2011 National Control Engineering Students Workshop

April 28 - May 1, 2011
University of Maryland

Thursday, April, 28, 2011

Session: Hybrid and Nonlinear Systems

Dissipativity for Switched Systems with Applications to Networked Control Systems, Michael McCourt, University of Notre Dame

This presentation focuses on passivity-based control methods for hybrid systems. This includes a summary of previous definitions of passivity and dissipativity for switched systems. This framework allows for the generalization of passivity index theory to this important class of hybrid systems. It is a method of quantifying the level of passivity of a given system and is closely related to conic systems theory. This original work on indices is a promising direction that provides new methods of analyzing stability in feedback interconnections of switched systems. Although some of this material is developed for delay-free implementations, most of this work is aimed at applications in network control. The networks of interest include non-ideal behavior such as lost data and time-varying delays that are measurable. Incorporating the realistic constraints of network applications into this theory strengthens its applicability to real implementations.

Bode-Like Integral for Stochastic Switched Systems, Dapeng Li, University of Illinois at Urbana-Champaign

In this presentation, we establish a Bode sensitivity integral formula for a class of feedback closed-loop systems with stochastic switched plants. Using information theory, we study the information conservation law, based on which a log integral theorem is obtained for the closed loops of interest. Furthermore we develop several algebraic conditions to explicitly capture the performance limitations.

Impulsive Control of Underactuated Dynamical Systems: Swing-up Control of Pendubot and Acrobot, Rouhollah Jafari, Michigan State University

In order to expand the range of application of impulsive control, the effect of impulses and challenges of implementation of impulsive control needs to be investigated. Although the theory of impulsive control has been widely studied, impulsive control inputs are typically not included in the set of admissible controls for most dynamical systems. This is mainly because it is difficult to generate Dirac-delta functions in practice. To further investigate this, we considered the swing-up control problems of the pendubot and the acrobot, which are benchmark problems in underactuated systems. For the pendubot, an impulse-momentum approach for swing-up was developed and it is shown through numerical simulations that the impulsive inputs need not be Dirac-delta functions; the algorithm is effective even *when the input is bounded and its time support is not infinitesimal provided that the impulse of the input equals the value needed for the desired jump in velocities. The swing-up algorithm was experimentally validated using a standard pendubot set-up. The experimental results proved that impulsive control is applicable using regular actuators and standard hardware. We have also developed two impulsive controllers for acrobot swing-up. A comparison of simulation results with those in the literature indicates faster swing-up and lower maximum continuous torque requirement. Current work is aimed at developing control strategies to enable bipeds reject disturbances.*

Two Hybrid Control Architectures for Passive Bilateral Teleoperation over the Internet, Ke Huang, University of Tennessee - Knoxville

The Internet, as a convenient and cost-effective communication means, has been utilized in many teleoperation systems. However, in most cases the Internet is not perfect, i.e. the transmitted data can be contaminated by varying-delay, packet loss, data duplication/swap, etc. It is well-known that such communication imperfectness can destabilize the teleoperation system and even cause injury to the human operator. Hence, guaranteeing the safety or interactive stability of the Internet bilateral teleoperation system is crucial in practice and also is our focus in this talk. In the first part, we will justify the sampled-data PD coupling control which is wildly used in practical bilateral teleoperation systems and show its fundamental limitation under communication imperfectness (by providing the passive gain setting condition). In the second part, a novel virtual-proxy based hybrid control architecture will be presented to provide improved gain tuning flexibility. Both control architectures can guarantee the closed-loop passivity of the teleoperation system over the Internet, thus, the interactive stability (given the human/environment are passive). We illustrate the stability and performance of these hybrid control architectures by simulations of two revolute-joint planar haptic devices interconnecting through simulated imperfect Internet.

Approximation of the Joint Spectral Radius via Multiple Lyapunov Functions on Path-Complete Graphs, Amir Ali Ahmadi, Massachusetts Institute Of Technology

We will present semidefinite programming based algorithms for approximating the joint spectral radius of a finite set of matrices with guaranteed accuracy. Our approach is based on the analysis of the underlying switched linear system via multiple Lyapunov functions associated to certain labeled graphs, which we call path-complete graphs. The method draws connections to concepts in automata theory and unifies and generalizes many existing techniques such as common quadratic, common sum of squares, and maximum/minimum-of-quadratics Lyapunov functions. We present approximation guarantees for analysis via several families of path-complete graphs. Joint work with R. Jungers, P.A. Parrilo, and M. Roozbehani.

