SPECIAL SESSIONS

Special Session I: Wednesday: 11:30AM – 1:10PM, *Grand Ballroom I*
Scanning Probe Microscopy
Organizer: Murti V. Salapaka (Iowa State University)

Scanning probe microscopy has revolutionized science and engineering in the past decade. As stated in the National Nanotechnology Initiative plan *"These instruments including the scanning tunneling microscopes, atomic force microscopes and near-filed microscopes, provide the eyes and fingers for nanostructure measurement and manipulation"*. There are significant advancements that have to be unraveled in this area where the control expertise can play a pivotal role. In this session the contribution of the control and systems perspectives to this area will be highlighted, and open research issues will be presented. Presenters will include Murti V. Salapaka (Iowa State University), Srinivasa Salapaka (University of Illinois, Urbana Champaign) Anil Gannepalli (Asylum Research), and Abu Sebastian (IBM, Zurich Labs.).

Special Session II: Wednesday: 11:30-1:10PM, *Grand Ballroom II*
Modeling of RNA Expressions
Organizer: Bijoy Ghosh (Washington University)

An important area of Systems Biology concerns the problem of controlling photosynthesis by environmental alterations. One is interested in the study of how `Genes Regulate' and one way to do this is to classify a set of co-regulated genes. There are many different criterion in the literature on how to assess that a set of genes are co-regulated, and a well known technique utilizes 'Pearson Correlation Coefficient'. Thus two genes are described as co-regulated, if their expressions over time are close. This session will focus on the construction of 'Dynamic Interaction Model' between co-regulated genes to study the effect of 'temporal causality' between interacting genes. The proposed model is linear, time-varying and captures the temporal interaction between gene clusters. The model is time varying, indicative of the fact that the interaction profile can change over the life cycle of the cell. Our model would utilize recently developed techniques in 'Smoothing Splines' and time series analysis methods that have been shown to be useful in spaces of large dimension such as 'Random Matrix Theory' and 'Sparse Principal Component Analysis.' We believe that the model so developed would find application in the study of the control of photosynthesis.

Special Session III: Wednesday: 6:00-7:30PM, *Grand Ballroom I*
History of Control
Organizer: Daniel Abromovitch (Agilent Labs)

This session will focus on early work on control systems carried out in the Soviet Union. Speakers will include Daniel Abromovitch, George Bekey, Petar Kokotovic, and Boris Kogan.

Special Session IV: Wednesday: 6:00-7:30PM, *Grand Ballroom II*
Mid-Career Professional: To Change or Not Change Your Jobs
Organizer: Karlene Hoo and F. Chowdhury (Texas Tech University)

This session provides a forum for discussing important aspects of job direction change for the mid-career professional. To make a change or to not make a change? What are the important factors to be considered? There will be presentations from successful mid-career women who changed jobs and moved to other positions, and there will be a question/answer period with audience participation.

Special Session V: Friday: 11:30-1:00PM, *Grand Ballroom I*
NSF Funding Opportunities
Organizers: Kishan Baheti and Mario Rotea (National Science Foundation)

National Science Foundation continues to be the funding source of choice for control systems engineers. However, programs at the NSF are being reorganized continually, and along with that arise new funding opportunities in emerging multidisciplinary areas of national importance. This session will be a forum to discuss such opportunities and challenges.

INTERACTIVE SESSIONS

WeA16:	**Cooperative Control with the MultiUAV Simulation**
	Grand Ballroom I
Organizer:	Ram Venkataraman Iyer (Texas Tech University)
	Phillip R. Chandler, Steven Rasmussen (Wright Patterson Air Force Base)

This session will showcase MultiUAV simulation software which has been developed recently at the Wright Patterson Air Force Base. Wright Patterson is at the forefront of UAV technology research for the Air Force. Software tools demonstrated are aimed at helping research community to test various algorithms in realistic scenarios.

FrA13:	**Control Applications in Ventricular Assist Device Development**
	Broadway I
Organizer:	Yih-Choung Yu (Lafayette College)
	Marwan A. Simaan (University of Pittsburgh)

Ventricular assist devices are becoming increasingly reliable, and thought to become an alternative to hear transplants in the near future. Methods of control theory are being increasingly used in the second generation Ventricular assist devices in order to regulate the device output to varying physiological conditions. This session will bring attention to these control issues via poster presentations, simulations, and display of recently developed ventricular assist devices.

ThA13:	**Modeling and Control of Systems for Critical Care Ventilation**
	Broadway I
Organizer:	Michael A. Borrello (Trex Enterprise)

In medical practice, critical care ventilation provides a vital life support function for patients that have difficulty or are unable to breath for themselves. The machine providing this function is known as a ventilator. There are presently four or five leading ventilator manufacturers that compete in a worldwide market of about 2.5 billion dollars. With the rising expense of healthcare, cost reduction has been the design priority although manufacturers still look to performance improvements and new features to differentiate their product and maintain a competitive edge in the market. Clinical experts in the field of respiratory care frequently publish studies that evaluate, analyze and compare performance between ventilators. The success or failure of this performance ultimately depends on the controls design.

