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as of 16-Mar-2023

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Date Received: 16-Mar-2023

Final Report for Period Beginning 01-Apr-2021 and Ending 31-Mar-2022

Title: Symposium on Stochastic Hybrid Systems and Applications

Begin Performance Period: 01-Apr-2021

End Performance Period: 31-Mar-2022

Report Term: 0-Other

Submitted By: George Yin

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Distribution Statement: 1-Approved for public release; distribution is unlimited.

STEM Degrees:

STEM Participants:

Major Goals: One of the distinct features of hybrid systems is the coexistence of continuous dynamics and discrete events and their interactions. A stochastic hybrid system is
one in which continuous dynamics or discrete events or both are random processes. The motivations for studying such systems stem from emerging and existing applications in wireless communications, signal processing, queueing networks, production planning, biological systems, ecosystems, neuroscience,
financial engineering, and control and optimization of systems (especially large-scale systems) under the influence of random environments. The symposium covers important areas of research, which spends a spectrum of applied and theoretical areas.

We aimed to bring together researchers from multi-disciplinary communities in mathematics, applied probability, engineering, biology,
ecology, and network science, to review, and substantially update the most recent progress. For broader impacts, we invited researchers from different fields covering a wide range of areas. The presentations ranged from theoretically oriented talks to application-intensive talks. Efforts were made for diversity and inclusion.

%%%%%%

Please note that the final report was first submitted to the Program Manager Dr. Robert Martin in March 2022, at that time the online version was not available. I just found that it is available now, so I am submitting also the report online.

Accomplishments: Part 1: The Virtual Part of the Symposium:
It featured in 14 invited talks representing researchers from multi-disciplinary fields including applied mathematics, engineering, and computer science.
It brought together 47 attendees.

Part 2: In-Person Part of the Symposium:

The second part of the symposium was held on Nov. 12 and 13, 2021.
For almost all of the speakers, this event was the first in-person conference they attended since the pandemic started in 2020. All of the attendees welcomed the opportunities to meet in person, exchange ideas, and discuss research problems.
The average daily attendance was about 35 people (constrained by the room capacity).

Because of the pandemic, the University's
rules on masks and social distancing were strictly followed.
In fact, the list of invited speakers and other participants was approved by the Associate Dean of the College of Liberal Arts and Sciences, at the University of Connecticut.

Training Opportunities: Part 1 of the conference (online):

A number of graduate students from different institutions attended the conference. The symposium provided an excellent opportunity for the students to learn from the experts and interact with speakers. Students actively participated in the conference.

Part 2 of the conference (in person):

A number of graduate students from the University of Connecticut (UConn)
and institutions within the vicinity of UConn
attended the conference. We organized a
student poster presentation session, which
provided an excellent opportunity for the students to interact with the invited speakers. The students benefited from attending the conference,
learning from the experts, and interacting with speakers in person.

Results Dissemination: The symposium website can be found at:

https://gyin.math.uconn.edu/conf.html

To enable a wide range of accessibility from the scientific community,
after the presentation of the first part of the conference, with the permission of the invited speakers,
we put the slides at

https://gyin.math.uconn.edu/conf_schedule1.html

For the second part of the symposium,
the program can be found at the link below;
the videos of the speakers who presented
virtually can also be found there.

https://gyin.math.uconn.edu/conf_schedule2.html

Honors and Awards: Nothing to Report

Protocol Activity Status:

Technology Transfer: The presentations cover a wide variety of application areas from control engineering to computer science and to ecology. The broad range of topics covered is unified through the framework of stochastic hybrid systems. The presented results provide great potential for technology transfers.

PARTICIPANTS:

Participant Type: PD/PI
Participant: George Yin
Person Months Worked: 1.00 **Funding Support:**

Project Contribution:
National Academy Member: N

Participant Type: Co PD/PI
Participant: Abhyudai Singh
Person Months Worked: 1.00
Funding Support:
Project Contribution:
National Academy Member: N

Partners

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I certify that the information in the report is complete and accurate:
Signature: George Yiin
Signature Date: 3/16/23 11:11AM

Final Progress Report: W911NF-21-1-0111
Proposal Number: 78350-MA-CF

"Symposium on Stochastic Hybrid Systems and Applications"

George Yin* and Abhyudai Singh†

Program Manager: Dr. Robert Scott Martin
robert.s.martin163.civ@army.mil

March 31, 2022

*Department of Mathematics, University of Connecticut, Storrs, CT 06269-1009, gyin@uconn.edu
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1 Introduction

Despite uncertainty and complication caused by Covid outbreaks and regulations, with great effort and devotion of the symposium participants, the symposium is a great success. Because of the pandemic, we designed the symposium as a hybrid event involving a virtual portion and an in-person portion. The virtual portion of the conference was held on July 8 and July 9, 2021, whereas the in-person portion took place on Nov. 12 and 13, 2021 on the campus of the University of Connecticut.

