MTNS 2026

INTERNATIONAL SYMPOSIUM ON MATHEMATICAL THEORY OF NETWORKS AND SYSTEMS

AUG 17–21, 2026 · WATERLOO, CANADA

27th International Symposium on Mathematical Theory of Networks and Systems

August 17–21, 2026 · Waterloo, Ontario, Canada

Program Booklet

Hosted by

UNIVERSITY OF WATERLOO

FACULTY OF MATHEMATICS

In cooperation with

IFAC

INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

Welcome to MTNS 2026 from the General Chair

Dear MTNS 2026 participants,

It is my great pleasure to welcome you to the 27th International Symposium on Mathematical Theory of Networks and Systems.

Since its inception, MTNS has provided a home for researchers who believe that deep mathematical ideas are essential to understanding and shaping complex dynamical systems. Over the years, the conference has evolved alongside our discipline, continually embracing new challenges while remaining firmly rooted in the mathematical foundations that define network systems and control.

Today, our community stands at an exciting moment. The questions we face are becoming increasingly ambitious, driven by autonomous systems, artificial intelligence, large-scale interconnected networks, sustainable energy, cyber-physical infrastructures, biological systems, and scientific discovery itself. These challenges call for new mathematical frameworks that bring together systems and control theory with optimization, learning, networks, and other emerging areas. MTNS has long been a place where these communities come together, where ideas developed in one field inspire advances in another, and where new collaborations and research directions often begin and to help define the next chapter of our discipline.

Scientific conferences are ultimately about people. They provide a rare opportunity to meet colleagues from around the world, reconnect with longstanding collaborators, welcome newcomers to our community, and foster the exchange of ideas in an open and collegial atmosphere. I encourage you to take full advantage of both the technical program and the social events, which are designed to promote these interactions.

On behalf of the Organizing Committee, I would like to thank all authors, speakers, session organizers, reviewers, committee members, sponsors, volunteers, and participants whose dedication and enthusiasm have made MTNS 2026 possible.

I wish you an enjoyable, inspiring, and memorable conference, and I hope that the conversations begun here will lead to lasting collaborations and the next generation of ideas in mathematical systems and control.

Roberto Guglielmi
General Chair
MTNS 2026

Welcome to MTNS 2026 from the Program Chair

Dear MTNS 2026 participants,

We are delighted to present a program in the MTNS tradition, bringing together mathematicians, engineers, and scientists to discuss and explore the latest advances in systems and network theory.

The program includes four plenary talks, eight semi-plenary talks, 144 contributed talks, and ten invited sessions. In addition to the conference's traditional areas of focus—including operator theory, infinite-dimensional systems, optimization, networks, and graphs—this year's program places particular emphasis on learning-based and data-driven control, with several invited sessions and plenary and semi-plenary talks devoted to recent developments in these areas. Continuing a longstanding MTNS tradition, the program also includes a plenary talk in mathematics, delivered this year by Robert McCann of the University of Toronto.

This outstanding program was made possible by the hard work of many volunteers, including members of the Steering Committee and International Program Committee, as well as the external reviewers. Thank you for your essential contributions.

The University of Waterloo provides a wonderful academic environment in which to discuss, think, and learn. I hope you find MTNS 2026 engaging and rewarding, and that the week brings many stimulating discussions and new insights.

John W. Simpson-Porco
Program Chair
MTNS 2026

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MTNS History:

1973: College Park, Maryland, USA
1975: Montreal, Canada
1977: Lubbock, Texas, USA
1979: Delft, the Netherlands
1981: Santa Monica, California, USA
1983: Beer Sheva, Israel
1985: Stockholm, Sweden
1987: Phoenix, Arizona, USA
1989: Amsterdam, the Netherlands
1991: Kobe, Japan
1993: Regensburg, Germany
1996: St. Louis, Missouri, USA
1998: Padova, Italy
2000: Perpignan, France
2002: Notre Dame, Indiana, USA
2004: Leuven, Belgium
2006: Kyoto, Japan
2008: Blacksburg, Virginia, USA
2010: Budapest, Hungary
2012: Melbourne, Australia
2014: Groningen, Netherlands
2016: Minneapolis, USA
2018: Hong Kong
2020: Cambridge, UK (cancelled)
2022: Bayreuth, Germany
2024: Cambridge, UK

Useful Information:

(Maps can be found on the last pages of this booklet, further information can be found on the MTNS 2026 website: https://uwaterloo.ca/international-symposium-mathematical-theory-networks-systems)

Conference Venue

The conference will be held at the University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1, in the Mathematics and Computer (MC) and Davis Centre (DC) buildings.

Information for Speakers

All lecture rooms of the conference are equipped with HDMI connectivity. It is recommended that speakers use their own laptops for their presentations, and make sure to have suitable adapters for an HDMI cable. Slots are 25 minutes, so please aim to speak for 20 minutes to allow time for questions and handover to the next speaker.

Registration Desk

The registration desk will be located at the Welcome reception venue (Pearl Sullivan Engineering (E7) Event Space) on Sunday evening, as well as at the coffee breaks of the conference.

Wifi

The Eduroam wifi network is available through the University of Waterloo campus.

Coffee Breaks

Coffee and tea will be served in MC 3rd floor in front of the Coffee & Donuts (C&D) eatery in MC at the following times

- Monday: 10:00 – 10:30 a.m. and 3:00 – 3:30 p.m.
- Tuesday: 10:00 – 10:30 a.m. and 3:00 – 3:30 p.m.
- Wednesday: 10:00 – 10:30 a.m.
- Thursday: 10:00 – 10:30 a.m. and 3:00 – 3:30 p.m.
- Friday: 3:00 – 3:30 p.m.

Local Transportation

Grand River Transit is the public transit operator for the Region of Waterloo, Ontario. It operates daily bus serving across Waterloo and the University of Waterloo campus. single-ride tickets may be purchased at any ION-LRT station, or by using the GRT Pay app.

ION is Waterloo Region's light rail transit (LRT) system. It runs between Kitchener's Fairview Park Mall and Waterloo's Conestoga Mall, with stops at the University of Waterloo campus. ION trains connect passengers to the existing bus system (Grand River Transit), making it easy to travel across the region.

Parking

Information on parking on campus is available at the following link https://uwaterloo.ca/sustainable-transportation/lots-and-rates in the sections Visitor lots and Residence visitor parking.

Social Program:

Conference Events

Welcome Reception. Sunday, August 16, 2026, 6:00-10:00 p.m.
Pearl Sullivan Engineering (E7) Event Space.

Lunches. Monday to Friday, August 17-21, 2026, 12:40-2:00 p.m.
St. Jerome's Servery. Please note that food service ends at 1:45 p.m.

Conference Banquet. Thursday, August 20, 2026, 6:00-10:00 p.m.
Federation Hall.

Farewell Reception. Friday, August 21, 2026, 6:00-10:00 p.m.
M3 Atrium.

Social Activities on Wednesday Afternoon

Participation in the social activities requires advance registration through the conference registration system. Accompanying persons are welcome to join by purchasing an additional ticket in their name. An activity may be cancelled if the minimum number of participants is not reached. Registered participants will be notified in advance and offered the opportunity to select an alternative activity or receive a refund.

- **Option 1: Excursion to Niagara Falls - $60.** The tour is expected to last from 1:00 p.m. to 9:00 p.m. A comfortable coach bus will take participants from the conference venue to Niagara Falls. Transportation to and from the conference venue is included, and a lunch box will be provided. Participants will have free time for views, photographs, the promenade, and optional attractions such as a boat tour or the walk behind the Falls; admission tickets for attractions are purchased separately.

- **Option 2: Guided Tour of the Mennonite Countryside - $45.** The tour is expected to last from 2:00 p.m. to 5:30 p.m. Participants will discover the heritage of Waterloo Region through a guided tour of the local Mennonite countryside, including the community's history, traditions, lifestyle, and rural landscape. Transportation to and from the conference venue and the guided tour are included.

- **Option 3: Canoeing on the Grand River - $75.** The activity is expected to last from 2:00 p.m. to 6:00 p.m. Participants will canoe along the Grand River, one of Ontario's designated Canadian Heritage Rivers. The activity is suitable for participants with little or no canoeing experience. Transportation, canoe rental, paddles, safety equipment, and basic instruction are included.

Registration to the activities is available through the conference registration portal https://university-of-waterloo.myshopify.com/products/mathematical-theory-of-networks-and-systems-mtns-symposium

School on Port-Hamiltonian Systems – August 14-15, 2026

https://uwaterloo.ca/international-symposium-mathematical-theory-networks-systems/ph-school

Summary: This mini-course introduces the fundamentals of modelling with Port-Hamiltonian systems and highlights their application to controller and estimator design. It also provides an introduction to structure-preserving discretization techniques. Each lecture will be followed by an interactive session, allowing participants to implement and explore the concepts.

Venue: The school will be held on the campus of the University of Waterloo, August 14-15 just before MTNS.

Lectures:

- General introduction on modelling of physical systems by Port-Hamiltonian systems
- Controller design
- Infinite-dimensional systems (PDEs)
- Analysis, stability and boundary control of infinite dimensional Port-Hamiltonian systems
- Discretization and control of infinite dimensional Port-Hamiltonian systems
- Irreversible Port-Hamiltonian systems

Speakers:

- David del Rey Fernandez (Waterloo, Canada)
- Hannes Gernandt (Wuppertal, Germany)
- Birgit Jacob (Wuppertal, Germany)
- Yann Le Gorrec (Besancon, France)
- Alessandro Macchelli (Bologna, Italy)
- Hector Ramirez (Valparaiso, Chile)

Organizers: Birgit Jacob (University of Wuppertal, Germany) and Kirsten Morris (University of Waterloo, Canada)

MTNS 2026 Technical Program Monday August 17, 2026

Plenary	Session	Session	Session
09:00-10:00 MoP_PL **MC 2065** **Plenary: Enhancing Closed-Loop Analysis of Neural Network-Controlled Systems Using Quadratic Abstractions**			

Coffee Break: 10:00-10:30 a.m., MC 3rd floor

10:30-12:35 MoAM_SE1 **DC 1304** Data-Driven Learning and Control with Formal Guarantees I	**10:30-12:35 MoAM_SE2** **MC 4058** Structure-Exploiting Methods in Control: Cones, Positivity, and Sparsity	**10:30-12:35 MoAM_SE3** **MC 4045** Infinite Dimensional Systems Theory	**10:30-12:35 MoAM_SE4** **MC 5501** Stochastic Control and Estimation

Lunch: 12:40-2:00 p.m., St. Jerome's Servery

14:00-15:00 MoSP_SP1 **MC 2065** **Semi-Plenary: Relaxation of Contraction Theory in Dynamical Systems**		**14:00-15:00 MoSP_SP2** **MC 2066** **Semi-Plenary: Analysis and Control in Poroelastic Systems with Applications to Biomedicine**	

Coffee Break: 3:00-3:30 p.m., MC 3rd floor

15:30-17:35 MoPM_SE1 **DC 1304** Data-Driven Learning and Control with Formal Guarantees II	**15:30-17:35 MoPM_SE2** **MC 4058** Algebraic Systems Theory	**15:30-17:35 MoPM_SE3** **MC 4045** Modeling, Estimation, and Control of Infinite-Dimensional Systems	**15:30-17:35 MoPM_SE4** **MC 5479** Nonlinear Systems and Control

Welcome Reception: Sunday, August 16, 6:00-10:00 p.m., Pearl Sullivan Engineering (E7) Event Space

MTNS 2026 Technical Program Tuesday August 18, 2026

Plenary	Session	Session	Session
09:00-10:00 TuP_PL **MC 2065** **Plenary: PTNS: Phase Theory of Networks and Systems**			

Coffee Break: 10:00-10:30 a.m., MC 3rd floor

10:30-12:35 TuAM_SE1 **MC 4058** Learning and Control of Dynamical Systems I	**10:30-12:35 TuAM_SE2** **MC 5417** Operator Theory for Quantum Information I	**10:30-12:35 TuAM_SE3** **MC 5501** Control of Distributed Parameter Systems I	**10:30-12:35 TuAM_SE4** **MC 5479** On the Geometry of Optimal Transport and Its Application to Physics and Control

Lunch: 12:40-2:00 p.m., St. Jerome's Servery

14:00-15:00 TuSP_SP1 **MC 2065** **Semi-Plenary: Reinforcement Learning for Control: Convergence, Stability, Sample Complexity**		**14:00-15:00 TuSP_SP2** **MC 2066** **Semi-Plenary: Synthesis & Analysis Tools for Dynamic Games – Model Based, Data-Driven and Nonlinear Perspectives**	

Coffee Break: 3:00-3:30 p.m., MC 3rd floor

15:30-17:35 TuPM_SE1 **MC 4058** Learning and Control of Dynamical Systems II	**15:30-17:35 TuPM_SE2** **MC 5417** Operator Theory for Quantum Information II	**15:30-17:35 TuPM_SE3** **MC 5501** Control of Distributed Parameter Systems II	**15:30-17:35 TuPM_SE4** **MC 5479** Networked Control Systems

MTNS 2026 Technical Program Wednesday August 19, 2026

Plenary	Session	Session
09:00-10:00 WeP_PL **MC 2065** **Plenary: The Monopolist's Free Boundary Problem in the Plane: An Excursion into the Economic Value of Private Information**		

Coffee Break: 10:00-10:30 a.m., MC 3rd floor

10:30-12:35 WeAM_SE1 **MC 4021** Learning and Control of Dynamical Systems III	**10:30-12:35 WeAM_SE2** **MC 5417** Advances in Optimal Transport Theory and Its Applications	**10:30-12:35 WeAM_SE3** **MC 5501** Port-Hamiltonian Systems and Dissipativity

Lunch: 12:40-2:00 p.m., St. Jerome's Servery

Social activities on Wednesday afternoon; see Social Program for options, registration, and fees.

MTNS 2026 Technical Program Thursday August 20, 2026

Plenary	Session	Session	Session
09:00-10:00 ThP_PL **MC 2065** **Plenary: Notions of Resilience in Large-Scale Networks, with Applications to Distributed Coordination, Optimization, and Learning**			

Coffee Break: 10:00-10:30 a.m., MC 3rd floor

10:30-12:35 ThAM_SE1 **MC 4058** Control and Estimation of Infinite-Dimensional Systems I	**10:30-12:35 ThAM_SE2** **MC 4060** Optimal Control	**10:30-12:35 ThAM_SE3** **MC 4064** Systems on Graphs	**10:30-12:35 ThAM_SE4** **MC 5501** Linear Systems

Lunch: 12:40-2:00 p.m., St. Jerome's Servery

14:00-15:00 ThSP_SP1 **MC 2065** **Semi-Plenary: Finite Dimensional Feedback Controllers for Distributed Parameter Systems**		**14:00-15:00 ThSP_SP2** **MC 2066** **Semi-Plenary: Large-Scale Network Processes: Achieving Tractability Via Graph Limits**	

Coffee Break: 3:00-3:30 p.m., MC 3rd floor

15:30-17:35 ThPM_SE1 **MC 4058** Control and Estimation of Infinite-Dimensional Systems II	**15:30-17:35 ThPM_SE2** **MC 4060** Optimization: Theory and Algorithms	**15:30-17:35 ThPM_SE3** **MC 4064** Hybrid Systems and Discrete Event Systems

Conference Banquet: Thursday, August 20, 6:00-10:00 p.m., Federation Hall

MTNS 2026 Technical Program Friday August 21, 2026

Session	Session	Session
10:00-12:05 FrAM_SE1 **MC 4058** Infinite-Dimensional Port-Hamiltonian Systems I	**10:00-12:05 FrAM_SE2** **MC 4060** Machine Learning and Control	**10:00-12:05 FrAM_SE3** **MC 4064** Robust and H-Infinity Control

Lunch: 12:40-2:00 p.m., St. Jerome's Servery

14:00-15:00 FrSP_SP1 **MC 2065** **Semi-Plenary: Physics-Informed Neural Certificates for Stability and Control**	**14:00-15:00 FrSP_SP2** **MC 2066** **Semi-Plenary: Control by Interconnection of Irreversible Port-Hamiltonian Systems**

Coffee Break: 3:00-3:30 p.m., MC 3rd floor

15:30-17:35 FrPM_SE1 **MC 4058** Infinite-Dimensional Port-Hamiltonian Systems II	**15:30-17:35 FrPM_SE2** **MC 4060** Collective Dynamics and Scalability in Multi-Agent Control Systems	**15:30-17:35 FrPM_SE3** **MC 4064** System Identification

Farewell Reception: Friday, August 21, 6:00-10:00 p.m., M3 Atrium

Plenary and Semi-Plenary Speakers

Plenary Lecture:

Sophie Tarbouriech (CNRS - Toulouse)

Title: Enhancing Closed-Loop Analysis of Neural Network-Controlled Systems Using Quadratic Abstractions

Abstract:

This presentation introduces an approach that leverages the known properties of isolated nonlinearities-referred to as quadratic abstractions-to analyze the closed-loop behavior of dynamical systems, including stability, performance, and robustness. Different ways to reduce the conservatism inherent in traditional quadratic abstraction methods are also proposed. This framework is particularly effective for analyzing activation functions in neural network architectures, such as multilayer perceptrons (MLPs), when used to control dynamical systems, offering a robust tool for closed-loop analysis.

The proposed methodology relies on Lyapunov functions, which can be either standard quadratic or sign-indefinite quadratic forms. The latter incorporates an extended quadratic structure to further mitigate conservatism, enhancing the accuracy and applicability of the analysis. By incorporating sign-indefinite quadratic Lyapunov functions with extended quadratic structures, our methodology not only mitigates conservatism but also enhances the accuracy and applicability of the analysis, paving the way for more reliable neural network-controlled systems.

Bio:

Sophie Tarbouriech received the Ph.D. degree in Control Theory in 1991 and the HDR degree (Habilitation à Diriger des Recherches) in 1998 from University Paul Sabatier, Toulouse, France. Currently, she is a Senior Researcher at CNRS and a member of LAAS- CNRS, Toulouse. Her main research interests include analysis and control of linear and nonlinear systems with constraints and hybrid dynamical systems. She is currently a recipient of the AFSR (French-Swedish Research Association) fellowship in collaboration with KTH, Sweden (2025-2026). She is Editor-in-Chief for Automatica since January 2026. She is an IFAC Pawel J. Nowacki Distinguished Lecturer (2023-2026), IEEE Fellow and IFAC Fellow. She served on the organizing committee and TPC of several IEEE and IFAC conferences, including being Publication Chair for IFAC World Congress in 2017, Program Chair for CDC 2024, Vice-program Chair for MICNON 2024 and will be Vice-program Chair for ECC 2027.

Plenary Lecture:

Li Qiu (The Chinese University of Hong Kong, Shenzhen)

Title: PTNS: Phase Theory of Networks and Systems

Abstract:

The phase or argument of a complex number is an elementary yet important concept, essential to almost all scientific disciplines. In SISO signal and system theory the concept of phase used to play an extremely important role. What are the phases of a complex square matrix? The answer does not seem to be unique. In this presentation, we will examine three different definitions: the principal phases (40 year old), the sectorial phases (6 year old), and the segmental phases (new born). We will compare the properties of these phase notions and use them to estimate the eigenvalue phase angles. We will also examine a network and system theory based on the phases, complementing and interconnecting with the existing gain (magnitude, singular value) based theory.

Bio:

Prof. Li Qiu received his Ph.D. degree in electrical engineering from the University of Toronto in 1990. After briefly working in the Canadian Space Agency, the University of Waterloo, and the University of Minnesota, he joined the Hong Kong University of Science and Technology in 1993 and is now a Professor Emeritus in Electronic and Computer Engineering. In September 2024, he started working in the Chinese University of Hong Kong, Shenzhen, as a Presidential Chair Professor.

Prof. Qiu's research interests include system, control, optimization theory, and mathematics for information technology, as well as their applications in manufacturing industry and energy systems. He served as an associate editor of the IEEE Transactions on Automatic Control and Automatica. He was the general chair of the 7th Asian Control Conference, which was held in Hong Kong in 2009. He was a Distinguished Lecturer from 2007 to 2010 and was a member of the Board of Governors in 2012 and 2017 of the IEEE Control Systems Society. He was the founding chairperson of the Hong Kong Automatic Control Association and a vice president of Asian Control Association. He is a Fellow of IEEE, a Fellow of IFAC, and an inaugural Fellow of Asian Control Association (ACA).

Plenary Lecture:

Robert McCann (University of Toronto)

Title: The monopolist's free boundary problem in the plane: an excursion into the economic value of private information

Abstract:

The principal-agent problem is an important paradigm in economic theory for studying the value of private information: the nonlinear pricing problem faced by a monopolist is one example; others include optimal taxation and auction design. For multidimensional spaces of consumers (i.e. agents) and products, Rochet and Chone (1998) reformulated this problem as a concave maximization over the set of convex functions, by assuming agent preferences are bilinear in the product and agent parameters. This optimization corresponds mathematically to a convexity-constrained obstacle problem. The solution is divided into multiple regions, according to the rank of the Hessian of the optimizer.

Apart from four possible pathologies, if the monopolists costs grow quadratically with the product type we show that a smooth free boundary delineates the region where it becomes efficient to customize products for individual buyers. We give the first complete solution of the problem on square domains, and discover new transitions from unbunched to targeted and from targeted to blunt bunching as market conditions become more and more favorable to the seller.

Based on works-in-progress including https://arxiv.org/abs/2412.15505

with Lucas O'Brien (MIT), Cale Rankin (Monash University) and Kelvin Shuangjian Zhang (Fudan University) in various combinations.

Bio:

Robert John McCann is a Canadian mathematician known for his work on optimal transportation and its applications. McCann studied engineering and physics at Queen's University before graduating with a degree in math, and earned a PhD in mathematics from Princeton University in 1994. He was a Tamarkin Assistant Professor at Brown University from 1994, before joining the University of Toronto Department of Mathematics in the fall of 1998. There he currently holds a Canada Research Chair in Mathematics, Economics, and Physics. He was an invited speaker at the International Congress of Mathematicians in Seoul in 2014, and was elected a Fellow of the American Mathematical Society in 2012, of the Royal Society of Canada in 2014, of the Fields Institute in 2015 and of the Canadian Mathematical Society in 2020. His recent awards include SIAM's WT & Idalia Reid Prize (2023), the AMS/SIAM Norbert Wiener Prize in Applied Mathematics (2025), and the CRM-Fields-PIMS Prize of the three Canadian Math Institutes (2026). His current interests include the regularity and free boundaries in optimal transport, the economics of asymmetric information, and the development of a new nonsmooth geometry for Einstein's theory of gravity.

Plenary Lecture:

Shreyas Sundaram (Purdue University)

Title: Notions of Resilience in Large-Scale Networks, with Applications to Distributed Coordination, Optimization, and Learning

Abstract:

A key challenge in large-scale networks is to allow each agent to learn the true state of the world, based on its own measurements and information that it obtains from others in the network. For example, in autonomous swarms and sensor networks, what information should the agents (drones and sensors) exchange with each other in order for the swarm to understand its environment? Similarly, in social networks, how should individuals incorporate the opinions of their friends when updating their own beliefs about the world? The challenge of learning in such settings is made even more difficult when malicious agents in the network spread misinformation to prevent the other agents from learning the true state.

In this talk, we will provide an overview of classes of networked dynamics (or algorithms) that have been studied over the past decade for resilient coordination and learning in networks. In particular, we will describe a simple general-purpose approach to enabling resilience to adversarial nodes in several classes of distributed coordination and optimization dynamics, based on each node removing a certain number of the most extreme values in its neighborhood at each time-step. In the process, we will identify key insights about the interplay between network topology and dynamics in the context of creating more resilient networked systems.

Bio:

Shreyas Sundaram is the Marie Gordon Professor in the Elmore Family School of Electrical and Computer Engineering at Purdue University, and Co-Director of the Institute for Control, Optimization and Networks (ICON). He received his Ph.D. in Electrical Engineering from the University of Illinois at Urbana-Champaign in 2009, and was a Postdoctoral Researcher at the University of Pennsylvania from 2009 to 2010. He was an Assistant Professor at the University of Waterloo from 2010 to 2014. His research interests include control of distributed and multi-agent systems, fault-tolerant and secure control, game theory, and network science. Dr. Sundaram is a recipient of the National Science Foundation CAREER award, and the Intel Outstanding Researcher Award. At Purdue, he received the Dean A. A. Potter Award for Teaching Excellence, the Dean H. T. Yang Leadership in Service Award, the HKN Outstanding Professor Award, the Outstanding Mentor of Engineering Graduate Students Award, the Hesselberth Award for Teaching Excellence, and the Ruth and Joel Spira Outstanding Teacher Award.

