Tutorial and Workshops

Tutorial 01

Tuesday September 6, 9:00-12:20, Room 15

Control barrier function: Fundamentals, designs and applications

Organizer:

Prof. Hisakazu Nakamura (Tokyo University of Science, Japan)

Abstract:

In recent years, control barrier functions (or its abbreviation CBF) have attracted much attention in control systems theory and engineering for safety-critical or state-constrained control problems. This tutorial introduces mathematical frameworks of safety assurance by using CBFs. This tutorial consists of three talks from Prof. H. Nakamura (Tokyo University of Science, Japan), Prof. T. Ibuki (Meiji University, Japan), and Dr. S. Kimura (Shimizu Corporation, Japan).

Prof. Nakamura introduces definitions and basic properties of CBFs and mathematical frameworks of safety assurance. This talk defines the forward-completeness of solutions of differential equations for state-constraint problems. Then, the definitions of two types of CBFs: reciprocal and zeroing CBFs, are introduced. Fundamental mathematical tools for these two types of CBFs have been given; a zeroing-type CBF can guarantee safety by Nagumo's theorem, and a reciprocal-type one by Gronwall's theorem. This talk elucidates the theoretical limitations of these theorems.

Prof. Ibuki introduces design examples of control barrier functions (CBFs) for safety-assurance control. This talk focuses on mobile robots as controlled targets for ease of understanding.

CBF design procedures are introduced for obstacle avoidance control of a single mobile robot and multi-robots. Then, distributed safety-assurance control of networked systems is introduced for general nonlinear dynamics. Moreover, the design of a data-driven CBF based on Gaussian processes is introduced for learning a safety set in a workspace of mobile robots.

Finally, various types of CBFs and those applications currently presented by many researchers in robotics and control communities are briefly summarized.

Dr. Kimura introduces an industry application of CBF-based control. This talk introduces the need for control barrier functions in the construction industry and how they can be adopted into our research and development projects.

We, as a corporation, also show how beginners can acquire the handling of control barrier functions and the steps to implementation on actual robots. Through our experience, the usability of control barrier functions will be mentioned.

Keywords:

control barrier function, safety critical system, human-in-the-loop system, mobile robot

Speaker:

1. Prof. Hisakazu Nakamura, (Tokyo University of Science, Japan)

Hisakazu Nakamura was born in Osaka on August 13, 1976. He received the M.S. in control engineering from the Tokyo Institute of Technology, Japan, in 2000 and the Ph.D. in information technology from the Nara Institute of Science and Technology, Japan, in 2003. From 2003 to 2011, he was an Assistant Professor at the Graduate School of Information Science of the Nara Institute of Science and Technology. From 2008 to 2009, he was a visiting researcher at the SYSTeMS Research Group of Ghent University in Belgium. He is a professor at the Department of Electrical Engineering of Tokyo University of Science. He won the SICE Young Researcher's Award in 2007, and the SICE Outstanding Paper Award in 2017. His research interests include nonlinear control theory and its application to robotics.

Title: Mathematical introduction to control barrier function-based safety assurance

Abstract: Recently, control barrier functions (or its abbreviation CBF) have attracted much attention in control systems theory and engineering for safety-critical or state-constrained control problems. This tutorial talk aims to introduce definitions and basic properties of CBFs and mathematical frameworks of safety assurance. Firstly, this talk defines the forward-completeness of solutions of differential equations for state-constraint problems. Secondly, the definitions of two types of CBFs: reciprocal and zeroing CBFs, are introduced. Then, fundamental mathematical tools for these two types of CBFs have been given; a zeroing-type CBF can guarantee safety by Nagumo's theorem, and a reciprocal-type one by Gronwall's theorem. This talk elucidates the theoretical limitations of these theorems.