This tutorial introduces the specific topics in critical care ventilation that concern control engineering, focusing primarily on modeling methods and control techniques for breath delivery. For simple modeling and analysis, fundamental elements of flow resistance, compliance and inertance are discussed and used to build linear lumped parameter models of the lung, patient circuit and ventilator control valves. Static nonlinear characteristics of these elements are further used to extend these models to linear parameter varying (LPV) systems that provide closer approximation suitable for simulation. The basic control functions of flow, mix, volume and pressure and the issues they impose on controls are discussed as well as more advanced applications such as SaO_2 control (blood oxygen saturation), impedance targeted controls, and methods of closed loop ventilation intended to aid or replace higher level decisions made by clinical personnel.

The main tutorial will be followed by three papers prepared by practicing control engineers from the ventilator industry and which address specific selected topics.

ThB02:	**Maximum Likelihood Subspace Identification for Linear, Nonlinear, and Closed-loop Systems**
	Senate
Organizer:	Wallace E. Larimore (Adaptices, Inc.)

Linear subspace system identification involves the direct determination of the state space subspace and estimation of the states based on only observational data, with no knowledge of the process dynamics. This involves reduced-rank regression that is implemented using computationally stable and accurate singular value decomposition calculations. Simple multivariate regression is then used to identify the system dynamics and estimate a parametric model description. This avoids the use of nonlinear iterative parameter optimization that is frequently ill-conditioned and may not produce a useful result. As a result, subspace identification can be completely automated for the identification of high-order multivariable dynamic systems leading to major new online and real-time applications such as online monitoring, fault detection, adaptive and robust control. Extensions of subspace identification to general nonlinear systems have similarly produced major results. However, a major issue over the past two decades has been the lack of theory describing the accuracy of subspace identification compared with other high-accuracy methods such as maximum likelihood (ML), particularly for closed-loop systems. New results on the accuracy of subspace methods are discussed in detail in the first paper. In the 1-hour tutorial paper, the basic concepts of subspace identification are developed for linear systems. Then, new results are discussed that show the canonical variate analysis (CVA) subspace method is equivalent to ML in the case of a large sample size for a linear time-invariant system including the case of closed-loop feedback. These ideas are then extended to very general nonlinear system that has many potential new applications. The second paper in the session develops subspace identification methods for Hammerstein nonlinear feedback systems that are applied to the nonlinear modeling of aircraft wing flutter and to nonlinear modeling of solar wind data. The third paper studies subspace identification of large space structures in both the time and frequency domain. The final paper discusses subspace and regression-based identification in process control applications.

ThB12:	**Mixed-integer Programming for Control – A Tutorial**
	Executive
Organizer:	Arthur Richards (University of Bristol), Jonathan P. How (MIT)

Mixed-integer programming (MIP) is a very general framework for capturing problems with both discrete decisions and continuous variables. This includes assignment problems, control of hybrid or piecewise-affine systems, and problems with non-convex constraints (e.g., collision avoidance in trajectory design). MIP methods naturally handle these types of problems because the integer decision variables can be used to encode discrete/logical decisions (e.g., assignment decisions or ``left'' vs. ``right'' for collision avoidance) in the optimization. Having cast the problem in MIP form, techniques from Model Predictive Control (MPC) can be used to build a feedback control law using the optimization online.

This tutorial will focus on the two major challenges associated with using MIP/MPC for online control. The first is to encode the problem as a MIP optimization that can be embedded in an MPC. Topics covered in this area will include MIP modeling of common problem types and requirements for stability and robustness when used in MPC. The second challenge, often the harder of the two, is to develop modifications to the problem statement to execute these optimizations in real-time. A successful deployment often requires judicious choice of approximation and solution techniques. General approaches will be described including approximations, constraint relaxation and cost-to-go functions, and talks by leading researchers in the field will give more application-specific details.

ThB13:	**Sum of Squares in Industry: An Algorithmic Analysis Approach**
	Broadway I
Organizer:	Antonis Papachristodoulou (Caltech), Stephen Prajna (Caltech),
	Sonja T. Glavaski (Honeywell)

The sum of squares technique for systems analysis was introduced nearly 5 years ago in Pablo Parrilo's thesis. The main advantage of this methodology is that it provides an algorithmic procedure for *verifying* certain properties that a designed system should enjoy: safety, functionality, performance, etc. This is done by algorithmically constructing proofs/certificates that ascertain these properties, rather than running exhaustive simulations, which is an inconclusive approach. This property is particularly important for safe-critical systems of industrial interest. In the past 5 years, the sum of squares technique has been applied at a theoretical level to answer a series of important questions on systems analysis and design that were impossible to be answered before. Such questions include, but are not limited to, stability and robustness analysis of nonlinear, hybrid, and time-delay systems, estimation of domain of attraction, LPV analysis and synthesis, model validation, safety verification of hybrid systems, nonlinear synthesis. In addition, software tools have been developed for analysis based on this methodology. These theoretical foundations have attracted the interest of industrial partners and the sum of squares methodology has been applied successfully for a series of systems of industrial importance. The objective of this tutorial session is to give an overview of recent progress in sum-of-squares-based systems analysis and present some successful industrial applications of the techniques in an integrated setting. The organizers and contributors of the session are among the leading researchers in the area, and the session will be of interest to a broad spectrum of the ACC audience, including industrial practitioners and people from academia interested in computational methods for analysis of nonlinear, hybrid, and time-delay systems. The session will start with an introductory talk in which we will explain in detail the theoretical background and applicability of the sum-of-squares-based techniques, through a series of illustrative academic examples. The introductory lecture will cover the following areas:

