ASCC 2024 Pre-Conference Workshop on
Recent Progress in Control Theory and Applications

Place: Guangzhou Room, Shangri-La Hotel, Dalian, China
Date and Time: PM1:45-5:30, 5th July, 2024



Organizer:
Prof. Ximing Sun
Dalian University of Technology

Co-organizers:
Prof. Tielong Shen,
alian University of Technology
Prof. Minyue Fu
Southern University of Science and Technology

Invited Speakers: *Ian Peterson*, Australian National University, Australia
Daizhan Cheng, Academy of Math and Systems Science, China
Lihua Xie, Nanyang Technological University, Singapore
Zhong-Ping Jiang, New York University, USA
Guoxiang Gu, Louisiana State University, USA
Qing-Long Han, Swinburne University of Technology, Australia
Huanshui Zhang, Shandong University of Science and Technology,China

Program:

PM1:45-1:50

Opening Remark

Prof. Ximing Sun, Dalian University of Technology, China

PM1:50-2:20

[1] Title: Memory Decoherence in Linear and Finite Level Quantum Systems

Speaker: *Ian Peterson,* Australian National University, Australia

Abstract: This talk is concerned with open quantum harmonic oscillators and finite-level quantum systems described by linear and quasi-linear Hudson-Parthasarathy quantum stochastic differential equations. This framework includes isolated systems with zero Hamiltonian, whose internal variables remain unchanged (in the Heisenberg picture of quantum dynamics) over the course of time, making such systems potentially applicable as quantum memory devices. In a more realistic case of system-environment coupling, we define a memory decoherence horizon as the time for a weighted mean square of the deviation of the vector of self-adjoint system variables on the system-field Hilbert space from its initial value to become relatively significant as specified by a real positive semi-definite symmetric weighting matrix and a fidelity parameter. The reference scale in this definition uses the real part of the matrix of second moments of the initial system variables. We consider a problem of maximizing this decoherence time or its approximation from a truncated Taylor series expansion involving the first and second derivatives of the decoherence time with respect to the fidelity parameter. The maximization of the decoherence time or its approximate version is carried out at a given value of the fidelity parameter over the energy and coupling parameters of the open system as a model of quantum memory in its storage phase. Conditions are discussed under which the zero Hamiltonian delivers a suboptimal solution. This optimization problem is also considered for system interconnections.

Ian R. Petersen was born in Victoria, Australia. He received a Ph.D in Electrical Engineering in 1984 from the University of Rochester. From 1983 to 1985 he was a Postdoctoral Fellow at the Australian National University. From 2017 he has been a Professor at the Australian National University in the School of Engineering. He was the Interim Director of the School of Engineering at the Australian National University from 2018-2019. From 1985 until 2016 he was with UNSW Canberra where he was a Scientia Professor and an Australian Research Council Laureate Fellow in the School of Engineering and Information Technology. He has previously been ARC Executive Director for Mathematics Information and Communications, Acting Deputy Vice-Chancellor Research for UNSW and an Australian Federation Fellow. He has served as an Associate Editor for the IEEE Transactions on Automatic Control, Systems and Control Letters, Automatica, IEEE Transactions on Control Systems Technology and SIAM Journal on Control and Optimization. He also served as an Editor for Automatica. He is a fellow of IFAC, the IEEE and the Australian Academy of Science. His main research interests are in robust control theory, quantum control theory and stochastic control theory.

PM2:20-2:50

[2] Title: Lie Group and Lie Algebra of Non-Square Matrices

Speaker: Daizhan Cheng, Academy of Math and Systems Science, China

Abstract: Using dimension-keeping semi-tensor product (DK-STP) of matrices, the analytic functions of non-square matrices (NSMs) are introduced. Particularly, the generalized Cayley-Hamilton theorem of NSMs is obtained. The Lie bracket of NSMs is proposed and used to construct the Lie algebra gl(m×n,R). Then the invertibility of NSMs is defined. Using generalized Cayley-Hamilton theorem, a necessary and sufficient condition for the invertibility is obtained. It leads to the construction of the corresponding Lie group GL(m×n,R). Finally, a homomorphism of gl(m×n,R)→ gl(t,R) (and GL(m×n,R)→GL(t,R)) is constructed, which verifies the famous Ado's theorem in Lie group and Lie algebra. This talk is part of our work "Cross-Dimensional Mathematics".

