybrid conditional averaging (HYCA) method — a technique for evaluating the dynamic interaction between tracking and imperfect detection. Extension to the radar case is the subject of this paper, and this is more than evolutionary, since in order that range-rate measurements be available from resolution cells it is necessary that coherent processing of multiple pulses be used.

Keywords: Target tracking, waveform, ambiguity function, resolution cell, radar.

A Radar Power Multiplier Algorithm for Acquisition of Low Observable Ballistic Missiles Using an ESA Radar

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Summary: The problem of acquiring an incoming theater ballistic missile (TBM) presents many complex challenges. The missile should be detected and its state estimated using the measurements available from a short window of time because the flight time is short. In this paper the acquisition of an incoming tactical ballistic missile using the measurements from a surface based Electronically Scanned Array (ESA) radar is presented. In view of the emergence of low radar cross section TBMs, it is important to be able to acquire low SNR targets at long range. Such targets are characterized by low detection probability and high false alarm rate. We present a batch Maximum Likelihood Estimator (MLE) to acquire the missile while it is exo-atmospheric. The proposed estimator, which combines MLE with the Probabilistic Data Association (PDA) algorithm to handle false alarms/clutter, also uses the amplitude information (signal strength), in addition to range and angle measurements, to obtain accurate target state estimates. The use of the amplitude information facilitates target acquisition under low SNR conditions. Typically, ESA radars operate at around 13dB, whereas the new estimator is shown to be effective even at 4dB SNR, for a Swerling III type fluctuating target, which represents significant counter-stealth capability. In other words, this algorithm acts as an effective "power multiplier" for the radar by a factor of 8 (9dB). In addition to the ML estimator, a track validation scheme, which is used to confirm the presence of an incoming missile at the estimated location, is also presented. The Cramer-Rao Lower Bound, which quantifies the state estimate accuracies attainable for this low-observable estimation problem, is also presented and shown to be achieved by the proposed estimator. It is also shown that the optimum detection threshold of the radar can be found by maximizing the information reduction factor that accounts for the loss of information.

Keywords: Ballistic missile defense, anti-stealth capability, maximum likelihood estimation, electronically scanned array radar, Cramer-Rao lower bound.

Trajectory and Launch Point Estimation for Ballistic Missiles from Boost Phase LOS Measurements

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Summary: This paper addresses the problem of estimating the trajectory and the launch point of a tactical ballistic missile using line of sight (LOS) measurements from one or more passive sensors (typically satellite-borne). The major difficulties of this problem include the ill-conditioning of the estimation problem due to poor observability of the target motion via LOS measurements, the estimation of the unknown launch time, and the incorporation of inaccurate target thrust profiles to model the target dynamics during the boost phase. We present a maximum likelihood (ML) estimator based on the Levenberg-Marquardt algorithm that provides both the target state estimate and the associated error covariance, taking into consideration the complications mentioned above. One important consideration in the defense against tactical ballistic missiles (TBM) is the determination of the target position and error covariance at the acquisition range of a surveillance radar located in the vicinity of the impact point. We present a systematic procedure to propagate the target state and covariance to a nominal time, when it is within the detection range of a surveillance radar to obtain a cueing region. We also provide an estimate and the error covariance of the (two dimensional) launch position, which can be used to search for the missile launch site. Monte Carlo simulation studies on typical single and multiple sensor scenarios indicate that the proposed algorithms are accurate in terms of the estimates and that the estimator calculated covariances are consistent with the errors.

Keywords: Tactical ballistic missile defense, boost phase estimation, maximum likelihood estimation, angle-only tracking, Cramer-Rao lower bound.

Artificial Neural Network Embedded Kalman Filter Bearing Only Passive Target Tracking

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Summary: Target tracking is an important issue in underwater surveillance systems. The tracking systems in Sea Warfare utilize Passive sonar to have bearing only information contaminated with noise, which is assumed here as additive zero mean Gaussian noise. In underwater warfare two dimensional target motion analysis is familiar. The Kalman Filter (KF) is used to obtain the target parameters with the help of bearing data coming from sensor. The error in target parameters of velocity, range, heading and bearing are estimated. For some of the scenarios the errors are unacceptable to real time combat systems. Hence alternative methods are surveyed and Artificial Neural Network (ANN) is coupled with Kalman filter to reduce the creeping errors in the solution in spite of Kalman adaptive filters exist. The network selected for this purpose is Backpropagation neural network. The network is pre- trained using different inputs to predict the said target parameters. The simulation results are presented and comparative studies are conducted. The ANN provides the adaptive capability the filter model needs.

Keywords: Gaussian noise, passive sonar, Kalman filter, neural network, backpropagation.

Adaptive Pole Placement Control of Linear Systems Using Periodic Multirate-Input Controllers

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Summary: A new indirect adaptive algorithm is derived for pole placement control of linear continuous-time systems with unknown parameters. The control structure proposed in the paper, relies on a periodic controller, which suitably modulates the sampled output and discrete reference signals by a multirate periodically time-varying function. Such a control strategy, allows us to assign the poles of the sampled closed-loop system to desired prespecified values and does not make assumptions on the plant other than controllability, observability and known order. The proposed indirect adaptive control scheme estimates the unknown plant parameters (and consequently the controller parameters) on-line, from sequential data of the inputs and the outputs of the plant, which are recursively updated within the time limit imposed by a fundamental sampling period . On the basis of the proposed algorithm, the adaptive pole placement problem is reduced to a controller determination based on the well known Ackermanns' formula. Known indirect adaptive pole placement schemes usually resort to the computation of dynamic controllers through the solution of a polynomial Diophantine equation, thus introducing high order exogenous dynamics in the control loop. Moreover, in many cases, the solution of the Diophantine equation for a desired set of closed-loop eigenvalues might yield an unstable controller, and the overall adaptive pole placement scheme is then unstable with unstable compensators because their outputs are unbounded. The proposed control strategy avoids these problems, since here gain controllers are needed to be designed. The adaptive scheme, presented in the paper, is readily applicable to nostably invertible plants having arbitrary poles and zeros and relative degree and to systems which do not possess the parity interlacing property (namely, they are not strongly stabilizable). Moreover, persistency of excitation and, therefore, parameter convergence, of the continuous-time plant is provided without making any assumption either on the existence of specific convex sets in which the estimated parameters belong or on the coprimeness of the polynomials describing the ARMA model, or finally on the richeness of the reference signals, as compared to known adaptive pole placement schemes.

Keywords: Adaptive control, parameter estimation, pole placement, multirate controllers, periodically varying controllers.

Development of a Self-Tuning PID Controller Based on Neural Network for Nonlinear Systems

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Summary: The key point of this research is to develop a fast tracker for time-varying nonlinear systems which previous knowledge (i.e., dynamic equations) about the plant were not known. In order to carry out this research goal, this paper suggests a novel error self-recurrent neural networks, and develops a fast on-line learning algorithm by using the recursive least squares method. The new neural networks are considerably faster than the backpropagation algorithm and have advantages of being less affected by poor initial weights and learning rate. Nonlinear adaptive PID controller based on these neural networks has been derived and tested for the fast tracking problem in a robot manipulator.

Multi-Drug Infusion Control Using a Robust Direct Adaptive Controller for Plants with Time Delays

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Summary: The control of hemodynamic variables, particularly mean arterial pressure (MAP) and cardiac output (CO), is a challenging problem. A good controller is difficult to design, due to the complex, nonlinear behavior of the system. Adding to this are the significant changes in dynamics from one patient to another, and even variations in the patients response to the drugs as his condition evolves. A robust direct model reference adaptive controller (DMRAC) is developed for such plants with uncertainty in both the time delay elements and in the transfer function coefficients. In order to satisfy the conditions for asymptotic model following, it is sufficient to satisfy certain passivity conditions for all possible values of the plant parameters. This is done by transforming the plant variations and time delays into a frequency dependent plant perturbation in the plant transfer function. Feedforward compensator design procedures are then developed using an optimization based robust stability analysis, so that the passivity conditions are satisfied.

Keywords: Control of hemodynamic variables, robust adaptive control, positive real.

Indirect Adaptive Control of Drug Infusion for a Circulatory System Model

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Summary: An indirect adaptive control algorithm using recursive identification and linear quadratic regulation was usedto compute the infusion of two drugs in order to control blood pressure and cardiac output in a realistic physiological nonlinear multiple-input multiple-output representation. Two types of recursive identification were considered; namely, conventional recursive least squares (RLS) and a modified version (MRLS) that penalizes large parameter changes. Results show that the adaptive procedures are capable of controlling the responses to within their specified tolerances and that initial tuning of the adaptation parameters can be reasonably performed using a linearized system model.

Optimal Adaptive Control of Uncertain Stochastic Discrete Linear Systems

Ilan Rusnak RAFAEL — ADA

Summary: The problem of optimal control of stochastic discrete linear time-invariant uncertain systems on finite time interval is formulated and partially solved. This optimal solution shows that previously published adaptive optimal control schemes and indirect adaptive control schemes do not need heuristics for their rationalization. It is shown that these schemes are suboptimal causal approximations of the optimal solution. The solution is achieved by the introduction of the State and Parameters Observability form - SPOF. This representation of linear time-invariant systems enables application of tools from the LQR-LQG theory of control and estimation of discrete linear time-varying systems. The optimal solution is exact and non causal. It is composed of a causal optimal estimator of the augmented state composed of the state of the system and the parameters and of a non-causal controller. The solution shows that certainty equivalence principle applies for the state and parameters, but the separation does not apply. A causal suboptimal controller, using certainty equivalence is proposed as an ad-hoc solution. This controller needs only the knowledge of the order of the system. The scheme is bibo stable for sufficiently low noises. As an example, the proposed algorithm, is applied to an unstable nonminimum phase model of a dynamic vehicle.

Keywords: Optimal control, adaptive control, uncertain linear systems, stochastic systems.

Improved Wiener-Hopf Method for H^2-Design of Sampled-Data Systems

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Summary: The paper deals with the direct design of sampled-data systems in the H^2-metric by applying the Wiener–Hopf method. The presented technique avoids basic controllers during the design procedure that are normally used to parametrize the set of stabilizing controllers. The suggested method is independent from the pole situation of the transfer matrices of the plant model and is also applicable if poles are placed on the imaginary axis.

Keywords: Sampled-data control, MIMO, parametric transfer matrix, Wiener-Hopf method, H^2-optimization.

H^∞ Design of Generalized Sampling and Hold Functions with Waveform Constraints

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Summary: This paper deals with the sampled-data H^∞ control problem where both the discrete-time part of the controller and the A/D (sampler) and D/A (hold) converters are design parameters. It is known that the optimal sampler and hold that solve this problem have continuous (exponential) waveforms and thus are not readily implementable on digital hardware. In this respect, in this paper the problem is treated subject to *waveform constraints* on hold and sampling functions. In partricular, the generalized hold is constrained to be piecewise-constant and the generalized sampler is constrained to have piecewise impulse waveform.

The paper presents complete solution to this problem. A separation between the design of the sampler and the hold is established. Moreover, some interesting interpretations of the resulting sampled-data controller are discussed. In particular, it is shown that the (sub) optimal hold attempts to "reconstruct" the H^∞ state-feedback control law of the single-rate sampled-data control system with faster sampling period.

Keywords: Sampled-data systems, generalized sampling and hold circuits, H^∞ control, lifting technique.

Sampling Zeros and Robust Sampled-Data Control Design

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Summary: In this paper, we investigate the implications for robust sampled-data feedback design of minimum phase sampling zeros appearing in the transfer function of discrete-time plants. Such zeros may be obtained by zero-order hold (ZOH) sampling of continuous-time models having relative degree two or greater. In particular, we address the robustness of sampled-data control systems to multiplicative uncertainty in the model of the continuous-time plant. We argue that lightly damped controller poles, which may arise from attempting to cancel, or almost cancel, sampling zeros of the discretized plant are likely to introduce peaks into the fundamental complementary sensitivity function near the Nyquist frequency. This in turn makes the satisfaction of necessary conditions for robust stability difficult for all but the most modest amounts of modeling uncertainty in the continuous-time plant. Some H_2- and H_∞-optimal discrete-time and sampled data designs may lead to (near-) cancellation, and we therefore argue that their suitability is restricted.

Keywords: Sampled-data systems, zeros, intersample, sampling zeros.

Self-Tuning PID Controller Using δ-Model Identification

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Summary: This contribution presents an application of a self-tuning digital PID controller for process control modelled by δ-models. The process is identified by the regression (ARX) models using the recursive least square method (RLSM) with LD decomposition and applied directional forgetting. Controller synthesis is designed on the basis of a modified Ziegler-Nichols criterion for digital PID control loops. The ultimate (critical) proportional gain and period of oscillations have been derived for the second-order δ-model. Control results using digital PID controller on the basic δ-models and z-models are compared.

Keywords: δ-model, recursive identification, PID controller, Ziegler-Nichols criterion, self-tuning control.

Multiple Model Control of a Pilot Distillation Column

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Summary: This paper discusses a complete controller design strategy required for implementing Multiple Model Control (MMC), applied to nonlinear systems. It is shown that the multiple model design can be recast into a supervisory arrangement, where a global supervisor is utilised to select the appropriate controller from a fixed family set. Unlike current techniques where Fuzzy Validity Functions or Bayesian Estimators are utilised in the selection mechanism, the approach of a Multiple Model Observer (MMO) is employed for the selection architecture within the supervisor. This notion, is a natural extension of the MMC design. Switching between the individual controllers is accomplished bumplessly by using a Multiple Model Bumpless Transfer Mechanism, thus producing a smooth and continuous control signal as the plant passes through different operating regions. The above notion is applied to a Pilot Binary Distillation Column, which is nonlinear in nature. The principal nonlinearity of the process is strongly related to its operating point. This paper illustrates that, as the distillation column moves from one operating point to another, the MMC self-regulates according to the operative trajectory, consequently ensuring that global stability and performance is maintained at an optimal point.

