Automated Verification and Control Synthesis for CPS with SHS Models

Alessandro Abate
University of Oxford

I will concentrate on systems represented by models that are probabilistic with heterogeneous dynamics (continuous/discrete, i.e. hybrid, as well as nonlinear). Such stochastic hybrid models (SHS) are a natural mathematical framework for CPS. With focus on model-based verification procedures, I will provide algorithms for quantitative model checking of temporal specifications on SHS with formal guarantees. This is attained via the development of formal abstraction techniques based on quantitative approximations.

Piecewise Deterministic Markov Processes

Michel Benaim and Tobias Hurth
Université de Neuchâtel

This talk is devoted to Piecewise Deterministic Markov Processes obtained by Markovian switching between finitely many odes. General conditions ensuring unique ergodicity, positive recurrence and convergence in distribution will be discussed and illustrated by a few examples in population dynamics.

Discounted control problems for piecewise deterministic Markov processes

Francois Dufour
Université de Bordeaux

The main objective of this talk is to review some control problems for a class of hybrid stochastic systems given by the family of piecewise deterministic Markov processes (PDMPs). PDMPs were introduced by M.H.A. Davis as a general family of non-diffusion stochastic models, suitable to formulate a large variety of applications We will discuss infinite-horizon expected discounted continuous-time optimal control problems in the constrained and unconstrained cases where the control acts continuously on the jump intensity and on the transition measure of the process.

Stochastic Optimization Without Integration

Joao Hespanha
University of California, Santa Barbara

This talk addresses the numerical optimization of criteria involving the expected value of a random variable or a stochastic process with respect to a vector of (deterministic) parameter. The explicit computation of an expected value requires an integration that can be computationally very expensive in high-dimensional spaces and is often replaced by Monte Carlos sampling, leading to methods like stochastic gradient descent. However, Monte Carlo-based method typically exhibit very slow convergence rates. Our focus here is on approaches that are computationally efficient without requiring Monte Carlo sampling, with the goal of solving stochastic optimization problems very fast, at the expense of some degree of sub optimality. This goal is motivated by problems of real-time stochastic optimal control, state and parameter estimation, and experiment design. We discuss two approaches to this problem: one based on computing and optimizing bounds on an expected value and the other on Laplaces method to approximate integrals.

On principal eigenvalue for time-periodic parabolic operators

Yuan Lou
The Ohio State University

We will discuss some recent progress on the asymptotic behavior of principal eigenvalues of time-periodic parabolic operators. We will focus on the dependence of principal eigenvalues on diffusion rate, frequency and drift rate.

Chaotic Behavior of Dynamical Systems Driven by an External Forcing

Kening Lu
Brigham Young University

This talk contains three parts: (1) The existence of SRB measures and their properties for infinite dimensional dynamical systems and SRB measures for parabolic PDEs undergoing Hopf bifurcations driven by a periodic forcing with applications to the Brusselator; (2) Positive entropy implying the existence of horseshoes for infinite dimensional random dynamical systems; (3) Chaotic behavior of Anosov systems driven by an external forcing. This is based on the joint works with Wen Huang, Zeng Lian, Peidong Liu, Qiudong Wang, and Lai-Sang Young.

Stabilisation of Highly Nonlinear Hybrid Stochastic Differential Delay Equations by Delay Feedback Control

Xuerong Mao
University of Strathclyde

Given an unstable hybrid stochastic differential equation (SDDE, also known as an SDDE with Markovian switching), can we design a *delay* feedback control to make the controlled hybrid SDDE become asymptotically stable? If the feedback control is based on the current state, the stabilization problem has been studied. However, there is little known when the feedback control is based on the past state. The problem becomes even harder when the coefficients of the underlying hybrid SDDE do not satisfy the linear growth condition (namely, the coefficients are highly nonlinear). The aim of this research is to tackle the stabilization problem for a given unstable highly nonlinear hybrid SDDE.

Stochastic Interventions and Hybrid Control Models

Jose Luis Menaldi
Wayne State University

This is a presentation based on joint works (with H. Jasso-Fuentes, T. Prieto-Rumeau, M. Robin) concerning hybrid control models in discrete and continuous time. As expected, only some raw ideas are sketched and attention to the proper references is not given, since every details can be found in the quotes joint works. Most of the time is used on a general Markov Decision Processes, where a discussion on stopping, impulse, switching and hybrid models is briefly given. Later, in a continuous time setting, impulse and switching controls are viewed as particular cases of hybrid control models for Markov-Feller processes. Moreover the constraint so-called 'wait for a signal' is used as a typical example, where most of the desired results are available.