On Tracking for the PVTOL Model with Bounded Feedbacks, Aleksandra Gruszka, Louisiana State University

We study a class of feedback tracking problems for the planar vertical takeoff and landing (PVTOL) aircraft dynamics, which is a benchmark model in aerospace engineering. After a survey of the literature *on the model, we construct new feedback stabilizers for the PVTOL tracking dynamics. The novelty of our contribution is in the boundedness of our feedback controllers and their applicability to cases where the velocity measurements may not be available, coupled with the uniform global symptotic stability and uniform local exponential stability of the closed loop tracking dynamics, the generality of our class of trackable reference trajectories, and the input-to-state stable performance of the closed loop tracking dynamics with respect to actuator errors. Our proofs are based on a new bounded backstepping result. We illustrate our work in a tracking problem along a circle.*

Investigating Control for Complex Systems Using Marionettes, Jarvis Schultz, Northwestern University

Classical stringed marionettes are extremely complex mechanical systems. They are under-actuated, they exhibit highly nonlinear hybrid dynamics, and they have many degrees-of-freedom. We are interested in using marionettes as a context for exploring the design and implementation of control strategies for complex mechanical systems requiring efficient management of large amounts of data. Puppeteers and choreographers for marionette plays use an algorithmic, low-fidelity language to describe the motions that a puppet will follow during a performance. It is then up to the puppeteer and their innate understanding of the system dynamics to morph this low-level description into dynamically feasible system trajectories. We are interested in e_ciently describing marionette trajectories for both choreographing marionette plays and usage in numerical optimization techniques for designing controls to implement these choreographed motions in a robotic system. To begin this investigation we developed a variational integrator-based dynamic simulation package capable of producing energy-conserving simulations of complex mechanical systems with little computational cost. We then began developing a robotic system capable of manipulating marionettes. At this time, the system is fully operational and has been used to experimentally validate an optimization technique applied to a simplified version of the marionette that has application in other areas. As this work progresses, this robotic platform will be utilized as an experimental test-bed for investigations into new optimization techniques employing low-fidelity representations of the system trajectories.

Adaptive Model Refinement: Using Data to Make Models Better, Anthony D'Amato, University of Michigan

All models are erroneous, but some are more useful than others. Large-scale models based on physics and empirical subsystem models may entail a variety of errors, such as parameter errors, missing or incorrect physics, and artifacts of discretization. When measured physical data are available, it is desirable to use the data to improve the model. This problem is variously known as empirical model correction, model updating, and model calibration. We call it model refinement. Model refinement is distinct from data assimilation and uncertainty quantification, although the former can enhance the latter. In this talk we will describe a technique for model refinement based on subsystem identification, where data are used to improve the accuracy of an uncertain subsystem model representing, for example, a static parameter or erroneous dynamics. The approach we take exploits the fact that subsystem refinement is equivalent to adaptive control. We thus apply methods from retrospective adaptive control, which is applicable to MIMO nonlinear systems. The effectiveness of the approach will *be demonstrated on the Global Ionosphere-Thermosphere Model, where simulation data from a truth model are used to correct a model with missing physics.*

Friday, April, 29, 2011

Session: Cyber Physical Systems

Robustness Analysis of Real-time Systems, Zhenwu Shi, Georgia Institute of Technology

Real-time systems have been widely applied in command and control systems, process control, robotics , avionics, and an abundance of embedded systems. The correctness of a real-time system not only depends on the logical correctness of the calculation but also upon the time at which the result is made available. A real-time system is schedulable if all results are made available before the pre-specified deadlines. A real-time system is robust if the schedulability is preserved under the perturbations. In this talk, we introduce a novel analytical approach to model the scheduled behavior of the real-time system, which further leads to a dynamic schedulability test that determines the schedulability of the real-time system within a finite time window. The dynamic schedulability test can then be used to measure robustness of the real-time system by evaluating the strength of the perturbations that break schedulability.