Semi-Plenary Lecture:

Daniele Astolfi (CNRS - Lyon)

Title: relaxation of contraction theory in dynamical systems.

Abstract:

Classical contraction theory is a well-established framework for analyzing nonlinear dynamics, with numerous applications in control thery. However, its strict requirements can often limit its practical applicability. This semi-plenary explores two relaxations of the contraction definition. First, we examine the transition from Incremental Global Exponential Stability to Incremental Global Asymptotic Stability. While relaxing the exponential bound provides theoretical flexibility, recent topological insights indicate that these two notions often coincide globally. Consequently, this relaxation, although analytically rigorous, results in a relatively minor shift in practical system behavior. Next, we explore the concept of k-contraction, which generalizes standard distance convergence to the shrinkage of k-dimensional volumes. We will briefly review existing analysis results before presenting recent developments in k-contraction theory.

Specifically, we will show how to derive sufficient conditions that avoid the use of compound matrices, thereby enabling the systematic design of k-contractive controllers.

Bio:

Daniele Astolfi obtained a joint Ph.D. degree in Control Theory from the University of Bologna, Italy, and from Mines ParisTech, France, in 2016. For his doctoral work, he was awarded the Best Italian PhD Thesis in Control by SIDRA in 2016. Since 2018, he has been a CNRS Researcher at LAGEPP, Lyon, France. His research interests include observer design, feedback stabilization and output regulation for nonlinear systems, networked control systems, hybrid systems, and multi-agent systems. He is a IEEE Senior Member since 2026 and actively contributes to the editorial community, serving as an Associate Editor for the IFAC journal Automatica since 2018 and for the European Journal of Control since 2023.

Semi-Plenary Lecture:

Lorena Bociu (North Carolina State University)

Title: Analysis and Control in Poroelastic Systems with Applications to Biomedicine

Abstract:

In biomechanics, local phenomena, such as tissue perfusion, are strictly related to the global features of the surrounding blood circulation. We propose a heterogeneous model where a local, accurate, 3D description of fluid flows through deformable porous media by means of poroelastic systems is coupled with a systemic 0D lumped model of the remainder of the circulation. This represents a multiscale strategy, which couples an initial boundary value problem to be used in a specific region with an initial value problem for the rest of the circulatory system. We present new results on wellposedness analysis, optimal control and solution methods for this nonlinear multiscale interface coupling of PDEs and ODEs. Our results have applications in biomedicine and bioengineering, including tissue perfusion, fluid flow inside cartilages and bones, and design of bioartificial organs.

Bio:

Lorena Bociu is a Professor and Associate Department Head in the Department of Mathematics at NC State University. She works in analysis, optimization, and control of partial differential equations, focusing on nonlinear structural acoustics, fluid-structure interactions, and fluid-solid mixtures. Professor Bociu received a NSF CAREER Award in 2016 and a Presidential Early Career Award in Sciences and Engineering (PECASE) in 2019. She has been a NC State Faculty Scholar since 2016. Professor Bociu is the Chair of the Working Group 7.2 (Computational Techniques in Distributed Systems) as part of IFIP TC 7 and was Chair of the SIAM Activity Group on Control and Systems Theory, 2024-2025. She is also on the Steering Committee for the AWM Research Network Women in Control (WIC). Professor Bociu is a Managing Editor for Networks and Heterogeneous Media, and an Associate Editor for the SIAM Journal on Control and Optimization (SICON), the Journal of Mathematical Analysis and Applications (JMAA), and Evolution Equations and Control Theory (EECT) Journal.

Semi-Plenary Lecture:

Bahman Gharesifard (Queen's University)

Title: Reinforcement Learning for Control: Convergence, Stability, Sample Complexity

Abstract:

I discuss a cohesive dynamical systems view of reinforcement learning as a methodology for feedback control, organized around three central questions: when learning dynamics converge, when the resulting closed loop remains stable, and how much data is required to achieve reliable performance. I present a high-level synthesis of how these strands fit together into a principled foundation for reinforcement learning in control, and highlight a few open challenges and directions.

Bio:

Bahman Gharesifard is a Professor with the Department of Mathematics and Statistics at Queen's University. He was a Professor with the Electrical and Computer Engineering Department at the University of California, Los Angeles from 2021 to 2024, where he was the Area Director for Signals and Systems 2023-2024. He was an Alexander von Humboldt research fellow with the Institute for Systems Theory and Automatic Control at the University of Stuttgart in 2019-2020. He held postdoctoral positions with the Coordinated Science Laboratory at the University of Illinois at Urbana-Champaign from 2012-2013 and with the Department of Mechanical and Aerospace Engineering at University of California, San Diego 2009-2012. He received the 2019 CAIMS-PIMS Early Career Award, an Alexander von Humboldt Foundation research fellowship for experienced researchers in 2019, an NSERC Discovery Accelerator Supplement in 2019, the SIAG/CST Best SICON Paper Prize in 2021, and the Canadian Society for Information Theory Best Paper Award in 2022, and the 2024 CSS TC on Robust and Complex Systems Outstanding Student Paper Prize. He is a Senior Member of IEEE and has served on the Conference Editorial Board of the IEEE Control Systems Society, IEEE Control System Letters, and IEEE Transactions on Network Control Systems.

Semi-Plenary Lecture:

Thulasi Mylvaganam (Imperial College London)

Title: Synthesis & Analysis Tools for Dynamic Games - Model Based, Data-Driven and Nonlinear Perspectives

Abstract:

Dynamic games provide a powerful framework for modeling interactions between multiple decision-makers. However, as infinite-dimensional problems, they are notoriously difficult to solve, and the coupling between players can generate emergent behaviours that are difficult to predict. In this talk, we will revisit some basics of dynamic games and (single-player) optimal control. Then, starting with the class of Linear Quadratic dynamic games, we will present iterative algorithms for obtaining feedback Nash equilibrium solutions that are amenable to both model-based and data-driven implementations. Turning our attention to general, nonlinear dynamic games we will then demonstrate how feedback Nash equilibria can be characterised in terms of invariant manifolds of a certain "lifted" dynamical system. This geometric perspective - analogous to the state/costate dynamics associated with Pontryagin's Minimum Principle (e.g. in the context of optimal control and open-loop Nash equilibria of dynamic games) - offers two key advantages. First, it allows us to recast the problem of obtaining feedback Nash equilibria as a static optimisation problem, which lays the basis for novel computational strategies, e.g. based on gradient-descent algorithms. Second, it provides a framework to analyse interactions between players in terms of energy exchange.

Bio:

Thulasi Mylvaganam received the M.Eng. degree in Electrical and Electronic Engineering and the Ph.D. degree in Nonlinear Control and Differential Games from Imperial College London, London, U.K., in 2010 and 2014, respectively. From 2014 to 2016, she was a Research Associate with the Department of Electrical and Electronic Engineering, Imperial College London. From 2016 to 2017, she was a Research Fellow with the Department of Aeronautics, Imperial College London, UK, where she is currently Associate Professor. Her research interests include nonlinear control, optimal control, game theory, distributed control and data-driven control. She is Associate Editor of the IEEE Control Systems Letters, of the European Journal of Control, of the IEEE CSS Conference Editorial Board and of the EUCA Conference Editorial Board. She is also Vice Chair of Education for the IFAC Technical Committee 2.4 (Optimal Control) and Member of the UKACC Executive Committee.

Semi-Plenary Lecture:

Hitay Ozbay (Bilkent University)

Title: Finite Dimensional Feedback Controllers for Distributed Parameter Systems

Abstract:

There are primarily two ways to obtain finite-dimensional stabilizing controllers for LTI infinite-dimensional systems: (i) approximate the plant transfer function, then design a rational controller for the approximant; (ii) design an infinite-dimensional controller for the original distributed parameter system, then approximate this controller. In both methods, approximation errors affect the robust stability and performance of the feedback system. In this talk, we discuss these methods and illustrate them on some typical examples. For method (i), we use H-infinity controllers to guarantee robust stability; for method (ii), we study the effects of approximating the infinite-dimensional stable part of a specific type of controller introduced recently.

Bio:

Hitay Özbay is a Professor of Electrical and Electronics Engineering at Bilkent University, Ankara, Turkey. He received the B.Sc., M.Eng., and PhD degrees from Middle East Technical University (1985), McGill University (1987), and the University of Minnesota (1989), respectively. His prior academic affiliations include the University of Rhode Island (1989-1990) and The Ohio State University (1991-2006), where he was a Professor of Electrical and Computer Engineering before joining Bilkent University. He also held visiting professor positions at INRIA, France (2009-2010) and at the University of California, Davis (2024-2025). Professor Özbay was a member of the Board of Governors of the IEEE Control Systems Society (2017-2019) and a general assembly member of the European Control Association (EUCA), representing Turkey (2013-2019). He served as Associate Editor for many journals, including IEEE Transactions on Automatic Control, SIAM Journal on Control and Optimization, and Automatica. He also served as Vice-Chair of IFAC Technical Committees on Networked Control Systems (2005-2011) and Linear Control Systems (2017-2023). He is a Fellow of IEEE.

Semi-Plenary Lecture:

Francesca Parise (Cornell University)

Title: Large-Scale Network Processes: Achieving Tractability via Graph Limits

Abstract:

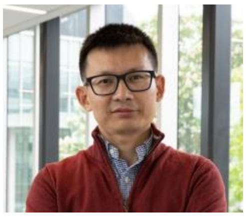
Network dynamical systems provide a versatile framework for studying the interplay between the structure of complex networks and the dynamic behavior of its constituent entities, offering insights into diverse phenomena across disciplines such as physics, biology, sociology, and engineering. As the size of the underlying network increases, however, a number of new challenges arise. For example, collecting exact network data may become too costly and planning optimal network interventions may become computationally intractable. In this talk I will show how the theory of graph limits can be used to provide new insights on graph processes evolving over large random networks. First, I will illustrate how graph limits can be used to define tractable infinite population models of network systems while maintaining agents' heterogeneity. Second, I will illustrate how insights derived for such infinite population models can be applied to study large but finite networks. The benefit of this graph limit approach will be demonstrated for broad classes of network processes including strategic interactions, multi-agent learning and synchronization dynamics.

Bio:

Francesca Parise is an Assistant Professor in the School of Electrical and Computer Engineering at Cornell University. Before joining Cornell in July 2020, she was a postdoctoral researcher at the Laboratory for Information and Decision Systems at MIT. She defended her PhD at the Automatic Control Laboratory, ETH Zurich, Switzerland in 2016 and she received the B.Sc. and M.Sc. degrees in Information and Automation Engineering in 2010 and 2012, from the University of Padova, Italy, where she simultaneously attended the Galilean School of Excellence. Her research focuses on analysis and control of large multi-agent systems, with application to transportation, energy, social and economic networks.

Francesca is the recipient of the NSF CAREER award, the 2024 AFOSR YIP, the Michael Tien '72 teaching award from Cornell University, the SNSF Early and Advanced Postdoc Fellowship, the ETH Medal and the Guglielmo Marin award from the "Istituto Veneto di Scienze, Lettere ed Arti".

Semi-Plenary Lecture:



Jun Liu (University of Waterloo)

Title: Physics-Informed Neural Certificates for Stability and Control

Abstract:

Neural networks are universal approximators, yet learned models rarely come with rigorous guarantees. Typical statistical learning generalization bounds are often too conservative, and such probabilistic guarantees fail to certify correctness of a specific computed solution.

In this talk, we present a formal verification framework that produces a posteriori error estimates for neural network solutions of partial differential equations (PDEs) arising in systems and control. We aim to provide rigorous guarantees for the learned models rather than mere probabilistic guarantees on the PDE residuals. The framework connects machine learning with rigorous control theory by turning physics-informed neural models into certifiable computational tools.

More specifically, we study PDE characterizations that arise in stability and contraction analysis, control synthesis, and estimation for nonlinear dynamical systems. By combining formal verification tools with theoretically derived estimates, we rigorously bound approximation errors and translate these bounds into provable guarantees of stability and safety. The resulting neural certificates enable verification of regions of attraction, construction of provably correct stabilizing neural feedback controllers, and design of neural state estimators with provable error bounds.

Bio:

Jun Liu received the B.S. degree in applied mathematics from Shanghai Jiao-Tong University in 2002, the M.S. degree in mathematics from Peking University in 2005, and the Ph.D. degree in applied mathematics from the University of Waterloo in 2011. Following an NSERC Postdoctoral Fellowship in Control and Dynamical Systems at Caltech, he became a Lecturer in Control and Systems Engineering at the University of Sheffield in 2012. He joined the Faculty of Mathematics of the University of Waterloo in 2015, where he is currently a Professor of Applied Mathematics and directs the Hybrid Systems Laboratory. Dr. Liu's main research interests are in the theory and applications of hybrid systems and control, including rigorous computational methods for control design with applications in cyber-physical systems and robotics. He was awarded a Marie-Curie Career Integration Grant from the European Commission in 2013, a Canada Research Chair from the Government of Canada in 2017 and 2022, an Early Researcher Award from the Ontario Ministry of Research, Innovation and Science in 2018, and an Early Career Award from the Canadian Applied and Industrial Mathematics Society and Pacific Institute for the Mathematical Sciences in 2020. His best paper awards include the Zhang Si-Ying Outstanding Youth Paper Award, the Nonlinear Analysis: Hybrid Systems Paper Prize, and the Oded Maler Award. Dr. Liu is a senior member of IEEE, a member of SIAM, and a lifetime member of CAIMS. He has served as the Chair of the IEEE Control Systems Society Technical Committee on Hybrid Systems, as the Vice Chair of the SIAM Control and Systems Theory Activity Group, and on the editorial boards and program committees of several journals and conferences, including Automatica, Systems & Control Letters, and Nonlinear Analysis: Hybrid Systems.

Semi-Plenary Lecture:

Hector Ramirez Estay (Technical University Federico Santa Maria)

Title: Control by interconnection of irreversible port-Hamiltonian systems

Abstract:

Irreversible port-Hamiltonian systems (IPHS) provide a thermodynamically consistent framework for modeling multi-physical processes in which thermal phenomena play a central role. While classical passivity-based control methods have been extensively developed for reversible mechanical and electrical systems, extending these techniques to irreversible systems introduces new challenges due to the presence of entropy dynamics and the co-energy dependence of the structure matrices.

In this talk, we present a systematic control-by-interconnection methodology for IPHS that enables energy shaping and entropy assignment through modulated output feedback. A central ingredient is the identification of closed-loop invariant functions, analogous to Casimir functions in standard port-Hamiltonian theory, which allow the closed-loop Hamiltonian to coincide with thermodynamic availability functions. This provides physically meaningful Lyapunov candidates and preserves the energy-entropy structure of the system.

The methodology will be illustrated on two representative examples: a continuous stirred tank reactor and a gas-piston system. In both cases, the closed-loop system exhibits asymptotic stabilization while respecting first- and second-law constraints, and the approach naturally decouples thermodynamic and mechanical domains when appropriate. Beyond these case studies, the results highlight how irreversible thermodynamics, geometric modeling, and passivity-based control can be brought together to address complex open systems with thermal interactions.

Bio:

Hector Ramirez (born in Tomé, Chile, 1981) is an Associate Professor in the Department of Electronic Engineering at Universidad Técnica Federico Santa María (UTFSM) in Valparaíso, Chile, where he also serves as Director of the Advanced Center for Electrical and Electronic Engineering (AC3E). He received his Engineering degree in Electronic Engineering and M.Sc. in Electrical Engineering from the University of Concepción (Chile), and in 2012 earned dual Ph.D. degrees in Automatic Control from Claude Bernard University (Lyon, France) and in Electrical Engineering from the University of Concepción. In 2019 he obtained the French Habilitation (HDR) from the University of Bourgogne - Franche-Comté. Dr. Ramirez's research lies at the intersection of geometric control, port-Hamiltonian systems, nonlinear and distributed parameter systems, and the control of multi-physical processes. He has made significant contributions to irreversible port-Hamiltonian system theory, energy-based modeling, structure-preserving discretization, and stability analysis, with applications spanning thermo-electro-mechanical systems, fluid-structure interaction, and boundary control problems. Before joining UTFSM in 2018, he was Maître de Conférences at Université de Franche-Comté and a researcher at the Automatic Control and Micro-Mechatronic Systems department (AS2M) of FEMTO-ST in France. He has supervised numerous Ph.D. and M.Sc. students and taught advanced courses on port-Hamiltonian modeling, energy-based control, and distributed parameter systems in Chile and Europe. Dr. Ramirez is active in the international control community, serving on IFAC and IEEE CSS technical committees (Nonlinear Control Systems, Distributed Parameter Systems), on editorial and program committees for major conferences and workshops, and as Associate Editor for ACC, CDC, and specialist IFAC/IEEE workshops. His leadership at AC3E and his collaborations with global research centers reflect a commitment to advancing both theory and technology in control systems engineering.

Technical Program

Sessions, Speakers, Titles, and Abstracts

MoP_PL MC 2065

Plenary: Enhancing Closed-Loop Analysis of Neural Network-Controlled Systems Using Quadratic Abstractions (Plenary Session)

Chair: Gruene, Lars — University of Bayreuth

09:00-10:00 MoP_PL.1

*Plenary: Enhancing Closed-Loop Analysis of Neural Network-Controlled Systems Using Quadratic Abstractions**

Tarbouriech, Sophie — LAAS-CNRS

This presentation introduces an approach that leverages the known properties of isolated nonlinearities—referred to as quadratic abstractions—to analyze the closed-loop behavior of dynamical systems, including stability, performance, and robustness. Different ways to reduce the conservatism inherent in traditional quadratic abstraction methods are also proposed. This framework is particularly effective for analyzing activation functions in neural network architectures, such as multilayer perceptrons (MLPs), when used to control dynamical systems, offering a robust tool for closed-loop analysis.

The proposed methodology relies on Lyapunov functions, which can be either standard quadratic or sign-indefinite quadratic forms. The latter incorporates an extended quadratic structure to further mitigate conservatism, enhancing the accuracy and applicability of the analysis. By incorporating sign-indefinite quadratic Lyapunov functions with extended quadratic structures, our methodology not only mitigates conservatism but also enhances the accuracy and applicability of the analysis, paving the way for more reliable neural network-controlled systems.

MoAM_SE1 DC 1304

Data-Driven Learning and Control with Formal Guarantees I (Invited Session)

Chair: Liu, Jun — University of Waterloo
Co-Chair: Meng, Yiming — University of Waterloo
Organizer: Liu, Jun — University of Waterloo
Organizer: Meng, Yiming — University of Waterloo
Organizer: Prabhakar, Pavithra — The University of New Mexico
Organizer: Yong, Sze Zheng — Northeastern University

10:30-10:55 MoAM_SE1.1

Model-Free Linear Quadratic Regulator without an Initial Stabilizing Policy (I), pp. 1-4

Neshaei Moghaddam, Amirreza — University of California, Los Angeles
Olshevsky, Alex — Boston University
Gharesifard, Bahman — Queen's University

We introduce a model-free receding-horizon algorithm for the discrete-time Linear Quadratic Regulator problem with infinite-horizon cost and unknown dynamics. Inspired by REINFORCE, our approach uses a gradient estimation technique that avoids the impractical assumptions of commonly used two-point methods, while maintaining the same order of sample complexity. In particular, these methods require access to zero-order evaluations for different policies driven by identical randomness, an assumption that is completely avoided in our work. Moreover, the receding-horizon structure of the algorithm removes the need for prior knowledge of an initial stabilizing policy, a ubiquitous requirement in existing literature. Beyond these improvements, we provide a refined analysis of error propagation by exploiting the contraction of the Riccati operator under the Riemannian distance, leading to better sample complexity rates and convergence guarantees.

10:55-11:20 MoAM_SE1.2

The Semidefinite Programs for Direct Data-Driven LQR Are Sensitive to Noise (I), pp. 5-6

Zeng, Xiong — University of Michigan
Ozay, Necmiye — University of Michigan

This extended abstract presents a negative result for the direct data-driven parametrization used for linear quadratic regulator (LQR) problem and the corresponding semi-definite program (SDP). While this SDP is shown to lead to correct LQR gains when the input-state data from the system is noise free, we show that it has a trivial solution with probability one whenever the system is subject to process or measurement noise. We also discuss why certain types of regularization do not mitigate this problem.

11:20-11:45 MoAM_SE1.3

Spectral Koopman Operator Theoretic Methods for Data-Driven Estimation and Control in Dynamical Systems (I), pp. 7-9

Vaidya, Umesh — Clemson University

In this extended abstract, we present results on a unified operator-theoretic framework for both emph{nonlinear optimal control} and emph{nonlinear state estimation}. We show that the solution to both these problems can be reduced to the solution of a Hamilton--Jacobi (HJ) equation, and that both problems admit an efficient emph{quadratic parameterization} in emph{Koopman eigenfunction coordinates}. The results presented in this extended abstract are reported from cite{vaidya_KoopmanspectrumTAC}cite{vaidya_Koopmanestimation}. The main idea is to (i) construct a low-dimensional Koopman coordinate map using principal eigenfunctions of the (open-loop) dynamics, (ii) parameterize the HJ value function quadratically in these Koopman coordinates, and (iii) compute the quadratic parameters through Riccati-type differential equations. The Koopman eigenfunctions are computed independently from the open-loop dynamics using a path-integral (Monte Carlo) procedure, which leads to a separation principle not only between estimation and control, but also at the level of value-function construction: the Riccati equations for the quadratic parameters can be solved separately from the Koopman eigenfunctions, which are reusable across multiple objectives.

11:45-12:10 MoAM_SE1.4

Extended Abstract: Learning Continuous-Time Governing Equations Via Koopman Resolvents (I), pp. 10-12

Meng, Yiming — The Hong Kong University of Science and Technology (Guangzhou)

A semigroup characterization, equivalently, a characterization via the generator, is a classical framework for describing continuous-time nonlinear dynamical systems. In a datadriven setting, learning an unknown nonlinear system amounts to estimating the generator of the semigroup of its Koopman operators from discrete-time observations and establishing convergence to the true generator in an appropriate sense. Existing methods either rely on accurate time-derivative estimation and therefore face limitations under restricted observation rates, or bypass derivative estimation by exploiting the logarithm of a Koopman operator, which is valid only on restrictive function spaces and depends on prior knowledge of spectral properties. In this extended abstract, we summarize the recent advances in Meng et al. (2026), which propose a resolvent-type generator learning method that relaxes observation-frequency requirements and constraints on the choice of observable functions.

12:10-12:35 MoAM_SE1.5

A Data-Driven Perspective on Geometric Conditions for Invariance (I), pp. 13-16

Strong, Amy — Duke University
Kashani, Ali — University of New Mexico
Danielson, Claus — University of New Mexico
Bridgeman, Leila — Duke University

Invariant sets are essential for ensuring safety, i.e. constraint adherence, of dynamical systems. With the increasing availability of sampled data from complex (and often unmodeled) systems, it is advantageous to leverage these data sets for control invariant set synthesis. This work will discuss the use of data to directly evaluate geometric conditions of invariance and synthesize positive and control invariant sets, without the benefit of a dynamical model. Beyond a data set and Lipschitz continuity, no additional information about the system is needed. A tree data structure partitioning the space is the crucial ingredient, enabling efficient set operations and construction of the invariant sets, while Lipschitz continuity is used to provide deterministic guarantees of invariance.