Keywords: Multiple Model Control, Multiple Model Bumpless Transfer Mechanism, LPV.

Online Outlier Detection and Removal

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Summary: Outliers occur regularly enough in real-world measurement data to constitute a significant practical problem that is not adequately addressed by traditional smoothing filters designed to reduce the effects of high-frequency noise. To address this problem, this paper describes a simple data cleaning filter for outlier detection and removal which is based on a causal moving data window that is appropriate to real–time applications like closed loop control. This filter is an extension of the well–known median filter: the observed data point y_k is compared to the median $y_k^\dagger$ of present and past data points. If the distance between these points is large relative to a specified threshold, y_k is declared an outlier and replaced with a more reasonable value $y_k^\star$. In the most favorable circumstances alters the above described data cleaning filter only outliers (e.g., shot noise) and does not modify nominal data points. Simple implementations of this filter require few tuning parameters and no explicit process model is required for filter tuning. This paper presents some useful tuning guidelines based on simple characterizations of the nominal variation seen in outlier-free portions of the data. To illustrate the utility of this filter, applications are presented for both real data examples and a simulation example where the exact results are known and performance can be assessed more precisely. It is also demonstrated that the data cleaning filter described here can be combined with traditional linear smoothing filters to achieve both protection against outliers and effective noise reduction, but the outlier filter should preceed the noise filter to achieve these results.

Keywords: Data cleaning, decision–based filtering, MAD scale estimate, nonlinear digital filter, outliers.

Identification for Control Purposes by Relay Techniques: Achievable Performance versus Complexity

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Summary: Relay techniques are very appealing to perform identification of chemical processes for control purposes; being fast and easy to use, they can be frequently repeated in order to perform an autotuning of PI/PID controllers. In the paper two relay techniques are compared in terms of ease of application. duration of experimental tests and achievable performance.

The first one is the Two Channel Relay (Friman and Waller, 1997) and makes use of two relays in parallel (one augmented by an integrator); it allows to identify a point in the third quadrant of the Nyquist plane having a specified phase angle and therefore to guarantee that the resulting PI/PID controller will have a desired gain and phase margin. The second one is the ATV+ technique (recently introduced by Scali *et al* (1999), as a modification of the ATV technique by Li *et al* (1991)); it allows to identify some more points in the third quadrant for a completely unknown process and then to build a process model for the design of a PI/PID or model based controller.

The two techniques are briefly recalled, putting into evidence their main features. Different indexes are introduced for a quantitative evaluation of the duration of tests and of achievable performance.

From the comparison of results for 45 sample processes, it can be concluded that the TCR is very effective, as it requires shorter times for the experimental tests and it allows to achieve reasonable performance for many cases. On the other side, the ATV+ requires about twice longer experimental times, but, being coupled with a an appropriate design of the controllers, allows to achieve better performance for all the cases with PI/PID controllers and further improvement with model based controllers.

Keywords: Relay feedback, identification, autotuning, PID control.

Algorithmic Internal Model Control of Unstable Systems

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Summary: An internally stable Algorithmic Internal Model Control (AIMC) strategy that uses linear or nonlinear model state feedback is proposed for unstable systems. The closed loop responses are those that would be obtained from a two degree of freedom IMC control system, if it were internally stable. Results of several simulations demonstrate the validity of the approach.

Keywords: Internal stability, unstable, linear, nonlinear, model state feedback.

Robust Stability Analysis of Nonlinear Processes Using Empirical State Affine Models and LMI's

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Summary: A novel methodology is proposed for the analysis of robust stability of a nonlinear process under linear control. The analysis is based on state-affine empirical models regressed from input-output data. The state model is represented by a set of polynomial matrices nonlinear with respect to the manipulated variables. This model in combination with a linear PI controller results in a closed loop model that can be shown to lie in a polytope of matrices. This allows for the formulation of a Lyapunov stability test in terms of a simple set of LMI's (Linear Matrix Inequalities). This set of inequalities can be also expanded to account for input saturation. The stability analysis produces regions of stability, in terms of the PI controller parameters, that are significantly larger than the regions previously calculated by a Structured Singular Value test. The conservativeness of the analysis is assessed by comparison to closed loop simulations of a highly nonlinear CSTR (Continuous Stirred Tank Reactor) under PI control.

Keywords: Robust stability, Linear Matrix Inequalities, CSTR reactor.

Model Predictive Control of a Continuous Granulation Process

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Summary: Granulation, the process by which granules are made fron powdered, slurried, solution, or molten feed material is an important process in many industries. This paper discusses the development and application of a control system for a specific granulation process. The discussion is used to illustrate the unique characteristics of granulation processes in general, and how, as a result, these processes present unique control problems that prevent the direct application of many traditional control techniques.

In practice, the objective in the granulation process it to produce granules with consistent product quality, as indicated by various industry standard variables that can be related to two fundamental process quantities: particle size distribution and bulk density. While it is customary to specify a desired setpoint value for bulk density, the specification on particle size distribution takes the form of an upper limit (d_U), and a lower limit (d_L), determined by the screen sizes used in product classification. The paper discusses the peculiar control problems arising from such a combination of product quality specifications and then develops a model predictive scheme that systematically addresses the problems. Results that illustrate the control system implementation and performance for various situations of practical importance will be presented.

Keywords: Chemical process control, Model Predictive Control, granulation process, particle size distribution.

Analytic Conditions for Stabilizability

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Summary: The Nyquist criterion gives a graphical condition for closed loop stability stated in terms of the Nyquist plot of the open loop system transfer function $G(s)$. In this paper we develop an equivalent, but new, *analytical* criterion for closed loop stability, based on analysis of the behaviour of a real polynomial function $X(u)$ constructed from $G(s)$. It is shown that the real negative zeros u_i of $X(u)$ and the signs of $\dot{X}(u)|_{u=u_i}$ determine the range of stabilizing gains K completely, and in closed form. Besides providing a nongraphical and computationally simpler alternative to the Nyquist criterion and root locus techniques, this solution is a first step towards investigating stabilizability by higher order controllers. Some illustrative examples are given.

Keywords: Constant gain stabilizability, Nyquist criterion, stabilizing gain, Root Locus, real axis.

Stability of Dynamical Systems with Parameter Perturbations

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Summary: New approach for the absolute stability analysis of nonstationary control systems is used for investigation of one special kind of dynamical systems. This approach is based on results from the inner theory, stability theory, optimal control theory, variational methods. Inner approach allows to obtain sufficient algebraic conditions of absolute stability for different kinds of dynamical systems. The way to obtain necessary and sufficient conditions for absolute stability of systems with parameter perturbations is shown in this paper. Inner approach is combined with use of the Poutriagin's Maximum Principle and solving of the Cauchy problem. This method leads in some cases to algebraic necessary and sufficient conditions of absolute stability, but in some cases the question about necessary and sufficient conditions of absolute stability obtained by use of developed method is open.

BIBO Stability of NARX Models

Andrzej Dzieliński Warsaw Univ. of Technology

Summary: The paper explains an approach to BIBO stability investigation of NARX control systems. The approach is based on difference inequalities and assumes the availability of an approximate NARX model and the system order. Sufficient conditions for modelling error are derived ensuring the boundedness of the error between model's and plant's outputs for the same inputs. For this class of bounded inputs sufficient conditions for BIBO stability are given and shown practicable. They also allow designing a controller using the model, leading to BIBO stable closed-loop system.

Keywords: BIBO stability, nonlinear systems, difference inequalities, NARX models.

Improving Efficiency in the Computation of Piecewise Quadratic Lyapunov Functions

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Andrey Ghulchak Lund Inst. of Technology
Anders Rantzer Lund Inst. of Technology

Summary: In a series of papers, the authors have developed a method for analysis of piecewise linear systems. The idea is to use Lyapunov functions that are piecewise quadratic. Such Lyapunov functions can be computed via convex optimization in terms of linear matrix inequalities. This paper presents two approaches for improving the efficiency of these computations. It is shown that by splitting the analysis computations into two distinct steps, one can decrease the computations with roughly 50% essentially without introducing conservatism. By using ellipsoidal boundings rather than polyhedral descriptions of the operating regimes, it is possible to reduce the computations even further. Combined, the two approaches allow the computation times to be reduced with an order of magnitude compared to previous formulations. However, it is shown that the use of ellipsoidal cell boundings in the S-procedure introduces conservatism in comparison with analysis based on polytopic region descriptions. An explicit formula for the minimal volume ellipsoid containing a simplex is also given, together with a complete proof.

Keywords: Piecewise linear systems, Lyapunov stability, convex optimization, convex polytopes, minimum volume ellipsoids.

Practical Stability of Synchronized Chaotic Attractors and its Control

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Krzysztof Czolczynski Technical Univ. of Lodz
John Brindley Univ. of Leeds

Summary: In the paper we discussed the application of the concept of practical stability to chaotic synchronized attractors located at the invariant subspaces, which should be very useful in the study of chaos synchronization problems. In such problems, having the practical device, we can estimate the bounds of the short time perturbations and define their sets ω (limits of the ucertainties in initial conditions and short time perturbations) and Ω (to which evovle the perturbed trajectories). If the synchronized chaotic state is practically stable in relation to the considered perturbation, we can be sure, that the evolution of the system will not leave the attractor further than allowed by the boundaries of the set Ω. Additionally, we present the controlling method which allows enlarging the practical stability regions.

Keywords: Chaos, attractors, practical stability.

Remarks on Open-Loop Stabilizability of Linear Infinite-Dimensional Time-Varying Discrete-Time Systems

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Summary: We study open-loop stabilizability of linear infinite-dimensional time-varying discrete-time systems described by a linear difference equation of the form $x_{k+1} = A_k x_k + B_k u_k$. In particular, we introduce the concept of 'stabilizability modulus' and present a theorem saying that for a broad class of systems open-loop stabilizability is preserved under small perturbations of system parameters.

Keywords: Stabilizability, time-varying systems, infinite-dimensional systems, linear systems, discrete-time systems.

On Oscillations in Resonant Equations with Complex Nonlinearities

Alexander M. Krasnosel'skii Russian Academy of Sc.

Summary: In the paper the analysis is presented of forced periodic oscillations in systems described by the second order ODE with resonant linear part and complex nonlinearities: with hysteresis and with delay. For such equations we give conditions of the existence of at least one periodic solution and conditions of the existence of unbounded sequences of such solutions. Analogous results are formulated for forced periodic oscillations in resonant control systems.

Keywords: Forced periodic oscillations, resonance, delay, hysteresis.

Feedback Resonance in 1-DOF and 2-DOF Nonlinear Oscillators

Alexander L. Fradkov Russian Academy of Sc.
Boris R. Andrievsky Russian Academy of Sc.

Summary: The possibilities of studying nonlinear physical systems by small feedback action are discussed. Analytical bounds of possible system energy change by feedback are established. It is shown that for 1-DOF nonlinear oscillator the change of energy by feedback can reach the limit achievable for linear oscillator by harmonic (nonfeedback) action which corresponds to the resonance phenomenon. The feedback resonance phenomenon is demonstrated also for 2-DOF system consisting of two coupled pendulums and illustrated by computer simulation results.

Keywords: Nonlinear control, control of oscillations.

Input-Output Models for a Class of Nonlinear Systems: Questions and Answers

Ülle Kotta Tallinn Technical Univ.

Summary: In this paper we investigate the possibility of having an input-output model, having a specific structure, for observable multi-input multi-output systems with vector relative degree. The interest in this input-output form arises from the fact that the model has been extensively used in control design, including sliding mode control. Since the subclass of systems having this specific structure is extremely restrictive, we suggest an alternative approach.

Keywords: Nonlinear system, input-output model, vector relative degree.

Aspects of Traction Control

Bernard Friedland New Jersey Inst. of Technology

Summary: Propulsion by traction raises several issues, including modeling of the friction force that produces traction and the design of appropriate control laws. The tradional "adhesion" model and several other static and dynamic friction models are described. Control laws that account in some manner for the severe nonlinearity of traction are investigated by simulation. It is shown that ignoring the nonlinear effects can result in an unstable system, but that the instability can be avoided by an appropriate control law design including an observer that accounts for the nonlinear friction model.

Keywords: Traction, friction, nonlinear systems.

Energy Control of Hamiltonian Systems under Disturbances

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Alexander L. Fradkov Russian Academy of Sc.

Summary: The problem of the energy level stabilization for Hamiltonian systems in presence of disturbances is considered. First, it is shown that for 1-DOF systems under sufficiently small uniformly bounded force disturbances the speed-gradient control law ensures ultimate boundedness of energy error. As an auxiliary result the new sufficient conditions for ultimate boundedness of Lyapunov function along the trajectories of nonlinear nonstationary dynamical system are obtained. Second, for n-DOF systems with dissipation-like disturbances the bounds for achievable energy level are given.

Keywords: Nonlinear control, control of Hamiltonian systems.

Nonlinear Systems Admitting Hybrid Feedback Control Stabilization

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Yurii V. Nepomnyashchikh — Perm State Univ.
Arcady Ponosov — Inst. for Matematiske Fag

Summary: A hybrid feedback controller appears as an interaction of two counterparts: one is continuous and the other is discrete. In other words, it is a continuous control law with an incorporated instrument to make logical decisions. Examples can be found in manufacturing systems, intelligent vehicle highway systems, various chemical plants, population dynamics.

It can be shown that in some cases a linear continuous plant (a system of differential equations) which cannot be stabilized by an ordinary feedback controller, admits at the same time a stabilizing feedback controller.