Structure Identification and Model Reduction of Nonlinear Building Thermal Dynamics, Siddharth Goyal, University of Florida

Buildings are one of the major consumers of energy worldwide. Inefficient operation and control of Heating, Ventilation and Air-Conditioning (HVAC) equipment is one of the primary reasons for the high energy footprint of buildings. As a result, there is a growing interest in developing control techniques to compute optimal control signals for the HVAC sys-tems in buildings that can minimize energy consumption while ensuring comfort and health of occupants. Such methods require a model of the thermal dynamics of the building, which requires modeling the heat conduction through walls and heat convection due to airflows among the zones. Due to the complexity of the underlying physical processes that determine variables of interest such as zone temperatures, constructing control oriented (reduced order) models is a challenging task. In this talk we will report on recent work in addressing some of these challenges. First we will address the problem identifying a network model of the thermal dynamics of a large, multi-zone building from measured data. The identification method consists of two parts - structure identification and parameter estimation. In structure identification, we identify paths of convective interaction among zones from estimates of conditional independence among zone temperatures. Paths of conductive interaction are identified from building geometry. Then a resistor-capacitor network model of the entire network is constructed, with some of the parameters of the model estimated by minimizing a prediction error cost function. However, even such a reduced order model suffers from a large state-space dimension, even for a small number of zones. We propose a method that *exploits the linear portion of the model to compute a transformation and a specific sparsity pattern of the non-linear portion to obtain the reduced order model.*

Secure Communication for Mobile Agents in an Adversarial Environment, Sourabh Bhattacharya, University of Illinois at Urbana-Champaign

Control and communication over a wireless network is an essential component of networked cyber-physical systems. The decentralized nature of wireless ad hoc networks in mobile platforms makes them vulnerable to security threats. In this talk, I will present some pursuit-evasion games that arise in various scenarios related to jamming in a team of autonomous vehicles. A framework based on the theory of multi-player differential games provides some interesting insights regarding the nature of solutions. Finally, I will present some recent results in team jamming problems.

Wireless Control Networks, Miroslav Pajic, University of Pennsylvania

We present a method to stabilize a plant using just a network of resource constrained wireless nodes. As opposed to traditional networked control schemes where the nodes simply route information to and from a centralized controller, our approach treats the wireless network itself as the controller. The key idea is that each node updates its internal state to be a linear combination of states of the nodes in its neighborhood. We show that this causes the entire network to behave as a linear dynamical system, with sparsity constraints imposed by the network topology. We provide a synthesis procedure to program the network and present a scheme that can handle node failures while preserving stability. In addition, we show how our design procedure can be modified to maintain mean square stability under packet drops in the network, along with conditions on the network topology that allow the system to be stabilized. We call this architecture a Wireless Control Network (WCN), and show that it introduces very low computational and communication overhead to the nodes in the network. Furthermore, as no specific node computes the control algorithm, WCN allows the use of simple transmission scheduling algorithms, and enables compositional design (where the existing wireless control infrastructure can be easily extended to handle new plants that are brought online in the vicinity of the network).

Optimal Sensor Placement for Parameter Estimation in Power Systems, Thomas Nudell, North Carolina State University

In this talk we discuss a sensor placement algorithm for parameter estimation in electric power system models using noisy Synchrophasor measurements. We pose the problem in terms of estimating the transmission line impedances and the generator inertias, and show that the estimation error bounds are non-linear functions of the sensor location on the line. We finally state conditions for finding the optimal location that minimizes these error bounds. The discussion is supported by simulations on a four-machine nine-bus IEEE prototype power system model.

On Event Triggered Trajectory Tracking for Control Affine Nonlinear Systems, Pavan Tallapragada, University Of Maryland

In this work we study an event based control algorithm for trajectory tracking in control affine nonlinear systems. Given a nonlinear dynamical system, a continuous-time control that guarantees uniform asymptotic tracking of the desired trajectory, and provided that the desired trajectory and it's derivative are uniformly bounded, we develop an event based controller that not only guarantees uniform ultimate boundedness of the tracking error but also ensures non-accumulation of inter-execution times. In the special case that the second derivative of the reference trajectory is also uniformly bounded the proposed control algorithm can be used to design an ultimate bound that is arbitrarily small. The main ideas in the work are demonstrated using two nonlinear systems and the algorithm is verified by numerical simulations.

Energy-Based Nonlinear Control for Stabilization of Faults in Electric Energy Systems, Milos Cvetkovic, Carnegie Mellon University

A smart grid is a unique synergy between traditional bulky electric energy infrastructure and state-of-the-art unconventional technologies. Smart grids are expected to operate in unexplored operating ranges as the alternative energy resources get connected to the existing system. At the same time the grid is being equipped with powerful accurate sensors and communications systems. This situation increases importance for controlling nonlinear system dynamics to ensure stability under unexpected working conditions. Faults are particularly critical source of instabilities. This talk proposes a solution for stabilization of electric grids under faults. The control strategy is designed for Flexible AC Transmission Systems (FACTS) group of devices. FACTS devices are controlled to improve system resilience by temporarily storing the energy released by faults.