- Introduce the sum of squares decomposition of multivariate polynomials, its algorithmic verifiability through convex optimization and SOSTOOLS, a free software package for sum of squares programming;
- Show how stability and robustness analysis of nonlinear uncertain systems described by ordinary differential equations (ODEs) or differential algebraic equations (DAEs) can be done through the construction of Lyapunov functions by sum of squares programming;
- Address analysis for time-delay systems based on Lyapunov-Krasovskii functionals constructed using the sum of squares technique;
- Present a sum-of-squares-based framework for stability and robustness analysis of switched and hybrid systems;
- Introduce the notion of barrier certificates and discuss how model validation and safety verification can be performed using sum of squares programming.

When the talk is complete, the audience will appreciate the advantages of using the sum of squares technique for systems analysis: other system classes, such as hybrid, nonlinear and time-delay can be analyzed exactly, and more complicated analysis questions can be answered. The rest of the session will continue with four industrial applications of the sum of squares techniques in the following areas:

1) Analysis of aircraft pitch axis stability augmentation system;
2) Safety verification of a controlled hybrid model of a life support system;
3) Determining optimal decentralized decision rules in discrete stochastic decision problems, such as medium-access control in communication systems; and
4) Assessing connection level stability in networks, such as the Internet.

In the first paper, the sum of squares decomposition is used to analyze the stability and robustness of the controlled pitch axis of a nonlinear aircraft model. The controller is a linear time-invariant dynamic inversion based control law designed for the short period dynamics of the aircraft. The closed loop system is tested for its robustness to uncertainty in the location of center of gravity along the body x-axis. The second paper demonstrates the use of barrier certificates as a method to verify safe performance of a hybrid Variable Configuration CO2 Removal (VCCR) system. A simple nonlinear feedback controller was designed that tracks a desired CO2 profile; the aim is to test whether the CO2 and O2 concentrations stay within acceptable limits. For this purpose, the sum of squares decomposition was used to construct a barrier certificate that verifies the safe performance of the system. The third paper considers the problem of determining optimal decentralized decision rules in discrete stochastic decision problems, such as medium-access control in communication systems. A static single-stage problem as well as a dynamic infinite horizon problem are considered. It is known that the static problem is NP-hard, even for the case of two decision makers. Here these complexity results are extended to the dynamic problem. It is shown that both problems have an equivalent formulation as minimization of a bilinear polynomial subject to linear constraints. By forming relaxations of these polynomial optimization problems using sum of squares techniques, suboptimal decentralized decision rules as well as bounds on the optimal achievable value can be computed. The methods are illustrated by an example of decentralized detection. Finally, the authors of the last paper investigate the use of the sum of squares technique to construct Lyapunov functions satisfying Foster's condition for stochastic stability of connection-level models of file transfer requests in the Internet. In particular, they consider the setting where connection arrivals to each route occur according to Poisson processes and the file-sizes have phase-type distributions. The sum of squares methodology is used to numerically establish connection-level stability of linear and star network topologies when the load on each link is less than its capacity.

ThC12:	**Adaptive Control of Rapidly Time-Varying Systems**
	Executive
Organizer:	Kumpati S. Narendra, Robert N. Shorten, and Matthias J. Feiler
	(Yale University)

New classes of problems are arising in the highly competitive industrial word, where time variations in the parameters of processes to be controlled are both large and rapid. The tutorial deals with the control of such dynamical processes. The objective of the tutorial is to discuss the many forms that such control problems can take, and describe methods that are currently being investigated which assure stability and satisfactory performance.

The tutorial will consist of three parts. In the first part, based on the prior information that is available concerning the controlled process, different formulations of the control problem will be presented. Examples from electrical, mechanical, chemical, and aeronautical systems will be described, which will be addressed in the following parts of the tutorial.

The second part of the tutorial will deal with switching (hybrid) systems. The principal assumption here is that the parameter values of the constituent systems are known. The main thrust of this part is to discuss the theory of stability of linear systems whose parameters vary discontinuously, and provide a mathematical framework for reviewing the major results. Quadratic and non-quadratic Lyapunov functions, as well as linear matrix inequalities, will be used to investigate the stability of switching systems. This part will conclude with the formulation of problems in which the switching laws are state dependent, and those in which the constituent systems are unstable. Applications will be chosen from communication networks where the techniques developed provide the basis for design.

The third part of the tutorial will deal with adaptive systems in which the process parameters are unknown and vary discontinuously. The principal objective is not merely to assure the stability of the overall system, but also to answer the question whether the methods suggested can maintain overall performance even as the operating conditions change discontinuously. In contrast to the second part, the parameters of the controlled process are assumed to be unknown and multiple models are used to estimate the plant parameters. The resulting control consequently involves both switching and tuning. A series of increasingly more complex problems, based on decreasing prior information concerning the process, are formulated, and in each case both stability and performance issues are discussed. The tutorial will conclude with a description of the improvement that can be achieved in different control systems using the above methodologies.