2 Major Goals

One of the distinct features of hybrid systems is the coexistence of continuous dynamics and discrete events, and their interactions. A stochastic hybrid system is one that the continuous dynamics or discrete events or both are random processes. The motivations for studying such systems stem from emerging and existing applications in wireless communications, signal processing, queueing networks, production planning, biological systems, ecosystems, neuroscience, financial engineering, and control and optimization of systems (especially large-scale systems) under the influence of random environments. The symposium covers important areas of research, which spends a spectrum of applied and theoretical areas.

We aimed to bring together researchers from multi-disciplinary communities in mathematics, applied probability, engineering, biology, ecology, and network science, to review, and to substantially update the most recent progress. For broader impacts, we invited researchers from different fields covering a wide range of areas. The presentations ranged from theoretically oriented talks to application intensive talks. Efforts were made for diversity and inclusion.

3 Accomplished

Part 1: The Virtual Part of the Symposium

It featured in 14 invited talks representing researchers from multi-disciplinary fields including applied mathematics, engineering, and computer science. It brought together 47 attendees.

Training. A number of graduate students from different institutions attended the conference. The symposium provided excellent opportunities for the students to learn from the experts and interact with speakers. Students actively participated in the conference.

Dissemination. The symposium website can be found at:

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To enable a wide range of accessibility from the scientific community, after the presentation, with the permission of the invited speakers, we put the slides at

https://gyin.math.uconn.edu/conf_schedule1.html

Part 2: In-Person Part of the Symposium

The second part of the symposium was held on Nov. 12 and 13, 2021. For almost all of the speakers, this event was the first in-person conference they attended since the pandemic started in 2020. All of the attendees welcomed the opportunities to meet in person, exchange ideas, and discuss research problems. The average daily attendance was about 35 people (constrained by the room capacity).

Because of the pandemic, the University's rules on masks and social distancing were strictly followed. In fact, the list of invited speakers and other participants was approved by the Associate Dean of the College of Liberal Arts and Sciences, at the University of Connecticut.

Training. A number of graduate students from the University of Connecticut (UConn) and institutions within the vicinity of UConn attended the conference. We organized a student poster presentation session, which provided excellent opportunities for the students to interact with the invited speakers. The students benefited from attending the conference, learning from the experts, and interacting with speakers in person.

Dissemination. The symposium website can be found at:

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For the second part of the symposium, the program can be found at the link below; the videos of the speakers who presented virtually can also be found there.

https://gyin.math.uconn.edu/conf_schedule2.html

4 Potential Technology Transfer

The presentations cover a wide variety of application areas from control engineering to computer science and to ecology. The broad range of topics covered is unified through the framework of stochastic hybrid systems. The presented results provide great potential for technology transfers.

5 Upload

The titles and abstracts of all the invited speakers are uploaded.

6 Participants

Please note that there is no salary for the PI and Co-PI, and no compensation for the invited speakers either. We put the list of PI, Co-PI, and invited speakers into the "Other Collaborators".

- George Yin, PI, Organizer of the conference: University of Connecticut Department of Mathematics
- Abhyudai Singh, Co-PI, Co-organizer of the conference: University of Delaware Department of Electrical and Computer Engineering

We list the invited speakers below together with their affiliations.

Part 1: Invited Speakers (July 8-9, 2021).

- Alessandro Abate, University of Oxford, Department of Computer Science
- Michel Benaim and Tobias Hurth, Université de Neuchâtel, Institut de mathématiques
- Francois Dufour, Institut de Mathmatiques de Bordeaux Université de Bordeaux
- Joao Hespanha, Univeristy of California, Santa Barbara, Department of Electrical and Computer Engineering
- Kening Lu, Brigham Young University, Department of Mathematics
- Yuan Lou, Ohio State University, Department of Mathematics
- Xuerong Mao, University of Strathclyde, Mathematics and Statistics
- Jose Luis Menaldi, Wayne State University, Department of Mathematics
- Pavithra Prabhakar, Kansas State University, Department of Computer Science
- Andre Platzer, Carnegie Mellon University, Department of Computer Science
- Andrew Teel, University of California, Santa Barbara, Department of Electrical and Computer Engineering
- Xiaodong Yan, University of Connecticut, Department of Mathematics
- Chenggui Yuan, Swansea University, Department of Mathematics
- Qing Zhang, University of Georgia, Department of Mathematics

Part 2: Invited Speakers (Nov. 12-13, 2021).