Session: Robotic and Sensor Systems

Active Classification: Theory and Application to Underwater Inspection, Geoffrey A. Hollinger, University of Southern California

There is growing interest in the use of Autonomous Underwater Vehicles (AUVs) for tasks such as ship hull inspection, ocean monitoring, and underwater search. This talk will discuss the problem of controlling an AUV to best classify an object of interest based on multiple views. We focus on the active classification setting, where the vehicle controls which views to select to best differentiate between possible object classes. The problem is formulated as an extension to Bayesian active learning, and we show connections to recent theoretical guarantees in this area. We formally analyze the benefit of acting adaptively as new information becomes available. The analysis leads to a probabilistic algorithm for determining the best views to observe based on information theoretic costs. We validate our approach in two ways, both related to underwater inspection: 3D polyhedra recognition in synthetic depth maps and ship hull inspection with imaging sonar. These tasks encompass both the planning and recognition aspects of the active classification problem. The results demonstrate that actively planning for informative views can reduce the number of necessary views by up to 80% when compared to passive methods.

A Formal Approach to Deployment of Robotic Teams in an Urban-Like Environment, Yushan Chen, Boston University

We present a computational framework for automatic synthesis of control communication strategies for a robotic team from task specifications given as formal languages about servicing requests in an environment. Our approach is based on two main ideas. First, we extend recent results from formal synthesis of distributed systems to check for the distributability of the task specification and to generate local specifications, while accounting for the service capabilities of the robots. Second, by using a technique inspired from LTL model checking, we generate individual control and communication strategies. We illustrate the method with experimental results in our Robotic Urban-Like Environment.

Utilizing Effective Resistance for Robust Consensus on Undirected and Directed Graphs, George Young, Princeton University

The ability of a group of independent agents to filter noise and reach accurate consensus is important for many applications. We use the H2 norm associated with the communication graph to characterize the robustness of the consensus system to noise. In particular, we exploit the correspondence between the H2 norm of an undirected graph and its effective resistance to develop a method to monotonically decrease the H2 norm of a tree through local changes. A proposed extension of the concept of effective resistance to directed graphs is also considered.

Path Planning, State Measurement and Controllability for The M3 Class of Modular Robots, Kevin C. Wolfe, Johns Hopkins University

An overview of the M^3 class of modular robots will be presented along with a problem associated with the self-assembly of the independently-mobile modules. While the problem is similar to nonholonomic path planning for a conventional differential-drive robot, there is an added constraint on one of the internal states of the system. This constraint ensures that wheel angles are suitable for module-to-module docking. Controllability of the new system is explored along with a method for encoding and measuring the full-state (pose and wheel angles) of a single module. The new wheel encoding system is based on visual tracking of error-tolerant cyclic sequences.

Multi-Vehicle Control and Optimization for Spatiotemporal Sampling, Nitin Sydney, University Of Maryland

We analyze the mapping accuracy of a sensor network using a quantitative measure of the mapping error as a performance metric. We use optimal interpolation to calculate the estimation error of a map of a spatiotemporal field produced by assimilating observations collected by a group of vehicles. The vehicles travel in a closed trajectory in a steady, uniform flowfield. The mapping error is analyzed for statistically homogeneous fields and inhomogeneous fields for which the correlation coefficient depends on position. For the homogeneous field, we design a closed-loop speed controller to minimize the average mapping error and, for the inhomogeneous field, we introduce an artificial flowfield to minimize a convex combination of the average error and maximum error.

Model-based State Estimation of a Gaseous Source in a 2D Spatial Domain Using a Sensor-based Grid Adaptation Approach, Jeffrey Court, WPI

The intentional or accidental release of a tracer in the atmosphere can pose a significant risk. The prediction and localization of the contaminant's flow can be very beneficial. A model-based estimation scheme is to be used in the state estimation of a concentration profile throughout a domain. A network of mobile sensors is used to measure the concentration at spatially varying points. It is assumed the sensors are affixed to a fixed-wing aircraft to create a mobile sensing agent (MSA). The motion of the MSA is determined with a Lyapunov-based guidance scheme that drives the sensor's position to areas in the spatial domain with a higher state estimation error. This attempts to minimize the overall state error in the domain. The Lyapunov control is based on the measured state error as well as the sensor's dynamics. In order to decrease computational requirements and provide a real time solution, grid adaptation is utilized in the form of stretched grids. A family of predetermined stretched grids reduces required computations while giving the required spatial accuracy in the area of interest.