MoAM_SE2	MC 4058
Structure-Exploiting Methods in Control: Cones, Positivity, and Sparsity (Invited Session)	
Chair: Rantzer, Anders	Lund Univ
Organizer: Meijer, Tomas	Technische Universiteit Eindhoven
Organizer: Pates, Richard	Lund University
Organizer: Rantzer, Anders	Lund Univ

10:30-10:55 MoAM_SE2.1

Cholesky Factorisation, and Intrinsically Sparse Linear Quadratic Regulation (I), pp. 17-19

Adlercreutz, Julia — Lund University
Pates, Richard — Lund University

We classify a family of matrices of shift operators that can be factorised in a computationally tractable manner with the Cholesky algorithm. Such matrices arise in the linear quadratic regulator problem, and related areas. We use the factorisation to uncover intrinsic sparsity properties in the control laws for transportation problems with an underlying tree structure. This reveals that the optimal control can be applied in a distributed manner that is obscured by standard solution methods

10:55-11:20 MoAM_SE2.2

Estimation and Control on the Positive Cone (I), pp. 20-23

Ohlin, David — Lund University
Rantzer, Anders — Lund Univ
Tegling, Emma — Lund University

This abstract shows that positive linear systems can be stabilized using positive Luenberger-type observers. This is achieved by structuring the observer as monotonically converging upper and lower bounds on the state. Analysis of the closed-loop properties under linear observer feedback gives conditions that cover a larger class than previous observer designs. The results are applied to nonpositive systems by enforcing positivity of the dynamics using feedback from the upper bound observer. The setting is expanded to include stochastic noise, giving conditions for convergence in expectation using feedback from positive observers.

11:20-11:45 MoAM_SE2.3

On the Stabilizability of Linear Systems on a Proper Cone (I), pp. 24-27

Vladu, Emil — Massachusetts Institute of Technology

This paper announces an equivalent condition for the notion of stabilizability on a cone, namely the solution to a conic inequality. This equivalence can be viewed as a generalization of a well-known stability result for unforced cone-preserving systems, and it collapses to a standard statement about stabilizing linear feedback in the case of the positive semidefinite cone. Of particular interest is the cone itself, which is constructed intuitively by stacking slices of a lower-dimensional cone: stabilizability then corresponds to stable closed-loop dynamics on these layers by means of linear feedback manifesting as an embedding of the latter cone into the former. This result along with its associated definitions is part of an ongoing effort to home in on and better understand certain cone analogs to some standard concepts and results in linear-quadratic theory.

MoAM_SE3	MC 4045
Infinite Dimensional Systems Theory (Regular Session)	
Chair: Baudouin, Lucie	LAAS-CNRS
Co-Chair: Singh, Shri Lal Raghudev Ram	University of Waterloo

10:30-10:55 MoAM_SE3.1

On the Asymptotic Behavior of Retarded Boundary Control Systems with Dynamic Boundary Conditions: Semigroup Approach, pp. 28-30

Budde, Christian — University of the Free State
Lasri, Marieme — University of the Free State

We investigate the exponential dichotomy of retarded-perturbed boundary control systems with dynamic boundary conditions. The perturbation consists of a delayed interior feedback term Lx_t and a coupling term Hx from the state to the boundary dynamics. Using the feedback theory of infinite-dimensional regular linear systems, we establish well-posedness of the system and prove that the associated semigroup is hyperbolic under suitable spectral conditions. Moreover, we study the robustness of exponential dichotomy under these perturbations. The theoretical findings are illustrated by a coupled ODE-transport PDE system.

10:55-11:20 MoAM_SE3.2

Exponential Output-To-State Stability of Linear Systems with Bounded Output Operators, pp. 31-36

Chen, Qiaoling — University of Passau
Mironchenko, Andrii — University of Bayreuth
Wirth, Fabian — University of Passau

For linear infinite-dimensional systems, exponential detectability is known to be stronger than exponential zero-detectability, and both these concepts are hard to extend to the nonlinear setting. In this work, we show that there is a broad hierarchy of detectability notions between these two concepts, centered around the concept of exponential output-to-state stability (eOSS). We study eOSS for linear infinite-dimensional systems with bounded output operators. It is shown that exponential detectability guarantees the existence of a coercive eOSS Lyapunov function and therefore eOSS. Several counterexamples demonstrate the fundamental differences between the detectability concepts employed in this work. However, if the system has only finitely many unstable eigenvalues, then all the concepts coincide. The results are illustrated with an example.

11:20-11:45 MoAM_SE3.3

Well-Posedness of a Passive Boundary Control System for Maxwell's Equations, pp. 37-38

Singh, Shri Lal Raghudev Ram — University of Waterloo
McNicol, Gordon Robert — University of Waterloo
Mora, Luis A. — University of Waterloo
Blankespoor, Devin — University of Waterloo
Morris, Kirsten A. — Univ. of Waterloo

We establish well-posedness of a passive boundary control system associated with Maxwell's equations. The analysis is based on trace spaces for curl-conforming vector fields, i.e., vector fields with square-integrable curl, together with operator-theoretic methods.

11:45-12:10 MoAM_SE3.4

Event-Triggered Controls in Abstract Setting, pp. 39-42

Baudouin, Lucie — LAAS-CNRS
Ervedoza, Sylvain — Universit ́e De Bordeaux

This work aims at providing a unified analysis of the exponential stabilization of some abstract infinite dimensional systems undergoing an event-triggering mechanism that samples the control input. The partial differential equation is supposed to be defined by a skew-adjoint operator and controlled and observed through bounded operators. The continuously controlled closed loop system is assumed to be exponentially stable and the goal is to prove that a well- designed event-triggering mechanism to rule the time updates of the sampled control will allow to keep such a stability property. The key of the proof relies on the existence of an adequate Lyapunov functional. Existence and regularity of the solution to the closed-loop event-triggered system are also proven, along with the avoidance of Zeno behavior.

MoAM_SE4	MC 5501
Stochastic Control and Estimation (Regular Session)	
Co-Chair: Trumpf, Jochen	The Australian National University

10:30-10:55	MoAM_SE4.1

Scalable Tensor GLRT for Massive MIMO Radar Target Detection, pp. 43-48

ALMUTAWA, Jaafar	Bahrain Polytechnic
Al-Hammali, Hussain	Alasala Colleges

We propose a tensor-based generalized likelihood ratio test (GLRT) for target detection in massive MIMO radar systems. Unlike conventional methods that vectorize multi-dimensional data and destroy the spatial-temporal-range structure, our approach operates directly on tensor-valued observations, exploiting their low-rank nature via canonical polyadic decomposition. The resulting detector achieves dramatic complexity reduction while retaining the optimality of conventional GLRT, enabling real-time processing for arrays with over one thousand antennas. Simulations confirm performance comparable to the optimal detector with orders-of-magnitude computational savings.

keywords: MIMO radar, tensor decomposition, GLRT, adaptive detection, massive arrays, canonical polyadic decomposition

10:55-11:20	MoAM_SE4.2

Stochastic Control Representation for the Schrodinger Equation with the Coulomb Potential, pp. 49-54

Zheng, Yifei	University of California San Diego
McEneaney, William	Univ of California, San Diego
Kaise, Hidehiro	Kumamoto University

A diffusion-based representation for the Maslov dequantization of the time-dependent Schrodinger equation is obtained, where the wave function corresponds to the statical value function of a complex-valued stochastic control problem. Whereas previous efforts along this line were restricted to holomorphic potentials, we here use an additional controller specifically constructed to generate the Coulomb potential via staticization. The solution to the Schrodinger equation is obtained from requantization of the representations. A demonstrative numerical example is included at the end.

11:20-11:45	MoAM_SE4.3

Scalable EM for High-Dimensional State Space Models Via Krylov Methods, pp. 55-60

ALMUTAWA, Jaafar	Bahrain Polytechnic

The Expectation-Maximization algorithm is fundamental for parameter estimation in state space models but becomes computationally intractable for high-dimensional systems due to cubic-complexity matrix operations. We develop a scalable variant that replaces direct linear solves with iterative Krylov subspace methods, achieving quadratic complexity per iteration. We establish convergence to stationary points under summable tolerance conditions, extending classical EM theory to accommodate controlled approximation errors. An adaptive tolerance schedule automatically adjusts solver precision as convergence progresses, requiring no problem-specific tuning. Warm-starting from previous iterates yields substantial computational savings. Experiments on high-dimensional tracking problems demonstrate order-of-magnitude speedups while preserving solution accuracy to machine precision.

11:45-12:10	MoAM_SE4.4

Improved Robustness of a Robot Pose Filter Using the Direct Product Geometry on SE(3), pp. 61-64

Trumpf, Jochen	The Australian National University
Zamani, Behzad	University of Melbourne

We apply a continuous discrete geometric approximate minimum energy filter design to the problem of estimating the pose (position and orientation) of a mobile robot moving in 3D space. The robot measures bearings to known landmarks in the environment and its own linear and angular velocities. We show that, surprisingly, the robustness of the resulting nonlinear deterministic filtering algorithm to different levels of initialization error heavily depends on the choice of Riemannian metric employed in the filter design. The obtained result is unintuitive since it turns out that endowing SE(3) with a direct product metric outperforms the a priori more natural choice of an invariant metric, pointing to an intriguing open question on quadratic approximation in-the-large of value functions defined on smooth manifolds.

MoSP_SP1	MC 2065
Semi-Plenary: Relaxation of Contraction Theory in Dynamical Systems (Plenary Session)	

14:00-15:00	MoSP_SP1.1

*Semi-Plenary: Relaxation of Contraction Theory in Dynamical Systems**

Astolfi, Daniele	CNRS - Univ Lyon 1

Classical contraction theory is a well-established framework for analyzing nonlinear dynamics, with numerous applications in control theory. However, its strict requirements can often limit its practical applicability. This semi-plenary explores two relaxations of the contraction definition. First, we examine the transition from Incremental Global Exponential Stability to Incremental Global Asymptotic Stability. While relaxing the exponential bound provides theoretical flexibility, recent topological insights indicate that these two notions often coincide globally. Consequently, this relaxation, although analytically rigorous, results in a relatively minor shift in practical system behavior. Next, we explore the concept of k-contraction, which generalizes standard distance convergence to the shrinkage of k-dimensional volumes. We will briefly review existing analysis results before presenting recent developments in k-contraction theory. Specifically, we will show how to derive sufficient conditions that avoid the use of compound matrices, thereby enabling the systematic design of k-contractive controllers.

MoSP_SP2	MC 2066
Semi-Plenary: Analysis and Control in Poroelastic Systems with Applications to Biomedicine (Plenary Session)	
Chair: Jacob, Birgit	Bergische Universität Wuppertal

14:00-15:00	MoSP_SP2.1

*Semi-Plenary: Analysis and Control in Poroelastic Systems with Applications to Biomedicine**

Bociu, Lorena	North Carolina State University

In biomechanics, local phenomena, such as tissue perfusion, are strictly related to the global features of the surrounding blood circulation. We propose a heterogeneous model where a local, accurate, 3D description of fluid flows through deformable porous media by means of poroelastic systems is coupled with a systemic 0D lumped model of the remainder of the circulation. This represents a multiscale strategy, which couples an initial boundary value problem to be used in a specific region with an initial value problem for the rest of the circulatory system. We present new results on wellposedness analysis, optimal control and solution methods for this nonlinear multiscale interface coupling of PDEs and ODEs. Our results have applications in biomedicine and bioengineering, including tissue perfusion, fluid flow inside cartilages and bones, and design of bioartificial organs.

MoPM_SE1	DC 1304
Data-Driven Learning and Control with Formal Guarantees II (Invited Session)	
Chair: Prabhakar, Pavithra	The University of New Mexico
Co-Chair: Liu, Jun	University of Waterloo
Organizer: Liu, Jun	University of Waterloo
Organizer: Meng, Yiming	University of Waterloo
Organizer: Prabhakar, Pavithra	The University of New Mexico
Organizer: Yong, Sze Zheng	Northeastern University

15:30-15:55 MoPM_SE1.1

Computable Error Bounds for Neural KKL Observers (I), pp. 65-68

Berin-Costain, Hannah — University of Waterloo
Wang, Zijin — University of Toronto
Liu, Jun — University of Waterloo
Morris, Kirsten A. — Univ. of Waterloo

Kazantzis-Kravaris/Luenberger (KKL) observers estimate the state of a nonlinear system by constructing an injective map that embeds the system state into a higher-dimensional observer state with linear, exponentially stable error dynamics. The corresponding inverse map then recovers the state estimate in the original coordinates. In practice, identifying a suitable transformation and its inverse remains a challenge. Recent work addresses this difficulty by approximating the forward map with a physics-informed neural network (PINN) and the inverse map with a conventional neural network. Although generalization bounds for these approximations have been derived, they depend on non-computable terms, and therefore do not yield concrete robustness guarantees. In this paper, we develop a computable estimation error certificate for learning-based KKL observers with the use of the neural network verification tool alpha beta-CROWN.

15:55-16:20 MoPM_SE1.2

Verifiably Safe and Fault-Tolerant Data-Driven Control (I), pp. 69-72

Cox, Jackson — Washington University in St. Louis
Jiang, Chuanrui — Washington University in St. Louis
Clark, Andrew — Washington University in St. Louis

Control Barrier Functions (CBFs) are a popular method to guarantee safety of autonomous systems, however, their safety guarantees can be invalidated by sensor faults that prevent the system from obtaining an accurate state estimate. In this paper, we introduce a sensor fault detection and mitigation algorithm to ensure safe operation of autonomous systems. Our approach is based on constructing a sequence of nested sets of state space, each with a corresponding CBF constraint, and proving that each set is invariant under a particular fault mode. Faults can then be detected and diagnosed by observing which invariance constraints are violated, effectively utilizing the CBFs as fault detectors. We present a loss-function construction for synthesizing data-driven fault-tolerant Neural CBFs and verify our results on unicycle obstacle avoidance.

16:20-16:45 MoPM_SE1.3

CAffNet: Guaranteed Constraint-Affine Neural Networks (I), pp. 73-76

Zhao, Yang — Northeastern University
Lee, Jungeun — Ulsan National Institute of Science and Technology
Jeon, Jeong hwan — Ulsan National Institute of Science and Technology
Yong, Sze Zheng — Northeastern University

We present a novel framework for embedding guaranteed constraint satisfaction into neural network (NN) architectures, specifically feedforward neural networks and transformers, with input-dependent affine constraints of arbitrary cardinality. Traditional constraint enforcement approaches either rely on penalty-based soft constraints, which offer no guarantee of satisfaction, or on post-processing methods that enforce constraints after the NN is trained, which may lead to suboptimality. We introduce a trainable constraint-affine (CAffine) layer into NNs, yielding CAffNet, which goes beyond enforcing affine constraints via fixed orthogonal or parallel projections and enables joint optimization with network parameters. Moreover, we impose no restrictions on the constraint space dimensions and establish that our construction preserves the universal approximation properties of NNs, while providing provable guarantees on constraint adherence for all inputs. Various simulations demonstrate guaranteed constraint satisfaction, including for enforcing control barrier function constraints for dynamical systems.

16:45-17:10 MoPM_SE1.4

Multilevel Control, Switching, and Expressivity in Learning Dynamics, pp. 77-78

Biccari, Umberto — University of Deusto
Zuazua, Enrique — Universidad Autónoma De Madrid

Many control systems are designed under with control signals continuous in time and amplitude. In applications, however, actuators often operate through finitely many admissible configurations combined with switching mechanisms. Motivated by this, we introduced the concept of ``multilevel control'', that is, piecewise constant in time controls taking values in a prescribed finite set. This multilevel structure is not imposed as a hard constraint, but rather encoded indirectly through nonsmooth convex penalties in the cost functional, allowing finite-valued and switching controls to emerge naturally from optimality conditions. This approach preserves the variational nature of the control problem and avoids the combinatorial complexity proper of switching optimization. This multilevel framework reveals deep connections with learning dynamics, particularly in the context of Neural Ordinary Differential Equations (Neural ODEs), where learning is naturally interpreted as a simulatneous controllability problem in which a time-dependent function steers the system's state from input data to desired outputs. Our results showed that such simultaneous controllability problems admit solutions with a simple temporal structure: optimal controls are piecewise constant in time, with a finite number of switches. Moreover, explicit bounds on the number of switches can be derived in terms of the data's geometry and distribution. These findings suggest that switching complexity plays a role analogous to model capacity in learning theory, providing a quantitative measure of the expressive power required to fit a given dataset. In this talk, we will present the multilevel control framework and its duality-based characterization, emphasizing how switches arise as intrinsic features of optimal solutions, and discuss how controllability and expressivity in Neural ODEs can be naturally interpreted within this setting.

17:10-17:35 MoPM_SE1.5

Safety Verification of Robust Neural Network-Controlled Dynamical Systems (I), pp. 79-82

LAL, RATAN — Northwest Missouri State University
Prabhakar, Pavithra — The University of New Mexico

Most existing neural network verification frameworks assume that network parameters are fixed and precisely known, and mainly focus on input uncertainty, such as adversarial perturbations. However, in real-world deployments, especially in cyber-physical systems, this assumption often does not hold. Neural network weights and biases can be uncertain due to quantization, hardware variability, and model updates, which may significantly alter closed-loop system behavior and compromise safety guarantees. To capture this, we model such networks as Interval Neural Networks (INNs), where parameter uncertainty is represented using interval-based perturbation sets. Accordingly, we study the problem of robust verification of INN-controlled dynamical systems. Our approach performs sequential reachability analysis of both the INN and the underlying dynamical system over a finite horizon of K iterations, and safety is verified by

checking whether the computed reachable set intersects with a given unsafe set. We extend both Big-M and Starset-based techniques to compute reachable sets for INN-controlled dynamical systems and evaluate the approach on Adaptive Cruise Control (ACC) and Translational Oscillator with Rotational Actuator (TORA) benchmarks. Experimental results show that the Big-M-based method is faster than the Starset-based approach.

MoPM_SE2	MC 4058
Algebraic Systems Theory (Regular Session)	
Chair: Zerz, Eva	RWTH Aachen University
Co-Chair: D'Souza, Rollen Sandeep	Independent Researcher

15:30-15:55	MoPM_SE2.1

Data Informativity for Observability and Its Duality from the Algebraic Approach, pp. 83-86

Tanaka, Yuki	Mitsubishi Electric Corporation
Kaneko, Osamu	The University of Electro-Communications

Since the formulation of Data Informativity, which assesses whether a model consistent with given data possesses desirable system characteristics, numerous results concerning controllability, observability, and other fundamental properties crucial to model-based control have been reported. In this way, while data-driven control draws on the subjects and methods of analysis and design in model-based control to a greater or lesser extent, approaches that focus on constructing the theoretical framework itself—as discussed in model-based control—remain relatively few. This paper focuses on Informativity for observability from an algebraic viewpoint. Inspired by the Geometric Approach in model-based control,observability is revisited starting from the definition of the unobservable subspace. By explicitly characterizing the geometric and algebraic structure between models and data, we derive observability Informativity conditions that are independent of the data acquisition dimension.

15:55-16:20	MoPM_SE2.2

Error Quantification for the Re-Centered Chen-Fliess Series, pp. 87-92

Boudaghi, Farnaz	University of Vermont
Duffaut Espinosa, Luis	University of Vermont

Successive re-centering of Chen-Fliess series (CFS) extends the domain of the series representation of systems beyond their finite execution horizon, which enables applications in receding horizon system analysis and control. However, each re-centering step introduces an approximation error due to truncation and re-centering coefficient deviations. {Systematically quantifying these stepwise errors is an essential first step toward understanding their behavior over successive re-centerings.} This paper develops a methodology for quantifying the error induced by the truncation and re-centering of a CFS. Explicit upper bounds are derived for truncation error, re-centering error, and their combined effect, in terms of the convergence properties of the associated CFS. Examples are provided to illustrate the results.

16:20-16:45	MoPM_SE2.3

The Dynamic Search for the Minimal Dynamic Extension, pp. 93-98

D'Souza, Rollen Sandeep	Independent Researcher

Identifying the dynamic precompensator that renders a nonlinear control system feedback linearizable is a challenging problem. Researchers have explored the problem --- dynamic feedback linearization --- and produced existence conditions and constructive procedures for the dynamic precompensator. These remain, in general, either computationally expensive or restrictive. Treating the challenge as intrinsic, this article views the problem as a search problem over a category. Dynamic programming applies and, upon restriction to a finite category, classic search algorithms find the minimal dynamic extension. Alternatively, a heuristic aiming towards feedback linearizable systems can be employed to select amongst the infinitely-many extensions. This framing provides a distinctive, birds-eye view of the search for the dynamic precompensator.

16:45-17:10	MoPM_SE2.4

Testing Backward-Flatness of Nonlinear Discrete-Time Systems, pp. 99-104

Schrotshamer, Johannes	Johannes Kepler University Linz
Kolar, Bernd	Johannes Kepler University Linz
Schöberl, Markus	Johannes Kepler University of Linz

Despite ongoing research, testing the flatness of discrete-time systems remains a challenging problem. To date, only the property of forward-flatness - a special case of difference-flatness - can be checked in a computationally efficient manner. In this paper, we propose a systematic approach for testing backward-flatness, which is another special case of difference-flatness, and for deriving a corresponding backward-flat output. Additionally, we discuss the relationship between the Jacobian matrices associated with the flat parameterization of backward- and forward-flat systems and illustrate our results by an academic example.

17:10-17:35	MoPM_SE2.5

Permutation Symmetry, Collision-Freeness, and Controlled Invariance in Particle Dynamics, pp. 105-106

Zerz, Eva	RWTH Aachen University

This presentation aims to give an overview of some algebraic aspects of the author's joint research project with Michael Herty (RWTH Aachen University) in the area of particle dynamics, which was funded by the German Research Foundation DFG within the framework of the Collaborative Research Center "Sparsity and Singular Structures", from mid-2022 to mid-2026. Thanks to this support, we were able to hire PhD student Melanie Harms, who submitted and defended her thesis in 2025, and postdoc researcher Chiara Segala, who obtained a position at the University of Italian-speaking Switzerland in late 2024.

MoPM_SE3	MC 4045
Modeling, Estimation, and Control of Infinite-Dimensional Systems (Invited Session)	
Chair: Xie, Junyao	University of Guelph
Co-Chair: Dubljevic, Stevan	Unversity of Alberta
Organizer: Xie, Junyao	University of Guelph
Organizer: Dubljevic, Stevan	Unversity of Alberta

15:30-15:55	MoPM_SE3.1

On Control of Large-Scale Hyperbolic PDEs Via Continuum Approximations (I), pp. 107-110

Humaloja, Jukka-Pekka	Technical University of Crete
Bekiaris-Liberis, Nikolaos	Technical University of Crete

This extended abstract considers PDE continua as approximations of large-scale hyperbolic PDEs. The continuum approximation aspect is considered from the viewpoints of approximating both solutions to hyperbolic PDEs and solutions to backstepping kernel equations, which can be employed in stabilization of such systems. Finally, we provide discussion on alternative ways of constructing continuum approximations, as well as on potential alternative frameworks for PDE continua.

15:55-16:20	MoPM_SE3.2

Excitable Control of a Heat Equation (I), pp. 111-114

Tokola, Tuulia	Tampere University
Fkirine, Mohamed	Tampere University
Paunonen, Lassi	Tampere University

We study the control of a one-dimensional heat equation with two inputs and two outputs. Our main goal is to design a controller that makes the closed-loop system excitable in the sense of the system's sensitivity to external inputs exceeding a given threshold. We achieve this with a nonlinear dynamic feedback controller. We demonstrate the excitability properties of the controlled heat equation.

16:20-16:45 MoPM_SE3.3

Multidimensional Spatial Hyperbolic Systems (I), pp. 115-118

Dubljevic, Stevan — Unversity of Alberta
Akbarnezhad, Mahdis — University of Alberta

This work addresses the control of spatially multidimensional hyperbolic PDE models that frequently arise in transport€"reaction processes in chemical engineering. The main contribution of this manuscript is a systematic analytical approach for obtaining the evolution of a multidimensional hyperbolic PDE system. In particular, the well-known Laplace transform is used in both space and time to obtain analytical expressions for the input-output mapping and the state evolution under arbitrary initial conditions. The stability analysis reveals the boundedness of the state evolution and provides insight into the system's minimum-time stability

16:45-17:10 MoPM_SE3.4

Moving Horizon Estimation of Distributed Parameter Systems under Limited and Noisy Measurements (I), pp. 119-122

Xie, Junyao — University of Guelph

This work addresses optimal constrained state and output estimation of distributed parameter systems under limited and noisy output measurements using moving horizon estimation (MHE). In particular, we consider the MHE design for the discrete-time infinite-dimensional system, which can be linked to the corresponding continuous-time infinite-dimensional system using the Cayley-Tustin time discretization method. To address the data scarcity issue in state and output estimation of the discrete-time infinite-dimensional system, we propose a new MHE framework to achieve a good balance between the feasibility of the algorithm execution and estimation performance. Furthermore, we show the stability analysis of the proposed MHE method and the relationship between the estimation error, MHE parameters, and the observability of the system. Finally, we provide numerical examples on a class of conservative distributed parameter systems (such as the Schrödinger equation) to demonstrate the effectiveness of the proposed MHE design.

