

**Advances in Discrete Event, Nonlinear and Stochastic Systems  
Modeling and Control**

**Symposium in Honor of Steven I Marcus**

**University of Maryland**

**Saturday, April 18, 2009**

**Program**

8:00-8:30: Registration and Continental Breakfast

8:30-8:45: Welcome and opening remarks

- Nariman Farvardin  
Senior Vice President for Academic Affairs and Provost  
University of Maryland, College Park

8:45-10:15: **Stochastic Decision and Control Theory**

Session Chair: Michael Fu

**1. Infinite-Horizon Control of Stochastic Systems**

Onesimo Hernandez-Lerma  
Mathematics Department  
CINVESTAV-IPN  
Mexico City, Mexico

**2. Uniform Recurrence Properties of Controlled Diffusions and Applications to Optimal Control**

Ari Arapostathis  
Professor and Texas Atomic Energy Research Foundation Centennial Fellow  
Department of Electrical and Computer Engineering  
The University of Texas at Austin

**3. Markov Process and the Synthesis of Hybrid Systems**

Roger Brockett  
An Wang Professor of Computer Science and Electrical Engineering,  
Division of Engineering and Applied Sciences,  
Harvard University

10:15-10:30 **Coffee Break**

10:30-12:00: **Discrete Event and Hybrid Systems**

Session Chair: Mark Shayman

**1. Real-time Estimation of Urban Travel Time by Matching Vehicle Magnetic Signatures**

Pravin Varaiya  
Nortel Networks Distinguished Professor  
Electrical Engineering and Computer Science  
University of California, Berkeley

**2. Composite Web Services in an Open World: Quality of Service Issues**

Albert Benveniste  
IRISA / INRIA, Campus de Beaulieu  
France

**3. Temporal Issues in Wirelessly Networked Systems**

P. R. Kumar  
Franklin W. Woeltge Professor  
Department of Electrical and Computer Engineering  
University of Illinois, Urbana-Champaign

Noon-1:30: **Lunch & Poster Session**

- *On observers via genetic algorithms.* Hong-Gi Lee, School of Electrical & Electronics Engineering, Chung-Ang University, Seoul, Korea.

1:30-3:30: **Estimation and Filtering**

Session Chair: John Baras

**1. Inference and Modeling Using Graphical Models**

Alan S. Willsky  
Edwin Sibley Webster Professor of Electrical Engineering and Computer Science  
Co-Director, Laboratory for Information and Decision Systems  
Massachusetts Institute of Technology

**2. Mutual Information and Estimation**

Tyrone E. Duncan and Bozenna Pasik-Duncan  
Department of Mathematics,  
University of Kansas

### **3. Cauchy Estimation for Linear Scalar Systems**

Jason L. Speyer  
Mechanical & Aerospace Engineering Department  
University of California, Los Angeles

### **4. Recent Results in Nonlinear Filtering**

Sanjoy K. Mitter  
Electrical Engineering and Computer Science  
Massachusetts Institute of Technology

3:30-4:00: **Coffee Break**

4:00-5:00: **Models, Decisions and Control**

Session Chair: Chang-Huan (William) Liu

#### **1. Fault Detection, Isolation, and Localization in Embedded Control Software**

Ratnesh Kumar  
Department of Electrical and Computer Engineering  
Iowa State University

#### **2. Decisions, Uncertainty and Risk: Performance Criteria, Models and Applications**

Emmanuel Fernandez  
Department of Electrical and Computer Engineering  
University of Cincinnati

#### **3. Feedback: Theorems, Cars, Chips and Robots**

**Jessy Grizzle**  
Jerry W. and Carol L. Levin Professor of Engineering  
EECS Department  
University of Michigan

7:00-10:00: **Banquet**

# **Uniform Recurrence Properties of Controlled Diffusions and Applications to Optimal Control**

**Ari Arapostathis**

Professor and Texas Atomic Energy Research Foundation Centennial Fellow  
Department of Electrical and Computer Engineering  
The University of Texas at Austin