Saturday, April, 30, 2011

Session: Distributed Systems

Tractability of Decentralized Control Problems, Laurent Lessard, Stanford University

We address the question of which decentralized control problems are tractable. The largest known class is the quadratically invariant systems. We broaden this set by characterizing a class of systems which are not quadratically invariant, but reduce to systems that are. We call this internal quadratic invariance. We give an algorithm for performing this reduction, and illustrate our method with examples.

Timeout Control in Distributed Systems Using Perturbation Analysis, Ali Kebarighotbi, Boston University

Timeout control is a simple mechanism used when direct feedback is either impossible, unreliable, or too costly, as is often the case in distributed systems. Its effectiveness is determined by a timeout threshold parameter and our goal is to quantify the effect of this parameter on such systems behavior. In this paper, we consider a basic communication system with timeout control, model it as a stochastic flow system, and use Infinitesimal Perturbation Analysis to determine the sensitivity of a "goodput" performance metric with respect to the timeout threshold parameter. In conjunction with a gradient-based scheme, we show that we can determine an optimal value of this parameter. A numerical example is included.

Coalition Formation and Motion Coordination for Optimal Deployment, Michael Ouimet, University of California-San Diego

This paper presents a distributed algorithmic solution to achieve network configurations where agents cluster into coincident groups that are distributed optimally over the environment. The motivation for this problem comes from spatial estimation tasks executed with unreliable sensors. We propose a *probabilistic strategy that combines a repeated game governing the formation of coalitions with a spatial motion component governing their location. We establish the convergence of the agents to coincident groups of a desired size in finite time and the asymptotic convergence of the overall network to the optimal deployment, both with probability 1. The algorithm is robust to agent addition and subtraction. From a game perspective, the algorithm is novel in that the players' information is limited to neighboring clusters. From a motion coordination perspective, the algorithm is novel because it brings together two basic tasks, rendezvous (individual agents into clusters) and deployment (clusters in the environment). The technical approach draws on tools from computational geometry, game theory, and probability theory.*

Consensus Algorithms for Camera Sensor Networks, Roberto Tron, Johns Hopkins University

Recent hardware innovations have produced low-power, embedded computers equipped with small cameras, which can be organized into wireless camera sensor networks. These new technologies provide a tremendous opportunity to devise new applications at the intersection of computer vision and sensor networks. However, such applications pose a number of fundamental challenges to existing algorithms. On the one hand, traditional computer vision algorithms are centralized and require computational resources not available in a camera sensor network. On the other hand, traditional sensor networks techniques, such as average consensus algorithms, are designed for low-dimensional Euclidean data, while computer vision tasks often involve high-dimensional data related by parameters lying on non-Euclidean spaces. In this talk, we present distributed algorithms for solving classical computer vision problems such as object localization, camera sensor network localization and others. We pose these problems as consensus problems in the space of rigid-body motions and show how classical consensus algorithms can be extended to operate in this space. We will also present our advancements in the theoretical understanding of these extensions.

Robust Blind Identification of Sparse Dynamical Networks, Mustafa Ayazoglu, Northeastern University

This work addresses the problem of identifying the topology of a sparsely interconnected network of dynamical systems from experimental noisy data. In this setup the observed data is assumed to have been generated by an underlying, unknown graph topology where each node corresponds to a given time-series and each link to an unknown autoregressive model that maps those time series. Contrary to related existing work, we also allow for exogenous outputs at each link, intended to model infrequent events (or ``shocks") and thus subject to a sparsity constraint. The goal is to recover the sparsest (in the sense of having the fewest number of links) structure compatible with some a-priori information and capable of explaining the observed data. As we show in this talk, both the network topology and the unknown inputs can be identified by solving a convex optimization problem, obtained by combining Group-Lasso type arguments with a re-weighted heuristics. The resulting algorithm has computationally attractive properties and is robust to noise and perturbations in the graph structure. These results are illustrated with several examples drawn from a very broad range of application domains, including computer vision, systems biology and finances.

Distributed Averaging of Uncertainties: Emergence of Levy Flights, Jing Wang, Iowa State University

In this talk, we focus on the fragility, rather than the stability, of a popular distributed averaging algorithm. We show that the otherwise well studied and benign multi-agent system can generate a collective global complex behavior. We characterize this behavior, common to many natural and human-made interconnected systems, as collective hyper-jump diffusion process. We further describe the mechanism for its emergence and predict its occurrence. By exploiting the structural properties of the system, we decompose it into two parts, namely, the deviation part and the conserved part. Under some standard assumptions, we show the state of the conserved part is a hyper-jump diffusion process if and only if the deviation system loses mean square (MS) stability, and prove it to be a Levy flight for a two-node system. We also show that the strong connectivity property of the network topology guarantees that complex behavior is global and affects all agents in the network. This work is the first, to the best of our knowledge, to establish the intimate relationship between propagation of channel uncertainties in networked systems, the MS stability robustness and the emergence of Levy flights, which may have far reaching consequence on the understanding and engineering of complex systems.