17:10-17:35 MoPM_SE3.5

Optimal Control in Poroelastic Systems (I), pp. 123-126

Alalabi, Ala' — University of Waterloo
Bociu, Lorena — North Carolina State University

Fluid flow in deformable porous media appears in many applications, from geomechanics to biomechanics, and is commonly modeled by coupled partial differential equations describing the interaction between fluid transport and mechanical deformation. A standard framework is Biot's theory of poroelasticity which, under quasi-static assumptions, yields a coupled parabolic–elliptic system that can be viewed as an implicit, degenerate evolution equation. While well-posedness and regularity are well-understood, optimal control problems constrained by such poroelastic dynamics, especially in biomedical settings where pressure and displacement must be regulated, remain relatively unexplored and mathematically challenging due to degeneracy and implicit coupling. In this work, we reformulate the flow–deformation model as an implicit dynamical system on Hilbert spaces and analyze it using E-radiality theory, a generalization of the Hille–Yosida framework for non-explicit evolution equations. This approach yields new well-posedness insights and provides a unified framework for linear control problems governed by degenerate evolution dynamics.

MoPM_SE4 — MC 5479

Nonlinear Systems and Control (Regular Session)

Chair: Fisher, Michael — University of Waterloo
Co-Chair: Astolfi, Daniele — CNRS - Univ Lyon 1

15:30-15:55 MoPM_SE4.1

Stability of Slow-Fast Nonlinear Dynamics: Non-Periodic Case, pp. 127-132

Tran, G. Q. Bao — University of Illinois Urbana-Champaign
Liberzon, Daniel — Univ. of Illinois at Urbana-Champaign
Shim, Hyungbo — Seoul National University

We present sufficient conditions for the semi-global exponential stability of nonlinear systems whose dynamics have both slow and fast time variations. Unlike most existing results, the fast variation is non-periodic, thereby allowing a wider class of systems, especially switched systems with fast (non-periodic) switching and those with quasi-periodic variations; we therefore rely on general averaging to construct an average system. It is assumed that the average system admits a time-invariant equilibrium that is globally exponentially stable when the slow variation is frozen, i.e., remaining at a fixed value. This slow variation is allowed to be discontinuous in time, provided its total variation (flows and jumps) is bounded. The main result is illustrated using a nonlinear switched system with slow-fast non-periodic switching.

15:55-16:20 MoPM_SE4.2

A Separation Principle in Local Exponential Stability of Discrete-Time Bilinear Systems, pp. 133-136

Hagiwara, Tomomichi — Kyoto Univ
Yang, Xi — Kyoto University

This paper is concerned with local stabilization of discrete-time bilinear systems through the combination of a stabilizing nonlinear state feedback control law and a bilinear state observer, leading to an observer-based controller and an observer-incorporated closed-loop system. More specifically, we assume that a state feedback control law with state and input constraints satisfied is designed through a quadratic Lyapunov function. We further assume that an observer is designed in such a way that a quadratic Lyapunov function ensures the associated estimation error dynamics to be stable robustly regardless of the sequence of the plant input, as long as it satisfies, via saturation treatment, the constraint that has been taken into account in the design of the nonlinear state feedback control law. With the knowledge by the preceding studies by the authors that such design procedures are indeed available, we are naturally interested in whether or not a separation principle holds for the combination of these procedures. This paper establishes a positive answer to this question by showing that the origin of the observer-incorporated closed-loop system is locally exponentially stable. In addition, the arguments are extended to accommodate the case without explicit control input constraints, and an implication of the established separation principle on the use of integral compensation is further discussed.

16:20-16:45 MoPM_SE4.3

A Minimal Monotone Model for the Interplay of Depression and Resilience, pp. 137-140

Rüffer, Björn — Bauhaus-Universität Weimar
Schoenlein, Michael — Bauhaus-Universität Weimar

We propose a two-dimensional nonlinear ODE model for the coupled dynamics of depression symptoms and resilience in response to adverse external stimuli. The model is monotone with respect to a natural partial order and exhibits bistability: a locally stable healthy equilibrium and a locally stable severe-depression equilibrium, separated by an unstable saddle that depends on the stimulus intensity. We characterize all equilibria, their stability properties, and domains of attraction using linearization, Lyapunov functions, and monotonicity arguments. The resulting trajectories qualitatively reproduce established resilience trajectory typologies (chronic, delayed, recovery, resilient).

16:45-17:10 MoPM_SE4.4

Enlarging the Region of Attraction Near the Current State by Varying Controller Parameter Values, pp. 141-144

Liu, Elin — University of Waterloo
Fisher, Michael — University of Waterloo

Enlarging the region of attraction (RoA) near the current state is an effective technique to improve robustness against disturbances. Existing methods for enlarging the RoA are typically conservative, limited to specialized settings such as polynomial systems, and attempt to expand the RoA in all directions rather than near the current state, thereby sacrificing improved robustness near the current state for additional robustness in distant regions of state space. This work develops a computationally efficient method for numerically varying parameter values to maximize the distance from the current state to the RoA boundary. Local convergence guarantees are provided for the method for a large class of general nonlinear systems. The algorithm is demonstrated successfully on a quadcopter simulation, where it improves the robustness to an unknown disturbance.

17:10-17:35	MoPM_SE4.5

Some Remarks on Relaxation of Banach's Contraction Principle, pp. 145-148

Kato, Rui	Université Claude Bernard Lyon 1
Astolfi, Daniele	CNRS - Univ Lyon 1
Andrieu, Vincent	Université De Lyon

In this paper, we review several generalized notions of contraction mappings and related fixed point theorems. We first present a new characterization of Rakotch contractions on geodesic metric spaces. We then show that a Rakotch contraction is almost the same as a Banach contraction in terms of the speed of convergence. On the other hand, we provide a generalization of Weissinger's theorem and discuss its relationship with stability concepts in the literature. Finally, we revisit incremental stability properties of dynamical systems through the lens of contraction mappings.

TuP_PL MC 2065

Plenary: PTNS: Phase Theory of Networks and Systems (Plenary Session)

Chair: Rantzer, Anders — Lund Univ

09:00-10:00 TuP_PL.1

*Plenary: PTNS: Phase Theory of Networks and Systems**

Qiu, Li — Chinese University of Hong Kong, Shenzhen

The phase or argument of a complex number is an elementary yet important concept, essential to almost all scientific disciplines. In SISO signal and system theory the concept of phase used to play an extremely important role. What are the phases of a complex square matrix? The answer does not seem to be unique. In this presentation, we will examine three different definitions: the principal phases (40 year old), the sectorial phases (6 year old), and the segmental phases (new born). We will compare the properties of these phase notions and use them to estimate the eigenvalue phase angles. We will also examine a network and system theory based on the phases, complementing and interconnecting with the existing gain (magnitude, singular value) based theory.

TuAM_SE1 MC 4058

Learning and Control of Dynamical Systems I (Invited Session)

Chair: Gruene, Lars — University of Bayreuth
Co-Chair: Kamalapurkar, Rushikesh — University of Florida
Organizer: Gruene, Lars — University of Bayreuth
Organizer: Kamalapurkar, Rushikesh — University of Florida
Organizer: Rosenfeld, Joel — University of South Florida
Organizer: Worthmann, Karl — TU Ilmenau

10:30-10:55 TuAM_SE1.1

The Stochastic Occupation Kernel Method (I), pp. 149-152

Wells, Michael — Portland State University
Lahouel, Kamel — Translational Genomics
Rielly, Victor — The Translational Genomics Research Institute
Jedynak, Bruno — Portland State University

We present a novel kernel-based method for learning multivariate stochastic differential equations (SDEs). The method follows a two-step procedure: we first estimate the drift term function, then the (matrix-valued) diffusion function given the drift. Occupation kernels are integral functionals on a reproducing kernel Hilbert space (RKHS) that aggregate information over a trajectory. Our approach leverages vector-valued occupation kernels for estimating the drift component of the stochastic process. For diffusion estimation, we extend this framework by introducing operator-valued occupation kernels, enabling the estimation of an auxiliary matrix-valued function as a positive semi-definite operator, from which we readily derive the diffusion estimate.

11:20-11:45 TuAM_SE1.3

Universal Signature Kernel for Data-Driven Path-To-Path Modeling (I), pp. 153-156

Chen, Haowei — University of Florida
Kamalapurkar, Rushikesh — University of Florida
Rosenfeld, Joel — University of South Florida
Wang, Yu — University of Florida

We present a non-parametric framework for data-driven system identification that learns mappings between input and output paths directly in signature space. Traditional methods often compress output trajectories to scalars, losing geometric information. By embedding truncated path signatures in an operator-valued reproducing-kernel Hilbert space (RKHS), we cast the problem as operator-valued kernel ridge regression. We prove the universality of a weighted Gaussian signature kernel, derive an $O(d_Llog d_L/N)$ non-asymptotic excess-risk bound, and develop a Nyström-based solver that reduces training time from cubic to nearly linear in the sample size. Experiments on a nonlinear stochastic system confirm state-of-the art accuracy with two orders-of-magnitude speed-ups.

11:45-12:10 TuAM_SE1.4

Occupation Kernel Hilbert Spaces for Fractional Order Liouville Operators and Dynamic Mode Decomposition (I), pp. 157-160

Rosenfeld, Joel — University of South Florida
Russo, Benjamin — Riverside Research Institute
Li, Xiuying — Changshu Institute of Technology

This manuscript gives a theoretical framework for a new Hilbert space of functions, the so called occupation kernel Hilbert space (OKHS), that operate on collections of signals rather than real or complex numbers. To support this new definition, an explicit class of OKHSs is given through the consideration of a reproducing kernel Hilbert space (RKHS). This space enables the definition of nonlocal operators, such as fractional order Liouville operators, as well as spectral decomposition methods for corresponding fractional order dynamical systems. In this manuscript, a fractional order DMD routine is presented, and the details of the finite rank representations are given. Significantly, despite the added theoretical content through the OKHS formulation, the resultant computations only differ slightly from that of occupation kernel DMD methods for integer order systems posed over RKHSs.

12:10-12:35 TuAM_SE1.5

Dynamical Frames and Hyperinvariant Subspaces (I), pp. 161-162

Bailey, Victor — Morehouse College

The theory of dynamical frames arose from practical problems in dynamical sampling where the initial state of a vector needs to be recovered from the space-time samples of future states of the vector. This leads to the investigation of structured frames obtained from the orbits of evolution operators. One of the basic problems in dynamical frame theory is to determine the semigroup representations, which we will call central frame representations, whose frame generators are unique (up to equivalence). In this talk, we will address the general uniqueness problem by presenting a characterization of central frame representations for any semigroup in terms of the co-hyperinvariant subspaces of the left regular representation of the semigroup. This result is not only consistent with the known result of Han and Larson in 2000 for group representation frames, but also proves that the frame vectors for a dynamical frame generated by a k-tuple of bounded commuting operators are equivalent. This is joint work with Deguang Han, Keri Kornelson, David Larson, and Rui Liu.

TuAM_SE2 MC 5417

Operator Theory for Quantum Information I (Invited Session)

Chair: Bene Watts, Adam — University of Calgary
Co-Chair: Klep, Igor — University of Ljubljana
Organizer: Bene Watts, Adam — University of Calgary
Organizer: Klep, Igor — University of Ljubljana
Organizer: Paddock, Connor — University of Calgary
Organizer: Renou, Marc-Olivier — INRIA Saclay

10:30-10:55 TuAM_SE2.1

Maximal Device-Independent Randomness in Every Dimension (I), pp. 163-164

Volčič, Jurij — University of Auckland

Device-independent quantum random number generation makes use of the intrinsic randomness of quantum processes to generate numbers that are fundamentally unpredictable. The difficulty of controlling quantum systems makes it desirable to harness the full power of the quantum degrees of freedom that one can control. It is known that no more than 2 log d bits of private device-independent randomness can be extracted from a quantum system of local dimension d. This talk presents protocols that achieve this bound for every d. This work is based on joint work with Máté Farkas, Sigurd A. L. Storgaard, Ranyiliu Chen and Laura Mančinska.

10:55-11:20 TuAM_SE2.2

Fermionic Nonlocality Beyond Bell: The Fundamental Fermion–Boson Distinction, pp. 165-165

Moradi Kalarde, Fatemeh	Inria Saclay
Xu, Xiangling	Inria Saclay
Boreiri, Sadra	University of Geneva
Tendick, Lucas	Inria Saclay
Beigi, Salman	Institute for Research in Fundamental Sciences (IPM)
Perinotti, Paolo	University of Pavia
Guaita, Tommaso	Freie Universität Berlin
Renou, Marc-Olivier	INRIA Saclay

Bell's theorem shows that entangled quantum particles can exhibit correlations that classical particles cannot reproduce without an additional nonlocal resource, such as communication. In this sense, quantum particles are fundamentally more nonlocal than classical ones, and entanglement becomes unavoidable in physics. Here we prove the analogous result within quantum theory itself: indistinguishable fermions transmitted through a quantum network can generate correlations that distinguishable particles or indistinguishable bosons cannot reproduce without additional communication. In the same sense, fermions are fundamentally more nonlocal than bosons or distinguishable particles, motivating fermionic anticommutation and indistinguishability as unavoidable operational resources. Our result further implies that fermions can strictly surpass all qubit-based protocols for certain distributed computing tasks, demonstrating that a complete understanding of information processing requires going beyond qubits to fermionic information carriers - febits.

11:20-11:45 TuAM_SE2.3

Classical Reductions for Entangled Constraint Satisfaction Problems (I), pp. 166-168

Culf, Eric	University of Waterloo
van Dobben de Bruyn, Josse	Charles University
Vernooij, Matthijs	TU Delft
Zeman, Peter	Charles University

A constraint satisfaction problem (CSP) is a decision problem where one needs to decide if a given systems of equations admits a solution. CSPs capture some fundamental computational problems, including linear equations, graph colourings, and variants and generalisations of satisfiability. A CSP can be presented via nonlocal games, so an entangled version of the CSP arises via the quantum strategies for this game. Due to the equality of complexity classes MIP*=RE, entangled CSPs can be undecidable, but this is not true of all of them. The current proof techniques to show undecidability of entangled CSPs are quantisations of the gadget reductions used to show NP-completeness of classical CSPs. These techniques rely on commutativity gadgets, which allow the CSP to express any classically achievable relation in the entangled setting. In this work, we show that there exist CSPs that do not admit a commutativity gadget and study the conditions under which CSPs admit commutativity gadgets. This implies that their complexity cannot be ascertained by directly lifting classical reductions, but will need natively quantum and perhaps more subtle reductions. Another possibility is that there may be classically hard CSPs that become easy in the quantum setting. We make use of quantum symmetries of the CSP to ascertain whether it admits a commutativity gadget, and hence whether the classical reductions lift to the quantum setting.

11:45-12:10 TuAM_SE2.4

XOR Games at Full Tilt (I), pp. 169-171

Cleve, Richard	University of Waterloo
Culf, Eric	University of Waterloo
Taller, Aviv	École Polytechnique Fédérale De Lausanne

It is well known that the quantum value of an XOR nonlocal game, where the winning condition depends only on the XOR of the two players' output bits, may approximated in polynomial time. We study a variant of the XOR game model, which we call tilted XOR games, where the winning condition can additionally depend on only one of the output bits. We show that this dramatically increases the expressive power: the computational complexity of the problem of approximating the quantum value of tilted XOR games to constant precision is RE-complete. Also, our result extends to succinct versions of tilted XOR games, where the questions can be polynomial-length binary strings, generated by a polynomial-time verifier. Since titled XOR games are a special case of binary games (where each party outputs one single bit), our result implies that binary games are RE-hard to approximate.

12:10-12:35 TuAM_SE2.5

On the Power of Multipartite Entanglement for Pseudotelepathy (I), pp. 172-172

Brassard, Gilles	Université De Montréal
Coiteux-Roy, Xavier	University of Calgary
Ligez, Rémi	Université De Montréal

As early as 1935, Schrödinger recognized entanglement as "not *one*, but rather *the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought". Indeed, most remarkable phenomena in quantum information science, such as quantum computing and quantum teleportation, spring from clever uses of entanglement. Among them, pseudotelepathy enables two or more players to win systematically at some cooperative games with no need for communication between them, a restriction that would make the task impossible in a classical world. We investigate the power of multipartite entanglement for pseudotelepathy. Some known games that can be won with tripartite entanglement cannot be won with bipartite entanglement, but they can be won with bipartite non-signalling resources such as the so-called Popescu–Rohrlich nonlocal box. We exhibit a five-player game that can be won with tripartite entanglement, but not with arbitrary bipartite non-signalling resources even in the presence of arbitrary five-partite classical resources. This illustrates both the power of bipartite non-signalling resources (over bipartite entanglement) and the even superior power of tripartite entanglement.

TuAM_SE3 MC 5501

Control of Distributed Parameter Systems I (Regular Session)

Chair: Chentouf, Boumediene	Kuwait University

10:30-10:55 TuAM_SE3.1

Remarks on a Linear Nonlocal Schrodinger Equation with Localized Damping, pp. 173-176

Chentouf, Boumediene	Kuwait University

This note is concerned with the well-posedness and stability of a one-dimensional linear Schrödinger equation in a bounded interval. We assume the presence of an infinite memory term and a localized damping control. Using two different approaches, we show that the problem is well-posed. Furthermore, the asymptotic behavior of the solutions is deduced.

10:55-11:20 TuAM_SE3.2

On the Stability Robustness of Filtered Feedback Control Laws for a Class of Boundary Controlled PDE, pp. 177-180

Michiels, Wim	KU Leuven
Bribiesca Argomedo, Federico	INSA Lyon, Laboratoire Ampère
AURIOL, Jean	CNRS, CentraleSupélec,

Université Paris-Saclay

The presentation addresses the boundary control of a class of hyperbolic PDEs, based on an equivalent representation in terms of an integral-difference equation. The situation is considered where direct compensation of reflection terms induces a fragile closed-loop system, in the sense of lack of strong stability. This problem is theoretically resolved by adding a low-pass filter to the control law, but the choice of its cut-off frequency is crucial in balancing robustness at high frequencies and performance at low frequencies. First, a result is presented on the exponential stability for small values of T, the inverse of the filter's cutoff frequency, thus demonstrating the efficacy of the filter. Next, model mismatch on the PDE parameters is considered and a sufficient stability condition is given in terms of allowable mismatch and cut-off frequency, satisfied in a region in the combined parameter space with a conic shape around T=0. Finally, this qualitative behavior is confirmed by exact stability charts for a special case where all model mismatch is contained into one scalar parameter. The fractal nature of the set of stability crossing curves is highlighted.

11:20-11:45 TuAM_SE3.3

Multiplicative Controllability of a One-Dimensional Fokker-Planck Equation through the Advection Term, pp. 181-186

Gu, Yixing — University of Waterloo

This paper investigates the approximate multiplicative (bilinear) controllability of parabolic partial differential equations, focusing on a special form of the one-dimensional Fokker-Planck equation. We first derive some properties of weak derivatives, which are used to extend some results of Sturm-Liouville theory to Sobolev spaces, and then establish a relationship between the control through the advection term and the control through the reaction term by means of a suitable transformation. The proposed method is constructive, and it leads to an implementable algorithm for finding a bilinear control through the advection term.

11:45-12:10 TuAM_SE3.4

Robust Exponential Stability of Interior Degenerate/Singular Parabolic Equations, pp. 187-192

Singh, Shri Lal Raghudev Ram — University of Waterloo

Cannarsa, Piermarco — Univ. Roma Tor Vergata

Guglielmi, Roberto — University of Waterloo

In this paper, we establish the exponential stability of interior degenerate parabolic equations under a class of relatively bounded perturbations. Our analysis relies on an abstract robustness result for exponentially stable semigroups, appropriate Hardy-Poincaré inequalities, LaSalle's invariance principle and a unique continuation property for elliptic operators. The study is divided into two main parts, depending on whether the principal diffusion operator is formulated in divergence or in non-divergence form.

12:10-12:35 TuAM_SE3.5

Stability and Instability Results for Weakly Coupled Plates with Delay Term in the Internal Feedback, pp. 193-196

Mekseh, Nedjema — University of Batna

Sidiali, Fatima Zohra — University of Batna 2

Rebiai, Salah Eddine — University of Batna 2

In this paper, we study a coupled system of two plate equations. One equation includes both damping and delay terms, while the other is conservative. We show that if the gain of the delayed damping term is smaller than that of the undelayed one, then the strong solution of the closed-loop system is both strongly and polynomially stable. Explicit decay rates are derived, and their optimality is discussed. In other cases, instability results are established by constructing specific sequences of delays and initial data.

TuAM_SE4 MC 5479

On the Geometry of Optimal Transport and Its Application to Physics and Control (Invited Session)

Chair: Bloch, Anthony M. — Univ. of Michigan

Co-Chair: Georgiou, Tryphon T. — Univ. of California, Irvine

Organizer: Bloch, Anthony M. — Univ. of Michigan

Organizer: Georgiou, Tryphon T. — Univ. of California, Irvine

10:30-10:55 TuAM_SE4.1

Schrodinger Bridge Over Averaged Systems: Theory and Algorithms (I), pp. 197-200

Adu, Daniel Owusu — Villanova University,

Chen, Yongxin — Georgia Institute of Technology

We consider a Schrodinger bridge problem where the Markov process is subject to parameter perturbations, forming an ensemble of systems. Our objective is to steer this ensemble from the initial distribution to the final distribution using controls robust to the parameter perturbations. Utilizing the path integral formalism, we demonstrate that the optimal control is a non-Markovian strategy, specifically a stochastic feedforward control, which depends on past and present noise. This unexpected deviation from established strategies for Schrodinger bridge problems highlights the intricate interrelationships present in the system's dynamics. Furthermore, built on a recent technique known as flow matching in generative AI, we develop a scalable algorithm to compute the optimal control.

10:55-11:20 TuAM_SE4.2

Sum-Of-Squares Programming for Ma-Trudinger-Wang Regularity of Optimal Transport Maps (I), pp. 201-204

Shivakumar, Sachin — Iowa State University

Bondar, Georgiy — University of California Santa Cruz

Khan, Gabriel — JPMorgan Chase

Halder, Abhishek — Iowa State University

For a given ground cost, the Monge optimal transport map realizes the pushforward of a given probability measure onto another. The fourth-order Ma-Trudinger-Wang (MTW) tensor associated with this ground cost provides a notion of curvature in optimal transport. In particular, the non-negativity of the MTW tensor becomes important for establishing continuity of the Monge optimal transport map. However, analytically verifying the non-negativity of MTW tensor is extremely challenging, and as a result, such results have so far been demonstrated for relatively simple ground costs. To expand the class of ground cost functions for which MTW non-negativity can be verified, we propose a computational approach which provides certificates of non-negativity for the MTW tensor using Sum-of-Squares (SOS) programming. Within the proposed computational framework, we call this verification as the solution of forward problem. The proposed method is also shown to be useful for solving the inverse problem--where our SOS technique can compute an inner approximation of the region where MTW non-negativity holds, i.e., provides local certificates.

11:20-11:45 TuAM_SE4.3

Optimal Transport, the Schur-Horn Theorem and the Dispersionless Toda Lattice Flow (I), pp. 205-208

Bloch, Anthony M. — Univ. of Michigan

Ratiu, Tudor — Fuyau Univertisy of Science and Technology

We analyze the discrete Monge–Kantorovich problem as well as its generalization to the setting of the diffeomorphism group of the annulus. We link it with the minimization problem of linear functionals over adjoint orbits as well as to convexity of the momentum map and the Schur-Horn theorem in particular. We also discuss the relationship of the optimization problem to dynamics, in particular double bracket on adjoint orbits and the discrete and dispersionless Toda lattice flows.