2. Prof. Tatsuya Ibuki, (Meiji University, Japan)

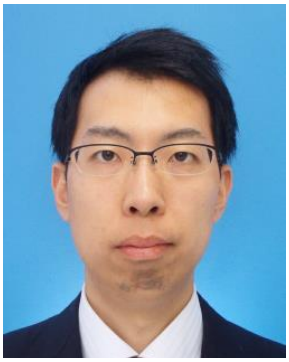
Tatsuya Ibuki received the B.Eng., M.Eng., and Ph.D. degrees in mechanical and control engineering from Tokyo Institute of Technology in 2008, 2010, and 2013, respectively. He was a research fellow with the Japan Society for the Promotion of Science from 2012 to 2013, an assistant professor with the Department of Systems and Control Engineering, Tokyo Institute of Technology from 2013 to 2020, and a visiting scholar with the School of Electrical and Computer Engineering, Georgia Institute of Technology in 2019. Since 2020, he has been a senior assistant professor with the Department of Electronics and Bioinformatics, Meiji University. His research interests include cooperative control of robotic networks, fusion of control theory and machine learning, and vision-based estimation and control.

Title: Design of control barrier functions for safety-assurance control of mobile robots

Abstract: This talk introduces design examples of control barrier functions (CBFs) for safety-assurance control. In this talk, mobile robots are mainly focused on as the controlled targets for the ease of understanding. First, design of a CBF for obstacle avoidance control of a single mobile robot is introduced. Secondly, this obstacle avoidance methodology is extended to a multi-robot system case: CBF-based distributed collision avoidance between mobile robots. The technique of distributed safety-assurance control is also generalized for networked systems with general nonlinear dynamics.

Thirdly, design of a data-driven CBF based on Gaussian processes is introduced for learning of safety area in work space of mobile robots. Finally, various type of CBFs and those applications, currently presented by many researchers in robotics and control communities, are briefly summarized.

3. Dr. Shunsuke Kimura, (Shimizu corporation, Japan)



Shunsuke Kimura received his bachelor's and master's degrees in engineering from Tokyo University of Science in 2013 and 2015, and his doctoral degree in engineering from Tokyo Institute of Technology in 2018, respectively. He is currently a researcher at the Institute of Technology of Shimizu Corporation. His research interests include nonlinear control theory, mobile robots, human robot interaction, and robot management systems. He is a member of IEEE, RSJ and SICE.

Title: Application examples of control barrier functions in the construction industry

Abstract: In recent years, the theoretical development of control barrier functions has attracted much attention. On the contrary, there are still few application examples of control barrier functions in industry. This talk introduces the needs of control barrier functions in the construction industry and how they can be adopted into our research and development projects. We, as a corporation, also show how beginners can acquire the handling of control barrier functions and the steps to implementation on actual robots. Through our experience, the usability of control barrier functions will be mentioned.

Program:

9:00–10:00	**Mathematical introduction to control barrier function-based safety assurance** Hisakazu Nakamura (Tokyo University of Science, Japan)
10:00–10:10	Break
10:10–11:10	**Design of control barrier functions for safety-assurance control of mobile robots** Tatsuya Ibuki (Meiji University, Japan)
11:10–11:20	Break
11:20–12:20	**Application examples of control barrier functions in the construction industry** Shunsuke Kimura (Shimizu corporation, Japan)

Tutorial 02

Tuesday September 6, 13:30-17:40, Room 15

New Trends in Machine Learning for Science and Engineering

Organizer:

Prof. Ichiro Takeuchi, (Nagoya University, Japan), Prof. Hiroyuki Okada (Nagoya University)

Abstract:

Machine learning and deep learning technologies have become crucial tools in engineering and science due to their ability to analyze large and complex datasets. They have revolutionized many fields, including robotics,

healthcare, science, and more, enabling researchers to discover new insights, make predictions, and improve decision-making processes. This tutorial session will cover three different topics related to artificial intelligence and machine learning from Prof. Matthias Rätsch, (Reutlingen University, Germany), Prof. Takashi Matsubara, (Osaka University, Japan) and Prof. Ichiro Takeuchi, (Nagoya University, Japan). Overall, this tutorial session will showcase how AI and machine learning can be applied to various fields and industries.

The first talk from Prof. Rätsch introduces research of 'Visual Systems for Intelligent Robots' (ViSiR) group and how large language models(LLMs) come close to super intelligence for the AI alignment problem. Practical examples for the human-robot-collaboration in RT-Lions team, wining world championships in RoboCup, is shown with the collaborations with big industrial partners.

The second talk from Prof. Matsubara discusses "geometric scientific machine learning," a technique that restricts deep learning to a subspace ensuring adherence to the laws of physics, making it suitable for rigorous fields such as natural science and industrial applications.