Session: Optimization

An Evolutionary Game Approach to Model-based Optimization, Yongqiang Wang, University Of Maryland

We propose a new framework for global optimization problems by building a connection between global optimization problems and evolutionary games, and we show that a particular equilibrium set of the evolutionary game is asymptotically stable. Based on this connection, we propose a Model-based Evolutionary Optimization (MEO) algorithm, which uses probabilistic models to generate new candidate solutions and uses dynamics from evolutionary game theory to govern the evolution of the probabilistic models. The MEO algorithm also gives new insight into the mechanism of model updating in model-based global optimization algorithms. Based on the MEO algorithm, a Population Model-based Evolutionary Optimization (PMEO) algorithm is proposed, which captures the multimodal property of global optimization problems. Simulation experiments demonstrate the effectiveness of the proposed algorithm.

Design of Distributed Game Strategies for Autonomous Vehicles, Wei Lin, University of Central Florida

This presentation will briefly give people an insight into a recent research conducted at the Control and Robotics Laboratory in University of Central Florida. The research deals with nonzero-sum differential game with a focus on the pursuit-evasion problem for mobile vehicles/robots. Differential game theory and cooperative control theory are integrated to cope with practical situations in which the information sharing is distributed and may change in time. Since the information is distributive, players have limited information of others. The distributed Nash strategies are proposed since the classical approach is not capable to handle the lack of information. The issue of entrapment strategies is then taken into account *for the pursuers to chase the evader in a more intelligent manner. Animated simulation results will be shown for various cases in the workshop.*

Optimal Control in the Presence of an Intelligent Jammer with Limited Actions, Abhishek Gupta, University of Illinois at Urbana-Champaign

This talk focuses on security attack on control systems using game theoretic analysis. The problem that we consider is a denial of service attack on a control system where a jammer blocks the control signal which is being sent to the plant over a unsecured communication channel. It is formulated as a dynamic zero-sum game between the controller and the jammer. The first player acts as a controller for a discrete time LTI plant, while the second player acts to jam the communication between the controller and the plant. The number of jamming actions is limited which captures the energy constraint of the jammer. We determine saddle-point equilibrium control and jamming strategies for the game under the full state, total recall information structure for both players, and show that the jammer acts according to a threshold-based policy at each decision step. Various properties of the threshold functions are derived and complemented by numerical simulation studies.

A Distributed Newton Method for Network Utility Maximization, Ermin Wei, Massachusetts Institute of Technology

Most existing work uses dual decomposition and first-order methods to solve Network Utility Maximization (NUM) problems in a distributed manner, which suffer from slow rate of convergence properties. This paper develops an al- ternative distributed Newton-type fast converging algorithm for solving NUM problems with self-concordant utility functions. By using novel matrix splitting techniques, both primal and dual updates for the Newton step can be computed using iterative schemes in a decentralized manner with limited information ex- change that is comparable to that involved in first-order methods. Similarly, the stepsize can be obtained via a distributed finite procedure. We show that even when the Newton direction and the stepsize in our method are computed within some error (due to finite truncation of the iterative schemes), the resulting objective function value still converges superlinearly in terms of primal iterations to an explicitly characterized error neighborhood. Simulation results demonstrate significant convergence rate improvement of our algorithm relative to the existing first-order methods based on dual decomposition.

Robust Optimization for Entropy-based Moment Closures, Graham Alldredge, University of Maryland

Entropy-based moment closures have attracted much interest as a fast method to solve problems in transport and kinetic theory while retaining fundamental properties of the underlying kinetic equations. Unfortunately, to implement a moment closure, one must solve an optimization problem which presents significant difficulties even in low-dimensional setting. We have developed a new stopping criterion and added a regularization procedure to address the optimization difficulties and have found success with difficult problems for as many as $N=15$ moments.