11:45-12:10 TuAM_SE4.4

Adapted Optimal Transport: The Gaussian Case (I), pp. 209-210

Gunasingam, Madhu | University of Toronto
Wong, Ting Kam Leonard | University of Toronto

Adapted optimal transport is a recently developed version of optimal transport tailored to the needs of stochastic analysis and mathematical finance. We study the Gaussian case under which explicit computations are possible. This leads to a novel extension of the Bures--Wasserstein distance to the adapted setting.

12:10-12:35 TuAM_SE4.5

Optimal Transport with Minimal Attention for Gauss-Markov Models (I), pp. 211-213

Sabbagh, Ralph | University of California, Irvine
Eldesoukey, Asmaa | University of California, Irvine
Abdelgalil, Mahmoud | University of California, San Diego
Georgiou, Tryphon T. | Univ. of California, Irvine

The dynamic formulation of Monge–Kantorovich transport endows the space of probability measures with a rich geometric structure and has catalyzed advances across control, fluid mechanics, and computation. Motivated by an apparent analogy between the concept of shear in fluid dynamics and that of Brockett's ‘attention' functional of a control law, we study a new class of variational problems for optimal transport. The present work develops this type of transport based on the basic Gauss-Markov paradigm of steering Gaussian distributions between specified marginal distributions. Specifically, we consider the flow generated by a linear drift U(t,x) = Atx for Gauss–Markov models and seek to design the control gain At so as to steer the law between the prescribed Gaussian marginals while minimizing a functional that combines spatial and temporal quadratic costs. The terms in the functional consist of the gradient and the time-derivative of the control action. Individually, these two terms penalize a notion of ‘attention' that a controller needs to dedicate in differentiating with respect to space and time, respectively. In contrast to the classical Monge-Kantorovich transport, the resulting optimization is nonconvex. Yet, the Gaussian structure enables a tractable characterization of optimal solutions and their existence under suitable conditions. The new formalism provides an “attention-penalized” counterpart to Wasserstein-2 transport and suggests connections to shear- penalized geodesic models of fluid flow.

Keywords: Stochastic control, Monge-Kantorovich Transport, Attention-minimizing control

AMS Classification: Primary 49Q22; Secondary 93E20, 60H10.

TuSP_SP1 MC 2065

Semi-Plenary: Reinforcement Learning for Control: Convergence, Stability, Sample Complexity (Plenary Session)

Chair: Smith, Stephen L. | University of Waterloo

14:00-15:00 TuSP_SP1.1

*Semi-Plenary: Reinforcement Learning for Control: Convergence, Stability, Sample Complexity**

Gharesifard, Bahman | Queen's University

I discuss a cohesive dynamical systems view of reinforcement learning as a methodology for feedback control, organized around three central questions: when learning dynamics converge, when the resulting closed loop remains stable, and how much data is required to achieve reliable performance. I present a high-level synthesis of how these strands fit together into a principled foundation for reinforcement learning in control, and highlight a few open challenges and directions.

TuSP_SP2 MC 2066

Semi-Plenary: Synthesis & Analysis Tools for Dynamic Games – Model Based, Data-Driven and Nonlinear Perspectives (Plenary Session)

14:00-15:00 TuSP_SP2.1

*Semi-Plenary: Synthesis & Analysis Tools for Dynamic Games: Model Based, Data-Driven and Nonlinear Perspectives**

Mylvaganam, Thulasi | Imperial College London

Dynamic games provide a powerful framework for modeling interactions between multiple decision-makers. However, as infinite-dimensional problems, they are notoriously difficult to solve, and the coupling between players can generate emergent behaviours that are difficult to predict. In this talk, we will revisit some basics of dynamic games and (single-player) optimal control. Then, starting with the class of Linear Quadratic dynamic games, we will present iterative algorithms for obtaining feedback Nash equilibrium solutions that are amenable to both model-based and data-driven implementations. Turning our attention to general, nonlinear dynamic games we will then demonstrate how feedback Nash equilibria can be characterised in terms of invariant manifolds of a certain "lifted" dynamical system. This geometric perspective — analogous to the state/costate dynamics associated with Pontryagin's Minimum Principle (e.g. in the context of optimal control and open-loop Nash equilibria of dynamic games) — offers two key advantages. First, it allows us to recast the problem of obtaining feedback Nash equilibria as a static optimisation problem, which lays the basis for novel computational strategies, e.g. based on gradient-descent algorithms. Second, it provides a framework to analyse interactions between players in terms of energy exchange.

TuPM_SE1 MC 4058

Learning and Control of Dynamical Systems II (Invited Session)

Chair: Rosenfeld, Joel | University of South Florida
Co-Chair: Gruene, Lars | University of Bayreuth
Organizer: Gruene, Lars | University of Bayreuth
Organizer: Kamalapurkar, Rushikesh | University of Florida
Organizer: Rosenfeld, Joel | University of South Florida
Organizer: Worthmann, Karl | TU Ilmenau

15:30-15:55 TuPM_SE1.1

HiPreNets: High-Precision Neural Networks through Progressive Training with Dynamical System Applications (I), pp. 214-217

Mulle, Ethan | University of California, Santa Cruz
Kang, Wei | Naval Postgraduate School
Gong, Qi | University of California, Santa Cruz

Deep neural networks are powerful tools in science and engineering, but training highly accurate models becomes challenging as problem complexity increases. To address these challenges, we present a progressive framework for training and tuning high-precision neural networks (HiPreNets). Our approach, inspired by the philosophy of learning from previous errors, improves an existing network by sequentially learning its prediction residuals using additional networks, leading to improved overall accuracy. We additionally discuss how to take advantage of the structure of the residuals to guide the choice of loss function. We validate the framework on a benchmark regression problem and a high-dimensional dynamical system based in power systems, where we observe significant accuracy gains.

15:55-16:20 TuPM_SE1.2

Solving Inverse Optimal Control by Adaptive Mesh Refinements (I), pp. 218-220

Othmane, Amine | Saarland University, Saarbrücken, Germany
Maslovskaya, Sofya | Paderborn University
Offen, Christian | University of Birmingham
Ober-Blöbaum, Sina | Paderborn University
Flaßkamp, Kathrin | Saarland University

Inverse optimal control provides a powerful framework for data-based modeling of optimally controlled processes, as it identifies cost functions for optimal control problems explaining the observed data by their optimal solutions. This work addresses nonlinear infinite-horizon optimal control problems and proposes a neural network-based algorithm for the simultaneous reconstruction of the underlying cost functions and stabilizing feedback laws from pure state data. The approach integrates data fidelity with stability constraints to ensure physically meaningful solutions. We explicitly consider Lyapunov-based constraints and approximate the value function by an adaptive grid refinement strategy integrated into the neural network training. Numerical experiments demonstrate the effectiveness of the method for different systems and under varying noise levels.

16:20-16:45	TuPM_SE1.3

GP Warm-Starting of Dual Decomposition - Learning How to Speed Up (I), pp. 221-226

Panicker, Rahul	Hamburg University of Technology
Faulwasser, Timm	Hamburg University of Technology

Dual decomposition is a well-established algorithm to solve strictly convex optimization problems in decentralized fashion. However, as dual decomposition is a first-order method, it often takes a significant number of iterations to converge to acceptable accuracy. We propose a novel dual warm-starting strategy based on learning a predictor of the optimal dual variable of the consensus constraints. We use Gaussian process regression to learn the predictor from pre-computed data. Furthermore, we exploit the posterior variance error bounds of Gaussian Processes and draw upon numerical examples to illustrate the advantages of our approach.

16:45-17:10	TuPM_SE1.4

Solving Multiobjective Optimal Control Problems with Optimality-Informed Neural Networks (I), pp. 227-232

Hoffmann, Matthias K.	Saarland University
Herrmann-Wicklmayr, Markus	Saarland University
Othmane, Amine	Saarland University, Saarbrücken, Germany
Flaßkamp, Kathrin	Saarland University

Optimal control problems become parametric when their constraints or dynamics depend on external parameters. Multiple objectives require a multiobjective formulation, and scalarizing it introduces further parametric dependencies. We propose a grid-free method to model the mapping from parameters to optimal solutions. Using few training samples, we obtain a neural network by combining (i) a KKT-residual loss penalizing first-order optimality violations under standard constraint qualifications, (ii) problem-specific output activations that enforce simple constraints by construction, and (iii) single-shooting-like state simulations within the network. On a trajectory-generation case study with a moving obstacle and competing objectives, the method generalizes to unseen parameters, attaining lower primal error and fewer constraint violations than interpolation and penalty-based training, and recovers the dual variables.

17:10-17:35	TuPM_SE1.5

Neural Expectation–Maximization for Learning Actuated Nonlinear Dynamics under Partial Observation (I), pp. 233-236

Rajkumar, Santosh Mohan	The Ohio State University
Narayanan, Sriram	West Virginia University
Otto, Samuel	Cornell University
Goswami, Debdipta	The Ohio State University

This work proposes a probabilistic framework for learning finite-dimensional bilinear Koopman generator models without prescribing an observable dictionary or imposing linear measurement structure. The unknown nonlinear system is modeled as a latent-variable bilinear state–space system whose lifted dynamics approximate a Koopman generator, while measurements are reconstructed through a nonlinear neural-network decoder. The resulting formulation admits a hidden Markov model representation and is identified using a Neural Expectation–Maximization algorithm that combines extended Kalman filtering and smoothing for latent-state inference with closed-form updates of Koopman generator matrices and gradient-based learning of the decoder.

TuPM_SE2	MC 5417
Operator Theory for Quantum Information II (Invited Session)	

Chair: Paddock, Connor	University of Calgary
Co-Chair: Renou, Marc-Olivier	INRIA Saclay
Organizer: Bene Watts, Adam	University of Calgary
Organizer: Klep, Igor	University of Ljubljana
Organizer: Paddock, Connor	University of Calgary
Organizer: Renou, Marc-Olivier	INRIA Saclay

15:30-15:55	TuPM_SE2.1

Unital Channels, Quantum Symmetries, and Dilation Problems (I), pp. 237-237

Brannan, Michael	University of Waterloo

The set of unital quantum channels on M_n is the natural quantum information theoretic analogue of the convex set of bistochastic matrices in M_n. For bistochastic matrices, we have the well-known Birkhoff-von Neumann theorem (B-vN theorem) which says that any bistochastic matrix is a convex combination of permutation matrices. For unital quantum channels, the situation is much more complicated. For instance, several attempts at a quantum version of Birkhoff's theorem are known to fail (e.g., based on mixed unitary channels or more generally factorizable maps). In this talk, we will look at unital quantum channels from the perspective of noncommutative (a.k.a. matrix) convexity - viewing unital channels as the first level of an enriched matricial convex structure. This naturally leads to a new nc convex set of unital channels we call ``mixed quantum unitary channels'', whose nc extreme points are given by quantum automorphisms of M_n. For some time, we conjectured that mixed quantum unitary channels would provide the correct framework for a quantum B-vN theorem, but our hopes have been dashed once again! I will present some examples of unital channels which fail to be mixed quantum unitary. Time permitting, I will also explain some consequences this result has on the structure of the operator space spanned by the generators of the free unitary quantum groups.

This is joint work with Jason Crann and Alec Gow.

15:55-16:20	TuPM_SE2.2

The Quantum Smooth Label Cover Problem Is Undecidable (I), pp. 238-241

Culf, Eric	University of Waterloo
Mastel, Kieran	University of Ottawa
Paddock, Connor	University of Calgary
Spirig, Taro	University of Copenhagen

We show that the quantum smooth label cover problem is undecidable and RE-hard. This sharply contrasts the quantum unique label cover problem, which can be decided efficiently by a result of Kempe, Regev, and Toner (FOCS'08). On the other hand, our result aligns with the RE-hardness of the quantum label cover problem, which follows from the celebrated MIP* = RE result of Ji, Natarajan, Vidick, Wright, and Yuen (ACM'21). Additionally, we show that the quantum oracularized smooth label cover problem is RE-hard. Our second result fits with the alternative quantum unique games conjecture recently proposed by Mousavi and Spirig (ITCS'25) on the RE-hardness of the quantum oracularized unique label cover problem. Our proof techniques include a quantum version of Feige's reduction from 3SAT to 3SAT5 (STOC'96) for BCSMIP*-protocols, which may be of independent interest.

16:20-16:45 TuPM_SE2.3

How to Parallelize Cascade Circuits and the (highly Pessimistic) Moore-Nilsson Conjecture Is False (I), pp. 242-245

Bene Watts, Adam — University of Calgary
Helton, J. William — Univ. of California at San Diego

Parallelization is a fundamental aspect of computation. In quantum computing it is very badly understood. A dramatic illustration of this fact is a very pessimistic conjecture in the 1998 by Cristopher Moore and Martin Nilsson, c.f. Moore and Nilsson (2001), the paper which initiated the study of concrete quantum circuit complexity. They define a class of circuits which look like a staircase with each step consisting of a controlled one qubit unitary. This circuit has n- layers of computation that must be done in sequence: you cannot start a computation at layer r without finishing the first r − 1 layers of computation. Here C(U) denotes the unitary produced by the circuit.

This talk describes how one constructs C(U) as a circuit which asymptotically has depth O(log(n)). The focus is on the following theorem and extensions of it.

Theorem 1. (Adam Bene Watts, Charles Chen, Bill Helton and Joe Slote, to appear STOC 2026). Any unitary matrix C(U) coming from a Moore-Nilsson staircase on n qubits can be produced exactly by an O(log n)-depth, ancilla-free (no extra qubits) circuit.

This presentation (with Adam Bene Watts and Joe Slote) of our strong refutation of the Moore–Nilsson Conjecture will attempt to be accessible to those who are not knowledgable about quantum circuits.

16:45-17:10 TuPM_SE2.4

Robust Certification of Quantum States Via an Uncertainty Principle for Conditional Fidelities (I), pp. 246-248

Slote, Joseph — University of Washington

A central task in quantum information science is *state certification*: testing that an unknown state is close to a fixed target state. Recent work gives surprisingly simple protocols---comprising only single-qubit measurements---for state certification. However, these protocols are not *robust*: they can only positively certify states within *O*(1/n) trace distance to the target, whereas in many experimental settings the appropriate error tolerance is *constant*. We present protocols robustly certifying almost all pure target states while utilizing small measurements. Our tests are based on a new *uncertainty principle for conditional fidelities* which may be of independent interest.

TuPM_SE3 MC 5501

Control of Distributed Parameter Systems II (Regular Session)

Chair: Chiri, Maria Teresa — Queen's University
Co-Chair: Guglielmi, Roberto — University of Waterloo

15:30-15:55 TuPM_SE3.1

A Convex Optimization Framework for Stabilization and Invariance of a Wave Equation with Integral Action, pp. 249-254

MA, Ling — University of Waterloo
Guglielmi, Roberto — University of Waterloo

This paper develops a Lyapunov-based pointwise convex optimization framework for boundary control of a 1-D wave equation and its cascade with an integral-action ODE under magnitude-bounded actuation. For the wave equation, a parameterized Lyapunov functional yields an explicit dissipation inequality, an explicit stabilizing input interval, and a unique minimum-norm input computed online by solving a pointwise convex quadratic program. A barrier functional enforces forward invariance of an energy-based safe set, and actuator bounds are incorporated by interval intersection. For the cascade, a forwarding coordinate motivates a projection-based boundary feedback that preserves invariance and stabilizes the cascade under an online feasibility condition.

15:55-16:20 TuPM_SE3.2

Design of an Optimal Positive State Observer for a Diffusion System with Point Observation, pp. 255-258

Piengeon, Violaine — University of Namur (UNamur)
Winkin, Joseph J. — University of Namur (UNamur)

An optimal state observer design problem for a diffusion system with point observation is studied. As the considered system is positive, the analysis takes into account this additional condition. The solution of the optimization problem is derived by means of a discretization approach, which consists in considering the analogous problem adapted for a spatially discretized version of the pure diffusion system.

16:20-16:45 TuPM_SE3.3

Optimization-Based One-Side Boundary Control of LWR Traffic Models, pp. 259-264

Vaid, Eryn — University of Waterloo
Chiri, Maria Teresa — Queen's University
Guglielmi, Roberto — University of Waterloo
Notomista, Gennaro — University of Waterloo

In this paper, we study the feasibility of a class of optimization-based boundary control of one-dimensional macroscopic traffic flow models, where stability and invariance are achieved by a single boundary control. We define the sets of controllers to stabilize the system to a desired state via Lyapunov functionals, and to ensure forward invariance of a desired subset via boundary control barrier functionals. The control input is then selected from the intersection of those sets via a convex optimization problem. We determine sufficient conditions to ensure the existence of an optimal boundary control problem achieving both stability and invariance for a generic traffic flux function. Simulation results showcase the behavior of the proposed optimization-based controller applied to conservation laws with several traffic flow functions.

17:10-17:35 TuPM_SE3.5

An Application of FEM to the Fokker-Planck Framework for Swarm Density Tracking, pp. 265-270

Qazi, Hassaan — University of Waterloo
Guglielmi, Roberto — University of Waterloo

We present a Model Predictive Control-based optimal control strategy for a swarm distribution to track a time-varying target distribution in the context of the Fokker-Planck–optimal control framework. The control, dependent on both time and space, appears as a drift term in the stochastic differential equation that describes the evolution of the agents. The main contribution is to design a Finite Element Method discretization formulation using the first-discretize-then-optimize approach for our 2D problem. We provide results for both static and time-varying target distributions, along with the convergence error.

17:10-17:35 TuPM_SE3.5

Sparse Control of Fluid Mixing Based on Cellular Flows, pp. 271-273

Hu, Weiwei — University of Georgia
Wu, Hao-Ning — University of Georgia
Brower, Alexander — University of Georgia

We investigate an optimal mixing problem for a passive scalar advected by an incompressible flow in two dimensions. The velocity field is represented as a finite superposition of smooth cellular flows, whose time-dependent intensities serve as control inputs. To promote temporal sparsity of the control actions, we incorporate an L^1-regularization term into the objective functional. This leads to a transport equation driven by sparse actuation and results in a bilinear optimal control problem. We derive the first-order necessary optimality conditions using tools from nonsmooth analysis.

TuPM_SE4 MC 5479

Networked Control Systems (Regular Session)

Co-Chair: Mironchenko, Andrii — University of Bayreuth

15:30-15:55 TuPM_SE4.1

Data-Driven Stabilizing Controller Design for Linear Infinite Networks, pp. 274-279

Zaker, Mahdieh — Newcastle University
Mironchenko, Andrii — University of Bayreuth
Nejati, Amy — Newcastle University
Lavaei, Abolfazl — Newcastle University

We propose a direct data-driven method for controller synthesis of infinite networks composed of unknown linear time-invariant subsystems. Using a single set of noise-corrupted input-state trajectories collected from each subsystem, and provided that certain linear matrix inequalities hold, each subsystem is rendered exponentially input-to-state stable (eISS) by locally constructing an eISS control Lyapunov function together with an exponentially input-to-state stabilizing feedback controller. We then compose these local components under a compositional small-gain condition in infinite-dimensional spaces to obtain a global control Lyapunov function and an associated stabilizing controller, ensuring uniform global exponential stability of the infinite network. The approach is validated on a physical case study with unknown dynamics.

15:55-16:20 TuPM_SE4.2

Learning, Misspecification, and Cognitive Arbitrage in Linear-Quadratic Network Games, pp. 280-285

Zhu, Quanyan — New York University
Han, Zhengye — New York University

We study strategic interaction in linear-quadratic network games where agents act on subjective, misspecified models of their environment. Agents observe noisy aggregate signals generated by local network externalities and interpret them through simplified conjectures, such as constant or mean-field representations. We characterize the long-run behavior using the Berk-Nash equilibrium (BNE) concept, establishing conditions under which BNE diverges from the Nash equilibrium of the perfectly specified game. We quantify this divergence using a Value of Misspecification (VoM) metric. Building on this framework, we introduce cognitive arbitrage—a design paradigm where a system designer strategically shapes agents' conjectures via minimal observation distortions to steer equilibrium outcomes. We formulate the cognitive arbitrage problem as a Stackelberg optimization with closed-form solutions and prove the convergence of a two-time-scale learning algorithm to the optimal BNE. Our results provide a principled framework for influencing behavior in networked systems with bounded rationality, offering a new perspective on mechanism design that operates on agents' representations rather than their incentives.

16:20-16:45 TuPM_SE4.3

On Two-Degrees-Of-Freedom Agreement Protocols, pp. 286-289

Barkai, Gal — Université De Lorraine, CNRS,
Mirkin, Leonid — Technion—IIT
Zelazo, Daniel — Technion - Israel Institute of Technology

We propose a distributed two-degrees-of-freedom (2DOF) architecture for driving autonomous, possibly heterogeneous, agents to agreement. The scheme mirrors classical servo structures, separating local feedback from network filtering. This separation enables independent network-filter design for prescribed noise attenuation and allows controller heterogeneity to reject local disturbances, including disturbances exciting unstable agreement poles -- which is known to be impossible via standard diffusive couplings. The potential of the framework is illustrated via two numerical examples.

16:45-17:10 TuPM_SE4.4

Dominance Analysis of Diagonally Stable Interconnections, pp. 290-293

Jagodzinski, Lukasz Andrzej — University of Toronto
Scardovi, Luca — University of Toronto

This work provides compositional conditions for k-dominance for a class of interconnected nonlinear systems. We show that if a k-dissipation matrix encoding both the interconnection structure and the k_i-passivity indices of the subsystems is diagonally stable, then the interconnected system is k-dominant with k being the sum of all k_i. This generalizes the dominance interconnection theory with a diagonal stability condition. We also introduce an output dominance result: under an incremental observability condition, a dominance inequality with a strict output term is sufficient to characterize the asymptotic flow on compact w-limit sets by a k-dimensional Lipschitz system. The results are illustrated on the Goodwin oscillator, where the proposed conditions establish two-dimensional asymptotic behavior and, together with instability of the unique equilibrium and boundedness in the positive orthant, almost global convergence to a limit cycle.

17:10-17:35 TuPM_SE4.5

Demodulation-Error Bounds for FM-Based Signal Transmission in Feedback Control, pp. 294-297

Morita, Ryosuke — Gifu University

This paper analyzes the impact of frequency modulation (FM) on control performance when FM is used to transmit signals in feedback loops. We develop an analytical characterization of quadrature FM detection and derive explicit upper bounds on demodulation errors for single-channel and multiplexed transmissions, including additive disturbances. The resulting performance deviation is quantified via the difference between modulated and nominal closed-loop outputs, providing design guidance for modulation and demodulation parameters.

WeP_PL MC 2065

Plenary: The Monopolist's Free Boundary Problem in the Plane: An Excursion into the Economic Value of Private Information (Plenary Session)

Chair: Georgiou, Tryphon T. — Univ. of California, Irvine

09:00-10:00 WeP_PL.1

*Plenary: The Monopolist's Free Boundary Problem in the Plane: An Excursion into the Economic Value of Private Information**

McCann, Robert — University of Toronto

The principal-agent problem is an important paradigm in economic theory for studying the value of private information: the nonlinear pricing problem faced by a monopolist is one example; others include optimal taxation and auction design. For multidimensional spaces of consumers (i.e. agents) and products, Rochet and Chone (1998) reformulated this problem as a concave maximization over the set of convex functions, by assuming agent preferences are bilinear in the product and agent parameters. This optimization corresponds mathematically to a convexity-constrained obstacle problem. The solution is divided into multiple regions, according to the rank of the Hessian of the optimizer.

Apart from four possible pathologies, if the monopolist's costs grow quadratically with the product type we show that a smooth free boundary delineates the region where it becomes efficient to customize products for individual buyers. We give the first complete solution of the problem on square domains, and discover new transitions from unbunched to targeted and from targeted to blunt bunching as market conditions become more and more favorable to the seller.

Based on works-in-progress including "The monopolist's free boundary problem in the plane" (https://arxiv.org/abs/2412.15505), with Lucas O'Brien (MIT), Cale Rankin (Monash University) and Kelvin Shuangjian Zhang (Fudan University) in various combinations.

