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WCCI 2014 Invited Lecture
Recent Advances in Fuzzy Modeling and Control: When Nonlinearities Met Fuzzy Logic

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Abstract

This talk presents an overview of recent advances in fuzzy modeling and control of nonlinear systems. A number of system-theoretical approaches, ranging from convex linear matrix inequality (LMI) based design to non-convex sum-of-squares (SOS) based synthesis, are discussed in detail. These approaches are characterized by their salient treatments of nonlinearities enabled by a progression of fuzzy modeling frameworks from the Takagi-Sugeno fuzzy model to polynomial fuzzy systems. The research covered in this talk has been conducted in our laboratory at the University of Electro-Communications (UEC), Tokyo, Japan, in collaboration with Prof. Hua O. Wang and his laboratory at Boston University, Boston, USA.

Today, there exists a large body of literature on fuzzy model-based control using LMIs. The first part of this talk presents a synopsis of LMI-based fuzzy control methodologies. A key feature of LMI-based approaches is that they result in simple, natural and effective design procedures as alternatives or supplements to other nonlinear control techniques that require special and rather involved knowledge. The LMI-based design approaches entail obtaining numerical solutions by convex optimization methods such as the interior point method.

The second part of this talk focuses on SOS-based approaches. Though LMI-based approaches have enjoyed great success and popularity, there still exist a large number of design problems that either cannot be represented in terms of LMIs, or the results obtained through LMIs are sometimes conservative. A post-LMI framework is the SOS-based approaches for control of nonlinear systems using polynomial fuzzy systems and controllers, which includes the well-known Takagi-Sugeno fuzzy systems and controllers as special cases.

The last part of the talk discusses non-convex approaches in SOS-based approaches. To obtain a polynomial fuzzy controller by solving design conditions efficiently, non-convex design conditions are transformed to convex design conditions. However the transformation often results in some challenging issues in SOS-based approaches. Conversely, non-convex design conditions can avoid the transformation problems, but it is difficult to solve non-convex design conditions efficiently. To this end, this talk presents a most recent result on an efficient numerical technique, the so-called path following technique, to deal with non-convex design conditions.

Throughout the talk, it will be reflected upon how to contend with nonlinearities via enabling fuzzy modeling paradigms coupled with system-theoretical approaches in development of toolkits for control of nonlinear systems.

Kazuo Tanaka is currently a Professor in Department of Mechanical Engineering and Intelligent Systems at the University of Electro-Communications, Tokyo, Japan. He received his Ph.D. in Systems Science from Tokyo Institute of Technology in 1990. He was a Visiting Scientist in Computer Science at University of North Carolina at Chapel Hill in 1992 and 1993.

He received the Best Young Researchers Award from the Japan Society for Fuzzy Theory and Systems in 1990, the Outstanding Papers Award at the 1990 Annual NAFIPS Meeting in Toronto, Canada, in 1990, the Outstanding Papers Award at the Joint Hungarian-Japanese Symposium on Fuzzy Systems and Applications in Budapest, Hungary, in 1991, the Best Young Researchers Award from the Japan Society for Mechanical Engineers in 1994, the Outstanding Book Awards from the Japan Society for Fuzzy Theory and Systems in 1995, 1999 IFAC World Congress Best Poster Paper Prize in 1999, 2000 IEEE Transactions on Fuzzy Systems Outstanding Paper Award in 2000, the Best Paper Selection at 2005 American Control Conference in Portland, USA, in 2005, the SICE Award at RoboCup Japan Open 2010, Osaka, Japan, in 2010, Best in class Autonomy Award at RoboCup 2011 Japan Open in Osaka, Japan, in 2011, the Best Paper Award at 2013 IEEE International Conference on Control System, Computing and Engineering (ICCSCE 2013) in Penang, Malaysia, in 2013, the Best Paper Finalist at 2013 International Conference on Fuzzy Theory and Its Applications (iFUZZY2013) in Taipei, Taiwan, in 2013.

He served as Vice Chair of IEEE International Symposium on Intelligent Control (ISIC09) (in 2009 IEEE Multi-conference on Systems and Control), Saint Petersburg, Russia, in 2009. He served also as Chair of Task Forces on Fuzzy Control Theory and Application, IEEE Computational Intelligence Society Fuzzy Systems Technical Committee. He is currently serving as an Associate Editor for Automatica and for the IEEE Transactions on Fuzzy Systems, and is on the IEEE Control Systems Society Conference Editorial Board.

His research interests include fuzzy systems control, nonlinear systems control, robotics, brain-machine interface and their applications. He published many papers in these areas, as well as 17 books, including: *Fuzzy Control Systems Design and Analysis: A Linear Matrix Inequality Approach* (*Wiley-Interscience, 2001*). His publications currently report over 5,500 citations according to Web of Science, with an h-index of 23.