We consider a nonlinear differential equation in the plane $\mathbb{R}^2$

$$\dot{x} = Ax + Bu + f(x),$$
$$u = u(y), \qquad y = Cx,$$

where $f(x) = o(|x|)$, (A, B) is controllable, (A, C) is observable. The following generalization of the main result of Artstein (1996) is proved:

Theorem 1. *Assume that the matrix A has no real eigenvalues. Then for any $\lambda > 0$ there exist positive constants M, ε and a hybrid feedback stabilizer $u = u(y(\cdot))$ with a finite number of locations such that any solution of the controlled system above satisfies*

$$|x(t)| \leq M \exp(-\lambda t)|x(0)|$$

for all $|x(0)| \leq \varepsilon$.

The proof exploits differential inequalities and a special technique recently developed by the authors.

Robust H_∞ Filtering of Stationary Discrete-Time Linear Systems with Stochastic Uncertainties

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Uri Shaked Tel-Aviv Univ.
I. Yaesh Taas Israel Industries

Summary: The problem of H_∞ filtering of stationary discrete-time linear systems with stochastic uncertainties in the state space matrices is addressed, where the uncertainties are modeled as white noise. The relevant cost function is the expected value of the standard H_∞ performance index with respect to the uncertain parameters. A previously developed stochastic bounded real lemma is applied which results in a modified Riccati inequality. This inequality is expressed in a linear matrix inequality form whose solution provides the filter parameters. The method proposed is applied also to the case where, in addition to the stochastic uncertainty, other deterministic parameters of the system are not perfectly known and are assumed to lie in a given polytope. The problem of mixed H_2/H_∞ filtering for the above system is also treated. The theory developed is demonstrated by a simple tracking example.

Keywords: Stochastic H_∞ filtering, polytopic uncertainty, mixed H_2/H_∞ filtering.

The J-Spectral Interactor Matrix in the Discrete-Time Singular H_∞ Filtering Problem

Patrizio Colaneri Politecnico di Milano
Massimo Maroni Politecnico di Milano

Summary: This paper introduces the concept of J-spectral interactor matrix (JSIM) which is intimately associated with the singular filtering problem in H_∞. An algorithm for the computation of a JSIM is proposed and the role of the system delays in the solution of the singular filtering problem is eventually clarified.

Keywords: Singular H_∞ filtering, Interactor matrix, Riccati equations.

Kalman Bucy Filtering for Singular Output-Noise Covariance

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Alfredo Germani L'Aquila Univ.
Costanzo Manes L'Aquila Univ.

Summary: For a linear Gaussian stochastic system, the filtering problem is considered, when the covariance matrix of the observation noise is not invertible. A method that allows to build up the optimal filter in a number of cases is presented.

Keywords: Kalman-Bucy filtering, ϵ-optimal filter, singular problems.

On the Feasibility and Convergence of H_∞ Multistep Predictors

Massimo Maroni Politecnico di Milano
Paolo Bolzern Politecnico di Milano

Summary: An H_∞ multistep predictor is designed so as to guarantee a prescribed level of energy attenuation from the disturbances to the prediction error. It is shown that, for a given value of the attenuation level, an admissible predictor exists over a finite horizon if and only if the solution of a suitable difference Riccati equation lies uniformly above a computable lower threshold, which depends on the prediction look-ahead horizon (feasibility condition). Moreover, sufficient conditions on the initial state uncertainty are worked out, which ensure the existence of the predictor over an arbitrarily long time interval and its convergence to steady-state.

Keywords: H_∞ estimation, multistep prediction, Riccati equations.

Nonlinear Observers for a Class of Differential Delay Systems

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Mohamed Darouach Univ. Henri Poincaré

Summary: This paper focuses on the design of observers for a class of nonlinear systems with time-varying delay. Sufficient convergence conditions are established from the Lyapunov-Krasovskii theory. These conditions are linked to the existence of a positive definite matrix satisfying a certain Riccati equation. Using an $\mathcal{H}_\infty$ theory result, we propose sufficient conditions to guarantee such an existence.

Keywords: Observers, nonlinear systems, time-varying delay, Riccati-type equation, Lyapunov-Krasovskii theory, H^∞ theory.

Boundary Control of the Korteweg–de Vries–Burgers Equation: Further Results on Stabilization and Numerical Demonstration

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Miroslav Krstic Univ. of California, San Diego

Summary: We consider the Korteweg–de Vries–Burgers equation on the interval $[0, 1]$. Motivated by poor decay rates of a recently proposed control law by Liu and Krstic which keeps some of the boundary conditions as homogeneous, we propose a strengthened set of feedback boundary conditions. We establish stability properties of the closed–loop system and illustrate the performance improvement by a simulation example.

Keywords: Korteweg–de Vries–Burgers equation, nonlinear boundary feedback control, global stabilization.

Finite Horizon H_∞ Control of Systems with State Delays

Emilia Fridman Tel-Aviv Univ.
Uri Shaked Tel-Aviv Univ.

Summary: The finite horizon H_∞ control of time-invariant linear systems with a finite number of point and distributed time-delays is considered. For controllers coupled Riccati type partial differential equations are derived. The solutions to these equations are related to the solutions of the associated Hamiltonian systems. For small time delays the solutions and the resulting controllers are approximated by series expansions in powers of the largest delay. Unlike the infinite horizon case, these approximations possess both regular and boundary layer terms. It is shown that the controller obtained by high-order approximations improves the performance of the system. The performance of the closed-loop system under the memoryless zero-approximation controller is analyzed.

Keywords: Delay systems, H_∞-state-feedback control, asymptotic approximations, continuous-time systems, small delays.

Numerical Criterion for Stabilizing Steady State Solutions of the Navier-Stokes Equations

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Chongsheng Cao Univ. of California, Irvine
Yannis Kevrekidis Univ. of California, Irvine

Summary: In this talk we show that by stabilizing a steady state solution to the Galerkin approximation of the Navier-Stokes equations, using certain linear feedback control, one in fact is stabilizing a near by steady state solution to the fully three dimensional Navier-Stokes equations. Similar results also hold in the context of Nonlinear Galerkin method. It is worth mentioning that all our conditions are explicit and verified by the computed approximate Galerkin solution and that no a priori assumptions are made on the unknown exact solution of the Navier-Stokes equations.

Lax-Phillips Scattering and Well-Posed Linear Systems

Olof J. Staffans Åbo Akademi Univ.

Summary: We discuss the connection between Lax–Phillips scattering theory and the theory of well-posed linear systems, and show that the latter theory is a natural extension of the former. As a consequence of this, there is a close connection between the Lax–Phillips generator and the generators of the corresponding well-posed linear system. All the essential information about these two systems is contained in the system operator $S = \left[\begin{smallmatrix} A & B \\ N & \end{smallmatrix}\right]$, where A is the generator of the (central) semigroup, B is the control operator, and N is the combined observation/feedthrough operator. If the system is compatible in the sense of Helton or regular in the sense of Weiss, then this system operator can be written in the more familiar form $S = \left[\begin{smallmatrix} A & B \\ C & D \end{smallmatrix}\right]$, where C is the observation operator and D is the (generalized) feedthrough operator. We show that S is closed and densely defined. In the reflexive case the adjoint of S is the system operator of the dual system. We give formulas for the Lax–Phillips generator and resolvent in terms of the system operator. By applying the Hille–Yoshida theorem to the Lax–Phillips semigroup we get necessary and sufficient conditions for the L^p-admissibility or joint L^p-admissibility of a control operator B and an observation operator C.

For more details see http://www.abo.fi/~staffans/.

Keywords: Lax–Phillips scattering theory, L^p-well-posed linear system, L^p-admissible control operator, L^p-admissible observation operator, L^p-admissible transfer function.

Identification and Adaptive Control of Some Stochastic Distributed Parameter Systems

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Summary: An important class of controlled linear distributed parameter control systems are those with boundary or point control. A survey of some existing adaptive control problems with their solutions for the boundary or the point control of a linear stochastic distributed parameter systems is presented. The distributed parameter system is modeled by an evolution equation with an infinitesimal generator for an analytic semigroup. Since there is boundary or point control, the linear transformation for the control in the state equation is also an unbounded operator. The unknown parameters in the model appear affinely in both the infinitesimal generator of the semigroup and the linear transformation of the control. Strong consistency is verified for a family of least squares estimates of the unknown parameters. For a quadratic cost functional of the state and the control, the certainty equivalence control is self-optimizing, that is the family of average costs converges to the optimal ergodic cost. Another control problem considered here is when the control occurs on the boundary. The "highest-order" operator is assumed to be known but the "lower-order" operators contain unknown parameters. Furthermore, the linear operators of the state and the control on the boundary contain unknown parameters. The noise in the system is a cylindrical white Gaussian noise. The performance measure is an ergodic, quadratic cost functional. This time for the identification of the unknown parameters a diminishing excitation is used that has no effect on the ergodic cost functional but ensures sufficient excitation for strong consistency. The adaptive control is the certainty equivalence control for the ergodic, quadratic cost functional with switchings to the zero control.

Interaction of Design and Control

Daniel R. Lewin Technion — IIT

Summary: Traditionally, plant controllability and operability has been considered rather late in the design process, or largely ignored, often leading to poorly performing systems. The indisputable fact that design decisions invariably impact on the controllability and resiliency of processes is driving modern design methods to handle flowsheet controllability implicitly in an integrated fashion. This paper describes the current state of the art in integration of process design and process control. A survey of the literature would suggest that two alternative approaches could be harnessed to ensure the controllability and resiliency of chemical plants. Controllability and resiliency analysis methods are used as screening methods relatively early on in the design process. Furthermore, the integrated design and control paradigms can be applied to fully optimize and integrate the design of the process and its operation. It is the objective of this presentation is to make a case for the necessary combination of these two approaches.

Keywords: Process design, process control, controllability and resiliency assessment, integrated design and control.

Simultaneous Process Design and Process Control: Application to Complex Separation Systems

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Summary: The design and control of a literature-based double-effect and an industrial azeotropic distillation system are considered. Rigorous dynamic modelling is used to capture the key operability characteristics of each process. The economic and operational benefits of considering the process design and process control tasks simultaneously are explored with the aid of advanced dynamic optimization techniques. The inclusion of structural decisions into the optimization is a very challenging area of research. In this regard, algorithmic developments are presented which show potential for the efficient solution of the resulting large-scale mixed-integer dynamic optimization problems.

Keywords: Dynamic modelling, design, process control, dynamic optimization.

Process Design with Complex Nonlinearities

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Summary: As process designs move into or closer to regimes of complex nonlinearity, they become more sensitive to model uncertainties and disturbances. This paper examines process designs that operate closer to or within these regimes often to achieve greater profitability and improved performance. Emphasis is placed on developments over the past decade. Considerations for process controllers in the operation of such processes are elucidated.

Keywords: Chemical reactors, distillation, chaotic mixing, process design, nonlinear control.

Towards Integration of Controllability into Plant Design

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Summary: In process design practice the plant piping and instrumentation diagram evolves iteratively using mainly experience and process reasoning to address questions related to plant controllability. It would be desirable to be able to address such questions more quantitatively at different abstraction levels during process design such that controllability evaluation can be integrated into the design process. Only few attempts have been reported towards integrating controllability investigations into early stages of plant design. This paper reviews literature on controllability from the perspective of controllability assessment with the aim of identifying tests, which may be used at different stages of plant design. First definitions of terms used within process flexibility design and controllability assessment for control structure design are given. Methods for controllability evaluation are reviewed for some modes of process operation. Basically two types of evaluation and design methods prevail. One type is based on linear model analysis, whereas another type is based on physical chemical insight and thus provides nonlinear information.

Control structure development for controllability is illustrated on an energy integrated distillation plant by using a heuristic process knowledge based method to develop a basic control structure and subsequently using an optimisation based approach for selecting a product purity control structure. Controllability properties of a more energy efficient process design alternative is discussed to illustrate the potential trade off by choice of the most energy efficient design that however has the lowest controllability. Based on the review and the examples a procedure for integrating controllability assessment for control structure development into plant design is proposed.

Controllability and Resiliency Analysis for a Heat-Integrated C3-Splitter

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Summary: Controllability and resiliency (C&R) diagnosis is carried out on an industrial heat-integrated propane/propylene distillation column (C3-splitter). The analysis is based on short-cut dynamic models, which are obtained directly from the steady-state material and energy balances solved using a commercial process simulator. The results indicate that the designed operating point is open loop unstable. Systematic C&R screen-ing of all of the alternative decentralized control configurations suggests that the preferable control pairings are in line with current efforts to stabilize the process. However, the severe bandwidth limitations due to dynamic interactions for the best possible decentralized configuration imply that multivariable control is required for adequate performance.

Keywords: Controllability and resiliency assessment, process design, heat-integrated processes, distillation.

On the Generation of the Most Promising Control Structure for Large Dimensional Systems

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Summary: Multivariable controllers have several advantages over single loop controllers for multivariable plants. However, in process control applications, decentralized control systems are far more common than any multivariable controller. This is due to several characteristics of the decentralized controller, such as flexibility in operation, failure tolerance and simplified design and tuning, that are particularly desirable in process control applications. In designing decentralized control systems, the first problem that has to be solved is the problem of control structure selection or input-output variable pairing problem, i.e. which of the available manipulated variables is to be used in order to control each of the controlled variables. In this respect, an algorithmic method for variable pairing selection of large dimensional systems is proposed in this paper. The proposed method relies on the main properties of the Relative Gain Array (RGA) and of the Relative Interaction Array (RIA) matrices and the concepts of interaction, integrity and stability. It is shown that the minimization of the overall interaction in multi-input, multi-output large scale systems under several stability and structural constraints can be formulated either as a Mixed Integer Nonlinear Programming problem or as a Mixed Integer Linear Programming problem when the RGA or the RIA matrices, respectively, are used as interaction measures. The proposed method can be readily applied to systems with arbitrarily large dimensions, providing a simple and quick solution to the problem of the generation of feasible and promising control structures. In order to demonstrate the usefulness of the proposed algorithm as a rigorous and systematic solution to the input-output variable pairing problem, two large scale industrial problems, namely the hydrodealkylation of toluene (HAD) process and the Tennessee Eastman problem, are considered in the paper.