WeAM_SE1 MC 4021

Learning and Control of Dynamical Systems III (Invited Session)

Chair: Gruene, Lars — University of Bayreuth

Co-Chair: Kamalapurkar, Rushikesh — University of Florida

Organizer: Gruene, Lars — University of Bayreuth

Organizer: Kamalapurkar, Rushikesh — University of Florida

Organizer: Rosenfeld, Joel — University of South Florida

Organizer: Worthmann, Karl — TU Ilmenau

10:30-10:55 WeAM_SE1.1

Data-Driven Stabilization of Nonlinear Systems Via Descriptor Embedding (I), pp. 298-301

Alsalti, Mohammad — Leibniz University Hannover

De Persis, Claudio — University of Groningen

Lopez, Victor G. — Leibniz University Hannover, Institute for Automatic Control

Muller, Matthias A. — Leibniz University Hannover

We introduce the notion of descriptor embedding for nonlinear systems and use it for the data-driven design of stabilizing controllers. Specifically, we provide sufficient data-dependent LMI conditions which, if feasible, return a stabilizing nonlinear controller of the form u = K(x)Z(x) where K(x) belongs to a polytope and Z is a user-defined function. A simulation example is used to illustrate the results and compare them to existing methods.

10:55-11:20 WeAM_SE1.2

Decaying Sensitivity of the Zero Solution for a Class of Nonlinear Optimal Control Problems (I), pp. 302-307

Gruene, Lars — University of Bayreuth

Sperl, Mario — University of Bayreuth

We study spatial decay properties of sensitivities in a nonlinear optimal control problem with a graph-structured interaction topology. For a problem with nonlinear decoupled dynamics and quadratic cost, we show that a perturbation of the zero initial condition at a single node induces an optimal trajectory whose node-wise norms decay exponentially with the graph distance from the perturbed node. The analysis, based on a nonlinear null-controllability condition, provides a first step toward extending known spatial decay results from linear–quadratic to nonlinear systems. A numerical example illustrates the theoretical findings.

11:20-11:45 WeAM_SE1.3

Automatic Feature Identification in Least-Squares Policy Iteration Using the Koopman Operator Framework (I), pp. 308-311

Zagabe, Christian Mugisho — TU Dortmund

Peitz, Sebastian — TU Dortmund

We present a Koopman autoencoder-based least-squares policy iteration (KAELSPI) algorithm in reinforcement learning (RL). The KAE-LSPI algorithm is based on reformulating the so-called least-squares fixed-point approximation method in terms of the extended dynamic mode decomposition (EDMD) matrix, thereby enabling automatic features learning via the Koopman autoencoder (KAE) framework. The approach is motivated by the lack of a systematic method for choosing features or kernels in linear approximation RL techniques. We apply the KAE-LSPI algorithm to a toy example of the stochastic chain walk problem. Unlike previous works, no features or kernels need to be fixed a priori in our approach.

11:45-12:10 WeAM_SE1.4

On the Nonexistence of Immersions for Continuous and Discrete-Time Systems with Multiple Omega Limit Sets and Its Implications for Learning Dynamics (I), pp. 312-313

Liu, Zexiang — University of Michigan

Ristich, Eron — University of Michigan

Sontag, Eduardo — Northeastern University

Ozay, Necmiye — University of Michigan

The idea of embedding or immersing a complex nonlinear dynamical system into a higher-dimensional yet simpler one has important applications in analysis, design, and learning of nonlinear systems. This extended abstract summarizes several recent results on when finite dimensional linear immersions exist for discrete-time and continuous-time dynamical systems. In particular, we show that the existence of countably many but more than one $omega$-limit sets constitutes an obstruction for linear immersibility with continuous mappings. We present several examples for existence and non-existence and discuss the implications of this obstruction in the context of learning dynamics.

WeAM_SE2 MC 5417

Advances in Optimal Transport Theory and Its Applications (Invited Session)

Chair: Taghvaei, Amirhossein — University of Washington Seattle

Co-Chair: Karlsson, Johan — Royal Institute of Technology (KTH)

Organizer: Taghvaei, Amirhossein — University of Washington Seattle

Organizer: Karlsson, Johan — Royal Institute of Technology (KTH)

Organizer: Uribe, Cesar — Rice University

10:30-10:55 WeAM_SE2.1

Fréchet Regression on the Bures-Wasserstein Manifold (I), pp. 314-317

Nguyen, Duc Toan — Rice University

Uribe, Cesar — Rice University

Fréchet regression, or conditional Barycenters, is a flexible framework for modeling relationships between covariates (usually Euclidean) and response variables on general metric spaces, e.g., probability distributions or positive definite matrices. However, in contrast to classical barycenter problems, computing conditional counterparts in many non-Euclidean spaces remains an open challenge, as they yield non-convex optimization problems with an affine structure. In this work, we study the existence and computation of conditional barycenters, specifically in the space of positive-definite matrices with the Bures-Wasserstein metric. We provide a sufficient condition for the existence of a minimizer of the conditional barycenter problem that characterizes the regression range of extrapolation. Moreover, we further characterize the optimization landscape, proving that under this condition, the objective is free of local maxima. Additionally, we develop a projection-free and provably correct algorithm for the approximate computation of first-order stationary points. Numerical experiments validate the performance of the proposed methods on regression problems of biological networks.

10:55-11:20	WeAM_SE2.2

Wasserstein Gradient Flow Structure in Mean-Field Oscillator Ising Machines (I), pp. 318-321

Emerick, Max	University of California Santa Barbara
Venkatakrishnan, Arvind Ragghav	University of California, Santa Barbara
Bamieh, Bassam	Univ. of California at Santa Barbara
Bullo, Francesco	Univ of California, Santa Barbara

Oscillator Ising Machines (OIMs) have emerged as promising computational architectures for approximating solutions to combinatorial optimization problems. We derive and analyze the mean-field limit of an OIM model and show that it inherits the gradient-flow structure of the finite-dimensional dynamics. We identify conditions under which this mean-field evolution admits an Eulerian formulation as a gradient flow on the Wasserstein space of probability measures, and contrast this with a general Lagrangian formulation that is always available. The gradient-flow structure strongly constrains the long-time dynamics and, in the totally symmetric case, enables a complete classification of limit solutions and their stability. In particular, all limit solutions are fixed points with a highly restricted phase structure. We also present numerical evidence that the mean-field model correctly predicts behavioral regimes in large Erdős–Rényi networks.

11:20-11:45	WeAM_SE2.3

A Proximal Approach to the Schrödinger Bridge Problem with Incomplete Information (I), pp. 322-325

Mascherpa, Michele	KTH Kungliga Tekniska Högskolan
Molnö, Victor	KTH Royal Institute of Technology
Kallesøe, Carsten Skovmose	Grundfos
Karlsson, Johan	Royal Institute of Technology (KTH)

We study a discrete Schrödinger bridge problem with partial marginal information, where only a subset of the state space is observed and the total transported mass is not fixed. In this setting, the problem is inherently ill-posed, preventing the direct use of classical Sinkhorn-type iterations, and potentially leading to non-uniqueness of solutions. To address this issue, we propose an entropic proximal point scheme that alternates between Schrödinger bridge problems with a fixed marginal and updates of the unobserved mass components. Each proximal step reduces to a Schrödinger bridge problem that can be solved efficiently using Sinkhorn-type iterations. We further analyze the structure of the solution set and derive conditions under which uniqueness of the optimal solution is recovered, relating these conditions to an observability property of an associated linear system.

11:45-12:10	WeAM_SE2.4

Causal Optimal Coupling for Gaussian Input-Output Distributional Data (I), pp. 326-329

Xu, Daran	University of Washington
Taghvaei, Amirhossein	University of Washington Seattle

We study the problem of identifying an optimal coupling between input–output distributional data generated by a causal dynamical system. The coupling is required to satisfy prescribed marginal distributions and a causality constraint reflecting the temporal structure of the system. We formulate this problem as a Schrödinger Bridge, which seeks the coupling closest—in Kullback–Leibler divergence—to a given prior while enforcing both marginal and causality constraints. For the case of Gaussian marginals and general time-dependent quadratic cost functions, we derive a fully tractable characterization of the Sinkhorn iterations that converges to the optimal solution. Beyond its theoretical contribution, the proposed framework provides a principled foundation for applying causal optimal transport methods to system identification from distributional data.

12:10-12:35	WeAM_SE2.5

On the Sub-Riemannian Structure of Optimal Transport (I), pp. 330-331

Abdelgalil, Mahmoud	University of California, San Diego
Georgiou, Tryphon T.	Univ. of California, Irvine

We introduce and discuss a new type of transportation problems, where particles/agents in the ensemble are labeled and their relative position along their journey is of interest. Of particular importance in our program are control laws that steer ensembles along cycles ensuring that individual particles return to their original position. This feature is in contrast with the classical theory of optimal transport where the primary object of study is the path of probability densities, without any concern about particle labels. We focus on the case Gaussian distributions and linear dynamics, and explore a hitherto unstudied sub-Riemannian structure of Monge-Kantorovich transport where the relative position of particles along their journey is modeled by the holonomy of the transportation schedule.

WeAM_SE3	MC 5501
Port-Hamiltonian Systems and Dissipativity (Regular Session)	
Chair: Bridgeman, Leila	Duke University

10:30-10:55	WeAM_SE3.1

Discretization of the Burgers' Equation As a Port-Hamiltonian System, pp. 332-337

Agostini, Lorenzo	Institut Supérieur De l'Aéronautique Et De L'Espace
Fournié, Michel	ISAE-Supaero
Haine, Ghislain	Institut Superieur De l'Aeronautique Et De L'Espace

The numerical simulation of the inviscid Burgers' equation is often hindered by spurious oscillations near discontinuities. To mitigate this issue, a viscous term can be introduced, leading to the viscous Burgers' equation. In this work, port-Hamiltonian formulations for both the inviscid and the viscous Burgers' equations are proposed, enabling a representation that incorporates both convective and dissipative effects. Boundary control and observation are naturally handled within this framework. Applying a dedicated finite element method, a finite-dimensional port-Hamiltonian system is derived. The relationship between time step, spatial resolution, and viscosity required to achieve numerical stability is analyzed. Numerical experiments validate the effectiveness of the approach.

10:55-11:20	WeAM_SE3.2

On Representations of Linear Port-Hamiltonian Systems Defined by Dirac and Lagrange Structures, pp. 338-343

Caballeria, Javier	Universidad Técnica Federico Santa María
Ramirez, Hector	Universidad Tecnica Federico Santa Maria

Lefevre, Laurent — Univ. Grenoble Alpes
Le Gorrec, Yann — FEMTO-ST, SupMicroTech Besançon

Linear port-Hamiltonian systems (PHS) defined by Dirac and Lagrange structures, referred to as port-Hamiltonian differential-algebraic equation systems (PH DAEs), incorporate a class of algebraic constraints arising from energy deficiency in the Hamiltonian definition, known as Lagrange algebraic constraints. This paper presents two novel equivalent characterizations of linear PH DAEs with Lagrange constraints, including resistive and external ports. Relations to constrained input–output PHS formulations are established. The constraints are shown to be transferable between Dirac and Lagrange structures, enabling equivalent representations in terms of state or effort variables. The proposed formulations are illustrated using a micro-robotic contact scenario model.

11:20-11:45 WeAM_SE3.3

Stieltjes Systems, pp. 344-346

Chaffey, Thomas Lawrence — University of Sydney
Pates, Richard — Lund University

We characterize a class of linear, time invariant systems whose state-space realizations form a Stieltjes matrix when stacked appropriately. These systems share properties of both passive and internally positive systems. The class is preserved under negative feedback, their inverses are internally positive and a diagonal storage function is necessary and sufficient for dissipativity. We show that Stieltjes systems arise naturally from a class of RC circuits.

11:45-12:10 WeAM_SE3.4

On Duality of Memristive Elements, pp. 347-350

Shali, Brayan — KU Leuven
Sepulchre, Rodolphe J. — University of Cambridge

Duality plays a fundamental role in circuit theory, where it arises both at the network level and at the component level. While component-level duality is well understood for resistive, capacitive, and inductive elements, its systematic treatment for memristive elements remains limited. In this extended abstract, we explore how duality emerges for memristive elements as an extension of the duality for resistive elements. Since memristive elements incorporate memory effects, the classical content-cocontent duality of resistive elements does not directly extend in a straightforward manner. To address this challenge, we adopt a Riemannian approach to modeling memristive elements and explore how notions of content, cocontent, and variational principles may be reformulated in this framework.

12:10-12:35 WeAM_SE3.5

From Compositional Dissipativity Analysis to Controller Synthesis for Nonlinear Networks, pp. 351-354

Jang, Ingyu — Duke University
Bridgeman, Leila — Duke University

Despite longstanding interest, stability analysis and controller synthesis remain challenging for large-scale interconnections of heterogenious, nonlinear systems. Moreover, improved computational efficiency and information privacy are increasingly important. This extended abstract reviews recent progress in dissipativity-based distributed stability analysis and introduces a distributed controller synthesis framework that integrates alternating direction methods of multipliers (ADMM), chordal decomposition, and iterative convex overbounding (ICO) to overcome current limitations in scaling and privacy.

ThP_PL MC 2065

Plenary: Notions of Resilience in Large-Scale Networks, with Applications to Distributed Coordination, Optimization, and Learning (Plenary Session)

Chair: Smith, Stephen L. — University of Waterloo

09:00-10:00 ThP_PL.1

*Plenary: Notions of Resilience in Large-Scale Networks, with Applications to Distributed Coordination, Optimization, and Learning**

Sundaram, Shreyas — Purdue University

A key challenge in large-scale networks is to allow each agent to learn the true state of the world, based on its own measurements and information that it obtains from others in the network. For example, in autonomous swarms and sensor networks, what information should the agents (drones and sensors) exchange with each other in order for the swarm to understand its environment? Similarly, in social networks, how should individuals incorporate the opinions of their friends when updating their own beliefs about the world? The challenge of learning in such settings is made even more difficult when malicious agents in the network spread misinformation to prevent the other agents from learning the true state.

In this talk, we will provide an overview of classes of networked dynamics (or algorithms) that have been studied over the past decade for resilient coordination and learning in networks. In particular, we will describe a simple general-purpose approach to enabling resilience to adversarial nodes in several classes of distributed coordination and optimization dynamics, based on each node removing a certain number of the most extreme values in its neighborhood at each time-step. In the process, we will identify key insights about the interplay between network topology and dynamics in the context of creating more resilient networked systems.

ThAM_SE1 MC 4058

Control and Estimation of Infinite-Dimensional Systems I (Invited Session)

Chair: Belhadjoudja, Mohamed Camil — Department of Applied Mathematics, University of Waterloo

Co-Chair: Mironchenko, Andrii — University of Bayreuth

Organizer: Belhadjoudja, Mohamed Camil — Department of Applied Mathematics, University of Waterloo

10:30-10:55 ThAM_SE1.1

Input-To-State Stability and Admissibility in Integral Norms for Linear Distributed Parameter Systems (I), pp. 355-360

Arora, Sahiba — Leibniz University Hannover
Mironchenko, Andrii — University of Bayreuth

We investigate input-to-state stability (ISS) for infinite-dimensional linear systems with inputs and trajectories in L^p-spaces. We begin by developing the corresponding admissibility theory for linear systems with unbounded input operators. We show that ISS in integral norms cannot be in general characterized by exponential stability together with finite-time admissibility, in contrast to classical ISS theory. For analytic semigroups, we derive a precise characterization based on maximal regularity theory. Finally, we establish direct Lyapunov theorems and construct Lyapunov functions for L^p-L^q-ISS systems. We illustrate the results with examples, including diagonal systems and diffusion equations.

10:55-11:20 ThAM_SE1.2

On the Stabilization of Timoshenko Beams Using Boundary Torque Control (I), pp. 361-366

AURIOL, Jean — CNRS, CentraleSupélec, Université Paris-Saclay
Wu, Yongxin — Université Marie Et Louis Pasteur
Le Gorrec, Yann — FEMTO-ST, SupMicroTech Besançon
Ramirez, Hector — Universidad Tecnica Federico Santa Maria

This study investigates the stabilization of a Timoshenko beam driven by a single torque actuator. Our approach begins by reformulating the system in Riemann coordinates, yielding a 2×2 hyperbolic system of balance laws. Due to the presence of a single actuator, the system is inherently underactuated. To address this limitation, we apply backstepping transformations to recast the system into an Integral Difference Equation with distributed actuation. Leveraging an approximate controllability condition, we then design a stabilizing controller featuring an auto-regressive structure. This controller relies on integrals of the system state and input history over a fixed-length time window. Finally, we validate the theoretical results through simulations, demonstrating the effectiveness of the proposed control strategy.

12:10-12:35 ThAM_SE1.5

A LaSalle-Datko Theorem for Abstract Linear Systems (I), pp. 367-369

Andrieu, Vincent — Université De Lyon
Astolfi, Daniele — CNRS - Univ Lyon 1
Wirth, Fabian — University of Passau

This note presents a sufficient condition for the exponential stability of abstract linear systems, akin to LaSalle's invariance principle but without requiring precompactness of trajectories. The result relies on a generalization of Datko's Lemma involving orthogonal projections. Complementing this qualitative analysis, we propose a constructive Lyapunov strictification technique that transforms a weak Lyapunov function into a strict one, thereby providing explicit decay rates. The effectiveness of this framework is illustrated through the stabilization of a finite-dimensional system coupled with a transport equation on a semi-infinite domain.

ThAM_SE2 MC 4060

Optimal Control (Regular Session)

Chair: Mirkin, Leonid — Technion—IIT

Co-Chair: Kashima, Kenji — Kyoto University

10:30-10:55 ThAM_SE2.1

Covariance Steering of Bilinear Systems with Soft Terminal Constraints Via Krotov's Method, pp. 370-372

Enami, Shoju — Kyoto University
Kashima, Kenji — Kyoto University

In this paper, we consider a covariance steering problem for bilinear systems with soft terminal constraints. Finding an optimal input of the addressed problem is difficult due to its nonconvexity. Instead, we propose to apply Krotov's method, which allows us to improve a provisional control input successively. As the main result of this paper, we construct so-called Krotov functions, which play an important role in Krotov's method.

10:55-11:20 ThAM_SE2.2

State Constraint Analysis for Powered Descent Guidance, pp. 373-378

HORNUS, Samuel — Inria
Caillau, Jean Baptiste — Université Côte d'Azur, CNRS, Inria, LJAD
Dell'Elce, Lamberto — INRIA
Pomet, Jean-Baptiste — INRIA

We further the study of the powered-descent guidance problem for soft planetary landing. This optimal control problem seeks the best trajectory for propulsively landing a vehicle at a given point while consuming as little propellant as possible and satisfying

constraints on the control (thrust direction) and the state (obstacle avoidance). As such, it is very relevant to applications to reusable launchers. The problem and its variants have been extensively studied using finite-dimensional optimization techniques (e.g. convex solvers), and less so with indirect methods. Even the variant with the simplest dynamics is not yet completely understood mathematically, as highlighted by the recent study of Leparoux and Jean (2022). We provide the expression of the control along state-constrained arcs. This allows us to implement the indirect method accounting for the control and state constraints. We then explore the space of trajectory structures by sampling the initial condition. This highlights the richness of the problem, and lets us envision, as future work, low computation MPC-style real-time controllers.

11:20-11:45 ThAM_SE2.3

Conditions for Complete Decentralization of the Linear Quadratic Regulator, pp. 379-384

McCurdy, Addie — University of Colorado Boulder
Collins, Isabel — CU Boulder
Jensen, Emily — University of Colorado, Boulder

An optimal control policy is completely decentralized if computing actuation for each subsystem only requires information directly available to its own subcontroller. Parameters that admit a completely decentralized optimal controller have been characterized in a variety of systems, but attempts to physically explain the phenomenon have been limited. As a step toward a general characterization of complete decentralization, this paper presents conditions for complete decentralization of Linear Quadratic Regulators for several simple cases and physically interprets these conditions with illustrative examples.

11:45-12:10 ThAM_SE2.4

Direct Optimal Control of Second Order Mechanical State Space Systems, pp. 385-390

Harker, Matthew — École De Technologie Supérieure
Handler, Johannes — Technical University of Leoben
Rath, Gerhard — Technical University of Leoben

In this paper, we derive a new numerical method for the solution of systems of second order ordinary differential equations, as well as the boundary value problems that arise in the optimal control of such systems. Systems of second order arise generally in mechanics, and are critical to problems in robotics, structural dynamics, and distributed parameter systems. Typically though, second order systems are transformed into systems of first order ordinary differential equations so that Runge-Kutta methods and allied methods can be invoked. The justification given for this is that first order system are more stable to solve numerically. The new algorithm, however, is shown to be stable, principally due to the proposed matrix-based approach, whereby the solution to the boundary value problems of optimal control are solved at all points simultaneously. The method is demonstrated by solving the optimal control problem of multiple pendulums of differing lengths on a single cart.

12:10-12:35 ThAM_SE2.5

What Is the Cost of Stabilization in Discounted LQR?, pp. 391-394

Daafouz, Jamal — Université De Lorraine, CRAN, CNRS
Mirkin, Leonid — Technion—IIT
Postoyan, Romain — CRAN, CNRS, Université De Lorraine

The optimal Discounted Linear Quadratic Regulator (DLQR) solution might yield unstable closed-loop dynamics due to the presence of the discount factor in the cost function. This paper addresses the problem of modifying a non-stabilizing DLQR optimal feedback law to enforce closed-loop stability while reducing the resulting performance loss, referred to as the cost of stabilization. We show that this cost is negligible if we look beyond linear time-invariant controllers.

ThAM_SE3 MC 4064

Systems on Graphs (Regular Session)

Chair: Erden, Onur Ege — University of Waterloo
Co-Chair: Zhang, Kexue — Queen's University

10:30-10:55 ThAM_SE3.1

Convergence Rate Bounds for Markovian Push-Sum Algorithms, pp. 395-397

Gerencsér, Balázs — HUN-REN Alfréd Rényi Institute of Mathematics
Kornyik, Miklós — HUN-REN Alfréd Rényi Institute of Mathematics

In this work our goal is to establish an upper bound for the almost sure convergence rate for a generous class of push-sum algorithms, more precisely for those where message passing events follow a Markovian dynamics, or a Hidden Markov Process. Furthermore, having a computationally accessible quantity at hand is of top priority. The result extends previous work by Gerencsér (2022), where a similar approach to the problem has been considered, but restricted to independent identically distributed message passing sequences.

Theoretical results are complemented with numerical demonstration, where the approximated rates via a simulated process is compared with the proven upper bounds.

10:55-11:20 ThAM_SE3.2

Split-Merge Dynamics for Shapley-Fair Coalition Formation, pp. 398-403

Zhu, Quanyan — New York University
Han, Zhengye — New York University

Coalition formation is often modeled as a static equilibrium problem, neglecting the dynamic processes governing how agents self-organize. This paper proposes a dynamic split-and-merge framework that balances two conflicting economic forces: individual fairness and collective efficiency. We introduce a control-theoretic mechanism where topological operations are driven by distinct signals: splits are triggered by fairness violations (specifically, negative Shapley values representing ``agent-responsible inefficiency''), while merges are driven by strict surplus improvements (superadditivity). We prove that these dynamics converge in finite time to a specific class of steady states termed Shapley-Fair and Merge-Stable (SFMS) partitions. Convergence is established via a vector Lyapunov function tracking aggregate fairness deficits and system surplus, leveraging a discrete-time LaSalle invariance principle. Numerical case studies on a 10-player game demonstrate the algorithm's ability to resolve fairness tensions and reach stable configurations, providing a rigorous foundation for endogenous coalition formation in dynamic environments.

11:20-11:45 ThAM_SE3.3

Lumpability in Networks Via Coprobability-Preserving Vertex Addition, pp. 404-409

Erden, Onur Ege — University of Waterloo
Atay, Fatihcan M. — Bilkent University

We consider the problem of lumpability in undirected networks by introducing the concept of coprobable vertices. We present an operation for adding and deleting vertices in networks with coprobable vertices, which induces lumpability in the network while preserving the coprobability of those vertices. This operation can be applied multiple times and allows one to attach an arbitrary graph to certain special vertices, thereby constructing large graphs in which the dynamical system induced by the adjacency matrix can be lumped over certain local subgraphs.