- Iddo Ben-Ari, University of Connecticut, Department of Mathematics
- Zhen-Qing Chen, University of Washington, Department of Mathematics
- Philip A. Ernst, Rice University, Department of Statistics
- Maria Gordina, University of Connecticut, Department of Mathematics
- Xin Guo, Department of IEOR, UC Berkeley [Presented virtually.]
- Vikram Krishnamurthy, Cornell University, Department of Electrical and Computer Engineering, [Presented virtually.]
- Oleksii Mostovyi, University of Connecticut, Department of Mathematics
- Dang Hai Nguyen, University of Alabama, Department of Mathematics

- Son Luu Nguyen, University of Puerto Rico, Department of Mathematics
- Kavita Ramanan, Brown Univeristy, Department of Applied Mathematics
- Sebastian Schreiber, University of California, Davis, Department of Evolution and Ecology
- Abhyudai Singh, University of Delaware, Department of Electrical and Computer Engineering
- Qingshuo Song, Worcester Polytechnic Institute, Department of Mathematics
- Gu Wang, Worcester Polytechnic Institute, Department of Mathematics [Presented virtually.]
- Le Yi Wang, Wayne State University, Department of Electrical and Computer Engineering [Presented virtually.]
- Jiongmin Yong, University of Central Florida, Department of Mathematics
- Chao Zhu, University of Wisconsin-Milwaukee, Department of Mathematics
- Bin Zou, University of Connecticut, Department of Mathematics

The programs can be found at
https://gyin.math.uconn.edu/conf_schedule1.html
https://gyin.math.uconn.edu/conf_schedule2.html

Summary and Final Thoughts

The symposium was a successful event. It accomplished the goals, of exchanging ideas, reviewing, substantially update the recent progress, and identifying future directions. Especially, for the in-person part of the conference, a number of participants got a chance to work on some new joint topics or projects together. It is also remarkable that all attendees returned to their home institutions safe and sound; no Covid infections were detected during that period for the attendees.

Let us summarize what we have learned in the process of organizing the symposium.

(1) It is the first conference we organized after the pandemic broke out. Although we faced many challenges, we managed to make it a great event. It may lead to many future advances in research of stochastic hybrid systems.

(2) This is the first hybrid conference we have ever organized. It is a good learning experience and process for us. The virtual presentations facilitate the invitations of invited speakers internationally even during the time when travel was not possible for European attendees. Because of the time difference, we tried our best to accommodate the speakers' requests for desirable times of presentations.

(3) All the invited speakers for the in-person part of the conference are from the U.S. They welcomed the opportunity of meeting in person and getting back to at least some form of normalcy.

(4) For the in-person part of the conference, because of the Delta variant of the virus and other matters, we slightly delayed the starting date of the conference by a few weeks. We thank the help and assistance provided by the Mathematics Department at UConn, the staff of the Mathematics Department, the cleaning crew, and the catering service at UConn. Our concerted effort of colleagues and all attendees made the conference a successful meeting meanwhile taking all the safety measures concerning the Covid 19.

(5) The effort of UConn, particularly, the Dean's office at UConn, the guideline of the university, and efforts on social distancing, etc., kept all the attendees stay safe and healthy.

(6) Finally, we thank the Army Research Office and the Program Managers Dr. Michael Lavine, Dr. Radhakrishnan Balu, Dr. Robert Martin, and Dr. Joseph Meyers for the encouragement, directions, and support. Without their encouragement and support, the meeting would not have been possible.

Appendix of Final Progress Report: W911NF-21-1-0111
Proposal Number: 78350-MA-CF

"Symposium on Stochastic Hybrid Systems and Applications"

George Yin[*] and Abhyudai Singh[†]

Program Manager: Dr. Robert Scott Martin
robert.s.martin163.civ@army.mil

March 16, 2023

In this appendix, the titles and abstracts are included.

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Abstracts: Part I (Virtual)

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.