Keywords: Process control, control structure selection, variable pairing problem, Relative Gain Array, Relative Interaction Array.

Integrated Design of Agile Missile Guidance and Control Systems

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Summary: Recent threat assessments by the Navy have indicated the need for improving the accuracy of defensive missiles. This objective can only be achieved by enhancing the performance of the missile subsystems and by finding methods to exploit the synergism existing between subsystems. Traditional approach for missile guidance and control systems has been to design these subsystems separately and then to integrate them together before verifying their performance. Such an approach does not exploit any synergistic relationships between these and other subsystems. As a first step towards the development of integrated design methodologies, this paper develops a technique for integrated design of missile guidance and control systems.

The application of the state dependent Riccati Equation (SDRE) method for integrated guidance/control system design is discussed in this paper. Satisfaction of terminal aspect angle constraints in the guidance/control problem is also discussed. Numerical results using a six degree-of-freedom missile simulation are given. Integrated guidance/control systems are expected to result in significant improvements in missile performance, leading to lower weight and enhanced lethality. Both of these factors will lead to a more effective, lower-cost weapon system. Integrated system design methods developed under the present research effort also have extensive applications in high performance aircraft control and guidance systems.

Keywords: Integrated, guidance, autopilot, missile.

Optimal Guidance with Time Delay for Continuous Time Systems

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Summary: The guidance problem with continuous time-delayed control is considered. The interception conflict we are dealing with involves a pursuer continuously measuring his relative position and velocity, and who is able to control his own acceleration subject to a given pure time delay, and an evader who can apply constant maneuvers. The cost function for this optimal control problem includes the control effort and a quadratically weighted version of the miss distance and final relative velocity. Within this setup, several guidance problems are formulated and analytically solved: proportional navigation (PN), augmented PN (APN), and augmented optimal rendezvous (AOR). The solution is obtained by applying results previously published by the authors to the corresponding discrete-time guidance problems and by using an alternative derivation based on the theory of continuous-time linear quadratic optimal control with an input delay. The resulting new guidance laws are compared to the numerically classical guidance laws. The examples demonstrate the advantage of the optimal guidance laws which take the delay into account over the classical ones.

Keywords: Optimal, guidance, delay, APN, AOR.

Optimal Guidance Laws with Uncertain Time-of-Flight

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Summary: The existing optimal guidance laws assume that time-to-go is known exactly. The time-to-go is usually estimated and thus is a random variable. This paper deals with the issue of optimal guidance with uncertain time-to-go. A problem of control of linear discrete systems with unknown time-to-go is formulated and solved. The solution is applied to derive guidance laws. The solution depends on the probability density function of the time-of-flight. This guidance law has the structure of a rendezvous guidance law where the guidance gains are time-dependent and depend on the distribution of the time-to-go. Examples that demonstrate these dependencies are presented.

Keywords: Guidance law, optimal guidance law, time-to-go, uncertain time-to-go.

Design of Non-Saturating Guidance Systems

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Summary: Design of non-saturating guidance systems is considered. Assuming linearized kinematics, a proportional navigation guidance model is introduced. The missile guidance loop discussed contains nonlinearities such as limited missile maneuverability, limited acceleration command and constrained measured line-of-sight angular rate. A novel approach, based on input-output stability, renders design guidelines that assure operation in the non-saturating region, given the missile-target maneuver ratio. These guidelines yield a proportional navigation based guidance law that assures zero miss distance for any bounded target maneuver. It is shown that if the total dynamics of the guidance loop is designed to be positive real, and the effective proportional navigation constant is chosen to be a simple function of the maneuver ratio, no saturation shall occur. The illustrative examples validate the analysis, and show that the new guidance law is robust enough to guarantee a significant performance improvement even if the design guidelines are somewhat loosened.

Keywords: Missile guidance, proportional navigation, L^{∞} stability, zero miss distance.

Robust Missile Guidance Law against Highly Maneuvering Targets

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Summary: Simulation studies of future anti-missile defense scenarios clearly indicated that currently available guidance laws and estimation techniques are unable to guarantee a hit-to-kill accuracy in the interception of the anticipated highly maneuvering targets.

In this paper the future interception scenarios of highly maneuvering anti-surface missiles are formulated as zero-sum pursuit-evasion games with imperfect information. The solution of the perfect information version of the game indicates that, if the actual target maneuver is known, a robust hit-to-kill homing accuracy can be guaranteed even with modest maneuverability and agility advantages. However, in a realistic environment with noise corrupted measurements the estimated target maneuver changes are observed with a delay, leading to a devastating affect on the guaranteed homing performance.

This paper describes the development of a new guidance law that explicitly takes into account the estimation delay and compensates for it. Applying this new guidance law leads to a significant reduction of the guaranteed miss distance and restores the robustness with respect to the actual target maneuver. The homing performance of the new guidance law was tested by a set of linearized Monte Carlo simulations, showing very promising results.

Keywords: Missile, guidance, estimation, delay, differential game.

From Physical Realizations to Nonlinear Stability, Passivity and Optimality

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Summary: In this paper we consider the following problem: Given a dynamical system, described by a differential equation, determine an appropriate measure for the energy stored in the system. This problem is of great importance because it is related directly to fundamental concepts such as stability, passivity, and optimality.

First, we solve the problem for linear dynamical systems. We realize the linear differential equation using a linear electrical circuit, so that the energy stored in the system is just the energy stored in the circuit's components. This leads to an intuitive proof of the Routh-Hurwitz stability criterion. In addition, we use the energy balance in the circuit to derive passivity and optimality relations.

Then, we extend the results to a class of nonlinear systems by replacing the linear components in the circuit with more general nonlinear ones. We derive explicit storage functions for passivity analysis of these nonlinear systems and for the formulation and explicit solution of a novel nonlinear optimal control problem.

Keywords: Nonlinear systems, Stability, Passivity, Optimal control.

Nonlinear State Estimation for Rigid Body Motion with Low-Pass Sensors

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Summary: In this paper we consider the state estimation problem for the nonlinear kinematic equations of a rigid body observed under low pass sensors. On the way to solve that problem, the convergence of a state estimator for a generic stable time-varying linear system is shown. The problem is motivated from a walking robot application where inclinometers and gyros are the sensors used. We show that a non local high gain observer exists for the nonlinear rigid body kinematic equations and that it under a small angle assumption is possible to use one inclinometer only to estimate two angles.

Keywords: Nonlinear state estimation, rigid body motion, linear time-varying systems, exponential observers, inclinometers.

Control Systems with Actuator Saturation and Bifurcations at Infinity

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Daniel Pagano Univ. Federal de Santa Catarina

Summary: It is known that unstable open-loop plants can be stabilized under constrained controls only locally. To understand this fact, it is shown how bifurcations at infinity are always involved in the stabilizing process. These bifurcations are easily detected by studying the Nyquist plots. The approach is illustrated with a concrete example of a anti-windup scheme taken from the literature.

Keywords: Nonlinear systems, local and global stability, anti-windup, bifurcations.

An Antiwindup Control Using μ-Synthesis

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Summary: This paper deals with a systematic approach to design a controller which, on one hand satisfies objectives of performance and on the other hand, prevents from noxious influence of saturation. These different constraints leads to an augmented plant on which the optimisation uses μ-synthesis and its D-K iteration procedure, judiciously initialised by a pre-scaling.

Keywords: Input saturation, anti-windup, μ-synthesis, describing function, decoupling.

A High Gain Observer for Robust State Feedback Controller

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Summary: Nonlinear control strategies; high gain feedback control, Lyapunov Min-Max control, and Variable Structure System (VSS) with Sliding Mode Control (SMC), assume that the system states are available for feedback. However some system states are often contaminated by high levels of noise and constraining the system performance such as the velocity measurement in electromechanical systems. Therefore it is important to design those control strategies by utilizing only output feedback rather than full state feedback. A high gain observer is introduced in this paper to reconstruct unmeasurable states for nonlinear feedback control strategies. This observer developed based on the teory of singular perturbation and variable structure systems. The validity its performance shown through numerical example in the presence of uncertainty in the system in order to implement such designs to the electromechanical systems.

Keywords: High-gain observer, output feedback control, sliding mode control, robot manipulators.

On the Role of Invariance in the Theory of Systems and Control — An Intelligible Introduction for the Beginners

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Summary: A framework of the introductory course to the control system theory is presented from the viewpoint of nonlinear theory. In the first part, the description is based on the input-output relations of the input affine systems. The notions appearing first are the relative order and the invariance. Geometric notions are gradually introduced for the beginners. Feedback design methods are given for the nonlinear systems and then for the linear systems. In the second part, the Hamiltonian formulation and the variational method are used to derive conditions of the optimality and the invariance. Both parts are linked via the notion of invariance. This style is partly realized in the author's lectures.

Keywords: Introductory course, input-output expression, invariance, Hamiltonian formulation, optimality.

A Directional Forgetting Algorithm Based on the Decomposition of the Information Matrix

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Summary: A novel directional forgetting algorithm is developed based on a decomposition of the information matrix. This algorithm performs forgetting only to a specified part of the information matrix, thus preventing the problem known as estimator windup which is a characteristic of the standard exponential forgetting algorithm. This algorithm is able to track fast parameter changes and is similar in complexity to the standard least square algorithm. The superior performance of the algorithm is verified via theoretical and simulation studies.

Keywords: Parameter estimation, recursive algorithm, exponential forgetting, directional forgetting.

A Parameter Estimation Method for a Special Class of Systems of Ordinary Differential Equations

Carla Seatzu Univ. of Cagliari

Summary: In this paper a special class of systems of ordinary differential equations is considered. This class is particularly common both in biological and medical field and is denoted as *S-Systems*.

The problem we deal with is the estimation of unknown parameters in a system of equations, when a set of observational data is available. The procedure we now propose arises from the requirement of overcoming the main difficulties typical of iterative gradient based methods. The main idea of the method is that of approximating each state variable by a fitting process and then splitting the overall estimation problem into a set of simpler independent problems, thus lessening the difficulty concerning high parameter vector dimensions. Each problem consists of the minimization of a differential residual and in particular cases reduces to the solution of an overdetermined linear algebraic system. It is also possible to take into account the parameter constraints with a modest computational effort.

The results of several numerical simulations are also presented. The robustness of the method has also been tested affecting data with different noise levels.

Keywords: Parameter estimation, S-Systems, B-splines, data fitting.

An Algorithm for Control System Loop Gain Identification

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Summary: The identification of a linear discrete-time control system's loop gain is addressed. The classical Kalman filter theory for linear control systems is extended and the control system's state and loop gain are jointly estimated. Explicit formulae for the loop gain's unbiased estimate and estimation error covariance are derived.

Keywords: System identification, Kalman filtering, adaptive control.

Real-Time Identification Using a Classical Nonlinear Optimization Algorithm and the Flatness Properties of a System: Application to an Intensity/Pressure Converter

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Summary: This article presents a modification of a classical nonlinear identification algorithm, which permits then on-line identification (or real-time identification). This modification is particularly based on using nonlinear optimization algorithm, not with a classical model of the process, which needs a numerical integration algorithm to solve it, but with the flatness properties of the model of the process (Fliess *et al.*, 1995). The states of the system are then obtained without any integration, which follows a significant saving of calculation time. This modified method is applied to on-line identification of the parameters of a nonlinear model of an intensity/pressure converter (i/p converter), used to supply air pressure inside an artificial pneumatic muscle used like actuator on the robots of the laboratory. To illustrate the method, experimental results are given and discussed.

Keywords: Real-time identification, nonlinear programming, flatness, intensity/pressure converter.

Stopping of Algorithms and Faults Detection in Kalman Filter Application

Chingiz Hajiyev Istanbul Technical Univ.

Summary: An approach to the generation of stopping rules in parametric identification problems is proposed on the basis of the computation of a statistic of the difference between two successive estimates. This statistic is also used for fault detection in the Kalman filter.

The developed decision rules are applied to a linear system identification problem. The domain of possible utilization of the Kalman filter is partitioned into three zones according to presented rule. When the value of above mentioned statistic lies between the confidence limits, the decision is made to continue the estimation. When its values attain the confidence limits, the decision is made to stop the estimation process and, accordingly, the kind of corrective actions in the estimation process is decided.

The stopping rule developed here has the advantage that its application does not require the specification of an admissible error ellipsoid, whose construction represents an independent problem.

Experimental results are presented to demonstrate the performance of the proposed algorithms.

Keywords: Kalman Filter, Stopping Rule, System Identification, Fault Detection, Decision rule.

Estimation Variance is not Model Structure Independent

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Fredrik Gustafsson Linköping Univ.

Summary: This paper establishes that when using a least squares criterion to estimate an output error type model structure, then the measurement noise induced variability of the frequency response estimate depends on the estimated (and hence also on the true) pole positions. This dependence on pole position is perhaps counter to prevailing wisdom that for any 'shift invariant' model structure, the variability depends only on model order, data length, and input and noise spectral densities. That is, it is counter to the belief that variance error is model-structure independent.

Keywords: Output error identification, estimation algorithms, estimation theory, identification algorithms, frequency domains, modelling errors.

Stability, Euler Approximations of Dynamical Systems and Fixed Point Iterations

Elza Farkhi Tel-Aviv Univ.