ThC14:	**Automotive Powertrain Controls: Fundamentals and Frontiers**
	Galleria II
Organizer:	Jing Sun (University of Michigan)
Contributors:	Julia Buckland (Ford), Kenneth Butts (Toyota Technical Center), Jeffrey Cook (Ford), Kumar Hebbale (GM), Ilya Kolmanovsky (Ford), Zongxuan Sun (GM)

This tutorial session brings together the powertrain control specialists from different areas to give a comprehensive overview of this rich and dynamic research and development topic. Technical leaders from three major automotive companies, Ford, GM, and Toyota, are joining the effort to provide technical perspectives from several different viewpoints: modeling, design, calibration and processes. Fundamentals will be reviewed, frontiers will be explored, and methodologies and tools will be discussed. The one-hour tutorial presentation will focus on technical fundamentals of engine control, for both gasoline and diesel engines. Three 20-minute presentations will concentrate on advanced transmission control, emission control, and processes/tools of engine control development. The goal of this tutorial session is to expose the fundamental and challenging powertrain control problems to those from academia, and to provide a forum to learn and discuss advanced design and analysis tools for others from industries.

ThC16:	**Cooperative Electronic Attack using Unmanned Air Vehicles**
	Grand Ballroom I
Organizer:	Mark J. Mears (Air Force Research Laboratory)

Cooperative Control of air vehicles for Electronic Attack is focus of this paper. The utility of Electronic Attack is described in the context of integrated air defense systems which rely on RADAR sites that act as a network to gather information about potential airborne threats. General concepts for use of multiple vehicles against RADAR systems are described and formulated in terms of cooperative path planning and resource allocation. Then some approaches to solving the technical problems are described. Although the interests expressed in this paper are motivated by capabilities that might be afforded by many unmanned autonomous vehicles, the concepts are relevant for manned aircraft working in concert with groups of air vehicles.

FrA11:	**Control and Pointing Challenges of Antennas and Telescopes**
	Studio
Organizer:	Wodek Gawronski (Caltech)

This session presents the control and pointing problems encountered during design, testing, and operation of antennas, radio-telescopes, and optical telescopes. This collection of challenges helps to evaluate their importance, and is a basis for discussion on the ways of improvement of antenna pointing accuracy.

The session presentation is based on the authors' extensive experience with the NASA Deep Space Network antennas, Very Large Telescope, Nordic Optical Telescope, ALMA Telescope, Multiple Mirror Telescope, The Large Millimeter Telescope, APEX Telescope, ESA Deep Space Antennas, and others.

We discuss telescope control system models (obtained from the finite element analysis and system identification); disturbances (wind and motor cogging torque acting on a telescope structure); performance of the position controllers of antennas (PI, LQG, and H_∞); nonlinearities of the antenna control system (rate and acceleration limits, friction, backlash); pointing error sources (thermal and gravity deformations, atmospheric refraction, encoder errors); pointing error calibration; conical scanning, and monopulse tracking.

We present an integrated (or mechatronic) approach to the design of telescope subsystems, with the focus on structural design, axes mechanisms, active surfaces, sensor placement, and system identification with application to the surface and pointing control.

The session presents our experience in the analysis and testing of the 12m ALMA telescope, in the adaptive correction of the periodic tracking errors, and the current and future work in servo development at the Multiple Mirror Telescope.

FrA16:	**Adaptive Flight Control**
	Grand Ballroom I
Organizer:	Eugene Lavretsky and Kevin A. Wise (Boeing Phantom Works)

This presentation describes the development and application of a direct adaptive / reconfigurable model following flight control design concept for manned and unmanned military aircraft. The design methodology is theoretically justified and derived based on the fundamentals of the Lyapunov Stability Theory. The adaptive control architecture includes a fixed robust baseline controller that is augmented by an online feed-forward neural network. While the former is designed to yield consistent nominal system performance, the latter provides for adaptation and reconfiguration in the presence of system uncertainties (e.g., battle damage), control failures, and environmental disturbances. Adaptation benefits and closed-loop system tracking performance are demonstrated in a flight simulation environment that incorporates an unmanned aircraft model data. The adaptive reconfigurable control design architecture employs radial basis functions (RBF) and feed-forward neural networks (NN). The inner-loop flight control adaptive design is performed. Through both theory and simulation it is verified that the adaptive controller provides bounded tracking and guarantees a uniform ultimate boundedness of all the signals in the corresponding closed-loop system.

The presentation material consists of two parts and it is organized as follows. In the first part, robust control design and analysis methods are introduced and a summary of theory and lessons learned in developing robust linear control is presented. This section summarizes the authors' vast experience of applying robust optimal control methods to aircraft and missiles within the Boeing Phantom Works. The second part begins with an overview of the Lyapunov stability theory, followed by an introduction to the design and analysis of classical linear in parameters adaptive control systems. Subsequently, approximation properties of artificial neural networks and their application to the design of direct adaptive systems are presented. Key design points are discussed and illustrated through various simulation examples. The presentation culminates in demonstration of applying direct adaptive neural control to autopilot design for an unmanned aircraft.