Abstracts: Part II (In Person)

Quasi-Stationary Distributions for the Voter Model on Complete Bipartite Graphs

Iddo Ben-Ari

Department of Mathematics, University of Connecticut

In this talk I will discuss the discrete-time voter model for opinion dynamics and its quasistationary distribution (QSD). The focus will be on the sequence of QSDs corresponding to the model on complete bipartite graphs with a "large" partition whose size tends to infinity and a "small" partition of constant size. In this case, the QSDs converge to a nontrivial limit featuring a consensus, except for a random number of dissenting vertices in the large partition which follows the heavy-tailed Sibuya distribution. The results rely on duality between the voter model and coalescing random walks through time-reversal. Time permitting, I'll expand the discussion on the duality and its application to a broader class of processes. The research presented in this talk was mostly performed in the Markov Chains REU and is joint work with Hugo Panzo and student participants Philip Speegle and R. Oliver VandenBerg.

Periodic homogenization of discontinuous Markov processes

Zhen-Qing Chen

Department of Mathematics, University of Washington

In this talk, I will present some recent results on homogenization of discontinuous Markov processes with Lévy type generators in periodic media. Under a proper scaling, the scaled Markov process is shown to converge weakly to a Lévy process. Different phenomena occur depending on the tails of the jumping kernel of the discontinuous Markov process. These results can be viewed as the non-local counterparts of the celebrated work of Bensoussan-Lions-Papanicoaou and Bhattacharya for diffusions. Based on joint work with Xin Chen, Takashi Kumagai and Jian Wang.

Quickest real-time detection of a Brownian coordinate drift, with applications to Markovian drifts

Philip Ernst

Department of Statistics, Rice University

This talk concerns two recent papers. In the first paper, we consider the motion of a Brownian particle in two or more dimensions, whose coordinate processes are standard Brownian motions with zero drift initially, and then at some random/unobservable time, one of the coordinate processes gets a (known) non-zero drift permanently. Given that the position of the Brownian particle is being observed in real time, the problem is to detect the time at which a coordinate process gets the drift as accurately as possible. We solve this problem in the most uncertain scenario when the random/unobservable time is (i) exponentially distributed and (ii) independent from the initial motion without drift. The solution is expressed in terms of a stopping time that minimizes the probability of a false early detection and the expected delay of a missed late detection. This paper is joint work with Goran Peskir (The University of Manchester) and is currently in press at *The Annals of Applied Probability*. The second paper considers the above problem in the random switching environment setting; one of the coordinate processes gets a (known) non-zero drift permanently depending on an underlying continuous time Markov chain with finite state space. This paper is joint work with Hongwei Mei (Rice University) and can be found at `https://arxiv.org/pdf/2107.14441.pdf`.

Ergodicity for Langevin dynamics with singular potentials

Maria Gordina
Department of Mathematics, University of Connecticut

We will discuss Langevin dynamics of N particles on $\mathbb{R}^d$ interacting via a singular repulsive potential, such as the Lennard-Jones potential, and show that the system converges to the unique invariant Gibbs measure exponentially fast in a weighted Sobolev norm. The proof relies on an explicit construction of a Lyapunov function using geometric methods. In contrast to previous results for such systems, our results imply geometric convergence to equilibrium starting from an essentially optimal family of initial distributions. This is based on the joint work with F. Baudoin and D. Herzog published in the Archive for Rational Mechanics and Analysis, as well as a paper with E. Camrud, D. Herzog and G. Stoltz. If time permits, we will mention related open problems.

Generative Adversarial Networks (GANs): Game and Control Perspectives

Xin Guo
Department of IEOR, University of California, Berkeley

Generative Adversarial Network (GANs) have enjoyed great successes in computer vision and image generation, and more recently in mathematical finance for its capability of financial data generation and computing solutions for high dimensional mean-field games.

Despite these empirical successes of GANs, GANs training, usually via the stochastic gradient approach, has been challenging, especially in terms of its stability and convergence. In this talk, we discuss the game structure of GANs in a stochastic differential equation framework, and present our latest work using the control approach to analyze the stability of GANs training. Based on joint work with Haoyang Cao of Alan Turing Institute and Othmane Mounjid of UC Berkeley.