Sunday, May, 1, 2011

Session: Stochastic Systems

Probability Constrained Stochastic Linear Quadratic Control, Zhou Zhou, University of Virginia

We consider a probability constrained stochastic linear quadratic control problem. This problem has linear dynamics and a quadratic cost, and is subjected to a joint probabilistic constraint. The joint probabilistic constraint in the model is converted to a conservative deterministic one using multi-dimensional Chebyshev bound. A maximum volume inscribed ellipsoid problem is solved to obtain this probability bound. We then show how this bound can be used in two main classes of controller design: state feedback control and disturbance-feedback control. Using the powerful probability bound, we developed an efficient state feedback controller for a special subset of state constrained stochastic LQR and a disturbance feedback controller for the general case using tractable convex programming. At the end of the talk we will show an experiment using our algorithms in an economic dispatch problem.

The Mean-field Control Approach for Particle Filtering, Tao Yang, University of Illinois at Urbana-Champaign

A new formulation of the particle filter for nonlinear filtering is presented, based on concepts from optimal control, and from the mean-field game theory framework. The optimal control is chosen so that the posterior distribution of a particle matches as closely as possible the posterior distribution of the true state given the observations. In the infinite-N limit, the empirical distribution of ensemble particles converges to the posterior distribution of an individual particle. The cost function in this control problem is the Kullback-Leibler (K-L) divergence between the actual posterior, and the posterior of any particle. The optimal control input is characterized by a certain Euler-Lagrange (E-L) equation. The resulting infinite-N limit is described by a coupled PDE model. A numerical algorithm is introduced and implemented in several examples.

A Counterexample to Aggregation Based Model Reduction of Hidden Markov Models, Georgios Kostalis, Georgia Institute of Technology

This talk will highlight a limitation of state space aggregation based model reduction of Hidden Markov Models. It is shown that there exist exactly reducible high dimensional Hidden Markov models and aggregation based reduction is guaranteed not to produce an error free low dimensional model.The generic nature of such instances is established by providing a randomized algorithmic process that produces such counterexamples with probability 1.

Tree-Structured Like Representations for Continuous and Graph Indexed Markov Random Fields, Divyanshu Vats, Carnegie Mellon University

Tree-Structured Like Representations for Continuous and Graph Indexed Markov Random Fields Markov random fields (MRFs) have been successfully used in many applications to model noncausal random spatial signals. In this talk, we present recent results on finding tree-structured like representations for MRFs. These representations are useful for deriving efficient algorithms for processing MRFs. For continuous indexed MRFs, we establish tree-structured like representations by parameterizing the MRF over appropriate hypersurfaces over the continuous index set. This allows us to extend the Kalman filter and popular recursive smoothers to random signals indexed over high-dimensional continuous domains. For MRFs indexed over graphs (also known as graphical models), we show that tree-structures can be found by disjoint clustering of nodes in the graph.

Study on Stochatic Self-assembly System Convergence Rate, Yuzhen Zhu, Georgia Institute of Technology

Two key issues in the stochastic self-assembly are whether the system will converge to the desirable global equilibrium and how quickly it converges. In this paper an optimal self-assembly design approach, which guarantees the unique desirable convergence and provides the fastest convergence rate, is proposed for active self-assembly systems. We adopt a Markov chain to model the self-assembly system. Based on the convergence theory of a Markov chain, we solve an optimization problem in which minimizing a certain function involved in the Markov chain results in both maximum yield of the target assemblies at the equilibrium and optimal convergence rate to the desired equilibrium. Several examples are carried out to further illustrate the importance and the effectiveness of the proposed approach.

System Theory over Random Networks: Control and Estimation, Marzieh Nabi, University of Washington

In this talk we present a framework for designing feedback controllers for directing a group of agents adopting consensus-type algorithms over random networks. In this direction, we first examine the pertinent necessary and sufficient conditions for controllability and observability of protocols overrandom networks. We then proceed to explore conditions on the underlying distribution for guaranteeing optimal infinite horizon linear quadratic regulators. On the estimation side, stability and convergence properties of random variations on the coordinated decentralized estimation are explored using contractive properties of the random Riccati map.

Session: Biological Systems

Circadian Rhythm Entrainment with Light Input, Jiaxiang Zhang, Rensselaer Polytechnic Institute

Circadian rhythm is the biological process critical to the well-being of all living organisms, from plants to insects and mammals. The circadian rhythms oscillate with a period of approximately 24 hours due to the 24-hour light-darkness pattern of the solar day. Circadian disruption, as experienced by night shift workers, travelers across multiple time zones, submariners or miners, can lead to lower productivity, sleep disorder, and more serious health problems. Using artificial light to regulate the circadian rhythm has long been proposed. In our work, we consider a commonly used nonlinear second order oscillator *model for the circadian rhythm response with light intensity as the input and discuss how light control may be used to promote circadian entrainment. We propose a feedback-based circadian entrainment strategy by reference tracking and an open loop optimal controller by solving the minimum time control problem. Through simulation we show that the recovery of a 12-hour jet lag can be shortened from 7 days to 3 days comparing the entrainment time cost with the natural light-darkness pattern. In all cases, external light input is much more efficient in delaying the phase shift (e.g., traveling westward from U.S. East Coast) than advancing the phase shift.*