Daizhan Cheng was born in 1946. He was graduated from Tsinghua University (1964-1970), received Master degree from Graduate School of Chinese Academy of Sciences (1978-1981), PhD from Washington University, St. Louis, USA (1981-1985). He is a professor of Academy of Math and Systems Science, CAS (retired), IEEE Fellow, IFAC Fellow, IFAC Counsel Member (2011-2014) and Member of Board of Governors of IEEE CSS (2010 and 2015), Chairman of Technical Committee of Control Theory, Chinese Association of Automation (2003-2010). He received the second National Natural Science Award twice (2008、2014, first recipient), Automatica 2008-2011Best Paper Award, Outstanding Science and Technology Achievement Prize of CAS(2015). He also received Province/Department first Award twice, second Award 5 times, and third Award twice. He has published over 20 academic books and over 300 journal papers.

PM2:50-3:20

[3] Title: Inverse Kalman Filtering for Linear Discrete-time Systems

Speaker: *Lihua Xie*, Nanyang Technological University, Singapore

Abstract: Inverse filtering has important applications in control, communication, fault diagnosis, etc. In this talk, we discuss the problem of the inverse Kalman filter where the unknown covariance matrix in a stochastic system is reconstructed from observations of its posterior beliefs. A novel duality-based formulation is proposed, where a well-defined inverse optimal control (IOC) problem is solved instead. Identifiability of the underlying model is proved, and a least squares estimator is designed and is shown to be statistically consistent. We also consider the inverse steady-state Kalman filtering and show that the problem is ill-posed. A canonical class of covariance matrices is then constructed which can be uniquely identified from the dataset with asymptotic convergence.

Lihua Xie obtained the PhD degree from the University of Newcastle, Australia, in 1992. He is currently President's Chair with the School of Electrical and Electronic Engineering, Nanyang Technological University and Director, National Research Foundation Center for Advanced Robotics Technology Innovation (CARTIN). He has served as Head of Control and Instrumentation Division and Director of Delta-NTU Corporate Laboratory for Cyber-Physical Systems. His research areas include robust control, multi-agent systems, learning-based control, and unmanned systems. He has published extensively in these areas and has been listed as a highly cited researcher. He is currently an Editor-in-Chief of Unmanned Systems and has served as an Editor of IET Book Series on Control and Associate Editor of IEEE Transactions on Automatic Control, Automatica, IEEE Transactions on Control Systems Technology, IEEE Transactions on Control of Network Systems, etc. He was an IEEE Distinguished Lecturer (2011-2014), a member of Board of Governors of IEEE Control System Society

(2016-2018) and the General Chair of the 62nd IEEE Conference on Decision and Control. He is currently Vice-President of IEEE Control System Society. Professor Xie is Fellow of Academy of Engineering Singapore and Fellow of IEEE, IFAC, CAA and AAIA.

PM3:20-3:50

[4] Title: A Generalization of Singular Perturbation Theory

Speaker: *Zhong-Ping Jiang*, New York University

Abstract: In this talk, a generalization of singular perturbation theory is presented for a broader class of nonlinear singularly perturbed systems in which constant perturbation coefficients are replaced by state-dependent perturbation functions. Under this framework, general results are obtained for the global robust stability and input-to-state stability of nonlinear singularly perturbed systems. Moreover, it can address emerging topics in control to which conventional singular perturbation theory is insufficient. Examples of these problems include nonlinear integral control, feedback optimization, and formation-based source seeking.