The focus of this talk is recurrence properties of nondegenerate controlled diffusions that are uniform over all stationary Markov controls. A diffusion is called positive recurrent if then the mean hitting times of bounded domains from a point in their exterior are finite, in which case the corresponding control is called stable. We present a relatively surprising result that if the diffusion is positive recurrent under every stationary control then the mean hitting times of a bounded domain from an exterior point are uniformly bounded over all controls, a concept which we call uniform positive recurrence. Next we show how to dispense with blanket Lyapunov type stability assumptions when addressing the optimal control problem with respect to the average criterion. For the average criterion, the mere stability of stationary Markov controls suffices for the characterization of optimality via the HJB equation. When the invariant measures of the controlled diffusion are tight, the controlled process is called uniformly stable, a concept introduced by Borkar. We present equivalent characterizations of uniform stability and how it relates to uniform positive recurrence. The talk has also a tutorial aspect with emphasis on invariant measures and their characterizations.

## **Composite Web Services in an open world: Quality of Service issues**

**Albert Benveniste**

IRISA / INRIA, Campus de Beaulieu  
France

Web services orchestrations or choreographies are compositions of different Web Services to form a new service. This type of infrastructure allows providers to offer packaged services at low development cost. Orchestrations or choreographies are also an infrastructure of choice for enterprise business and workflow management. Their use in e-business sector raises a number of issues. Security and privacy -- which also apply to large audience services -- are well identified and studied aspects. Other aspects are given less attention, mainly due to the "best effort" philosophy underpinning the Web. The correctness of the function delivered is one important aspect of composite Web services. The notion of Quality of Service collects a number of performance related criteria that an orchestration is expected to deliver to its client in the context of enterprise business and workflow management: response time, query rate, validity and quality of response, plus security. In the open world of the Web, performance studies cannot rely on fine resource modeling (as developed for networks). An orchestration calling a service is agnostic of the corresponding server performance and constraints. In this context, QoS is managed through contracts, i.e., agreements between the orchestration and its sub-contractors regarding performance characteristics; in turn, the orchestration must negotiate a contract with its clients. The relation between these different contracts is called contract composition. Contracts with sub-contractors must be monitored by the orchestration, for possible violation; violation in turn may cause the orchestration to reconfigure. Variability in the Web infrastructure leads to considering a probabilistic framework for such QoS contracts. I shall review all these aspects of QoS management in composite Web services and point the differences with QoS management in networks. One deep difference is the interplay of carried data and control, as well as the need to view data and control as equal citizens -- today, workflow and data base technologies are essentially kept separate. This is joint work with Sidney Rosario, Claude Jard, and Stefan Haar; our work benefits from cooperations with the group of William Cook and Jayadev Misra at UT Austin (who develop Orc), and with the data base group of Serge Abiteboul at INRIA (who develops Active XML).

## **Markov Process and the Synthesis of Hybrid Systems**

**Roger Brockett**

An Wang Professor of Computer Science and Electrical Engineering,  
Division of Engineering and Applied Sciences,  
Harvard University

The study of Markov Process with external inputs entering the generator multiplicatively has a long history and intersects the work of Steve Marcus in more than one way. In this talk we consider some variations on this theme involving the coupling continuous time, finite state Markov processes with continuous time, continuous state systems. Our main results concern the use of such models in the design of finite state, randomized controllers for unstable linear systems and to suggest some extensions.

## **Mutual Information and Estimation**

**Tyrone E. Duncan and Bozenna Pasik-Duncan**

Department of Mathematics,  
University of Kansas

Mutual information provides a quantitative relation between two stochastic processes. It is a basic notion in information theory and it provides an empirical measure of the relation between two families of data. In this talk two pairs of processes are considered, one pair is stochastic signal and the sum of this signal and a fractional Brownian motion (fractional Gaussian noise) and the second pair is a stochastic signal and a discontinuous Levy process whose “rate” is modulated by the signal. Fractional Brownian motion is a family of Gaussian processes that includes Brownian motion as well as other processes that arise empirically as models for physical phenomena. The mutual information between either of these pairs of processes is expressed as a filtering error and the rate of change of the mutual information with respect to a parameter scaling the signal is expressed as a smoothing error.