Summary: Consider an infinite time autonomous dynamical system:

$$\dot{x}(t) \in F(x(t)) \quad \text{for a.e. } t \in (0,\infty), \quad x(0) = x^o,$$

where F is an upper semi-continuous set-valued mapping with convex compact images, from $\mathbb{R}^n$ to itself. Looking for stationary (equilibrium) points of this system is equivalent to looking for fixed points of the Euler map $G_h(x) = x + hF(x)$ for each scalar $h > 0$. Assume that F is bounded on bounded sets and satisfies the following *one-sided Lipschitz condition (OSL)* (weak monotonicity condition) with a constant $L < 0$:
For each $x, y \in X$ and each $u \in F(x)$ there is $v \in F(y)$ such that

$$\langle x - y, v - w\rangle \le L\|x - y\|^2.$$

OSL condition may be formulated also in a Hilbert space or a Banach spaces with an uniformly convex conjugate space. Generally, OSL dynamical systems have more than one trajectory, which differs from the classical monotonicity case. The above assumptions imply, from one side, nonemptiness and uniform boundedness on the infinite time interval of the trajectories and the equilibrium points sets, and, from the other, set-valued asymptotic stability of the attainable set and of the trajectories set.
We study the following explicit Euler iterative process, approximating the continuous dynamical system:

$$y_{k+1} \in G_{h_k}(y_k) = y_k + h_k F(y_k), \quad y_0 = y^o,$$

$k = 0, 1, \dots$ The iteration is stationary if $h_k = h_0$ for a fixed h_0, or nonstationary with $\sum_{k=0}^{\infty} h_k = \infty$, $\sum_{k=0}^{\infty} h_k^2 < \infty$.
It is shown that in our case the multifunction G_h is almost contractive, while for F Lipschitz and negatively monotone it is strictly contractive. On this base convergence estimates are proved for stationary and nonstationary Euler iteration, which extend known results for classical monotone mappings.

Keywords: Fixed points, monotone mapping, one sided Lipschitz, stability, differential inclusions, Euler method.

Asymptotic Behavior of Infinite Products of Order-Preserving Mappings in Banach Space

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Summary: In this paper we present several results concerning the asymptotic behavior of (random) infinite products of generic sequences of order-preserving mappings on intervals and cones in an ordered Banach space. Such operators find application in many areas of mathematics and, in particular, in dynamical models of economics and biology. In addition to weak ergodic theorems we also obtain convergence to a unique common fixed point (for self-mappings of an interval) and to an operator of the form $f(\cdot)\eta$, where f is a functional and η is a common fixed point. More precisely, we show that in appropriate complete metric spaces of sequences of operators there exists a subset which is a countable intersection of open everywhere dense sets such that for each sequence belonging to this subset the corresponding infinite products converge. Thus, instead of considering a certain convergence property for a single sequence of operators, we investigate it for a space of all such sequences equipped with some natural metric, and show that this property holds for most of these sequences. This allows us to establish convergence without restrictive assumptions on the space and on the operators themselves.

Keywords: Fixed point, generic property, ordered Banach space, order-preserving mapping, random infinite product.

Exponential Stabilization of Vibrating Systems by Collocated Feedback

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Summary: We consider regular linear systems described by $\dot{x} = Ax + Bu$, $y = B_\Lambda^* x$, where A generates a strongly continuous semigroup on the Hilbert space X and A is essentially skew-adjoint and dissipative. This means that the domains of A^* and A are equal and $A^* + A = -Q$, where Q is a bounded nonnegative operator. The control operator B is possibly unbounded, but admissible and B_Λ^* is the Λ-extension of B^*. Such a description fits many wave and beam equations and it has been shown for many particular cases that the feedback $u = -\kappa y$, with $\kappa > 0$, stabilizes the system, strongly or even exponentially. We show, by means of a counterexample, that if B is sufficiently unbounded, then such a feedback may be unsuitable: the closed-loop semigroup may even grow exponentially. However, if κ is sufficiently small, and if the original system is exactly controllable and observable, then the closed-loop system is exponentially stable. The above assumptions may be relaxed in various directions, for example, regularity may be replaced by well-posedness, exact controllability may be replaced by optimizability etc.

Keywords: Well-posed linear systems, positive transfer functions, exact controllability and observability, skew-adjoint operators, collocated sensors and actuators.

A Composite Semigroup for the Infinite-Dimensional Differential Sylvester Equation

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Summary: This paper presents a certain approach to the study of the operator differential Sylvester equation which arises in various control problems on finite time horizon. A crucial role in this approach is played by the so-called composite semigroup. It is a strong-operator continuous semigroup defined on a Banach space of linear bounded operators obtained as a composition of two 'classical' strongly continuous semigroups defined on a Hilbert space. We investigate basic properties of the solution to this equation in the case when the operators occuring in in the equation are unbounded.

Keywords: Sylvester differential equation, composite semigroup.

Input-Output Stability of Systems Governed by Nonlinear Second Order Evolution Equations in Hilbert Spaces

Michael I. Gil' Ben-Gurion Univ.

Summary: We consider systems governed by nonlinear second order evolution equations in a Hilbert space and establish explicit conditions for the input-output stability.

Keywords: Infinite dimensional systems, second order evolution equations, input-output stability.

Wood Chip Refiner Control

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Summary: On a chip refiner the gain of the transfer function between the refiner motor load and the plate gap is both nonlinear and time-varying, with reversal in the sign of the gain indicating the onset of pulp pad collapse towards lower values of the plate gap. The control objective is to regulate the motor load while avoiding pad collapse. The problem is principally stochastic in nature, since the gap at which gain reversal occurs can wander unpredictably. An active suboptimal dual controller is designed to control the motor load by manipulating the plate gap. It uses an adaptive Kalman filter to track both slow drifts and sudden sign changes in the gain. The controller minimizes a myopic nonlinear performance index designed especially to reflect the peculiarities of the process. Thus, no heuristic logic is needed. Simulations show the superior performance offered by this strategy.

Keywords: Dual control, adaptive control, time-varying systems, adaptive Kalman filtering, pulp industry.

Automatic Tuning of the Window Size in the Box Car Backslope Data Compression Algorithm

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Summary: In process industries, as well as in other controlled processes, there is a need to record and store for posterity measurement data from a large number of sensors in such a way that the exact time and size of a significant change can be retrieved and analyzed. Even with today's computer memories, a short sampling interval will yield an unwieldy amount of data. Therefore various data compression algorithms are used, one of which is the Box Car Backslope (BCBS) filtering algorithm which does not store data within a preset window around the current prediction.

The window size should be chosen such that normal measurement noise is ignored but significant changes are recorded. Until now the window size of each data channel had to be tuned manually. In this paper the BCBS algorithm is explained and a novel algorithm for the automatic on-line tuning of the window size is suggested, based on the minimization of a criterion weighing the data reduction rate, and the variance of the error between filtered and measured data.

The algorithm was found to work very well in a paper manufacturing plant.

Keywords: Data compression, process control, time series.

Experimental Tests of Digital Filters for Control of a Pilot-Scale Batch Distillation Column

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Summary: Measurement signals that a computer uses to take control actions are usually contaminated by noise. The presence of noise is undesirable because it may be detrimental to the operational control. In order to reduce the noise level in a batch distillation column control loop, two digital filters were experimentally tested: the double exponential filter and the moving average filter. The moving average was less effective than the double exponential filter. The profile of the controlled variable was smoother but the control actions were more delayed when the moving average was used. The runs have shown how important the choice of the digital filter is to achieve a good control performance. For control tasks, this choice must be a compromise between data smoothing and the ability to respond rapidly to real changes in the process.

Keywords: Batch distillation, digital filtering, computer control.

A Linear Time-Varying State-Space Model of Batch Distillation Columns for Control Applications

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Summary: Batch distillation is widely used in the production of fine chemicals, which must be manufactured according to high and well-defined standards of purity. However, due to the strongly nonlinear and time-varying behaviour of batch distillation columns, the composition control is not merely a task but a real challenge. One of the first steps towards control is developing a mathematical model of the process of interest. A rigorous model is not always appropriated for on-line control tasks, especially for batch systems, which are characterised by frequent changes in process conditions. In this work, a linear time-varying state-space model for batch distillation columns was developed and tested. The model is suitable for on-line implementation and to predict the system behaviour from measurable and easily available information. Comparing the model predictions with rigorous simulation results, the state-space model was able to predict the batch distillation column behaviour accurately, even for the nonideal mixture ethanol-water.

Keywords: State-space models, batch distillation, computer control.

Neuro-Fuzzy Modeling in Petrochemical Industry

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Summary: In the last few years, problems concerning with both air pollution and quality of products have gained a particular attention in industrial companies. A great interest in new technologies for the process of manufacturing optimization and quality control has raised. Mathematical models for quality control are highly nonlinear and need very expensive and sophisticated instruments. Soft-Computing, an innovative approach for constructing computationally intelligent systems, has just come into the limelight. The quintessence of designing intelligent systems of this kind is Neuro-Fuzzy computing. In this paper a Neuro-Fuzzy prediction model for the quality control of benzene is proposed.

Keywords: Quality control, petrochemical industry, modeling, soft-computing.

An Integrated Algorithm for Path Planning and Flight Controller Scheduling for Autonomous Helicopters

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Summary: This article investigates the problem of generating optimal flight trajectories for an autonomous helicopter. We propose a planning strategy that partitions the optimization problem into isolated segments. Given a set of nominal waypoints we then generate trajectories that interpolate close to these points. This path generation is done for two different cases, corresponding to the two flight controllers that either govern position or velocity of the helicopter. Based on a given cost functional, the planner selects the optimal one among these multiple paths. This approach thus provides a systematic way for generating not only the flight path, but also a suitable switching strategy, i.e. when to switch between the different controllers.

Keywords: Optimal control, path planning, unmanned aerial vehicles.

Actuator Design for Aircraft Robustness Versus Category II PIO

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Summary: In this paper we deal with the analysis of Pilot in the Loop Oscillations (PIO) of Category II (with rate and position limiting), a phenomenon usually due to a misadaptation between the pilot and the aircraft response during some tasks in which tight closed loop control of the aircraft is required from the pilot, with the aircraft not responding to pilot commands as expected by the pilot himself. We propose an approach, based on robust stability analysis, which assumes that PIO are characterized by a limit cycle behaviour. In this approach the nonlinear elements are substituted by fictitious linear parameters, which can be considered time-invariant or time-varying; in this way we obtain two criteria for robustness versus Category II PIO. If, using the proposed criteria, the aircraft under consideration is shown to be Category II PIO prone, since limit cycles occurrence is due to a bad design of the nonlinear actuators, we propose an algorithm which, taking into account the trade-off between realization costs and performances, provides the guidelines for the design of actuators which should guarantee robustness versus Category II PIO. Finally, to demonstrate the use of the new proposed method, we apply our technique to a case study, namely the X-15 aircraft PIO, occurred on June 8, 1959 during a landing flare.

Keywords: Robust stability, nonlinear systems, pilot in the loop oscillations (PI0), actuator design.

On Algorithms for Attitude Estimation Using GPS

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Summary: This paper discusses algorithms for attitude determination using GPS differential phase measurements, assuming that the cycle integer ambiguities are known. The problem of attitude determination is posed as a parameter optimization problem. One proposed set of optimal solutions, which includes solutions of Wahba's problem, is based on least squares fit of some attitude parameters to a set of vector measurements. The use of these algorithms requires the conversion of the basic GPS scalar phase measurements into unit vectors. Another possible approach is based on a least squares fit of the attitude quaternion to the GPS phase measurements themselves. The cost function of the fit is given in the literature in the most straightforward formulation as a function of the attitude matrix. The paper presents the conversion of the matrix-based cost function to a quaternion-based cost function, which corresponds to the cost function minimized by QUEST. However, unlike the QUEST cost function, the converted cost function is not a simple quadratic form, therefore the simple QUEST solution is not applicable in this case. Three iterative solutions for finding the optimal quaternion are derived. The first algorithm is a linearly convergent one whose convergence rate is slow. The other two converge very fast. The algorithms presented in this paper can handle cases of planar antenna arrays and thus cover a deficiency in earlier algorithms. The efficiency of the new algorithms is demonstrated through numerical examples.

Every Stabilizing Dead-Time Controller has an Observer-Predictor-Based Structure

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Summary: This paper considers the stabilization problem for systems with a single delay h in the feedback loop. The state-space parametrizations of all stabilizing regulators are derived. These parametrizations have simple structures and clear interpretations. In particular, it is shown that every stabilizing controller consists of a delayed state observer x_o, an h time units ahead predictor x_p, and a stabilizing state feedback, i.e.:

$$\begin{aligned}\dot{x}_o(t) &= Ax_o(t) + Bu(t-h) - L\big(y(t-h) - Cx_o(t)\big)\\ x_p(t) &= e^{Ah}x_o(t) + \int_{t-h}^{t} e^{A(t-\tau)}Bu(\tau)d\tau\\ u(t) &= Fx_p(t) + v(t),\end{aligned}$$

where F and L are any matrices so that $A + BF$ and $A + LC$ are Hurwitz and $v = Q\epsilon$, where $\epsilon(t) = y(t-h) - Cx_o(t)$ is the innovation and $Q(s) \in H^\infty$ but otherwise is arbitrary.

Applications of the proposed parametrization to the H^2 optimal control and the robust stabilization of dead-time systems are discussed.

Keywords: Delay systems, parametrization, H^2 control, robust stability.

The Structure at Infinity of Linear Delay Systems and the Row-by-Row Decoupling Problem

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Summary: For linear finite dimensional systems with transfer function matrix $T(s)$, the behavior of $T(s)$ at infinity plays an important role in several control problems. This behavior can also be interpreted as that of the system at time $t = 0$, and may be described by the so-called structure at infinity or the canonical form at infinity. As, in this case, the matrix $T(s)$ is rational and strictly proper, the computation of the canonical form is easy and this form is invariant under state feedback. This allows to characterize the existence of solutions to the model matching, the disturbance rejection and the row-by-row decoupling problems. For linear time delay systems with transfer function matrix $T(s, e^{-s})$ we consider the row-by-row decoupling problem. We use the concept of weak structure at infinity (the variable s is real) and strong structure at infinity (s is a complex variable). This allows to design a decoupling precompensator which is weak biproper. This precompensator is then realized by generalized static state feedback which can include delayed derivatives of the new control, and thus requires some smoothness of the new control. If the new control is not smooth enough, then the decoupling problem cannot be solvable by generalized static state feedback.