Zhong-Ping JIANG received the M.Sc. degree in statistics from the University of Paris XI, France, in 1989, and the Ph.D. degree in automatic control and mathematics from ParisTech-Mines, France, in 1993, under the direction of Prof. Laurent Praly. Currently, he is a professor in the Department of Electrical and Computer Engineering and an affiliate professor in the Department of Civil and Urban Engineering at the Tandon School of Engineering, New York University. His main research interests include stability theory, robust/adaptive/distributed nonlinear control, robust adaptive dynamic programming, reinforcement learning and their applications to information, mechanical and biological systems. Prof. Jiang is a recipient of the prestigious Queen Elizabeth II Fellowship Award from the Australian Research Council, CAREER Award from the U.S. National Science Foundation, JSPS Invitation Fellowship from the Japan Society for the Promotion of Science, Distinguished Overseas Chinese Scholar Award from the NSF of China, and several best paper awards. He has served as Deputy Editor-in-Chief, Senior Editor and Associate Editor for numerous journals, and is among the Clarivate Analytics Highly Cited Researchers and Stanford's Top 2% Most Highly Cited Scientists. In 2022, he received the Excellence in Research Award from the NYU Tandon School of Engineering. Prof. Jiang is a foreign member of the Academia Europaea (Academy of Europe) and an ordinary member of the European Academy of Sciences and Arts, and also is a Fellow of the IEEE, IFAC, CAA, AAIA and AAAS.

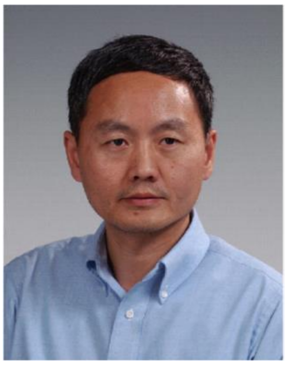
PM3:50-4:00 Coffee Break

PM4:00-4:30

[5] Title: Distributed Adaptive Control for Vehicle Platoons and A Solution to the String Stability

Speaker: *Guoxiang Gu,* Louisiana State University, USA

Abstract: Dynamic models of vehicle systems are inherently nonlinear, and involve unknown and time-varying parameters, mostly ignored in the literature. We propose to adaptively control the vehicle's longitudinal motion and show that the proposed adaptive control law globally stabilizes the operating point. A passivity approach is adopted to analyze the string stability associated with the platoon of closed-loop adaptive uncertain nonlinear vehicle systems. The distributed adaptive control law achieves the string stability in the presence of nonlinearities and uncertainties against the worst-case energy bounded disturbances. Vehicle platoon achieves the required speed limit while maintaining required safe inter-vehicle distance over predecessor-follower (PD), bidirectional (BD), and mixed PF and BD topologies.



Guoxiang Gu received the Ph.D. degree in Electrical Engineering from University of Minnesota, Minneapolis, MN, USA, in 1988. From 1988 to 1990, he was with the Department of Electrical Engineering, Wright State University, Dayton, OH, USA, as a Visiting Assistant Professor. He has held visiting positions with Wright-Patterson Air Force Base, OH, USA, and with the Hong Kong University of Science and Technology, Hong Kong. Since 1990, he joined Louisiana State University (LSU), Baton Rouge, LA, USA, where he is currently a Professor of Electrical and Computer Engineering. He has authored two books, over 80 archive journal papers, and numerous book chapters and conference papers. His research interests include networked feedback control, system identification, and statistical signal processing. Dr. Gu served as an Associate Editor for IEEE Transactions on Automatic Control from January 1998 to December 2001 and from January 2018 to December 2021, SIAM Journal on Control and Optimization from 2006 to 2009, and Automatica from 2006 to 2012. He is currently the F. Hugh Coughlin/CLECO Distinguished Professor of Electrical Engineering at LSU.

PM4:30-5:00

[6] Title: Hyperbolic Tangent Function-Based Protocols for Global/Semi-Global Finite-Time Consensus of Multi-Agent Systems

Speaker: *Qing-Long Han*, Swinburne University of Technology, Australia

Abstract: In this talk, the problem of global/semi-global finite-time consensus is investigated for integrator-type multi-agent systems. New hyperbolic tangent function-based protocols are proposed to achieve global and semi-global finite-time consensus for both single-integrator and double-integrator multi-agent systems with leaderless undirected and leader-following directed communication topologies. These new protocols not only provide an explicit upper-bound estimate for the settling time, but also have a user-prescribed bounded control level. In addition, compared to some existing results based on the saturation function, the proposed approach considerably simplifies the protocol design and the stability

analysis. Illustrative examples and an application demonstrate the effectiveness of the proposed protocols.