**Decisions, Uncertainty and Risk:  
Performance Criteria, Models and Applications**

**Emmanuel Fernandez-Gaucherand**  
Department of Electrical and Computer Engineering  
University of Cincinnati

In this talk, an overview of previous and current work in the study of performance criteria and models is presented, for situations in which decisions have to be made under imperfect model or state information, and within an uncertain and risky environment. In particular, work on average cost and risk-sensitive criteria for controlled Markov processes will be discussed, as well as models and applications in learning and adaptive systems, intelligent autonomous systems, logistics, and complex manufacturing operations.

**Feedback: Theorems, Cars, Chips and Robots**

**Jessy Grizzle**  
Jerry W. and Carol L. Levin Professor of Engineering  
EECS Department  
University of Michigan

When these words are assembled as a special directed graph, they form a puzzle, the solution of which lies in a paper I wrote with Steven I. Marcus. Who will be the first one in the audience to solve the enigma? The rest of the talk will focus on the design of the power management system for HEVs (hybrid electric vehicles) via shortest-path stochastic dynamic programming.

**Infinite-Horizon Control of Stochastic Systems**

**Onesimo Hernandez-Lerma**  
Mathematics Department  
CINVESTAV-IPN  
Mexico City, Mexico

Optimal control problems in an infinite horizon can be traced back (at least) to a 1928 paper by Frank P. Ramsey, in the context of economic growth. Ramsey studied a restrictive version of what is now known as overtaking optimality (also called catching up optimality), which was later weakened by several authors, e.g. Atsumi. An apparently different infinite-horizon problem was introduced by Bellman, namely the long-run expected average reward, also known as the ergodic reward problem. My first encounter with infinite-horizon control problems occurred in the early 80's, when I spent a postdoctoral year with Steve Marcus at the University of Texas. The main objective of this talk is to make a brief description of the problems we studied in those days, and also of more recent related research work, for instance, on bias optimality,  $n$ -discount optimality, ergodic reward with minimum variance,... The latter work refers to discrete and continuous time stochastic systems, such as continuous-time controlled Markov chains, and controlled diffusions.

## **Temporal issues in wirelessly networked systems**

**P. R. Kumar**

Franklin W. Woeltge Professor  
Department of Electrical and Computer Engineering  
University of Illinois, Urbana-Champaign

We examine some issues related to the role of "time" in wireless networks and networked embedded systems. We consider two problems, time permitting: (i) How to provide for deadline based QoS in wireless systems (ii) How and to what extent can we synchronize clocks in wireless networks [Joint work with V. Borkar, A. Giridhar, I-H. Hou, R. Solis].

## **Fault Detection, Isolation, and Localization in Embedded Control Software**

**Ratnesh Kumar**

Department of Electrical and Computer Engineering  
Iowa State University

Embedded control software react to underlying plant and environment conditions in order to enforce a desired functionality, and exhibit hybrid dynamics: control-loops together with switching logic. Control software can contain errors (faults), and fault-tolerance methods must be developed to enhance system safety and reliability. We present an approach for fault detection and isolation that is key to achieving fault-tolerance. Detection approach is hierarchical involving monitoring both the control software, and the controlled-system. The latter is necessary to safeguard against any incompleteness of software level properties. A model of the system being monitored is not required, and further the approach is modular and hence scalable. When fault is detected at the system level, an isolation of a software fault is achieved by using residue methods to rule out any hardware (plant) fault. We also proposed a method to localize a software fault (to those lines of code that contain the fault). The talk will be illustrated through a servo control application.



## **Recent Results in Nonlinear Filtering**

**Sanjoy K. Mitter**

Electrical Engineering and Computer Science  
Massachusetts Institute of Technology

In joint work with Nigel Newton, I have shown how the Bayesian Inference problem of estimating a random variable  $X$  taking values in a Polish space given a related random variable  $Y$ , also taking values in a Polish space in the sense of characterizing the conditional distribution, can be solved by minimizing an appropriate free energy. This generalizes the characterization of Gibbs measures on a finite state space through minimization of free energy. The generalization of this result to an infinite setting leads to the Gibbs Variational Principle for characterizing Gibbs measures which is a deep result in Statistical Mechanics. In this talk, I show how problems of path estimation on nonlinear diffusion processes given noisy observations and the Noisy Channel Coding Theorem can be proven using a limiting form of Free Energy Minimization.