FrB16:	**Introduction to the Multi-UAV Simulation and Its Application to Cooperative Control Research**
	Grand Ballroom I
Organizer:	Steven Rasmussen (General Dynamics)

This tutorial session will introduce the MultiUAV simulation and its application to unmanned air vehicle (UAV) cooperative control problems. MultiUAV is capable of simulating many UAVs, targets and threats as well as communications between vehicles. It has been used to evaluate cooperation during missions such as wide area search and destroy; lethal intelligence, surveillance, and reconnaissance; and suppression of enemy air defenses. In addition, cooperative control algorithms based on ideas ranging from capacitated transshipment network flow to stochastic search have been evaluated with the MultiUAV simulation. The Mathworks' Simulink symbolic programming language is used to organize and control MultiUAV. Subfunctions are constructed in MATLAB's script language and in C++. Using Simulink and MATLAB in this manner makes the MultiUAV simulation very accessible to researchers. MultiUAV was developed by the United States Air Force's Control Science Center of Excellence and is distributed freely to the public.

FrB18:	**Industry Needs for Embedded Control Education**
	Parlor C
Organizer:	Jim Freudenberg (University of Michigan) ,
	Bruce Krogh (Carnegie Mellon University)

In this tutorial session we describe the needs of industry for engineers capable of working in the highly multidisciplinary field of embedded control systems, and ways in which two universities (University of Michigan and Carnegie Mellon) are developing courses to train students to meet these needs.

The session should be of interest to (i) people from industry who want an update on embedded controls in the automotive industry and on recent curricular developments in the embedded control field, (ii) people from academia who want to learn about the embedded control field and how it might impact curriculum at their institutions, and (iii) a general audience who simply wants to know about embedded control systems, what they are, and why they are important.

FrC16:	**Active-Vision Control Systems for Complex Adversarial 3-D Environments**
	Grand Ballroom I
Organizer:	Eric N. Johnson (Georgia Tech), Anthony J. Calise (Georgia Tech),
	Allen Tannenbaum (University of Minnesota), Stefano Soatto (UCLA),
	Naira Hovakimyan (Virginia Tech), Anthony Yezzi (Georgia Tech)

This tutorial session covers methods that utilize 2-D and 3-D imagery (e.g., from LADAR, visual, FLIR, acoustic-location) to enable aerial vehicles to autonomously detect and prosecute targets in uncertain complex 3-D adversarial environments, including capabilities and approaches inspired by those found in nature, and without relying upon highly accurate 3-D models of the environment. These capabilities of autonomous sensing and control are enabling Unmanned Aerial Vehicle (UAV) and guided munition operations: in a clandestine/covert manner; in close proximity to hazards, structures, and/or terrain; and in uncertain/adversarial 3-D environments. The critical technical innovations include:

1. Knowledge-based segmentation;
2. Adaptation and estimation in geometric active contours;
3. Adaptive control frameworks for active vision systems;
4. Multi-grid and polygonal methods for optical flow;
5. Imaging sensors designed to produce sensor information for control.

Several related active-vision control systems that utilize these methods are discussed, as is the advances made in these technical areas to support these systems. The key challenges relate to the use of non-traditional vision-derived information for control, accommodating the properties of real-world imagery (noise, lighting, occlusions, drop-out, etc.), and the requirement to perform computations in real time.

In addition, a robust and productive simulation and flying testbed activity is discussed. This ensures that these methods are sound in the sense that they are: (1) implementable in real-time, (2) capable of practical use in the field, and (3) based on realistic/achievable sensor capabilities. Results discussed including a glider flown with vision only, formation and cooperative flight using vision only, vision-aided inertial navigation, and automated visual search.

TUTORIAL WORKSHOPS

Workshop 1: June 6 & 7, 2005 (2 days), *Broadway I*
Practical Techniques in Control Engineering
Dennis S. Bernstein (University of Michigan)
Carl R. Knospe (University of Virginia)

This course will provide a bridge between recent developments in control theory and their practical application in the laboratory and industry. Beginning with an overview of fundamental tradeoffs and issues that affect control-system performance, the course will systematically cover topics in linear and nonlinear modeling, linear and nonlinear controller synthesis, and robust and adaptive tuning. Controller implementation issues such as saturation, quantization, and state constraints will also be discussed. The theoretical foundation of each topic will be reviewed along with a discussion of practical ramifications and limitations. The course is suitable for students, instructors, and researchers who wish to obtain a broad perspective of the control engineering enterprise as well as control engineers from all industrial applications seeking a coherent, self-contained overview of recent developments relevant to control practice.

Monday, June 6, 2005

1. Defining the Issues and Challenges in Control Engineering
    1. Course Overview (8:30-8:45)
    2. Control-System Design: Strategy, Physics, Architecture, and Hardware (8:45-9:30)
    3. Plant Properties and Achievable Performance (9:30-10:30)

    Break (10:30-10:45)
2. Developing Linear Models for Control
    1. Linear Plant Modeling: Representation and Properties (10:45-11:30)
    2. Empirical Linear Modeling: System Identification (11:30-12:30)

    Break (12:30-1:30)
3. Synthesizing Linear Controllers for Performance and Robustness
    1. Uncertainty Measures and Robust Synthesis (1:30-3:15)

    Break (3:15-3:30)

4. Reducing Model Dependence in Controller Synthesis
    1. Minimal-Information Control: The Art and Science of PID Tuning (3:30-4:15)
    2. Adaptive Control: What Do You Need to Know, and How Well Do You Need to Know It? (4:15-4:45)
    3. Adaptive Stabilization and Command Following (4:45-5:30)