Keywords: Linear time delay systems, structure at infinity, decoupling problem.

Stabilization of Singularly Perturbed Linearly Systems with Delay and Saturating Control

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Vasile Dragan Romanian Academy

Summary: The paper deals with the feedback control law design methodology that applies to singularly perturbed linearly systems with time-delay control under saturation constraints. The results obtained by a scalar inequalities allows us to investigate a variety of control problems.

Keywords: Singular perturbed systems, input-delay, saturation, stabilizing feedback gain.

Near Optimal PLL Design for Decision Feedback Carrier and Timing Recovery

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Summary: A new design method is presented for the design of PLL loop filters for carrier recovery, bit timing or other synchronization loops given phase noise spectrum and noise level. Unlike the conventional designs, our design incorporates a possible large decision delay and S-curve slope uncertainty. Large decision delays frequently exists in modern receivers due to, for example, a convolutional decoder or an equalizer. The new design also applies to coherent optical communications where delay in the loop limits the laser line width. We provide an easy to use complete design procedure for second order loops. We also introduce a design procedure for higher order loops for near-optimal performance. We show that using the traditional second order loop is suboptimal when there is a delay in the loop, and also show large improvements, either in the amount of allowed delay, or the phase error variance in the presence of delay.

Keywords: PLL, delay, margin, optimal, QFT, feedback carrier.

Modelling and Identification of a High Temperature Short Time Pasteurization Process Including Delays

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Mario Garcia-Sanz Public Univ. of Navarra

Summary: In this paper, an improved mathematical model for a High Temperature Short Time (HTST) pasteurization plant is proposed. The main differences from previous models are that the four interconnected blocks of the heat exchanger model are assumed to be of third order; therefore fundamental physical properties of the plant are not neglected. In addition, time delays at the output of the heat exchangers are considered in order to take into account the fact by which the temperature sensor is not physically within the heat exchanger. Following the proposed model, a parameter identification procedure is suggested, by using stable filtering for the input and output signals.

Keywords: Time-delay, interconnected systems, pasteurization process, parameter identification.

Parameter Identification In Nonlineaer Systems Using Hopfield Neural Networks

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Summary: In this study, we use Hopfield neural network (HNN) for identifying parameters of a nonlinear system. We use a linearization process and develop the equations for a parameter identification algorithm. we use a scalar time varying problem and a complex nine-state nonlinear problem to demonstrate the potential of this method.

Keywords: Parameter estimation, nonlinear, neural networks.

Optimal Combination of Identification and Control for Bounded-Noise ARX Systems

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Summary: An optimal combination of sequential identification and control for linear bounded-input bounded-noise discrete-time ARX system is considered. Various configurations of identyfy-ing/ controlling sequences are investigated in order to find an optimal trade-off. The tracking control of second-order system is simulated showing an optimal trade-off between identifica-tion and control periods.

Keywords: Identification, control, optimal trade-off, ARX system, bounded-input, bounded-noise.

Closed-loop model-free subspace-based LQG-design

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Summary: When only input/output data of a system are available the classical way to design a linear quadratic Gaussian controller consists of mainly three separate parts. First a system identification step is performed to find the system parameters. With these parameters a Kalman filter is designed to find an estimate of the state of the system. Finally, this state is then used in an LQ-controller. In the literature these three steps are hardly ever considered as one joint identification/control problem. In a previous paper it was shown that, based on techniques from the field of subspace system identification, the three steps of the LQG-controller design can be replaced by a QR and a SV-decomposition. A drawback of the method is that the input and output data available for the LQG-design must be retrieved in open loop. In the present paper, a generalization of the results previously presented results to the case where the data is measured on a system working in closed-loop. It is shown that under mild conditions the closed-loop subspace-based controller and the classical LQG-controller are equivalent. The effectiveness of the method is illustrated by the hand of a simulation example. It is shown that the open-loop subspace-based LQG-controller gives biased results whereas the closed-loop version converges to the classical LQG-controller when the length of the backward horizon increases.

Keywords: Subspace identification, identification for control, LQG-control, Kalman filter, closed-loop.

Measurement of Impedance Characteristics of Computer Keyboard Keys

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Summary: The aim of this project is to gain a more complete understanding of the tactile "feel" of computer keyboard keys by quantifying their mechanical impedance. To achieve this goal, a computer-controlled test rig that can measure computer key displacement, velocity, and contact force has been designed, constructed and tested. This paper describes the hardware and software configuration, including the data acquisition method and motion control system. Preliminary results show that the key dissipates energy during a depression-return stroke, indicating the presence of damping.

Keywords: Computer keyboard, impedance, damping, ergonomics.

Structure of Optimal Solutions of Infinite Dimensional Control Problems

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Summary: In this paper we present several results concerning the structure of optimal solutions for infinite-dimensional optimal control problems. The primary area of applications of these problems concerns models of regional economic growth, cattle ranching models and systems with distributed parameters and boundary controls arising in certain engineering applications. We are concerned with the existence of an overtaking optimal trajectory over an infinite horizon. The existence result that we obtain extends the result of Carlson, Haurie and Jabrane (1987) to a situation where the trajectories are not necessary bounded. We show that an optimal trajectory defined on an interval $[0, T]$ is contained in a small neighborhood of the optimal steady-state in the weak topology for all $t \in [0, T] \setminus E$ where $E \subset [0, T]$ is a measurable set such that the Lebesgue measure of E does not exceed a constant which depends only on the neighborhood of the optimal steady-state and does not depend on T. Moreover, we show that the set E is a finite union of intervals and their number does not exceed a constant which depends only on the neighbborhood.

Lipschitz Stability of Solutions to Parametric Optimal Control for Parabolic Equations

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Summary: Let H be a Banach space of parameters and $G \subset H$ an open set of feasible parameters. Moreover, let $\Omega \in \mathbb{R}^n$ be a bounded domain with regular boundary $\partial\Omega$ and let $T > 0$ be a fixed time. Denote $Q = \Omega \times (0,T)$ and $\Sigma = \partial\Omega \times (0,T)$. For each $h \in G$ consider the following optimal control problem for semilinear parabolic equation

(P_h) Find $(y_h, u_h) \in C(\overline{Q}) \times L^\infty(Q)$ such that

$$J_h(y_h, u_h) = \min_{y,u} \left\{ J_h(y,u) := \int_Q \psi(x,t,y,u,h)\,dx\,dt \right\}$$

subject to

$$\begin{aligned} y_t(x,t) + Ay(x,t) + a(x,t,y(x,t),u(x,t),h) &= 0 \text{ in } Q, \\ \partial_\nu y(x,t) + b(x,t,y,h) &= 0 \text{ in } \Sigma, \\ y(x,0) - \chi(x) &= 0 \text{ in } \Omega, \end{aligned}$$

and

$$r(x,t) \le u(x,t) \le s(x,t) \quad \text{a.e. in } Q,$$

where A is an elliptic operator, ν is the outword normal to $\partial\Omega$, ψ, a, b, r, s are given functions. All data functions are as smooth as it is needed.

We assume that for a given reference value $h_0 \in G$ of the parameter, problem (P_{h_0}) has a solution (y_0, u_0) and we are going to characterize conditions under which this solution is stable in the following sense:

(S) *There exist neighborhoods G_0 and Z_0 of h_0 and (y_0, u_0), respectively, such that, for each $h \in G_0$ there is a unique in Z_0 solution (y_h, u_h) of (P_h), which is a Lipschitz continuous function of h.*

The main difficulty in solving (S) is connected with the nonsmoothness introduced by the presence of inequality control constraints. This nonsmoothness makes it impossible to use the classical implicit function theorem. Instead of that, Robinson's (1980) implicit function theorem for generalized equations (inclusions) is used. This theorem allows to reduce the stability analysis for the original problem (O_h), to such an analysis for a *linear-quadratic* accessory problem, subject to additive perturbations. It was shown by Tröltzsch (1999) that the needed stability of the solutions to the accessory problem is satisfied if the so called *strong coercivity condition* holds with a certain *margin of freedom*. By Robinson's theorem this condition is a *sufficient* condition of (S). Using a generalization of Robinson's theorem due to Dontchev (1995), we show, that this condition is also *necessary*, provided that the dependence of data on the parameter is sufficiently strong.

Optimal Control of Differential Inclusions Involving Partial Differential Operators

Alexander Ioffe Technion — IIT

Summary: We shall consider optimal control problem for systems governed by operator inclusions of the form $Lx \in F(x)$, where F is a set valued mapping from R^n into itself (with possibly unbounded and non-convex values), L is a densely defined closed linear operator in a suitable space of mappings in R^n (typically one or another Sobolev space) with compact inverse and solutions of the inclusion are understood in the weak sense. The main content of the talk is connected with application of methods of non-smooth analysis in the theory of necessary conditions (maximum principles).

On the Existence of Optimal Strategies for Multichain Markov Decision Processes

Arie Leizarowitz Technion — IIT

Summary: In this work we address the question of whether a given finite state MDP has a Markov stationary optimal strategy. The optimality criterion which we consider is the long run average cost, and the action set is a compact metric space. We consider general multichain MDPs and provide a sharp answer to this question, namely conditions which are necessary and sufficient for existence of optimal solutions. A consequence of this characterization is a procedure with the following property. When applied to a given MDP then either the procedure yields an optimal strategy, or else it indicates that such an optimal strategy does not exist. In case optimal strategies do exist this procedure yields a detailed description of the structure of optimal strategies rather than merely establishing their existence.

Feedback Control for Descriptor Systems

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Summary: The control in the feed-back form is obtained for five linear-quadratic optimal control problems in a Hilbert space with the state equation unresolved with respect to the derivative, namely, the problem with the quadratic or linear-quadratic performance index, the problem with fixed points, the periodic problem, the regulation problem on an infinite interval. For the first four problems the operator $K(t)$ which is the solution of the following differential operator Riccati equation

$$\frac{d}{dt}(A'K(t)) = -K'(t)C(t) - C'(t)K(t) - W(t) + (K'(t)B(t) + S(t))R^{-1}(t)(K'(t)B(t)S(t))'$$

is used under different conditions. Here A is the operator standing before the derivative in the state equation, the prime with a notation of an operator denotes the conjugate operator. For the solving of the fifth problem the solution K of the operator Riccati equation

$$K'C + C'K - (K'B + S)R^{-1}(K'B + S)' + W = 0$$

satisfying the symmetry condition

$$A'K = K'A$$

is used. In the present paper it is not necessary to select from the state equation an equation resolved with respect to the derivative as it was made in numerous works devoted to linear-quadratic control problems for descriptor systems. Besides, the form of relations, defining the control in the feed-back form, is identical both for a singular operator, standing before the derivative, and for a nonsingular operator, that is very convenient is a research of singularly perturbed control problems. For the entry of the control in the feed-back form the operator is used which is the solution of the operator Riccati equation and it acts in all state space, unlike in a subspace in the case of a singular operator before the derivative, as it was in previous works of other authors. In contrast to previous works of other authors the regularity of the pencil of the operators from the state equation is not required.

Keywords: Feedback control, descriptor systems.

Optimal Design of Transfer Lines and Multiposition Machines

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Summary: Automatic transfer lines and multi-position equipment for machining large parts in mass production are investigated. Mathematical models and methods for optimal cost design of these production systems are considered. The following designed system parameters are determined: number of workstations; assignment of operations to the workstations; orientation of the parts, number of positions and cutting modes for each workstation. For solving the obtained optimization problem, a special multilevel decomposition scheme is proposed. It uses the decomposition approaches in combination with the methods of nonlinear and discrete programming.

Keywords: CAD/CAM, automatic transfer lines, optimization, parametric decomposition.

Conrol Architecture of a Flexible Microrobot-Based Microassembly Station

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Summary: The assembly of complex microsystems consisting of several single components (i.e., hybrid microsystems) is a task which has to be solved to make mass production of microsystems possible. Therefore, it is necessary to introduce flexible, highly precise and fast microassembly methods. In this paper, the control system of a microrobot-based microassembly desktop station that has been de-ve-loped at the University of Karlsruhe, will be presented from the lower to the planning levels. This comprises vision-based closed-loop control, user interfaces, a re-configurable computer-array, execution planning and assembly planning algorithms tailored to the needs of the microassembly station.

Keywords: Planning, control, microassembly, microrobotics, micromanipulation.

The Relationship between Planning and Production Activities in Process Industries

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Summary: In contrast to assembly industries, the CIM concept has not yet gained full acceptance in process industries. One of the reasons for this is that in process industries functional relations between the different management levels are sometimes difficult to define. This article deals with the problem of the strict realisation of a short-term plan on the production line of a process-oriented factory. This problem, caused by the complexity and uncertainty of process industries, can sometimes be overcomed. The case study in the second part of this article briefly describes the solution of this problem during the implementation of a brick production control system.

Keywords: Computer integrated manufacturing, management system, integration, factory automation, process control system.

Strategies for Integrating Preparation and Realisation — The Case of Product Models

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Phillip Kirkby The Technical Univ. of Denmark
Johan Vesterager The Technical Univ. of Denmark

Summary: The purpose of this paper is to discuss the integration of the Product Model (PM) and the Product State Model (PSM). Focus is on information exchange from the PSM to the PM within the manufacturing of a single ship. The paper distinguishes between information and knowledge integration. The paper provides some overall strategies for integrating PM and PSM. The context of this discussion is a development project at Odense Steel Shipyard (OSS).