## **Cauchy Estimation for Linear Scalar Systems**

**Jason L. Speyer**

Mechanical & Aerospace Engineering Department  
University of California, Los Angeles

An estimation paradigm is presented for scalar discrete linear systems entailing additive process and measurement noises that have Cauchy probability density functions (pdf). For systems with Gaussian noises, the Kalman filter has been the main estimation paradigm. However, many practical system uncertainties that have impulsive character, such as radar glint, are better described by stable non-Gaussian densities, for example, the Cauchy pdf. Although the Cauchy pdf does not have a well defined mean and does have an infinite second moment, the conditional density of a Cauchy random variable, given its linear measurements with an additive Cauchy noise, has a conditional mean and a finite conditional variance, both being functions of the measurement. For a single measurement, simple expressions are obtained for the conditional mean and variance, by deriving closed form expressions for the infinite integrals associated with the minimum variance estimation problem. To alleviate the complexity of the multi-stage estimator, the conditional pdf is represented in a special factored form. A recursion scheme is then developed based on this factored form and closed form integrations, allowing for the propagation of the conditional mean and variance over an arbitrary number of time stages. In simulations, the performance of the newly developed scalar discrete-time Cauchy estimator is significantly superior to a Kalman filter in the presence of Cauchy noise, whereas the Cauchy estimator deteriorates only slightly compared to the Kalman filter in the presence of Gaussian noise. Remarkably, this new recursive Cauchy conditional mean estimator has parameters that are generated by linear difference equations with stochastic coefficients, providing computational efficiency.

## **Real-time Estimation of Urban Travel Time by Matching Vehicle Magnetic Signatures**

**Pravin Varaiya**

Nortel Networks Distinguished Professor  
Electrical Engineering and Computer Science  
University of California, Berkeley

A practical system is described for the real-time estimation of urban travel time. The system relies on matching vehicle signatures from wireless magnetic sensors. A correct match of signatures at two locations gives the corresponding travel time of the vehicle. The matching algorithm is based on a statistical model of the signatures. The statistical model itself is estimated from the data, and does /not/ require measurement of ground truth. The optimal matching procedure is based on a sequence comparison algorithm used in molecular biology. Simulation and field test results are shown. Other applications are discussed. The wireless sensor network technology is briefly described.

## **Inference and Modeling Using Graphical Models**

**Alan S. Willsky**

Edwin Sibley Webster Professor of Electrical Engineering and Computer Science  
Co-Director, Laboratory for Information and Decision Systems  
Massachusetts Institute of Technology

In this talk I'll describe several components of a long-term research project aimed in part at ignoring all of the methods and models that Steve Marcus and I pursued in our early professional lives – starting with my dissertation under Roger Brockett's supervision and Steve's Ph.D. research under mine. In particular, Steve and my early work dealt with estimation for stochastic processes  $x(t)$  in which  $x$  takes values in spaces with interesting structure (namely Lie groups) and  $t$  is time. Turning the tables, the focus of this talk will be on problems in which, for the most part,  $x$  takes on values and has distributions that are more-or-less garden variety (e.g., Gaussian), but  $t$  is more complex. In particular, I'll be dealing with the domain of graphical models in which  $t$  indexes nodes in a graph and will describe a sampling of lines of inquiry that we've been exploring. One of these is an investigation of the behavior of the well-known Belief Propagation (BP) algorithm for Gaussian graphical models, describing results using what we refer to as *walk-sum analysis* that provides the basis for sufficient and *almost* necessary conditions for BP convergence. Walk-sum analysis is useful for other things as well, among them the development of adaptive algorithms for fast convergence for distributed estimation. I'll also describe some of our work on problems that in machine learning are often referred to as *structure learning* – i.e., learning the structure of the set on which  $t$  takes values. This has close ties to maximum entropy modeling, but there are very interesting generalizations, in particular to a new class of multiscale models that have structure reminiscent of ARMA models (AR across scales and MA within) which also have ties to so-called multipole algorithms in solving PDEs.