Professor Han is Pro Vice-Chancellor (Research Quality) and a Distinguished Professor at Swinburne University of Technology, Melbourne, Australia. He held various academic and management positions at Griffith University and Central Queensland University, Australia. His research interests include networked control systems, multi-agent systems, time-delay systems, smart grids, unmanned surface vehicles, and neural networks.

Professor Han was awarded The 2021 Norbert Wiener Award (the Highest Award in systems science and engineering, and cybernetics) and The 2021 M. A. Sargent Medal (the Highest Award of the Electrical College Board of Engineers Australia). He was the recipient of The IEEE Systems, Man, and Cybernetics Society Andrew P. Sage Best Transactions Paper Award in 2022, 2020, and 2019, respectively, The IEEE/CAA Journal of Automatica Sinica Norbert Wiener Review Award in 2020, and The IEEE Transactions on Industrial Informatics Outstanding Paper Award in 2020.

Professor Han is a Member of the Academia Europaea (The Academy of Europe). He is a Fellow of The Institute of Electrical and Electronic Engineers (FIEEE), a Fellow of The International Federation of Automatic Control (FIFAC), an Honorary Fellow of The Institution of Engineers Australia (HonFIEAust), and a Fellow of Chinese Association of Automation (FCAA). He is a Highly Cited Researcher in both Engineering and Computer Science (Clarivate). He has served as an AdCom Member of IEEE Industrial Electronics Society (IES), a Member of IEEE IES Fellows Committee, a Member of IEEE IES Publications Committee, Chair of IEEE IES Technical Committee on Network-Based Control Systems and Applications, and the Co-Editor-in-Chief of IEEE Transactions on Industrial Informatics. He is currently the Editor-in-Chief of IEEE/CAA Journal of Automatica Sinica and the Co-Editor of Australian Journal of Electrical and Electronic Engineering.

PM5:00-5:30

[7] Title: Optimal decentralized control and optimization based on optimal control

Speaker: *Huanshui Zhang*, Shandong University of Science and Technology, China

Abstract: The decentralized LQ control has a long history of study, and majority of the works is contingent on the scenario of history-control sharing. In the case of no history-control sharing, the problem poses a challenge, and the solution in general cannot be obtained explicitly because it is generally nonlinear. For these reasons, research effort has been by and large focused on special systems such as those with a nested structure, or sub-optimal solutions.

By proposing a method based on linear optimal control, we derive an analytical solution of decentralized controllers with feedback of a linear optimal estimator for cases including information inclusion and delayed information sharing. The decentralized LQ control for deterministic systems with general information pattern is also investigated. We show that the controller approaches to the optimal centralized controller if

the observer is stable. The approach is further shown to have the advantage to be readily extendable to study consensus control problems, leading to optimal consensus controllers with fast converge speed. In particular, when applied to solve nonlinear optimization problems, the approach circumvents effectively the weaknesses of gradient descent (slow convergence) and Newton iteration (instability and divergence).

Huanshui Zhang obtained his doctoral degree in engineering from Northeastern University in 1997. He was promoted to associate professor in 1994 and further advanced to the position of full professor in 1999. In August 2003, he was appointed as a professor and doctoral supervisor at Harbin Institute of Technology. In 2006, he was elected as one of the first "Taishan Scholars" in Shandong Province and joined the School of Control Science and Engineering at Shandong University. Currently, he holds a special professorship at the School of Automation at Shandong University/Shandong University. Professor Zhang's research focuses on optimal control theory, stochastic systems, time-delay systems, network control systems, distributed control, and game control. He has proposed methods such as the class-Kalman approach for optimal estimation and information fusion in multi-delay measurement systems. Additionally, he has introduced a decoupling solution method for general forward-backward differential equations (FBDEs), addressing fundamental problems in stochastic LQ control, non-canonical LQ control, and distributed linear optimal control under time-delay conditions. He has served as an editorial board member for various international and domestic journals, including IEEE Transactions on Automatic Control.