11:45-12:10 ThAM_SE3.4

Event-Triggered Impulsive Pinning Control of Complex Dynamical Networks with Coupling Delay, pp. 410-413

Saleem, Hamza — Queen's University
Zhang, Kexue — Queen's University

This study investigates event-triggered impulsive pinning control for complex dynamical networks with time-varying coupling delays. Impulsive control inputs are applied to a subset of nodes according to an exponentially decaying event condition. By constructing suitable Lyapunov functions and employing delay differential inequality technique, sufficient conditions are established to guarantee exponential stability of the unpinned subsystem and asymptotic stability of the entire network. Explicit admissible delay bounds, control gain conditions, and event-triggering constraints are derived. A closed-form lower bound on the inter-event time is obtained, ensuring exclusion of Zeno behavior. The proposed framework provides a systematic co-design methodology for delay tolerance and impulsive gains in delayed networked systems.

12:10-12:35	ThAM_SE3.5

Convergence Rate Analysis of Ratio Consensus Algorithms with Column-Allowable Matrices, pp. 414-417

Gerencsér, Balázs	HUN-REN Alfréd Rényi Institute of Mathematics
Szemerédi, Levente	HUN-REN Alfréd Rényi Institute of Mathematics; Eötvös Loránd University

We give explicit convergence rate results of ratio consensus algorithms when the protocol can be reformulated to be linear updates of vector values on a possibly larger, augmented network. This is an improvement of the results of Gerencsér and Gerencsér (2021) by allowing zero values on auxiliary nodes infinitely often which makes the technique applicable to a much larger family of algorithms.

ThAM_SE4	MC 5501
Linear Systems (Regular Session)	
Chair: Simpson-Porco, John W.	University of Toronto
Co-Chair: Verriest, Erik I.	Georgia Inst. of Tech

10:30-10:55	ThAM_SE4.1

On the Solvability of Quasi-Regulator Equations in Non-Smooth Output Regulation, pp. 418-423

Niu, Zirui	Imperial College London
Astolfi, Daniele	CNRS - Univ Lyon 1
Scarciotti, Giordano	Imperial College London

Motivated by the prevalence of non-smooth, possibly non-periodic signals in real-world applications, the output regulation of linear systems subject to non-smooth non-periodic exogenous signals has emerged as a challenging problem. A fundamental prerequisite for solving this problem is the existence of solutions to the so-called ``quasi-regulator equations''. In this paper, we investigate the solvability of these equations. To this end, we reformulate the quasi-regulator equations as differential-algebraic equations and highlight the critical role played by the system's relative degree. We finally propose a ``non-smooth non-resonance condition'' that, under specific relative degree requirements, provides a necessary and sufficient characterization of the solvability of the quasi-regulator equations.

10:55-11:20	ThAM_SE4.2

Some Extensions of the Classical Laplace Transform: Initial Value Theorem and Inverson Formula, pp. 424-429

Verriest, Erik I.	Georgia Inst. of Tech

The relation between the Fourier and Laplace transforms leads to an extension to a more general class of right-sided functions (and distributions). The initial value theorem, which classically enabled the computation of the initial value without explicit inversion, is generalized. With a precise notion of strict properness, it also generalizes to a boundary value theorem. In turn, novel inversion formulas are derived, avoiding the classical inversion formula, with its averaging as found in the Fejér theory. A Laplace-domain derivation is then given to characterize the instantaneous effect of impulsive inputs for linear time-invariant (LTI) systems.

11:20-11:45	ThAM_SE4.3

The Moving-Average Region of Stability for Linear Systems, pp. 430-433

Epperlein, Jeremias	Universität Passau
Wirth, Fabian	University of Passau

We consider moving-average iteration for fixed matrices. Necessary and sufficient spectral conditions for the asymptotic stability of the iteration are presented in dependence of the fixed window length. The limiting stability region as the window size tends to infinity is determined.

11:45-12:10	ThAM_SE4.4

Performance Enhancement of Primal-Dual Feedback-Based Optimization Using Estimators, pp. 434-437

Yousefi, Niloufar	University of Toronto
Simpson-Porco, John W.	University of Toronto

Feedback-based optimization (FBO) regulates a stable dynamical system to the solution of a constrained optimization problem under disturbances. However, closed-loop stability typically requires the controller to operate on a slower time scale than the plant, limiting closed-loop performance. An estimator-enhanced FBO (EE-FBO) removes this time-scale separation by incorporating plant model information via an extended-state observer. In this work, we extend EE-FBO for LTI systems to a class of primal-dual FBO controllers, and demonstrate its effectiveness via an application to fast power system frequency control using inverter-based resources.

12:10-12:35	ThAM_SE4.5

A Study of Sliding Interval Balanced Realization Parameterization, pp. 438-441

Verriest, Erik I.	Georgia Inst. of Tech

Due to the importance of finite-time Gramians in Sliding Interval Balancing (SIB-δ) as applied to nonlinear balancing, we consider here the simple LTI case for SISO systems. As an n-th order system has 2n free parameters, we can match these with the n elements of the canonical Gramian, which are essential in deciding the reduced model. Then we discuss the role of the remaining n parameters. We illustrate their influence for infinite-time balancing. We then proceed to introduce finite-time Gramians and show how these can be derived from the infinite-time balanced realizations. We discuss a topological impediment in obtaining global reduced order models in the time-variant (and thus also nonlinear) case.

ThSP_SP1	MC 2065
Semi-Plenary: Finite Dimensional Feedback Controllers for Distributed Parameter Systems (Plenary Session)	
Chair: Georgiou, Tryphon T.	Univ. of California, Irvine

14:00-15:00	ThSP_SP1.1

*Semi-Plenary: Finite Dimensional Feedback Controllers for Distributed Parameter Systems**

Ozbay, Hitay	Bilkent University

There are primarily two ways to obtain finite-dimensional stabilizing controllers for LTI infinite-dimensional systems: (i) approximate the plant transfer function, then design a rational controller for the approximant; (ii) design an infinite-dimensional controller for the original distributed parameter system, then approximate this controller. In both methods, approximation errors affect the robust stability and performance of the feedback system. In this talk, we discuss these methods and illustrate them on some typical examples. For method (i), we use H-infinity controllers to guarantee robust stability; for method (ii), we study the effects of approximating the infinite-dimensional stable part of a specific type of controller introduced recently.

ThSP_SP2	MC 2066

Semi-Plenary: Large-Scale Network Processes: Achieving Tractability Via Graph Limits (Plenary Session)

Chair: Maggiore, Manfredi — Univ of Toronto

14:00-15:00 — ThSP_SP2.1

*Semi-Plenary: Large-Scale Network Processes: Achieving Tractability Via Graph Limits**

Parise, Francesca — Cornell University

Network dynamical systems provide a versatile framework for studying the interplay between the structure of complex networks and the dynamic behavior of its constituent entities, offering insights into diverse phenomena across disciplines such as physics, biology, sociology, and engineering. As the size of the underlying network increases, however, a number of new challenges arise. For example, collecting exact network data may become too costly and planning optimal network interventions may become computationally intractable. In this talk I will show how the theory of graph limits can be used to provide new insights on graph processes evolving over large random networks. First, I will illustrate how graph limits can be used to define tractable infinite population models of network systems while maintaining agents' heterogeneity. Second, I will illustrate how insights derived for such infinite population models can be applied to study large but finite networks. The benefit of this graph limit approach will be demonstrated for broad classes of network processes including strategic interactions, multi-agent learning and synchronization dynamics.

ThPM_SE1 — MC 4058

Control and Estimation of Infinite-Dimensional Systems II (Invited Session)

Chair: Belhadjoudja, Mohamed Camil — Department of Applied Mathematics, University of Waterloo

Co-Chair: Bociu, Lorena — North Carolina State University

Organizer: Belhadjoudja, Mohamed Camil — Department of Applied Mathematics, University of Waterloo

15:30-15:55 — ThPM_SE1.1

Backstepping Control of Reaction Diffusion PDEs on Directionally Convex Domains (I), pp. 442-444

Belhadjoudja, Mohamed Camil — Department of Applied Mathematics, University of Waterloo

Despite the extensive body of work on backstepping for one-dimensional PDEs, results in higher dimensions remain comparatively limited. Most available methods either exploit particular symmetries of the PDE or address problems posed on paral- lelepiped domains. To the best of our knowledge, the only approach that enables the design of backstepping controllers on non-parallelepiped regions without symmetry assumptions is the domain extension technique. This method, however, presents some drawbacks. In particular, the control input at each time instant is obtained by simulating a PDE on an extended domain, from which the actual input on the original domain is approximated. By contrast, in the one-dimensional setting, once the time-independent backstepping gain kernel is known, the control input can be computed in closed form as a feedback depending solely on the state at that same instant. Moreover, problems such as adaptive and robust control do not appear straightforward to address with the domain extension method, at least to the best of our knowledge. These considerations motivate the search, whenever possible, for alternatives that preserve the main advantages of one-dimensional backstepping.

A motivating example for the domain extension method is the control of the heat equation on a piano-shaped domain, with actuation applied at the tail of the piano. In this extended abstract, we show through a simple calculation that the domain extension method is not required in this setting. Instead, a strategy akin to that used for parallelepiped domains can be adopted. This result constitutes a first instance of a broader framework for backstepping control of asymmetric PDEs posed on non-parallelepiped regions, which we refer to as directionally convex domains. The general framework is developed in a forthcoming paper.

15:55-16:20 — ThPM_SE1.2

Infinite Horizon Control Problems for Semilinear Parabolic Equations with Pointwise State Constraints (I), pp. 445-448

Bociu, Lorena — North Carolina State University

Casas, Eduardo — University of Cantabria

We study an optimal control problem for semilinear parabolic equations with infinite horizon, pointwise state contraints and control constraints. We prove first-order necessary conditions and then we provide a second-order sufficient condition for local optimality. The second-order condition is formulated using an extended cone that considers the infinite horizon and the control and state constraints.

16:20-16:45 — ThPM_SE1.3

Backstepping Observer for the Quasilinear Heat Equation with Estimated Region of Attraction (I), pp. 449-452

Belhadjoudja, Mohamed Camil — Department of Applied Mathematics, University of Waterloo

Morris, Kirsten A. — Univ. of Waterloo

We consider the one-dimensional quasilinear heat equation with state-dependent heat capacity and thermal conductivity, subject to homogeneous Neumann boundary conditions. We design a backstepping observer to estimate the state from boundary outputs. We establish the existence of a unique forward-complete classical solution to the observer and provide an explicit characterization of the region of attraction. The main result proves that the observation error converges exponentially in the H1 norm, and at a prescribed rate, towards zero.

ThPM_SE2 — MC 4060

Optimization: Theory and Algorithms (Regular Session)

Chair: Kashima, Kenji — Kyoto University

Co-Chair: Simpson-Porco, John W. — University of Toronto

15:30-15:55 — ThPM_SE2.1

Set-Theoretic Output Feedback Tracking Control Via Linear Programming, pp. 453-458

Kumar, Avaneet — Indian Institute of Technology Roorkee

Kothyari, Ashish — Indian Institute of Technology Roorkee

This paper presents a set-theoretic framework for tracking a set-point reference signal in constrained discrete-time linear systems subject to bounded additive disturbances via output feedback. The proposed approach jointly synthesizes a stabilizing output-feedback controller and a robust control-invariant (RCI) set within the state and input constraints using zonotopic set representations. By exploiting zonotope inclusion properties, sufficient conditions for robust invariance are derived as tractable algebraic constraints, allowing the controller synthesis and RCI set computation to be formulated as a single linear program, thereby avoiding bilinear or nonconvex optimization, as is the case in state-of-the-art methods. Subsequently, a feedforward gain is designed to achieve robust set-point tracking. This feedforward gain also allows for computation of a set of admissible set-points. In addition, the explicit expressions for the steady-state tracking error bounds are derived, revealing their dependence on the disturbance set. The proposed method provides a computationally efficient and scalable solution for robust tracking control with guaranteed performance and constraint satisfaction. Finally, simulation results show the effectiveness of the proposed approach.

15:55-16:20 — ThPM_SE2.2

Entropy-Based Optimal Sensor Network Design for Kalman Filtering Using Generalized Benders Decomposition, pp. 459-464

Kumar, Manjay	Indian Institute of Technology Tirupati
M U, Abuthahir	Indian Institute of Technology Tirupati
Magbool Jan, Nabil	Indian Institute of Technology Tirupati

Sensor placement for state estimation in linear dynamical systems is a combinatorial problem of significant practical importance. In this work, we formulate optimal sensor network design within a Kalman filtering framework using a log-determinant entropy criterion, and show that the resulting problem can be cast as a binary semidefinite program (BSDP). We propose a novel distance-based generalized Benders decomposition algorithm that exploits deepest cuts. The performance of the proposed approach is illustrated on a process flow network.

16:20-16:45 ThPM_SE2.3

A Proximal Point Algorithm for the Composition of Monotone Operators, pp. 465-468

Qu, Haoming	The University of Sydney
Wu, Yefan	University of Sydney
Chaffey, Thomas Lawrence	University of Sydney

We introduce a generalisation of the proximal point algorithm which solves the zero of the composition of two monotone operators. The application of this algorithm is demonstrated in electrical circuit simulation. Two extensions are developed, one which solves the cascade of two monotone operator equilibrium networks, and one which solves an arbitrary electrical circuit containing nonlinear capacitors and inductors.

16:45-17:10 ThPM_SE2.4

Unbalanced Optimal Transport and Density Control for Discrete-Time Linear Systems, pp. 469-472

Nakashima, Haruto	Kyoto University, Graduate School of Informatics
Ganguly, Siddhartha	Georgia Institute of Technology
Kashima, Kenji	Kyoto University

This article studies unbalanced optimal transport (UOT) and its dynamical extension, unbalanced density control (UDC), for discrete-time linear systems. UOT compares measures with unequal total mass by balancing transport cost and fidelity to reference measures, while UDC incorporates controlled linear dynamics into this framework. Focusing on Gaussian references and discrete-time linear systems, we show that both problems can be solved globally through convex moment optimization and a closed-form mass update, analogous to covariance steering. A numerical experiment is provided to illustrate our approach.

17:10-17:35 ThPM_SE2.5

Decentralized Low-Gain Integrators for LTI Systems with Application to Decentralized Feedback-Based Optimization, pp. 473-476

Casasanta, John-Paolo	University of Toronto
Simpson-Porco, John W.	University of Toronto

Decentralized control architectures are widely used for the control of large-scale and networked systems. We review classical formulations and results in decentralized integral control, and illustrate how the results can be applied to derive stability conditions for decentralized feedback-based optimization controllers.

ThPM_SE3 MC 4064

Hybrid Systems and Discrete Event Systems (Regular Session)

Chair: Maggiore, Manfredi — Univ of Toronto

15:30-15:55 ThPM_SE3.1

Hybrid Stabilization of Rotational Motion in Mechanical Systems with Degree of Underactuation One, pp. 477-480

Navarro, Luiz Dias	University of Toronto
Maggiore, Manfredi	Univ of Toronto

This extended abstract addresses the orbital stabilization problem for mechanical systems with underactuation degree one, with a focus on stabilizing rotational motions. A common approach to generating closed orbits in such systems is through virtual holonomic constraints VHCs, which reduce the system dynamics to a lower-dimensional manifold. Building on recent work on event-based VHCs for oscillation stabilization, we propose a new hybrid control framework to stabilize rotations with a guaranteed basin of attraction.

15:55-16:20 ThPM_SE3.2

System Comparison across Time Domains, pp. 481-484

Pirastehzad, Armin	University of Groningen
Besselink, Bart	University of Groningen

We develop a formal framework for the behavioral comparison of linear systems across different time domains by introducing the notion of system interpolation, which determines whether the input-state trajectories of a continuous-time system can be realized as piece-wise polynomial interpolations of the input-state trajectories of a discrete-time system. We obtain a computationally efficient characterization of this notion, which we then exploit to discretize a given continuous-time system into a discrete-time one. Lastly, given a control specification, we exploit system interpolation to synthesize controllers that ensure satisfaction at each given sampling instant, while they measure the extent of (possible) violation over intervals between these instants.

16:20-16:45 ThPM_SE3.3

A Case Study on the Use of Invertible Functions to Detect Attacks in Cooperative Discrete-Event Systems, pp. 485-490

Laporte, Bryony	Queen's University
Rudie, Karen	Queen's Univ

In this work we explore a novel use of the style of encryption function used to enforce confidentiality in discrete-event systems. While these encryption functions typically secure a system against passive attackers, by leveraging stealthiness one can design an encryption function that detects active attacks. In this work we shall demonstrate this concept and show with examples how risk can be minimized, even if the attacker is capable of altering communications without restriction. With this method, a system can be secured against both active and passive attackers.

16:45-17:10 ThPM_SE3.4

Hierarchical Modeling for Automated Design of Neuromorphic Circuits, pp. 491-494

Scheres, Koen	STADIUS, KU Leuven
Reniers, Michel	TU/e
Sepulchre, Rodolphe J.	University of Cambridge

Although excitable neuromorphic circuits are physical models which produce continuous-time trajectories, these trajectories consist of sequences of discrete events. This mixture of the continuous and the discrete allows us to do hierarchical control, that is, reference tracking and decision-making, with the same building blocks. In order to investigate the possibility of using automated synthesis for generating neuromorphic circuits whose ordering of events is fixed, we explore the concept of forcible events to make the model hierarchical.

17:10-17:35 ThPM_SE3.5

Interplay between Excitability and Noise in Analog Spiking Neurons, pp. 495-498

Van Brandt, Léopold	Université Catholique De Louvain
Ascoli, Alon	Department of Electronics and Telecommunications, Politecnico Di Torino

Bonnin, Michele	Politecnico Di Torino
Brandsteert, Grégoire	ICTEAM Institute, UCLouvain
Corinto, Fernando	Department of Electronics and Telecommunications, Politecnico Di Torino
Flandre, Denis	ICTEAM Institute, UCLouvain
Delvenne, Jean-Charles	UCLouvain

Famous neuroscience experiments by Mainen and Sejnowski revealed that the spike times of some biological neurons are more reliable when subject to time-fluctuating stimuli compared to constant ones. Provided with a rigorous physics-based transient noise simulation framework, we have demonstrated similar behaviours for a CMOS analog spiking neuron designed for neuromorphic computing hardware platforms. Under constant excitation current, the neuron operates in oscillatory regime and the spike times suffer from accumulated jitter during successive cycles, mainly due to the thermal noise of the transistors. A fluctuating input is reported to be capable of triggering output spikes according to a controlled state-transition mechanism, thereby significantly reducing the spike jitter in the excitability regime. A forthcoming stochastic dynamical model of the neuron would confirm and strengthen the preliminary observations and assumptions raised in this paper.

FrAM_SE1 MC 4058

Infinite-Dimensional Port-Hamiltonian Systems I (Invited Session)

Chair: Hastir, Anthony	University of Namur
Co-Chair: Jacob, Birgit	Bergische Universität Wuppertal
Organizer: Hastir, Anthony	University of Namur
Organizer: Jacob, Birgit	Bergische Universität Wuppertal

10:25-10:50 FrAM_SE1.2

Mean-Field Limit and Stability for Port-Hamiltonian Interacting Particle Systems (I), pp. 499-501

Happ, Daniel Jannik	Bergische Universität Wuppertal
Jacob, Birgit	Bergische Universität Wuppertal
Totzeck, Claudia	Bergische Universität Wuppertal

Interacting particle systems model the collective behavior arising from binary interactions between agents. As such, they provide a mathematical framework for e.g. pedestrians dynamics or animal flocks. We consider a Cucker-Smale-type model and formulate it in a port-Hamiltonian framework, which allows us to study their asymptotic stability and convergence to a common velocity. The analysis is carried out on the mean-field level in an infinite-dimensional measure-valued setting.

10:50-11:15 FrAM_SE1.3

On the Well-Posedness of a Class of Boundary Controlled Port-Hamiltonian Systems (I), pp. 502-504

Elghazi, Bouchra	Bergische Universität Wuppertal
Jacob, Birgit	Bergische Universität Wuppertal
Zwart, Hans	University of Twente

We study the well-posedness of a class of infinite-dimensional port-Hamiltonian system on a one-dimensional spatial space. This class includes in particular the Euler-Bernoulli beam equations and the Schrödinger equation. We provide a sufficient and necessary condition for the well-posedness that can be verified through a simple matrix check.

11:15-11:40 FrAM_SE1.4

A Combined Energy Method and Multiplier Approach for Improving Exponential Decay Rates of Port-Hamiltonian Systems (I), pp. 505-508

Gernandt, Hannes	Wuppertal University
Roschkowski, Marco	University of Wuppertal

Distributed-parameter port-Hamiltonian systems provide a unified framework for modeling and analyzing a broad class of energy-based systems. The study of their exponential stability and long-time decay behavior remains an active area of research. Recently, a multiplier-based approach has been employed by Mora and Morris to derive explicit exponential decay rates under the assumption of sufficiently strong boundary damping. In this work, we establish long-time energy bounds under significantly weaker assumptions by applying a recently developed energy method. The theoretical results are illustrated through an interconnection of vibrating strings.

FrAM_SE2 MC 4060

Machine Learning and Control (Regular Session)

Co-Chair: Gao, Shuang	Polytechnique Montreal

10:00-10:25 FrAM_SE2.1

Data-Driven Network LQG Mean Field Games with Heterogeneous Populations Via Integral Reinforcement Learning, pp. 509-514

Zhu, Jean	Polytechnique Montréal
Gao, Shuang	Polytechnique Montreal

This paper establishes a data-driven solution for infinite-horizon linear quadratic Gaussian Mean Field Games with network-coupled heterogeneous agent populations where the dynamics of the agents are unknown. The solution technique relies on Integral Reinforcement Learning and Kleinman's iteration for solving algebraic Riccati equations (ARE). The resulting algorithm uses trajectory data to generate network-coupled MFG strategies for agents and does not require parameters of agents' dynamics. Under technical conditions on the persistency of excitation and on the existence of unique stabilizing solution to the corresponding AREs, the learned network-coupled MFG strategies are shown to converge to their true values.

10:25-10:50 FrAM_SE2.2

On the Emergence of Dominant Manifolds in Reservoir Computing Networks, pp. 515-518

Kaplan, Noa	Cornell University
Padoan, Alberto	University of British Columbia
Bizyaeva, Anastasia	Cornell University

Understanding how training shapes neural network dynamics is a central problem in time-series modeling. We study the emergence of low-dimensional dominant manifolds in Reservoir Computing (RC) networks trained for forecasting. For a simplified linear reservoir model, we link the dominant modes to a weighted Dynamic Mode Decomposition (DMD) of the input dynamics, with the weighting fixed by the reservoir contraction rate. We illustrate the resulting eigenvalue motion during training in simulation, and discuss generalization to nonlinear RC via tangent dynamics and differential p-dominance, where bounded nonlinearities allow dominant modes to cross into unstable directions without producing unbounded trajectories.

11:15-11:40 FrAM_SE2.4

Observer Design for Systems with Unknown Dynamics and Limited Measurements, pp. 519-524

Bartlett, Joel	Queen's University
Hudon, Nicolas	Queen's University
Guay, Martin	Queen's Univ

We propose a method to design Kazantzis--Kravaris--Luenberger (KKL) observers for nonlinear systems with unknown dynamics using only output measurements. The order of the unknown dynamics is assumed to be known, and the system is assumed to be observable. The proposed approach first consists in approximating a model for the system from noise free output datasets using the SINDy algorithm. The obtained dynamics are then used to construct an approximate inverse of the KKL mapping using a SiLU neural network. Convergence of the proposed approach is demonstrated. A numerical example is provided to illustrate the approach and demonstrate its application for the observation of systems in the presence of measurement noise.

11:40-12:05 FrAM_SE2.5

On Pontryagin-Type Optimality Conditions for Mean-Field Self-Attention Dynamics, pp. 525-528

Hoshino, Kenta	Institute of Science Tokyo, Denso IT Laboratory

This study investigates the self-attention dynamics of Transformers from the perspective of mean-field optimal control. Recent studies have shown that self-attention dynamics can be analyzed as mean-field dynamics. Since the weight parameters in the self-attention layer can be regarded as control variables, we formulate Transformer self-attention dynamics as a mean-field optimal control problem. This study provides a formal characterization of the corresponding first-order necessary optimality conditions based on the Pontryagin maximum principle.