Prediciting Tumor Suppressing Genes in Colorectal Cancer, Nitin Singh, University of Texas at Dallas

Mutations in oncogenes and tumor suppressor genes cause cancer. However, not all mutations found in cancer cells have causative relationship to cancer. Mutations leading to tumorigenesis are termed as “drivers" and other mutations are called passengers. Currently, identifying drivers among all mutations is a challenge faced by the cancer research community. Here, we study the same problem. We attempt to distinguish driver mutations in colorectal cancer from passengers using machine learning techniques. We hypothesize that mutation frequencies alone are not sufficient to differentiate between them. Therefore, we use the developmental stage gene expression profile (GEP), a seven-dimensional vector obtained from Unigene, a public database, as an additional feature to achieve the differentiation. We focused on 151 key genes known as CAN-Genes, identified by Wood et al. (2007) that are likely to have a role in tumor-suppression in colorectal cancer. Using the K-means algorithm, GEP vectors were grouped into two clusters. The membership of the two clusters was then compared against experimental evidence in which an isogenic human colorectal epithelial cell (HCEC) transformation model was employed to identify tumor suppressors. In 151 studied genes, 65 including TP53 knockdown promoted HCEC proliferation. These 65 genes were thus dubbed as `hits' while the remaining 86 were dubbed as misses. However, only 140 of them were found in Unigene and studied computationally. Out of these 140 genes, 63 were hits and 77 were misses. In the K-mean clusters, one cluster had statistically significant enrichment of hits and thus recommended for further experimental studies. Specifically, a set of 71 additional genes have been recommended to our collaborators for experimental testing. We also used Support Vector Machines (SVMs) to distinguish between hits and misses in the classified genes. However, it was observed that SVM does not perform any better than blind guessing, achieving accuracies barely higher than 50%. Such behavior is typical in the case of mislabeled data points, which is inevitable due to nature of the experiments. Specifically, while a hit is definitely a hit, a miss could become a hit under other experimental conditions.

Cancer Therapy Design Based on Pathway Logic, Ritwik Layek, Texas A&M University

Cancer encompasses various diseases associated with loss of cell cycle control, leading to uncontrolled cell proliferation and/or reduced apoptosis. Cancer is usually caused by malfunction(s) in the cellular signaling pathways. Malfunctions occur in different ways and at different locations in a pathway. Consequently, therapy design should first identify the location and type of malfunction to arrive at a *suitable drug combination. We consider the growth factor (GF) signaling pathways, widely studied in the context of cancer. Interactions between different pathway components are modeled using Boolean logic gates. All possible single malfunctions in the resulting circuit are enumerated and responses of the different malfunctioning circuits to a 'test' input are used to group the malfunctions into classes. Effects of different drugs, targeting different parts of the Boolean circuit, are taken into account in deciding drug efficacy, thereby mapping each malfunction to an appropriate set of drugs.*

Optimal Control Mechanism Involving The Human Kidney, Yu Jiang, Polytechnic Institute NYU

In this paper we study the control mechanism that regulates water and the concentration of sodium in human body. For this reverse engineering problem, a control system model is developed using a modification of the standard LQR theory. The control law derived in this paper reflects the realistic situation in which the body is in a supine position or a standing position, and also takes into account feedback time lag. The theoretical model is validated by experimental data fitting. Both computer simulations and experimental data fitting show that the proposed model can capture the main trends of water and salt outputs, and achieve tight control of the plasma concentration of salt as recorded from an experiment.

Bacterial Persistence: Mathematical Modeling and Optimal Treatment Strategy, Nicholas Cooper, Rensselaer Polytechnic Institute

Bacterial persistence is an epigenetic phenomenon in which some bacteria cells become immune to antibiotic treatment without undergoing genetic mutation. In this paper, we develop a population dynamic model that captures both short term and long term persistence in bacteria. We subsequently pose the problem of designing an optimal treatment strategy, in terms of minimizing the number of persister cells that transition into long term dormancy. We find that the infinite time horizon optimal control strategy is not unique, and it can be expressed as a feedback law using the information about the population sizes of normal and persister cells. We also show the existence of a theoretical lower bound for the optimal cost value.