The 37th Chinese Control Conference

Pre-conference Workshop

Speaker： Jie Chen, Dan Ma, Tian Qi and Jing Zhu

Title： **S**tability and Stabilization of Time-Delay Systems: An Operator-Theoretic Development

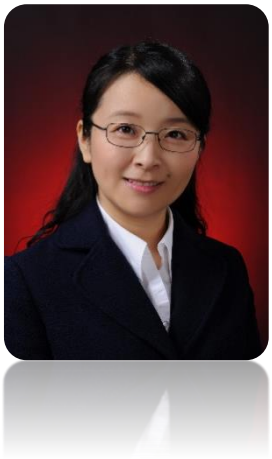
Biography：

Jie Chen (Department of Electronic Engineering, City University of Hong Kong, Tat Chee Avenue, Kowloon, Hong Kong, China. Email: jichen@cityu.edu.hk) is a Chair Professor in the Department of Electronic Engineering, City University of Hong Kong, Hong Kong, China. He received the B.S. degree in aerospace engineering from Northwestern Polytechnic University, China in 1982, the M.S.E. degree in electrical engineering, the M.A. degree in mathematics, and the Ph.D. degree in electrical engineering, all from The University of Michigan, Ann Arbor, Michigan, in 1985, 1987, and 1990, respectively.

Prior to joining City University, he was with School of Aerospace Engineering and School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia from 1990 to 1993, and with University of California, Riverside, California from 1994 to 2014, where he was a Professor and served as Professor and Chair for the Department of Electrical Engineering from 2001 to 2006. His main research interests are in the areas of linear multivariable systems theory, system identification, robust control, optimization, time-delay systems, networked control, and multi-agent systems. He is the author of several books, among which most related to time-delay systems are Stability of Time-Delay Systems (with K. Gu and V.L. Kharitonov, Birkhauser, 2003), and Limits of Stability and Stabilization of Time-Delay Systems: A Small-Gain Approach (with J. Zhu, T. Qi, and D. Ma, Springer, 2017).

An elected Fellow of IEEE, Fellow of AAAS, Fellow of IFAC and a Yangtze Scholar/Chair Professor of China, Dr. Chen was a recipient of 1996 US National Science Foundation CAREER Award, 2004 Japan SICE International Award, and 2006 Natural

Science Foundation of China Outstanding Overseas Young Scholar Award. He served on a number of journal editorial boards, as an Associate Editor and a Guest Editor for the IEEE Transactions on Automatic Control, a Guest Editor for IEEE Control Systems Magazine, an Associate Editor for Automatica, and the founding Editor-in-Chief for Journal of Control Science and Engineering. He is currently an IEEE Control Systems Society (CSS) Distinguished Lecturer and serves as an Associate Editor for SIAM Journal on Control and Optimization. He was a member on IEEE CSS Board of Governors in 2014 and has served as IEEE CSS Chapter Activities Chair since 2015.



Dan Ma (College of Information Science and Engineering, Northeastern University, Shenyang, China, Email: madan@mail.neu.edu.cn) received the B.S. degree in Automation from Liaoning Institute of Technology, Jinzhou, China in 1999, the M.S. degree from Shenyang University of Technology in 2004, and the Ph.D. degree from Northeastern University in 2007, Shenyang, China, both in Control Theory and Control Engineering.

Since 2006, she has been with School of Information Science and Engineering, Northeastern University, Shenyang, where she is appointed an Associate Professor. She was a Postdoctoral Fellow at Northeastern University from 2008 to 2010, a Guest Professor with Department of Electrical Engineering, University of Notre Dame, South Bend, Indiana, USA, in 2012, and a Research Fellow at Department of Electronic Engineering, City University of Hong Kong, China in 2017. Her main research interests include network-based control systems, switched systems, and time-delay systems. She is a member of CAA Youth Committee, and a member of TCCT Technical Committee on Nonlinear Systems and Control.

Tian Qi (School of Automation Science and Engineering, South China University of Technology, Guangzhou, China, Email: auqt@scut.edu.cn) was born in Chaoyang, Liaoning Province, China in 1981. She received the B.S. degree in automation from Hangzhou Dianzi University, Hangzhou, China in 2003, the M.S. degree and the Ph.D. degree in control theory and control engineering, from South China University of Technology, Guangzhou, China in 2006 and 2009, respectively.