FrAM_SE3 MC 4064

Robust and H-Infinity Control (Regular Session)

Chair: ter Horst, Sanne	North West University
Co-Chair: Mironchenko, Andrii	University of Bayreuth

10:00-10:25 FrAM_SE3.1

Optimal Interpolation in Certain Reproducing Kernel Banach Spaces, pp. 529-532

Groenewald, Gilbert	North-West University
ter Horst, Sanne	North West University
Woerdeman, Hugo J.	Drexel Univ

One of the seminal results used in many applications in machine learning, is the so-called Representer Theorem, which in a simplified form (the First Representer Theorem) can be interpreted as a solution to an optimal interpolation problem in reproducing kernel Hilbert spaces. More recent versions of the Representer Theorem extend the theory to reproducing kernel Banach spaces, subject to some geometric conditions on the norm, proving existence and uniqueness, and reducing the problem of finding the unique optimal solution to a problem with finitely many parameters. This approach provides a theoretical framework, in which determining optimal solutions is reduced to optimizing nonlinear (if $pneq 2$) equations in finitely many variables. In practice, however, there are various technical complications one has to overcome, such as concretely determining the dual of the reproducing kernel Banach spaces and identifying it as reproducing kernel Banach spaces itself, and computing the semi-inner product. To illustrate the framework, and the complications that arise, we investigate this solution strategy works out concretely in the context of some Hardy and Bergman spaces.

10:25-10:50	FrAM_SE3.2

Lyapunov Criterion for Boundedness of Reachability Sets, pp. 533-538

Bachmann, Patrick	Julius-Maximilians-Universität Würzburg
Mironchenko, Andrii	University of Bayreuth

We provide a converse Lyapunov theorem for boundedness of reachability sets for a general class of control systems whose flow is Lipschitz continuous on compact intervals with respect to trajectory-dominated inputs. We show that this condition is satisfied by many semi-linear evolution equations. For ordinary differential equations, as a consequence of our results, we obtain a converse Lyapunov theorem for forward completeness, without a priori restrictions on the magnitude of inputs.

10:50-11:15	FrAM_SE3.3

Structure-Preserving Updates from Dissipative Hamiltonian Systems, pp. 539-541

George, Joshua Joseph	University of Waterloo
Morris, Kirsten A.	Univ. of Waterloo
Del Rey Fernandez, David	University of Waterloo

We propose and analyze structure-preserving momentum methods for first-order optimization of a smooth nonconvex objective $L(\vartheta)$ by viewing the dynamics as a dissipative Hamiltonian system with energy $H(\vartheta, \omega) = L(\vartheta) + (\|\omega\|^2)/2$. We adopt a discrete-gradient (DG) time discretization that inherits an exact discrete-time energy dissipation law, providing a stability certificate beyond explicit momentum descent updates. Building on this construction, we propose a variant with additional damping in the parameter updates, reducing oscillations, strengthening per-step energy decrease and improving robustness to ill-conditioned objectives. Under standard smooth nonconvex assumptions, we prove monotone energy decay, boundedness of iterates and an $O(1/K)$ best-iterate stationarity guarantee, where K is the number of iterations

FrSP_SP1	MC 2065
Semi-Plenary: Physics-Informed Neural Certificates for Stability and Control (Plenary Session)	
Chair: Smith, Malcolm C.	University of Cambridge

14:00-15:00	FrSP_SP1.1

*Semi-Plenary: Physics-Informed Neural Certificates for Stability and Control**

Liu, Jun	University of Waterloo

Neural networks are universal approximators, yet learned models rarely come with rigorous guarantees. Typical statistical learning generalization bounds are often too conservative, and such probabilistic guarantees fail to certify correctness of a specific computed solution. In this talk, we present a formal verification framework that produces a posteriori error estimates for neural network solutions of partial differential equations (PDEs) arising in systems and control. We aim to provide rigorous guarantees for the learned models rather than mere probabilistic guarantees on the PDE residuals. The framework connects machine learning with rigorous control theory by turning physics-informed neural models into certifiable computational tools. More specifically, we study PDE characterizations that arise in stability and contraction analysis, control synthesis, and estimation for nonlinear dynamical systems. By combining formal verification tools with theoretically derived estimates, we rigorously bound approximation errors and translate these bounds into provable guarantees of stability and safety. The resulting neural certificates enable verification of regions of attraction, construction of provably correct stabilizing neural feedback controllers, and design of neural state estimators with provable error bounds.

FrSP_SP2	MC 2066
Semi-Plenary: Control by Interconnection of Irreversible Port-Hamiltonian Systems (Plenary Session)	

14:00-15:00	FrSP_SP2.1

*Semi-Plenary: Control by Interconnection of Irreversible Port-Hamiltonian Systems**

Ramirez, Hector	Universidad Tecnica Federico Santa Maria

Irreversible port-Hamiltonian systems (IPHS) provide a thermodynamically consistent framework for modeling multi-physical processes in which thermal phenomena play a central role. While classical passivity-based control methods have been extensively developed for reversible mechanical and electrical systems, extending these techniques to irreversible systems introduces new challenges due to the presence of entropy dynamics and the co-energy dependence of the structure matrices.

In this talk, we present a systematic control-by-interconnection methodology for IPHS that enables energy shaping and entropy assignment through modulated output feedback. A central ingredient is the identification of closed-loop invariant functions, analogous to Casimir functions in standard port-Hamiltonian theory, which allow the closed-loop Hamiltonian to coincide with thermodynamic availability functions. This provides physically meaningful Lyapunov candidates and preserves the energy-entropy structure of the system.

The methodology will be illustrated on two representative examples: a continuous stirred tank reactor and a gas-piston system. In both cases, the closed-loop system exhibits asymptotic stabilization while respecting first- and second-law constraints, and the approach naturally decouples thermodynamic and mechanical domains when appropriate. Beyond these case studies, the results highlight how irreversible thermodynamics, geometric modeling, and passivity-based control can be brought together to address complex open systems with thermal interactions.

FrPM_SE1	MC 4058
Infinite-Dimensional Port-Hamiltonian Systems II (Invited Session)	
Chair: Jacob, Birgit	Bergische Universität Wuppertal
Co-Chair: Hastir, Anthony	University of Namur
Organizer: Hastir, Anthony	University of Namur
Organizer: Jacob, Birgit	Bergische Universität Wuppertal

15:30-15:55	FrPM_SE1.1

H^2-Optimal Control for Hyperbolic PDEs on a One-Dimensional Spatial Domain (I), pp. 542-544

Hastir, Anthony	University of Namur
Jacob, Birgit	Bergische Universität Wuppertal
Morris, Kirsten A.	Univ. of Waterloo

The solution to an H^2-optimal control problem is given for a class of boundary controlled and observed port-Hamiltonian systems defined on a 1-D spatial domain, that may be viewed as a network of interconnected waves. The solution is deduced by taking advantage of the equivalent description of this class as an infinite-dimensional discrete-time system. The main results are applied to a boundary controlled and boundary observed vibrating string.

15:55-16:20 FrPM_SE1.2

Constrained Control by Interconnection of Nonlinear Port-Hamiltonian Systems (I), pp. 545-548

Preuster, Till	Chemnitz University of Technology
Gernandt, Hannes	Wuppertal University
Schaller, Manuel	Technische Universität Chemnitz

Model Predictive Control (MPC) is a well-established optimization-based control strategy, but its real-time implementation often poses significant computational challenges. A way to deal with these challenges are suboptimal MPC approaches, in which the optimal control solver for feedback computation is terminated prematurely. In this note, we present a suboptimal MPC scheme for port-Hamiltonian systems. The approach exploits the inherent dissipativity of the optimality system, which arises from its primal–dual structure, together with the dissipativity of the underlying port-Hamiltonian dynamics. This allows us to formulate the MPC scheme as a control-by-interconnection of two port-Hamiltonian systems. Using the dissipativity of the resulting closed-loop system, we establish well-posedness and convergence of the method in function space, thereby showing in particular mesh-independent convergence of the scheme.

16:20-16:45 FrPM_SE1.3

Dissipativity-Based Time Decomposition for Optimal Control (I), pp. 549-551

Farkas, Bálint	University of Wuppertal
Jacob, Birgit	Bergische Universität Wuppertal
Schaller, Manuel	Technische Universität Chemnitz
Schmitz, Merlin	University of Wuppertal

We propose a time domain decomposition approach to optimal control of partial differential equations (PDEs) based on semigroup theoretic methods. We formulate the optimality system consisting of two coupled forward-backward PDEs, the state- and adjoint equation, involving a sum of dissipative operators, which enables a Peaceman-Rachford-type fixed-point iteration. The iteration steps may be understood and implemented as solutions of many decoupled, and therefore highly parallelizable, time-distributed optimal control problems. We prove the convergence of the state, the control, and the corresponding adjoint state in function space. Due to the general framework of C_0-(semi)groups, the results are particularly well applicable, e.g., to hyperbolic equations, such as beam or wave equations. We illustrate the convergence and efficiency of the proposed method by means of two numerical examples subject to a 2D wave equation and a 3D heat equation.

FrPM_SE2 MC 4060

Collective Dynamics and Scalability in Multi-Agent Control Systems (Invited Session)

Chair: Kalise, Dante	Imperial College London
Co-Chair: Peters, Andrés A.	Universidad Adolfo Ibáñez
Organizer: Kalise, Dante	Imperial College London
Organizer: Peters, Andrés A.	Universidad Adolfo Ibáñez

15:30-15:55 FrPM_SE2.1

Scalable Equilibrium Selection of Coarse Correlated Equilibria in Mean-Field Games (I), pp. 552-555

Kelbel, Frederik	Imperial College London
Inoue, Daisuke	Imperial College London
Kalise, Dante	Imperial College London
Lauriere, Mathieu	New York University Shanghai
Russo, Alessandra	Imperial College London

Mean Field Nash Equilibria (MFNE) often yield suboptimal social outcomes in non-monotonic regimes or fail to exist uniquely. Coarse Correlated Equilibria (CCE) offer a robust relaxation that convexifies the solution set, allowing for textit{equilibrium selection} to target socially beneficial outcomes. We propose a scalable numerical framework for computing CCEs in continuous-space Mean-Field Games using a textit{Tensor Train Finite Difference Method (TT-FDM)}. The method adapts policy-space response oracles to the continuous-space partial differential equation (PDE) setting, making correlated equilibrium selection tractable beyond low-resolution grids. We validate the approach on an emission abatement game and motivate its use for rescue-corridor formation in crowd and traffic evacuation.

15:55-16:20 FrPM_SE2.2

Computational Methods for Generalized Schroedinger Bridge Problems (I), pp. 556-559

Inoue, Daisuke	Imperial College London
Kalise, Dante	Imperial College London
Liu, Wenxin	Imperial College London

We present two complementary computational frameworks for generalized Schrödinger Bridge Problems (SBPs). The first addresses trajectory planning in geometrically complex domains by formulating a Reflected Schrödinger Bridge Problem (RSBP) with prior drift; after a Hopf–Cole linearization, the optimality system is discretized via standard finite elements, naturally enforcing Neumann (reflecting) boundary conditions without particle-based collision detection. The second framework extends the Deep Generalized Schrödinger Bridge (DeepGSB) to interacting particle systems with nonlocal mean-field interactions, whose direct pairwise evaluation costs $O(N^2)$. By introducing neural surrogate models for the interaction terms, we reduce trajectory evaluation and inference to $O(N)$ and establish Grönwall-type stability bounds on the resulting approximation error in the forward–backward SDE system. Experiments on 3D spiral-maze navigation (RSBP) and 2D crowd navigation with nonlocal interactions confirm fast convergence, mass conservation, and accurate transport with reduced computation time, respectively.

16:20-16:45 FrPM_SE2.3

Delay-Induced Performance Degradation in Platoons under Leader-Predecessor Following (I), pp. 560-563

Gordon, Marco A.	Universidad Técnica Federico Santa María
Vargas, Francisco J.	Universidad Técnica Federico Santa María
Peters, Andrés A.	Universidad Adolfo Ibáñez
Chen, Jie	City University of Hong Kong

This work analyzes the performance of a vehicle platoon with leader-predecessor following topology where multiple delays are considered. We evaluate the impact on the string stability of three distinct delays: leader communication delay, predecessor communication delay, and onboard sensors measurement delay. The analysis distinguishes between delays that directly induce string instability and those that primarily cause non-zero convergence of the spacing errors, leading to potential collisions. Through numerical examples we show that sensor measurement delays compromise both, string stability and formation accuracy. In contrast, delays occurred on the vehicle-to-vehicle communication channels affect only the steady-state formation error. Besides, we discuss the effects that a simple delay compensation causes on string stability. Finally, we provide insights for future research on platoon control under heterogeneous delays.

16:45-17:10 FrPM_SE2.4

A Computable MATI Test for Sampled-Data Cucker-Smale Flocking (I), pp. 564-567

Peters, Andrés A.	Universidad Adolfo Ibáñez

Maass, Alejandro I. — Pontificia Universidad Católica De Chile

We study Cucker-Smale flocking with sampled velocity broadcasts: agents transmit at instants $t_k = k\tau$ (sampling period τ) and steer using zero-order-hold neighbor velocities between transmissions. Using an ISS emulation framework, we derive a computable scalar test for the regime $\beta \geq 1$: under a bounded-diameter assumption, alignment at sampling instants is certified when a contraction ratio $\rho(\tau)$ satisfies $\rho(\tau) < 1$. For the uniform complete graph with frozen weights, we derive exact disagreement/error dynamics and show that velocity disagreement contracts at every sampling instant for any $\tau > 0$ ($n \geq 3$) in that surrogate.

17:10-17:35 FrPM_SE2.5

Minimum Time Headway for String Stability: A Continuous-Time Analysis of Predecessor-Following Topology (I), pp. 568-571

Wang, Miaomiao	City University of Hong Kong
Wu, Wuwei	City University of Hong Kong
Sanhueza, Fernando	City University of Hong Kong
Vargas, Francisco J.	Universidad Técnica Federico Santa María
Peters, Andrés A.	Universidad Adolfo Ibáñez
Chen, Jie	City University of Hong Kong

In vehicular platooning, string stability is a critical requirement to ensure that disturbances are attenuated as they propagate along the string of vehicles. The predecessor-following topology, while simple to implement, presents challenges for achieving string stability, particularly under a constant time headway spacing policy. Focusing on continuous-time linear time-invariant systems to capture the underlying physical constraints, this paper analytically characterizes the fundamental lower limit on time headway required for string stability. We establish the intrinsic relationship between time headway and the non-minimum phase characteristics of the vehicle dynamics.

FrPM_SE3 — MC 4064

System Identification (Regular Session)

Chair: Smith, Malcolm C. — University of Cambridge

15:30-15:55 FrPM_SE3.1

The Case against Process Noise: Input and State Estimation without Priors, pp. 572-574

Gakis, Grigorios	University of Cambridge
Smith, Malcolm C.	University of Cambridge

The classical Kalman filter problem formulation imposes symmetrical assumptions on the process and measurement noise. This extended abstract considers the case where the assumption that the exogenous inputs are Gaussian with known mean and covariance is unrealistic. In such cases a model-based approach is required which places the unknown inputs and states on an equal footing in filtering and smoothing problems. The solution of this problem will be examined with various approaches: a zero informational limit of a regular Kalman filter; a direct stochastic formulation; and a least-squares formulation.

15:55-16:20 FrPM_SE3.2

Universal Experiment Design for System Identification Using Prior Knowledge, pp. 575-578

Shakouri, Amir	University of Groningen
van Waarde, Henk J.	University of Groningen
Camlibel, Kanat	University of Groningen

We consider the problem of designing input signals for an unknown linear time-invariant system in such a way that the resulting input-state data is suitable for system identification. We will take into account general prior knowledge on the system parameters. Central in our study is the concept of universal inputs. An input is called universal for identification if, when applied to any system complying with the prior knowledge, yields data suitable for identification. We provide new methods for designing such universal inputs. Our results generalize the experiment design approach based on Willems et al.'s fundamental lemma that relies on persistently exciting inputs and that only uses prior knowledge on controllability. It turns out that for other types of prior knowledge, there exist universal inputs that are not necessarily persistently exciting. In such cases, our results outperform the fundamental lemma in terms of sample efficiency.

16:20-16:45 FrPM_SE3.3

Virtual Sensing for Diffusion Processes Via the Sylvester Matrix Equation, pp. 579-584

Harker, Matthew	École De Technologie Supérieure

In this paper, we develop a new numerical algorithm for solving an inverse heat conduction problem from sparse localised temperature or concentration measurements. From noisy temperature measurements over time, the integral surface is reconstructed as a global least-squares fit to the measurement data while applying only a smoothness regularization criterion on the estimated initial heat distribution. The new approach is to use the Sylvester matrix equation to solve the associated PDE, which yields an O(n^3) algorithm, as opposed to the classic vector equation approaches to solving PDE, which are typically O(n^6). The method provides a consistent numerical approximation to the continuous problem, and thereby eliminates any need to estimate or calculate probability distributions or analytic solutions to the diffusion equations. From the reconstructed integral surface in matrix form, virtual sensors for temperature, heat flux, etc., are obtained via linear operations, whereby the covariance propagation through the entire process is derived in order to provide confidence intervals about the virtual measurements. The method is shown to recover significant structure of the initial distribution from a single sensor, and is thereby well suited to the virtual sensing task.

16:45-17:10 FrPM_SE3.4

Kernel-Based Models for Passive Operators on Finite Dimensional Spaces, pp. 585-588

Shali, Brayan	KU Leuven
Sepulchre, Rodolphe J.	University of Cambridge
van Waarde, Henk J.	University of Groningen

Nonlinear passive systems are difficult to parametrize using classical autoregressive or state-space models, which can limit model expressiveness and hinder identification. To address this limitation, we introduce a kernel-based model class for passive input-output operators on finite-dimensional spaces. In particular, we extend an existing kernel-based model for nonnegative operators by additionally enforcing causality, thereby ensuring passivity. We show that the resulting class of passive operators is universal, in the sense that it can approximate any continuous passive operator on compact sets to arbitrary precision. Moreover, we formulate an associated identification problem and prove a representer theorem that leads to an equivalent finite-dimensional reformulation and, thus, a computationally tractable solution.

17:10-17:35 FrPM_SE3.5

Learning Models from Online–Offline Social Dynamics on Networks Using WSINDy, pp. 589-592

Tian, Moyi	University of Colorado Boulder
Bortz, David	University of Colorado-Boulder

In social systems, agents are often connected and interact through networks, motivating the need to understand the mechanisms of network dynamics. We study how to identify effective models from data for an online-offline social system using Weak form Sparse Identification of Nonlinear Dynamics (WSINDy). We learn continuum models for stochastic data that offer more effective approximations than the traditional mean-field approximation on sparse networks. Our results show that 2 or 3 trajectories provide most of the gain in learning accuracy.

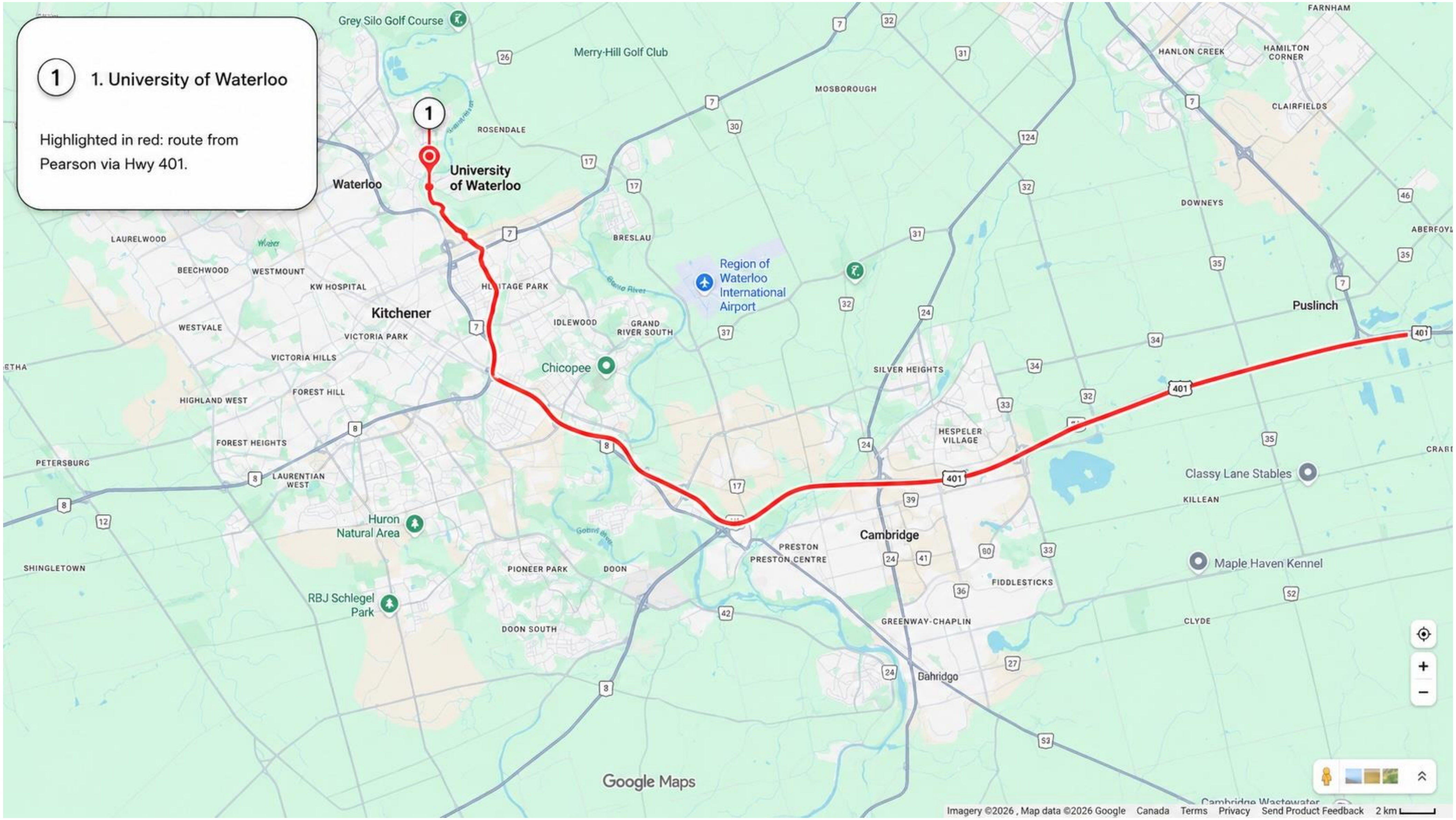
Technical Program

Author Index

MTNS 2026 Author Index

Campus Locations

1. MC (Main Entrance) Peter Russell Rock Garden
2. M3
3. DC (Davis Centre)
4. St. Jerome's University
5. Federation Hall
6. PSE (Former E7)
7. ION LRT Station
8. Bus Station


1
1. University of Waterloo
Highlighted in red: route from
Pearson via Hwy 401.
University
of Waterloo
Waterloo
Kitchener
Cambridge
Puslinch
Region of
Waterloo
International
Airport
Grey Silo Golf Course
Merry-Hill Golf Club
Chicopee
Huron
Natural Area
RBJ Schlegel
Park
Classy Lane Stables
Maple Haven Kennel
ROSENDALE
MOSBOROUGH
BRESLAU
LAURELWOOD
BEECHWOOD
WESTMOUNT
KW HOSPITAL
WESTVALE
VICTORIA PARK
VICTORIA HILLS
IDLEWOOD
GRAND
RIVER SOUTH
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FOREST HILL
FOREST HEIGHTS
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Approx. 105 km
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King
Richmond Hill
Vaughan
Toronto
Mississauga
Brampton
Amaranth
Mono
Orangeville
Grand Valley
East Garafraxa
Caledon
Erin
Centre Wellington
Halton Hills
Guelph/ Eramosa
Woolwich
Guelph
Milton
Waterloo
Kitchener
Puslinch
Cambridge
Oakville
Burlington
North Dumfries
Hamilton
Blandford-Blenheim
Brantford
Grimsby
Lincoln
St. Catharines
401
427
407
410
403