Keywords: Manufacturing, realisation, product model, product state model, integration strategies, conditioning.

Aided Decision and Authentication of Lamellated Wood Frameworks

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Summary: The lameleted gluthed timber frame design needs many actors: architect, carpenter, different reseach departements . . . each of them has their work worry. Because of the increasing difficulty of the buildings, it becomes necessary to develop somes logiciel tools to choose the assembly beetveen the beams, to respect the mechanical resistance safety, to keep in conformity with the European standard.

Keywords: Lamellated wood frameworks, expert system, aided decision, assembly, structure.

An Estimate to the Energy Function of a Rigid Robot with a Stabilizing PD Controller

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Summary: This study presents an explicit upper bound to the energy function of an n-degree of freedom rigid robot while it is under the action of a PD controller. The resulting upper bound is an exponential function that reflects the effect of the controller gains on the form of the system response. A tuning-rule for setting the controller gains and adjusting the system rate of convergence towards the desired operating point in any given ball, centered at the system equilibrium point, has been demonstrated. As shown, the effect of the controller structure on the proposed upper bound is similar to the one resulted in the case of a second-order linear system.

Keywords: Rigid robot, PD controller, solution estimates.

Hierarchical Fuzzy Behavior-Based Control of a Multi-Agent Robotic System

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Yael Edan Ben-Gurion Univ.
Mohammad Jamshidi The Univ. of New Mexico

Summary: A hierarchical fuzzy behavior-based architecture for the control of a multi-robot system is presented. The arbitration of distinct behaviors is achieved by weighing each behavior according to its applicability to the current control cycle. This applicability is determined using global constraints. Combining fuzzy logic and behavior-based control increases the systems adaptability and robustness. Simulation results of the proposed methodology are discussed and a future hardware implementation is outlined.

Keywords: Robot, multi-agent, behavior-based,control, fuzzy logic.

Geometric and System Decomposition Techniques in Application to Control of a Mobile Robot with Trailer

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Summary: The trajectory interception approach in its original form primarily applies to systems whose controllability Lie algebra is nilpotent and involves only Lie brackets of relatively low order. High order Lie brackets in the controllability Lie algebra of the system lead to excessively complex formulations of the open-loop trajectory interception problem which can no longer be solved analytically (in terms of the parameters which represent the values of a feedback control for an extended system). The purpose of this paper is to demonstrate that even in such difficult cases the trajectory approach can still be made use of. The model of a mobile robot with trailer used in this paper is not nilpotent and requires system motion in the directions of third order Lie brackets. To compensate for the lack of nilpotency of the original model, a nilpotent approximation of the system is introduced. System decomposition is further employed to obtain an analytically solvable trajectory interception problem formulation. The example of the mobile robot with trailer has the most complex algebraic structure of all the systems to which the trajectory interception problem was ever applied.

Keywords: Vehicle control, nonholonomic systems, stabilization.

Following a Path of Varying Curvature as an Output Regulation Problem

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Summary: Given a path of nonconstant curvature, local asymptotic stability can be proven for the general n-trailer whenever the curvature can be considered as the output of an exogenous dynamical system. It turns out that the controllers that provide convergence to zero of the tracking error chosen for the path following problem are composed of a prefeedback that input-output linearizes the system plus a linear part that can be chosen in an optimal way.

Keywords: Path following, nonholonomic vehicles, ouptut regulation, input-output linearization.

On Enhancing GJK Algorithm for Distance Computation Between Convex Polyhedra: Comparison of Improvements

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Jing-Sin Liu Academia Sinica

Summary: The computation of Euclidean distance between two convex polyhedra is an important problem in robotics, computer graphics and animation. By geometric reasoning, we present an improvement of the well-known distance computation algorithm made by Gilbert, Johnson, and Keerthi (GJK). Some comparative simulations are shown to verify the algorithmic improvement in the process of distance computation. In addition, our work provides a simple and efficient algorithm for finding out the information where the closest point of a convex polyhedron to a reference point is on the face, the edge, or on one vertex of the polyhedron.

Keywords: GJK, distance algorithm, convex polyhedra, comparison of improvements, TCSO.

Links Between Robust and Quadratic Stability of Uncertain Discrete-Time Polynomials

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Summary: An uncertain polynomial is robustly stable, or stable in the sense of Kharitonov, if it is stable for any admissible value of the uncertainty, provided the uncertainty is not varying. The same polynomial is quadratically stable, or stable in the sense of Lyapunov, if it is stable for any admissible value of the uncertainty, regardless of whether the uncertainty is varying or not. In this paper, relationships between robust and quadratic stability of discrete-time uncertain polynomials are studied.

Keywords: Robust stability, quadratic stability, Lyapunov theorem, Kharitonov theorem, discrete-time uncertain polynomials.

Development of the Modal Regulator Design Method for a Plant with Interval Parameters

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Irina Brewer USA

Summary: We consider a problem of a modal P-regulator synthesis for a linear multivariable dynamical system with uncertain (interval) parameters: $dx/dt = [A]x + [B]u$, where $x = x(t)$ is a state vector, $u = u(t)$ is an input vector, the matrices $[A]$ and $[B]$ are matrices with interval elements. The designed feedback regulator $u = Kx$ has to place all coefficients of the characteristic polynomial of the closed-loop system: $dx/dt = ([A] + [B]K)x$ within assigned intervals. We develop the approach proposed in the previous works of the authors and prove a direct correlation between system controllability and existence of a modal P-regulator.

Keywords: Robust control, multivariable system, interval parameters, P-regulator.

Robust Stability Condition for the System with Feedback Connected Uncertainty and Uncertain Number of Unstable Poles

Kou Yamada Yamagata Univ.

Summary: In this paper, we consider the robust stabilization problem for single-input/single-output continuous time-invariant systems with feedback connected uncertainty such that the number of poles of the plant in the right half plane is not necessarily equal to that of the nominalplant. First of all, we define a class of uncertainty to be considered. The necessary and sufficient robust stability condition for the system with such class of uncertainty is presentedby using a relation between the plant and the nominal plant.

Real and Complex Stability Radii in Automatic Load-Frequency Control Systems via LQG/LTR and LMI

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Summary: In this work, two techniques of robust control (LQG/LTR and LMI), applied to a power electric system, are available via stability radii of the system. The structured uncertainties of the nominal model are considered in both designs. A set of models is generated considering the combinations of the parametric uncertainties. The structured singular values of the both systems are analysed.

Keywords: Robust control, LQG/LTR, LMI, real and complex stability radii, μ-analysis and power systems.

Robust Control for a Class of Linear Infinite Dimensional Systems with Multiplicative Disturbances

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Guillermo Fernández-Anaya UIA

Summary: In this paper the problem of robust control for a class of linear infinite dimensional systems under mixed disturbances of the multiplicative type is addressed. The Lyapunov function approach is used for proving that there is a controller that stabilizes this class of systems under the presence of uncertainties and perturbations, and guarantees some tolerance level for the joint cost functional. A comment is added to the Riccati operator equation's solution for this problem.

Keywords: Infinite-dimensional systems, robust control, mixed disturbances.

About Some Interconnection Between LTR and RPIS

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Summary: In this paper, the Loop Transfer Recovery design procedure is extended to non stabilizable systems. After a brief description of the systems considered in this paper, we revisit some results concerning the RPIS (Regulator Problem with Internal Stability), and give the structure of the controller. Thereafter we consider the LTR dual approach and stress the particular configuration of the output sensitivity function of the closed-loop system. We show that it is sufficient to recover only a part of the sensitivity function to guarantee the stability robustness of the loop. Finally the adjustment rules which lead to the desired result are described.

Keywords: Linear Control, robust control, LTR, RPIS.

A Novel Architecture for Digital Pulse Height Analysis with Application to Radiation Spectroscopy

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Summary: A novel digital approach to real-time, high-throughput, low-cost pulse height analysis (PHA) for radiation spectroscopy is presented. The analog nuclear signal is sampled at a high rate using an analog-to-digital converter (ADC), and analyzed by a state-of-the-art field programmable gate array (FPGA). A customized fixed-point polynomial fitting algorithm is utilized for pulse-height estimation. Other pulse parameters, such as width and asymmetry, are attainable for pulse shape analysis (PSA) purposes, such as particle identification. The mathematical complexity of the algorithm is strongly reduced by applying parallel arithmetic, resulting in complete elimination of processing dead-time. The proposed scheme is easily scalable by substituting the FPGA and ADC with more advanced integrated circuits as they appear.

Keywords: Digital pulse height analysis, digital pulse processing, FPGA.

Real-Time Adaptive Filtering for Nonstationary Image Restoration Using Gaussian Input

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Summary: A new real-time adaptive filter algorithm is presented for the restoration of the images which are degraded by the Atmospheric turbulence or imaging systems. Filter model parameters of the proposed algorithm adaptively converge degradation model parameter in a given time duration. Then, a restoration filter is constructed using mentioned filter parameter. Considerable results have been obtained after the real-time restoration.

Keywords: Real-time adaptive filter, gaussian model, image restoration.

The Edge Point Detection Problem in Image Sequences: Definition and Comparative Evaluation of Some 3D Edge Detecting Schemes

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Summary: When dealing with image sequences it is important to take into account the temporal correlation among consecutive frames to improve the performance of image processing techniques. In this paper the edge detection problem is considered and some 3D edge detectors exploiting the information carried by the spatio-temporal correlation of the 3D signal are proposed. Their performance is quantitatively and qualitatively evaluated.

Keywords: Edge detection, three-dimensional signals, image sequence processing.

Model-Based Detection Observer of Component Failures for Distributed Parameter Systems

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Summary: In this note, fault detection techniques based on finite dimensional results are extended and applied to a class of infinite dimensional dynamical systems. This special class of systems assumes linear plant dynamics having an abrupt additive perturbation as the fault. This fault is assumed to be linear in the (unknown) constant (and possibly functional) parameters. An observer-based model estimate is proposed which serves to monitor the system's dynamics and its well posedness is summarized. Using a Lyapunov synthesis approach applied to infinite dimensional systems, a stable parameter learning scheme is developed. The resulting parameter adaptation rule is able to "sense" the instance of the fault occurrence. In addition, it identifies the fault parameters using the additional assumption of persistence of excitation. Simulation studies are used to illustrate the applicability of the theoretical results.

Keywords: Detection observers, failure diagnosis, distributed parameter systems.

Parameter Estimation Problem for a Nonlinear Parabolic Equation with a Singular Nonlocal Diffusion Term

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Summary: We study a quasilinear reaction-diffusion problem that models the dynamics of a population that is eager to quickly get out of zones with low population densities. A least squares technique for identifying the singular diffusion coefficient is developed. Numerical results indicating the feasibility of this approach are presented.

Parameter Identification in a Nonautononous Nonlinear Volterra Integral Equation

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Summary: We propose a least squares technique for identifying parameters in a nonautonomous nonlinear Volterra integral equation. Numerical results indicating the feasibility of this method are presented.

Adaptive Control of a Time-Varying Parabolic System: Averaging Analysis

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Summary: Related to the error dynamics of an adaptive system, averaging theorems are developed for coupled differential equations which consist of ordinary differential equations and a parabolic partial differential equation. The results are then applied to the convergence analysis of the parameter estimate errors to zero in the model reference adaptive control of a nonautonomous parabolic partial differential equation with slowly time varying parameters.

Keywords: Adaptive control, averaging method, convergence analysis, parabolic partial differential equation, slow varying system.

Approximation of High-Order Lumped Systems by using Non-Integer Order Transfer Functions

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Summary: Non-integer order systems have been studied by several authors to model particular physical systems (electrical, biological etc.). In particular it can be shown that a non integer order system is equivalent to an infinite order LTI system. This feature can be useful considered for model order reduction purposes . The main aim of this paper is to show the mathematical background of this new approximation theory, the criteria for selecting the order of a non-integer order model which behaves as the original integer order ones and the quality indexes that can be considered for assessing the goodness of the approximated model. The introduction of non integer order systems resulted to be an efficient way to compress frequency response information usually intrinsic in an high number of poles and zeros. The comparison with a traditional method of model order reduction proved that a reduced model with the same number of parameters is not able to get the same good performance in the frequency domain. To this aim, some examples and simulations are reported.

Keywords: Model order reduction, non-integer order systems, lumped systems, frequency domain methods.

Closed-Loop Robust Controllers with Fuzzy Gain Scheduling for FNS Assisted Walking of Paraplegics

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Summary: The FNS closed-loop control for assisted walking of paraplegics is studied on the 5-link biped model. The design objectives is that the tracking errors of the joint angles reference trajectories must be reasonably bounded. The disturbances affecting the musculoskeletal model come mainly from the uncertain nonlinear dynamics of the muscle actuator. Two robust control schemes are proposed: the Sliding Mode control and the LQR control with fuzzy gain scheduling. The fuzzy scheduler output provides the relative degree (weights) of the system uncertainty according to the joint angles tracking error. These fuzzy weights schedules the appropriate gain from the control gain vs. tracking error interpolated function. It turns out that the additional tuning of the control moments by the muscle inverse dynamics Neural Network is essential for the successful tracking. The extensive simulations show that the performance of the Neural Network static learning depends on the initial position of the musculoskeletal system, and the Neural Network weights initialization. The simulation results demonstrate that the desired uncertainty attenuation properties of the proposed control algorithms have been achieved. They can be used as a prototype of the real FNS control schemes.

Keywords: Rehabilitation engineering, functional neurostimulation, robust control, fuzzy logic, neural networks.