Tuesday, June 7, 2005

5. Developing Nonlinear Models for Control
    1. Nonlinear Plant Modeling: Model Properties and Structure (8:30-9:00)
    2. Nonlinear Identification Methods for Block-Structured Models (9:00-10:00)
6. Inexact Approaches to Nonlinearity
    1. Treating Nonlinearity as Uncertainty: Absolute Stability, LMIs, and IQCs (10:00-10:30)

    Break (10:30-10:45)

    2. Treating Nonlinearity as Linearity: Gain Scheduling, LPVs, and Frozen Linear Methods (10:45-12:15)

    Break (12:15-1:15)
7. Exact Approaches to Nonlinearity: Part I (1:15-2:15)
    1. Feedback Linearization: Methods and Pitfalls
8. Exact Approaches to Nonlinearity
    1. Backstepping: A Constructive Nonlinear Approach (2:15-2:45)
9. Implementing Real Control Systems in Real Hardware
    1. Facing the Reality of Constraints: Traditional and Modern Approaches (2:45-3:15)

    Break (3:15-3:30)
10. Fitting the Pieces Together
    1. Adaptive Disturbance Rejection with Applications to Noise and Vibration Control (3:30-4:30)
    2. A Case Study for Controller Design and Implementation: Active Chatter Control (4:30-5:30)

Workshop 2: June 6 & 7, 2005 (2 days), *Broadway II*

Engineering Applications in Genomics

Aniruddha Datta (Texas A&M University)

Genomics concerns the study of large sets of genes with the goal of understanding collective function, rather than that of individual genes. Such a study is important since cellular control and its failure in disease result from multivariate activity among cohorts of genes. Very recent research indicates that engineering approaches for prediction, signal processing, and control are quite well suited for studying this kind of multivariate interaction. The aim of this workshop will be to provide the attendees with a state of the art account of the research that has been accomplished in this field thus far and to make them aware of some of the open research challenges.

The workshop will provide a tutorial introduction to the current engineering research in genomics. The necessary Molecular Biology background will be presented and techniques from signal processing and control will be used to (i) unearth intergene relationships (ii) model genetic regulatory networks and (iii) alter (i.e. control) their dynamic behavior. The workshop will be divided into two parts. On the first day, we will focus on building up the necessary molecular biology background. NO PRIOR EXPOSURE TO MOLECULAR BIOLOGY WILL BE ASSUMED. On the second day, we will discuss the application of engineering approaches for attacking some of the challenging research problems that arise in genomics related research. A more detailed description of the material to be covered on each day follows.

Monday, June 6, 2005

1. Review of Organic Chemistry: Sugars, Fatty Acids, Amino Acids and Nucleotides (1 hour 45 minutes)
2. DNA, RNA and Proteins: Transcription, Translation, the Genetic Code, Chromosomes and Gene Regulation (2 hours)
3. Genetic Variation, Genetic Engineering: Recombinant DNA Technology and Microarrays (1 hour 45 minutes)
4. Procaryotes, Eucaryotes, Eucaryotic Cell Structure, Cell Cycle, Mitosis, Meiosis, Apoptosis, Cancer as the breakdown of Cell Cycle control (2 hours)

Tuesday, June 7, 2005

5. Analysis of cDNA Microarray Images (1 hour 45 minutes)
6. Unearthing Genomic Relationships using the Coefficient of Determination (2 hours)
7. Models of Genetic Regulatory Networks (1 hour 45 minutes)
8. Intervention and Control in Genetic Regulatory Networks (2 hours)

Workshop Materials

Detailed notes covering the material on the first day will be handed out at the workshop. The material for the second day will consist of the following journal articles, copies of which will be included in the workshop notes.

1. Chen, Y., Dougherty, E. R. & Bittner, M. L. (1997). Ratio-Based Decisions and the Quantitative Analysis of cDNA Microarray Images. Journal of Biomedical Optics, Vol. 2, No. 4, 364-374.
2. Kim, S., Dougherty, E. R., Bittner, M. L., Chen, Y., Sivakumar, K., Meltzer, P., & Trent, J. M. (2000). A General Framework for the Analysis of Multivariate Gene Interaction via Expression Arrays. Biomedical Optics, Vol. 4, No. 4, 411-424.
3. Shmulevich, I., Dougherty, E. R., Kim, S., & Zhang, W. (2002a). Probabilistic Boolean Networks: A Rule-based Uncertainty Model for Gene Regulatory Networks. Bioinformatics, 18, 261-274.
4. Shmulevich, I., Dougherty, E. R., & Zhang, W. (2002c). Gene Perturbation and Intervention in Probabilistic Boolean Networks. Bioinformatics, 18, 1319-1331.
5. Shmulevich, I., Dougherty, E. R., & Zhang, W. (2002d). Control of Stationary Behavior in Probabilistic Boolean Networks by Means of Structural Intervention. Biological Systems, Vol. 10., No. 4, 431-446.
6. Datta, A., Choudhary, A., Bittner, M. L., & Dougherty, E. R. (2003). External Control in Markovian Genetic Regulatory Networks. Machine Learning, Vol. 52, 169-191.
7. Datta, A., Choudhary, A., Bittner, M. L., & Dougherty, E. R. (2004). External Control in Markovian Genetic Regulatory Networks: The Imperfect Information Case. Bioinformatics, Vol. 20, No. 6, 924-930.