Inverse Reinforcement Learning

Vikram Krishnamurthy
Department of Electrical & Computer Engineering, Cornell University

Inverse reinforcement learning aims to estimate the utility function of a decision maker by observing its decisions. This talk presents three approaches to inverse reinforcement learning. The first approach uses Afriat's theorem and Bayesian generalizations of revealed-preferences to reconstruct the utility function of a constrained Bayesian utility maximizer as a convex feasibility problem. The second approach uses passive Langevin dynamics to reconstruct utility functions given noisy gradient information. The third approach discusses inverse filtering problems - reconstructing the posterior given noisy information.

Stability of Coupled Jump Diffusions and Applications

Hai-Dang Nguyen
Department of Mathematics, University of Alabama

This work develops stability and stabilization results for systems of fully coupled jump diffusions. Such systems frequently arise in numerous applications where each subsystem (component) is operated under the influence of other subsystems (components). We derive sufficient conditions under which the underlying coupled jump diffusion is stable. The results are then applied to investigate the stability of linearizable jump diffusions, fast-slow coupled jump diffusions. Moreover, weak stabilization of interacting systems and consensus of leader-following systems are examined.

A Stochastic Maximum Principle for Forward-Backward Stochastic Control Systems with General Conditional Mean-Fields

Son Luu Nguyen

Department of Mathematics, University of Puerto Rico

In this talk, we investigate a recursive optimal control problem with regime-switching. The main feature is that general conditional mean-fields are used in the controlled forward-backward systems. Analysis of variational equations are carried out and the second-order expansions for both forward and backward equations are obtained using a new L_p estimate of conditional mean-field backward equations driven by discontinuous martingales and derivatives with respect to the measure. A necessary condition for the optimal control problem is proved without assuming the convexity of the control domain.

Stochastic domination of various orders and its applications in stochastic control

Oleksii Mostovyi

Department of Mathematics, University of Connecticut

In this talk, we will start by discussing the stochastic domination of various orders and provide its characterizations in terms of the appropriate class of test functions. The motivation for this work comes from the regularity analysis of the value function in Mayer's formulation of the optimal investment problem in general incomplete semimartingale settings. Here, we show that stochastic domination of the infinite order in the dual domain and complete monotonicity of the inverse marginals in the utility function allows for the analyticity of the value function. Two counterexamples of independent interest illustrate that analyticity fails if either of the conditions above is not satisfied. Finally, we show that for the dual domain of the optimal investment problem in Mayer's formulation, stochastic domination of infinite order is equivalent to the apparently stronger domination of the second order. This talk is based on the joint work with Mihai Sîrbu and Thaleia Zariphopoulou.

Hydrodynamic Limits of non-Markovian Interacting Particle Systems on Sparse Graphs

Kavita Ramanan

Division of Applied Mathematics, Brown University

We study empirical measures of a large system of (possibly non-Markovian) interacting jump processes in which the infinitesimal evolution of each particle depends on the states of neighboring particles with respect to a sparse underlying interaction graph. Such systems model a variety of applications in statistical physics, neuroscience and engineering. We show that when the sequence of graphs converges in a suitable sense to a limit graph, the corresponding sequence of empirical measures also converges weakly to a deterministic limit. We also provide counterexamples to show when this convergence could fail. These results can be seen as complementary to mean-field limits for interacting particles on complete (or sufficiently dense) graphs. This is based on joint work with A. Ganguly.

Coexistence and competitive exclusion in serial passage experiments

Sebastian J. Schreiber

Department of Evolution and Ecology, University of California, Davis

Serial passage is the successive transfer of a bacterial or viral populations through a series of cultures or experimental animals. This method was employed by Louis Pasteur to produce a rabies vaccine in the late 1800s. During serial passage, the population is grown in one environment, and then a portion of that population is removed and put into a new environment. Recently, these serial passage experiments have been used to understand the maintenance of genetic diversity due to fluctuating environments. In this talk, I will present preliminary results about a mathematical framework for understanding coexistence and extinction for stochastic, hybrid system models of serial passage experiments. Applications to two types of serial passage experiments will be given.

Time-triggered stochastic hybrid systems with two timer-dependent resets

Abhyudai Singh

Department of Electrical & Computer Engineering, University of Delaware

In this talk, I will present a class of time-triggered stochastic hybrid systems where the state-space evolves as per a linear time-invariant dynamical system. This continuous-time evolution is interspersed with two kinds of stochastic resets. The first reset occurs based on an internal timer that measures the time elapsed since it last occurred. Whenever the first reset occurs the states-space undergoes a random jump and the timer is reset to zero. The second reset occurs based on an arbitrary timer-depended rate, and whenever this reset fires, the state-space is changed based on a given random map. For this class of systems, we provide exact conditions that lead to finite statistic moments, and the corresponding exact analytical expressions for the first two moments. This framework is applied to study random fluctuations in the concentration of a protein in a growing cell. Our analysis provides closed-form formulas for the noise in the protein concentration and leads to a striking result-the noise in the protein concentration is invariant of the noise in the cell-cycle time.