Mathematical Formulation of Fuzzy Cognitive Maps

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Peter P. Groumpos Univ. of Patras

Summary: This paper presents an overview in existing representations of Fuzzy Cognitive Maps (FCM) and a new approach in the formulation of Fuzzy Cognitive Maps is examined. The description and construction of Fuzzy Cognitive Maps (FCM) is briefly represented and some new ideas for the modeling of Fuzzy Cognitive Maps are presented. Research in this area was mainly focalized on the representation, construction and application of FCM, and now in this paper different types and mathematical description of Fuzzy Cognitive Maps are examined and FCMs are mathematically transformed in forms that are analogous to Recurrent Neural Networks. This similarity stimulates the investigation of Forward Accessibility for discrete-time FCM models. Finally, an example of a process is presented and it is formulated in form that controllability aspects can be examined.

Keywords: Fuzzy Cognitive Maps, controllability.

An Outline for a Universal Logic System: A Logic System in Eight Truth Values

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Summary: A Universal Logic System establishes a truth value termed neutral between the contrary terms of truth and falsity. The Universal Logic System is composed of three primary logic sets: truth, falsity and neutrality together with three secondary sets: not-true, not-false and not-neutral. Furthermore, there are the Universal and Null logical sets. The Universal set is the union of all primary logical states. Distinction is made between the True set and the Universal set in the Universal logic system, unlike Boolean logic in which they are equated. This has fundamental implications as a many valued logic system. Traffic light states at a controlled intersection have been used as an illustration of Universal Logic.

Keywords: Universal, neutral, not-neutral, null, validity.

Using Soft Computing Methodologies for Multistage Supervisory Control of Complex Systems

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Peter P. Groumpos Univ. of Patras

Summary: In this paper, a structure to supervise and control complex systems is presented. The proposed multistage supervisory control system is structured as a hierarchy of three levels - control, supervision and co-ordination levels. While the controllers at control level exercise direct action over the process, the supervision level generates decisions to govern the operations of the control algorithms at the lower level. The co-ordination level governs the supervisory level to assure proper overall system behavior. The system possesses different control and supervisory strategies to accommodate different operating conditions, adaptive behavior to react under uncertain or unfamiliar situations and the capability to coordinate distributed controllers to accomplish the system task. The bottom control level is constituted of conventional controllers or soft control technologies based on Neural Networks, Fuzzy Logic and Genetic Algorithms. The supervisor is modeled as a Fuzzy Cognitive Map. Based on the process status, the set of active control and supervisory algorithm is chosen.

Keywords: Supervisory control, complex systems, fuzzy cognitive maps, fuzzy logic.

Variable Structure Control with Varying Bounds of Robot Manipulators

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Summary: A controller for robot manipulators is proposed in this paper. The design is based on a Lyapunov approach with V.S.C. and sliding mode technique. Fundamental properties of the robot, as well as some engineering considerations are taken into account during the design procedure. Chattering is tackled by indexing the magnitude of the switching bound to the tracking error. Simulations reveal a great reduction of chattering while maintaining good controller performances.

Keywords: Robotics, V.S.C., sliding-mode, chattering, Lyapunov.

An MRAC Output Feedback Controller for Robot Manipulators

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Summary: An adaptive controller is proposed, for the tracking control of robotic manipulators that does not require the measurement of joint velocities. The controller belongs to the class of model-reference adaptive controllers. An observer is used to generate an estimate of the joint velocities and an observer-based identifier with projection is used to update the parameter vector estimate. Simulation results are given to show the effectiveness of the control algorithm.

Keywords: Robot control, feedback linearization, output feedback, adaptive systems.

Basic Fairing Principles of Fiberglass Pits and Patches

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Summary: There are many reasons compelling us to automating surface finishing of fiberglass composites. Harmful dusts, repetitive motion injury, and product quality are just a few reasons for automation. We have developed a methodology for robotic surface finishing of fiberglass composite pits and patches. Methods for the filling of pits and patches with a fill material, the subsequent forming of the uncured fill material, and the fairing of the various workpiece features are examined.

An anthropomorphic manipulator is used with "around the arm" force control along with custom developed software called RobSurf. RobSurf provides for the reverse engineering of the samples used, and creation of robot programs based upon the reverse engineered surface. The necessary filling, forming, and fairing process parameters are explored and the subsequent experimentally determined parameters are described. Factory implementation suggestions are provided that utilize commercially available components for workcell development.

Keywords: Robotic, surface, fairing, fiberglass, composite.

RobSurf: A Near Real Time OLP System for Robotic Surface Finishing

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Summary: In this paper we will discuss the development and use of a CAD based robot path and process-planning environment for surface finishing of conventional (metal) and non-conventional material (fiberglass composites) workpieces. This system is based on a modular and parametric approach process modeling for experimentation in determining "optimum" process parameters. It can operate upon workpieces of various characteristics due to the integrated soft setup methodologies.

RobSurf is a surface modeling and path generation system developed specifically for experimentation and identification of process parameters for processes associated with surface finishing. Using a coordinate measuring device interfaced with AutoCAD, the system is capable of generating a CAD model of any surface through reverse engineering techniques and generating native robot control code with embedded process parameters for various routines such as fill, form, and fair as well as information of the process tooling employed. The generated robot control code is then transferred to the robot controller via an RS-232C interface connection.

Keywords: Robotic, OLP, soft-setup, reverse-engineering.

Adaptive Nonlinear Visual Servoing Using Lyapunov-Based Design

Fabio Conticelli Scuola Superiore Sant'Anna
Benedetto Allotta Scuola Superiore Sant'Anna

Summary: In this paper, an adaptive nonlinear control scheme is designed to solve the problem of controlling the relative pose between a robot camera and a rigid object. The image-based visual system of the camera-object interaction is expressed in terms of global coordinates fully defined in the image plane, then a discrete time interaction model is derived, since the visual sampling time is not negligible at the actual state of technology. By exploiting nonlinear controllability properties, a nonlinear control law is designed based on Lyapunov's direct method. Moreover, we propose a 3-D estimation procedure based on prediction errors to cope with the unknown depth of the object. Experimental results with a 6-DOF robot manipulator in eye-in-hand configuration validate the theoretical framework.

Keywords: Nonlinear visual model, controllability, discrete time visual servoing, asymptotic stability, experimental validation.

On the Inclusion of Robot Dynamics in Visual Servoing Systems

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Summary: In this paper the problem of including the robot dynamics in the control loop of visual servoing systems is considered. After introducing the image-based visual interaction model between a robot camera and a rigid object parametrized by a finite number of image features, the problem of local feedback stabilization is considered, in both the cases of interconnection to a linear subsystem and to a nonlinear open-chain manipulator. The proposed control system design uses backstepping approach to ensure local stablity of the equilibrium of the whole system, assuming that the linear subsystem is minimum phase of relative degree one. In the case of inclusion of the nonlinear lagrangian dynamics of the robot, the obtained control law is similar to the well-known computed torque law. A case study is also reported to validate the developed control design, approximating the robot and its local controller by a diagonal linear subsystem.

Keywords: Image-based visual interaction, robot dynamics, backstepping approach, asymptotic stability.

Partial Lipschitz Nonlinear Sliding Mode Observers

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Summary: The stability of a nonlinear observer for systems with uncertainties usually requires some sufficient conditions. The Lipschitz condition is a restrictive condition which many classes of systems may not satisfy. In this paper we consider a class of systems with two uncertain parts; one which satisfies the Lipschitz condition, whilst the other does not satisfy the Lipschitz condition but is a bounded uncertainty. Sliding mode theory is applied to yield feedforward compensation control to stabilize the error estimation system with non-Lipschitz uncertainty. New sufficient conditions for stability of the Thau observer are proposed. These conditions ensure the stability of the nonlinear observer by selecting a suitable observer gain matrix.

Keywords: Sliding observers, nonlinear observers, sliding mode.

Dynamical Adaptive First and Second Order Sliding Mode Control of Nonlinear Non-Triangular Uncertain Systems

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Antonella Ferrara Univ. of Pavia
Luisa Giacomini Aston Univ.
Miguel Rios-Bolívar Univ. de Los Andes

Summary: In this paper combined algorithms for the control of non-triangular nonlinear systems with unmatched uncertainties will be presented. The controllers consist of a combination of Dynamical Adaptive Backstepping (DAB) and Sliding Mode Control (SMC) of first and second order. In order to solve a tracking problem, the DAB algorithm (a generalization of the backstepping technique) makes use of virtual functions as well as tuning functions to construct a transformed system for which a regulation problem has to be solved. The new state is extended by an $(n-\rho)$-th order subsystem in canonical form where n is the order of the original system and ρ is the relative degree. The role of the sliding mode control is to replace the last step of the design of the control law to obtain more robustness towards disturbances and unmodelled dynamics. The main advantages of the *second order* sliding mode algorithm are the prevention of chattering, higher accuracy and a significant simplification of the control law. A comparative study of these first and second order sliding controllers will be presented.

Keywords: Backstepping, sliding mode control, comparative study.

Adaptive Sliding Backstepping Control of Nonlinear Semi-Strict Feedback Form Systems

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Summary: This paper considers the application of a combined adaptive backstepping sliding mode control (SMC) algorithm to a class of nonlinear continuous uncertain processes which can be converted to a semi-parametric strict form. The algorithm follows a systematic procedure for the design of dynamical adaptive SMC laws for the output regulation of observable minimum phase nonlinear systems.

Keywords: Backstepping, sliding mode control, adaptive control, output regulation, sliding surface.

A Feedforward-Feedback Interpretation of a Sliding Mode Control Law

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Koshy George Delft Univ. of Technology
Jacquelien M.A. Scherpen Delft Univ. of Technology
Michel Verhaegen Delft Univ. of Technology

Summary: In this paper we provide a feedforward-feedback interpretation of a sliding mode control scheme. Given a desired trajectory, the feedforward signal is generated using a stable inversion method, and the feedback signal includes the switching term of the sliding mode control law. In this manner, we introduce robustness into the stable inversion technique. This approach is motivated by the need to replicate time signals typically in the automobile industry. The application of such an interpretation to a quarter car benchmark model yields encouraging results. Special attention will be given to non-minimum phase systems illustrated by a simulation example of the lunar roving vehicle.

Keywords: Sliding mode, non-linear systems, Model Inversion.

Nonminimum Phase Output Tracking via Sliding Mode Control: Stable System Center Technique

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Summary: Nonlinear output tracking in multi-input/multi-output (MIMO) nonminimum phase systems with matched nonlinearities as well as matched and unmatched disturbances is considered in sliding modes. The output tracking problem has been transformed to an equivalent state control problem. The nonminimum phase output tracking problem is solved using an extension of the method of system center for nonminimum phase systems and the dynamic sliding manifold technique. The asymptotic motion of the output tracking error with given eigenvalue placement for noncausal output tracking is provided in absence of unmatched disturbance. Linear bounded error dynamics with desired eigenvalue placement forced by unmatched disturbance and an arbitrary reference output profile are provided for causal output tracking in sliding mode. The theoretical results are illustrated on two numerical examples.

Keywords: Nonminimumphase systems, MIMO nonlinear tracking, sliding mode control.

2-Sliding Mode with Adaptation

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Summary: Sliding mode is used in order to retain a dynamic system accurately at a given constraint and is the main operation mode in variable structure systems. Such mode is a motion on a discontinuity set of a dynamic system and features theoretically-infinite-frequency switching. The standard sliding modes are known to feature finite-time convergence, precise keeping of the constraint and robustness with respect to internal and external disturbances. In realization their sliding precision is proportional to the time interval between measurements. Having generalized the notion of sliding mode, higher order sliding modes preserve or generalize its main properties and remove the chattering effect. With discrete measurements they may provide for up to the rth order of sliding precision with respect to the measurement interval. The main implementation problem of these modes is the information demand growing with the sliding order. If the aim is to nullify some output variable σ then r-sliding mode realization generally requires measurements of the time derivatives of up to the $(r-2)$th order of σ to be available. A new approach demonstrated in the paper provides for 3-sliding accuracy realization while only σ itself is available. That is the first controller of such kind.

Keywords: Nonlinear control, sliding mode, adaptation.

The Optimal Markov Strategy for Access in ISDNs with Reserves of Channels

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Summary: In this paper, the use of the Markov Decision Process (MDP) to find the optimal strategy for access in ISDNs with reserves of channels is proposed. ISDN provides multiple channels for telecommunications access. The problem is formulated as a multi-resource queuing (MRQ) system where different types of customers require a random number of channels simultaneously. The algorithm that realizes the optimal strategy for access when heterogeneous customers demand service in ISDNs is developed.

Keywords: Optimal Markov strategy, Markov Decision Process (MDP), access in ISDNs, reserves of channels.

Tbit/sec Switching Scheme for ATM/WDM High-Speed Computer Networks

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Summary: A novel high throughput, reservation-based switch architecture for ATM/WDM networks is presented. The scheme is contention-free and highly flexible yielding a powerful solution for high-speed broadband packet-switched networks. Switching management and control is studied for data rates of up to 10 Gbit/sec/port, providing aggregated throughput of over 1 Terabit/sec.

Keywords: Switching architectures, ATM/WDM, packet-switching computer networks, Tbps.

Grid-based ATM Switch Architecture: A New Fault-Tolerant Space-Division Switch Fabric Architecture

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Summary: Asynchronous Transfer Mode (ATM) has been chosen to be employed in the implementation of B-ISDN because of its superiority in fast packet switching. The deployment of ATM in Wide Area Networks has revealed the necessity of ATM switches with large number of input and output ports. Unfortunately, it has become obvious that ATM switch fabrics form a bottleneck in Wide Area ATM Networks. In this paper we present a new grid-based ATM switch, which is fault-tolerant, self-routing and easily expandable. The switch's architecture is described in detail, along with the internal routing algorithm, and its simplicity in comparison to the Banyan networks is demonstrated. The analytical model of the performance as well as simulation results are presented. The characteristics of the switch regarding fault tolerance are also briefly discussed.

Keywords: ATM, switch fabric, grid-based, fault tolerance.

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