Workshop 3: June 6 & 7, 2005 (2 days), *Broadway III*

Recent Advances in Subspace System Identification: Linear, Nonlinear, Closed-Loop, and Optimal with Applications

Wallace E. Larimore (Adaptics, Inc.)

This workshop presents a first principles development of subspace system identification (ID) using a fundamental statistical approach. This includes basic concepts of reduced rank modeling of ill-conditioned data to obtain the most appropriate statistical model structure and order using optimal maximum likelihood methods. These principles are first applied to the well developed subspace ID of linear dynamic models; and using recent results, it is extended to closed-loop linear systems and then general nonlinear closed-loop systems.

The fundamental statistical approach gives expressions of the multi-step likelihood function for subspace identification of both linear and nonlinear systems. This leads to direct estimation of the parameters using singular value decomposition type methods that avoid iterative nonlinear parameter optimization. The result is statistically optimal maximum likelihood parameter estimates and likelihood ratio tests of hypotheses. The parameter estimates have optimal Cramer-Rao lower bound accuracy, and the likelihood ratio hypothesis tests on model structure, model change, and process faults produce optimal decisions.

The extension to general nonlinear systems determines optimal nonlinear functions of the past and future using the theory of maximal correlation. This gives the nonlinear canonical variate analysis. New results show that to avoid redundancy and obtain Gaussian variables, it is necessary to determine independent canonical variables that are then used in the likelihood function evaluation. This gives a complete likelihood theory for general nonlinear stochastic system with continuous dynamics and possibly feedback.

These new results greatly extend the possible applications of subspace ID to closed-loop linear and nonlinear systems for monitoring, fault detection, control design, and robust and adaptive control. The precise statistical theory gives tight bounds on the model accuracy that can be used in robust control analysis and design. Also precise distribution theory is available for tests of hypotheses on model structure, process changes and faults. Potential applications include system fault detection for control reconfiguration, autonomous system monitoring and learning control, and highly nonlinear processes in emerging fields such as bioinformatics and nanotechnology. Applications are discussed to monitoring and fault detection in closed-loop chemical processes, identification of vibrating structures under feedback, online adaptive control of aircraft wing flutter, and identification of the chaotic Lorenz attractor.

The intended audience includes practitioners who are primarily interested in applying system identification techniques, engineers who desire an introduction to the concepts of subspace system identification, and faculty members and graduate students who wish to pursue research into some of the more advanced topics.

Monday, June 6, 2005

<u>Linear Systems With Feedback</u>

8:30-9:15 *Overview of Subspace Systems Identification*
Approaches and Algorithms
Positivity, Stability, Accuracy, Computation

9:15-10:00 *Rank of a Stochastic Dynamic System*
Statistical Rank
Canonical Variate Analysis (CVA)
Rank as Minimal State Order
Break
10:30-11:15 *Subspace Maximum Likelihood Estimation*
Multi-step Likelihood Function
State Space Regression Equations
11:15-12:00 *Statistical Model Order/Structure Selection*
Kullback Information and Akaike Information
Accuracy of Estimated Model
Lunch Break
1:00-2:00 *Comparison of Alternative System Identification Approaches*
Model Structure Selection and Parameter Estimation
Computational Issues and Software
2:00-2:45 *Optimal Identification of I/O and Closed-loop Systems*
Removing Effect of Future Inputs
Model Nesting and Sufficient Statistics
3:15-4:00 *Process Monitoring Using CVA*
Low Rank Process Characterization by CVA
Testing Hypotheses of Process Change
Break
4:00-4:45 *Process Monitoring Applications*
Tennessee Eastman Challenge Problem
Comparison with SPC and PCA Methods
4:45-5:30 *Identification and Control Applications*
Vibrating Structures
On-line Adaptive Control of Aircraft Wing Flutter

Tuesday, June 7, 2005

Nonlinear Systems
8:30-9:15 *Overview of Nonlinear System Identification Methods*
Hammerstein and Wiener Systems
Nonlinear State Space Models
9:15-10:00 *Nonlinear Canonical Variate Analysis*
Nonlinear Functions of Past and Future
Multivariate Reduction by Maximal Correlation
Break
10:30-11:15 *Maximal Correction and Projection*
Definition and Properties
Outline of Function Space Concepts
11:15-12:00 *Minimal State Rank and Independent CVA*
Redundancy Problem with CVA
Optimal Transformations to Gaussian Variables
Lunch Break
1:00-2:00 *Likelihood Function for Nonlinear Systems*
Multi-step Likelihood
Optimality of Independent CVA

2:00-2:45	*Optimality in Closed Loop* Remove Future Inputs with NARX Model Nesting and Nonlinear Regression
3:15-4:00	*Comparison with Other Methods* Neural Networks, Statistical Learning Support Vector Machines
Break	
4:00-4:45	*Computational Methods* Alternating Conditional Expectation (ACE) Kernel based Computation
4:45-5:30	*Lorentz Attractor Identification* Nonlinear Dynamics and Noise Computation and Identification Accuracy

Workshop 4: June 7, 2005 (1 day), *Galleria III*

Scheduling, Cycle-Time Reduction, and Debottlenecking of Batch Processes

Charles Siletti (Intelligen, Inc., Mt. Laurel, NJ)

Cycle-time reduction in batch processes can often be challenging. There are many cases where utilization and up-time are misleading indicators of a true cycle-time limit. This workshop will cover cycle-time reduction and capacity debottlenecking in batch processes. First, we will review basic cycle-time calculations and bottleneck identification. We will then show how to use scheduling software to reduce cycle-time in multi-product plants with resource constraints. Finally, we will focus on variability and upsets and approaches to minimizing their effect on cycle-time.