Regime Switching Mean Field Games with Quadratic Costs

Qingshuo Song

Department of Mathematical Sciences, Worcester Polytechnic Institute

This paper studies Mean Field Games with a common noise given by a continuous time Markov chain under a Quadratic cost structure. The theory implies that the optimal path under the equilibrium is a Gaussian process conditional on the common noise. Interestingly, it reveals the Markovian structure of the random equilibrium measure flow, which can be characterized via a deterministic finite dimensional system

Optimal Fee Structure of Variable Annuities

Gu Wang

Department of Mathematical Sciences, Worcester Polytechnic Institute

We study the design of fee structures of variable annuities as a stochastic control problem, in which an insurer is allowed to choose the fee structure in any form that satisfies the budget constraint, and seeks an optimal one to maximize its business objective. Under the no surrender assumption, we show that the optimal fee structure is of barrier type with a time-dependent free boundary. The insurer's optimal strategy is to charge fees if and only if the account value of variable annuities hits the free boundary from below.

Stochastic Observability and State Estimation of Randomly Switched Unobservable Linear Systems

Le Yi Wang

Electrical & Computer Engineering, Wayne State University

This talk will present some recent results on observability and observer design for randomly switched linear systems in which subsystems may not be observable. We introduce switching speed conditions under which off-line collectively observable systems can support stochastic observability in real-time operation. Asymptotic observability of randomly switched linear systems is presented. Observer design for unobservable subsystems and their coordination algorithms are introduced. Convergence properties are established, including strong convergence and exponential convergence rate. Estimation error probabilities under finite data are derived by using large deviation principles.

Time-Inconsistent Optimal Control Problems with Equilibrium Recursive Cost Functionals

Jiongmin Yong

Department of Mathematics, University of Central Florida

This talk is concerned with a class of stochastic optimal control problems for stochastic differential equations with the cost functionals determined by backward stochastic Volterra integral equations. Such kind of problems are time-inconsistent, which means that an optimal control selected at given initial pair might not stay optimal afterwards. Therefore, instead of finding optimal controls for a given initial pair, one should find an equilibrium strategy which is time-consistent and locally optimal. Such a strategy can be determined by an equilibrium HJB equation. This is a joint work with Hanxiao Wang.

Stochastic Damping Hamiltonian Systems with State-Dependent Switching

Chao Zhu

Department of Mathematical Sciences, University of Wisconsin-Milwaukee

This work focuses on a class of stochastic damping Hamiltonian systems with state-dependent switching, where the switching process has a countably infinite state space. After establishing the existence and uniqueness of a global weak solution via the martingale approach under very mild conditions, we next establish the strong Feller property for regime-switching stochastic damping Hamiltonian systems by the killing technique together with some resolvent and transition probability identities. The commonly used continuity assumption for the switching rates $q_{kl}(\cdot)$ in the literature is relaxed to measurability in this work. Finally we provide sufficient conditions for exponential ergodicity and large deviations principle for regime-switching stochastic damping Hamiltonian systems. Several examples on regime-switching van der Pol and (overdamped) Langevin systems are studied for illustration.

Monotone Mean-Variance Portfolio Selection

Bin Zou

Department of Mathematics, University of Connecticut

We study a portfolio optimization problem for a representative investor with the monotone mean-variance preference in an incomplete financial market. The price processes of the risky assets are given by non-Markovian regime-switching models. We employ the theories of stochastic Hamilton-Jacobi-Bellman equations and backward stochastic differential equations (BSDEs) to solve the problem. We obtain the optimal investment strategy and the value function in semi-explicit forms, subject to the unique solution of a regime-switching BSDE. Moreover, we derive a continuous-time version of the efficient frontier and the capital asset pricing model under the monotone mean-variance preference. We show that the optimal strategy to the monotone mean-variance problem is the same as the pre-commitment strategy to the classical mean-variance problem from time zero, and vice versa. To illustrate our result, we obtain closed-form solutions in special path-dependent regime-switching models.