Stochastic Differential Dynamic Logic for Stochastic Hybrid Programs

Andre Platzer
Carnegie Mellon University

Logic is a powerful tool for analyzing and verifying systems, including programs, discrete systems, real-time systems, hybrid systems, and distributed systems. Some applications also have a stochastic behavior, however, either because of fundamental properties of nature, uncertain environments, or simplifications to overcome complexity. Discrete probabilistic systems have been studied using logic. But logic has been chronically underdeveloped in the context of stochastic hybrid systems, i.e., systems with interacting discrete, continuous, and stochastic dynamics. We aim at overcoming this deficiency and introduce a dynamic logic for stochastic hybrid systems. Our results indicate that logic is a promising tool for understanding stochastic hybrid systems and can help taming some of their complexity. We introduce a compositional model for stochastic hybrid systems. We prove adaptivity, cadlag, and Markov time properties, and prove that the semantics of our logic is measurable. We present compositional proof rules, including rules for stochastic differential equations, and prove soundness.

Specification Guided Verification of Stochastic Hybrid Systems

Pavithra Prabhakar
Kansas State University

Stochastic Hybrid Systems (SHS) capture mixed discrete, continuous and stochastic behaviors of Cyber-physical systems (CPSs) that combine control, computation and communication to achieve sophisticated functionalities as in autonomous driving in driverless cars. Verification of SHS is computationally challenging and requires abstraction-based simplification techniques to scale the analysis. In this talk, we present an abstraction-based approach for scalable verification of stochastic hybrid systems that is guided by specification. We will provide verification algorithms for bounded and unbounded safety analysis and present a counterexample guided abstraction refinement approach for safety analysis of SHS. We present our experimental analysis illustrating the benefits of the method.

Stochastic hybrid decision-making networks for global almost sure unanimity

Andrew Teel
University of California, Santa Barbara

Inspired by the recent appearance of deterministic, continuous-time, decision-making models for almost global unanimity, we propose a stochastic hybrid model for decision-making tasks. In particular, we develop a stochastic hybrid inclusion that ensures robust, global, almost sure unanimous selection among a finite set of possible decision states. For simplicity, in this talk we focus on the case of homogeneous, linear, continuous-time agent dynamics and all-to-all communication. Each agent is equipped with a logic variable that is subject to random updates. Spontaneous transitions of the logic variables occur. These resets are randomly assigned among those indices of the decision states that nearly minimize the value of a parametrized Lyapunov function; the Lyapunov function is parametrized by the selected decision state and quantifies the size of the mismatch between the average of the agent states and the corresponding decision state. In order to satisfy regularity properties that confer robustness, the resulting update rule corresponds to an inclusion, i.e., a set-valued mapping. We establish global, almost sure decision making using a classical Lyapunov function argument that has been extended to stochastic hybrid inclusions. To provide background for these results, we also discuss recent, general developments on modeling and analysis of stochastic hybrid inclusions.

Phase field models for dislocation self-climb of prismatic dislocation loops

Xiaodong Yan
University of Connecticut

We present phase field models for self-climb motion of prismatic dislocation loops. The conserved dynamics is developed under the framework of the Cahn-Hillard equation with incorporation of the climb force on dislocations. Such model has the advantage of being able to handle the topological and geometrical changes automatically during the simulations. Asymptotic analysis indicates that the proposed model gives accurate dislocation self-climb velocity in the sharp interface limit. Numerical simulations show excellent agreement with experimental observations. Joint work with Yang Xiang and Xiaohua Niu.

Invariant Measure of Regime-Switching Processes

Chenggui Yuan
Swansea University

This presentation are divided into four main parts: 1) existence and uniqueness of invariant measure of the solutions of regime-switching processes, 2) existence and uniqueness of invariant measure of the EM numerical schemes of regime-switching processes, 3) existence and uniqueness of invariant measure of the backward EM numerical schemes of regime-switching processes, 4) the convergence of the numerical invariant measure as the stepwise tends to zero.

An optimal pairs trading selling rule under a regime-switching model

Qing Zhang
University of Georgia

This talk is about an optimal selling rule for pairs stock trading under a regime-switching model. A pair's position consists of a long position in one stock and a short position in the other. The problem is to find an optimal stopping time to close the pairs position by selling the long position and buying back the short position. We consider the optimal pairs-trading selling rule by allowing the stock prices to follow general two-dimensional geometric Brownian motions coupled by a two-state Markov chain. The optimal policy is characterized by threshold curves obtained by solving the associated HJB equations (quasi-variational inequalities). Moreover, numerical examples are provided to illustrate optimal policies and value functions.