Dr. Tian Qi joined the South China University of Technology in 2009, where she is currently a Lecturer. From May 2011 to August 2011, she was with the Department of Electronic Engineering, City University of Hong Kong, as a postdoctoral researcher. From January 2012 to December 2012, she was a Research Associate in the Department of Electrical and Computer Engineering, Hong Kong University of Science and Technology. Her main research interests are in the areas of networked control, multi-agent systems, time-delay systems, robust control and optimization.

Jing Zhu (College of Automation Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing, China. Email: drzhujing@nuaa.edu.cn) received the B. Eng. degree in Communication Engineering from Nanjing University of Posts and Telecommunications, Nanjing, China, in 2010, and the Ph.D degree in Electronic Engineering from City University of Hong Kong, Hong Kong, China, in 2015.

He was a visiting scholar with the Department of Electrical and Computer Engineering, University of California, Riverside, US, from December 2013 to June 2014. Currently, she is a Lecturer with the College of Automation Engineering, Nanjing University of Aeronautics and Astronautics. Her research interests include time-delay systems, stochastic systems and robust control.

Abstract: Time delays arise in the transport of energy, mass, information and such, and are omnipresent in natural and engineered systems. Modern interconnected networks

are especially prone and indeed, are vulnerable to long and variable delays; systems and networks in this category are many, ranging from communication networks, sensor networks, cyber-physical systems, to biological systems. Except on rare instances, time delays are likely to result in degraded performance, poor robustness, and even instability, which consequently pose significant challenges to the analysis and design of control systems under delayed feedback.

While a recurring subject of study, over the last two decades or so there have been particularly notable advances in the stability analysis of time delay systems, thanks to the development of analysis methods drawing upon robust control theory, and the development of computational methods in solving linear matrix inequality (LMI) problems. An extraordinary volume of the literature is in existence on stability problems, and various time- and frequency-domain stability criteria have been developed. Of these developments, while an overwhelming majority of the available results are obtained based upon time-domain Lyapunov-Krasovskii methods and require the solution of LMIs, frequency-domain conditions in the spirit of small-gain theorem have also been sought after. Generally, time-domain stability conditions are applicable to both constant and time-varying delays, but are known to suffer from a varying degree of conservatism. In contrast, frequency-domain tests are largely restricted to constant delays though often provide tight conditions and appear more susceptible to feedback synthesis.

Despite the considerable advances on stability analysis, control design problems for time-delay systems prove far more challenging. Feedback stabilization of time-delay systems poses a difficult problem and has been somewhat an underdeveloped research area. Fundamental robustness issues have been seldom investigated as well. Furthermore, recent advances in broad fields of science and engineering brought forth new issues and problems to the area of time-delay systems; time delays resulted from the interconnected systems and networks present new challenges unexplored in the past and are increasingly seen to have far more grave effects, which the existing theories do not seem to be well equipped with.

In the workshop we intend to discuss a wide variety of subjects on the stability and stabilization of time-delay systems. We ask such questions as when will a delay system be stable or unstable, and for what values of delay? When can an unstable delay system

be stabilized? What range of delay can a feedback system tolerate to maintain stability? Fundamental questions of this kind have long eluded engineers and mathematicians alike, yet ceaselessly invite new thoughts and solutions. We shall present tools and techniques that answer to these questions, seeking to provide exact and efficient computational solutions to stability and stabilization problems of time-delay systems. In particular, we shall develop in full an operator-theoretic approach that departs from both the classical algebraic and the contemporary LMI solution approaches, notable for both its conceptual appeal and its computational efficiency. Extensions to networked control and multi-agent systems will also be addressed.

Topics included:

We propose a 3~4 hour, half-day pre-conference workshop that addresses the following subjects, all unified under an operator-theoretic, small-gain theorem approach:

- Classical stability tests for time-delay systems.
- Eigenvalue perturbation theory.
- Eigenvalue series for stability analysis of time-delay systems.
- Small gain stability conditions for time-delay systems.
- Robust stability of delay systems.
- Stabilization of delay systems: The delay margin problem.
- Fundamental bounds on delay margin.
- Delay margin achievable by PID controllers.
- Delay effects on networked feedback stabilization.
- Delay effects on multi-agent consensus.