Part I (Morning)

- Batch Process Basics: Cover definition & examples of batch, semi-batch, and continuous processes.
- Cycle Time in Batch Processes: Discuss cycle-time and cycle-time limits.
- Bottleneck Identification: Discuss how to calculate and use the following statistics: uptime, utilization, and throughput increase potential.
- Cycle Time Reduction Strategies: Discuss how to break bottlenecks.
- Example 1: A batch process with dedicated equipment. This example is taken from a biotech process.
- Example 2: A batch process with multi-purpose equipment. This example is a chemical synthesis process.

Part II (Afternoon)

- Review example: Recap of the morning.
- Downtime/Shift Constraints: How operating hours affect cycle-time.
- QA/QC Time: How the lab affects cycle-time
- Auxiliary Equipment: How small items can limit capacity.
- Multiple Processes: Can two simultaneous processes share equipment?
- Uncertainty: Do you need to add “slack” contingencies? How much?

Workshop 5: June 7, 2005 (1 day), *Broadway IV*

Real Time Optimization by Extremum Seeking Control

Miroslav Krstic (University of California at San Diego)
Kartik Ariyur (Honeywell Aerospace Electronic Systems)
Andrzej Banaszuk, Dobrivoje Popovic (United Technologies Research Center)
Eugenio Schuster (Lehigh University)

Extremum seeking control, a popular tool in control applications in the 1940-50's, has seen a resurgence in popularity as a real time optimization tool in aerospace and automotive engineering. This workshop will present the theoretical foundations and selected applications of extremum seeking.

In addition to being an optimization method, extremum seeking is a method of adaptive control, usable both for tuning set points in regulation/optimization problems and for tuning parameters of control laws. It is a non-model based method of adaptive control, and, as such, it solves, in a rigorous and practical way, some of the same problems as neural network and other intelligent control techniques.

The first half of the workshop will teach the attendees the extremum seeking algorithms, the basics of their stability analysis, the design guidelines. Both single-parameter and multivariable problems will be covered, as well as both the continuous and discrete time implementations. A novel "slope seeking" extension applicable to some unstable plants will be introduced. An application of extremum seeking to minimize limit cycles caused by actuator limitation will be presented.

In the second half of the workshop, applications to aerospace and propulsion problems (formation flight, combustion instabilities, flow control, compressor rotating stall), automotive problems (anti-lock braking, engine mapping), bioreactors, and charged particle accelerators will be presented.

Presented by researchers who spearheaded the revival of extremum seeking, the workshop will be one well integrated mini-course, designed as such by organizers who have been working jointly on these problems since 1996, rather than patched up from distinct pieces of research by an ad hoc team.

The workshop will be of interest to a broad audience of ACC attendees interested in nonlinear and adaptive control (from IEEE CSS), in optimization (from SIAM and INFORMS), as well as to industrial control engineers working on applications in electrical, mechanical (ASME), aerospace (AIAA), chemical (AIChE), and biomedical engineering.

8:00-9:00	History of extremum seeking, introductory algorithm for a static map, elements of stability analysis (Krstic)
9:00-9:50	ES in the presence of plant dynamics, ES compensators for performance improvement, ES with internal model principle for tracking parameter changes (Ariyur)
Break	
10:20-11:10	Multi-parameter ES and slope seeking (Ariyur)
11:20-12:00	Limit cycle minimization via ES, discrete time ES (Krstic and Ariyur)
Lunch	
13:30-13:45	Application to anti-lock braking (Ariyur)
13:45-14:05	Control of combustion instabilities (Banaszuk)
14:05-14:35	Control of flow separation in diffusers (Banaszuk)

14:35-15:00 Formation flight optimization via ES (Ariyur)
Break
15:30-16:00 Compressor rotating stall control (Krstic and Ariyur)
16:00-16:30 Automotive engine mapping (Popovic)
16:30-16:45 Bioreactor optimization (Krstic and Ariyur)
16:45-17:00 Beam matching in particle accelerators (Schuster)

Workshop 6: June 7, 2005 (1 day), *Council*

A New Paradigm for Real-Time Operator Training for the Process Industries

Charles Cutler and Matthew Hetzel, (Cutler Technology Corporation, San Antonio, TX)

With the rise of multivariable advanced control, the operators spend less time operating process units. With less hands-on time, operator skills have degraded. This effect has increased the need for operator training. This need is often met with an operator training simulator. CTCSim is a program that can function as an off-line training simulator as well as an on-line "operator advisor." This program will keep a FIR model continuously adapted to the process unit. The operator may then use the model to quickly determine an appropriate course of action to take when a process change is required and the unit is operated without advanced control. The FIR model is identified from plant step-test data using another program called UPID. UPID allows the identification of an open-loop FIR model from closed-loop data. The algorithm used to remove the PID dynamics from a closed-loop model will be presented.