The third talk from Prof. Takeuchi introduces the machine learning-based data analysis for the hypothesis exploration and generation by effectively combining Bayesian experimental designs and deep generative models, specifically in the field of chemical compound designs.

Keywords:
Intelligent Systems, Computational Intelligence, Innovative Systems Approach for Realizing Smarter World

Speaker:

1. Prof. Dr. rer. nat. Matthias Rätsch, (Reutlingen University, Germany)

Prof. Rätsch is a professor at the Reutlingen University for Artificial Intelligence and Interactive Mobile Robots since 2013. He is the head of the Visual Systems and Intelligent Robots group (www.ViSiR.org). In 2008, he received his Ph.D. degree in the graphics and vision research group (GraVis) at the University of Basel, Switzerland in 3DMM face analysis. Until 2013 he was with the world-leading company Cognitec Systems for face recognition. His research interests are Image Understanding, Computer Vision, Artificial Intelligence, Deep Learning, Edge-AI, Autonomous Driving, Humanoid Robots, Bionic Intelligence and Grasping, Human Robot Collaboration, Large Language Models, Intelligent ChatBots, and AI-Ethics. He is the head of the RoboCup team RT-Lions (www.rt-lions.de). The team was World Champion in 2009 and German Master in 2010, after changing to the RoboCup@Home league, the team could win the Portuguese Open and the SICK Robot Day, and joined the World Championship in Nagoya, Japan and in Sydney, Australia. Recently the team obtained the 3rd Prize at World Championship Worldwide Virtual. He was a member of the program committee and session chair for several international conferences and invited speeches in Artificial Intelligence, Face Analysis, and Robot Vision. He published more than 50 international academic research papers and journals, like at IEEE Transactions on Image Processing or at the IEEE SIGGRAPH conference. He was leading the 1.1 Mill € founded industrial project "KollRo 4.0" (with BMBF, BOSCH, Mercedes Benz), two ZIM projects (0.4 Mill). He leads current the ProFö "BInGO" and the InvestBW "FAIR" projects (0.6 Mill €), and a further 2.4 Mill € are proposed. He joined several funded industrial projects, like RTMO (BMBF), GES 3D (BMBF), Face-HMI (SAB, COG), and I-Search (BMBF).

Title: A Tutorial how to Train Humanoid Robots with Artificial Super Intelligence. Are they the End or the Last Hope for Humans?

Abstract: Recent research in artificial intelligence and robotics, termed as fourth industrial or robot revolution, is changing our world. In this tutorial I will introduce research of our group 'Visual Systems for Intelligent Robots' (ViSiR). We will discuss, how LLMs (like ChatGPT) come close to super intelligence,

taking over power, if we cannot solve the alignment problem. On practical examples we will learn to train an AI for human-robot-collaboration. All is illustrated on robots of our RT-Lions team, wining world championships in RoboCup. Practical examples are shown from collaborations with strong industrial partners, like BMW, Mercedes Benz, BOSCH, FESTO or KUKA

2. Prof. Takashi Matsubara, (Osaka University, Japan)

Takashi Matsubara was born in Nara, Japan in 1988. He received his B.E., M.E., and Ph.D. degrees from Osaka University, Osaka, Japan, in 2011, 2013, and 2015, respectively. From 2015 to 2020, he worked as an assistant professor at the Graduate School of System Informatics, Kobe University, Hyogo, Japan. Since 2020, he is serving as an associate professor at the Graduate School of Engineering Science, Osaka University, Osaka, Japan. In 2021, he was appointed as a researcher under the Japan Science and Technology Agency (JST) PRESTO program. He also serves as an editorial committee member for the Journal of the Japanese Society for Artificial Intelligence (JSAI) and as a representative for the Institute of Electronics, Information and Communication Engineers (IEICE). His research interests focus on integrating inductive bias into deep learning for data-driven modeling. In 2021, his research was awarded the Strategic Information and Communications R&D Promotion Program (SCOPE) Research Encouragement Award by the Ministry of Internal Affairs and Communications, Japan.

Title: Geometric Deep Learning for Modeling Dynamical Systems and Incorporating Laws of Physics

Abstract: Artificial intelligence has made remarkable strides due to deep learning, which is an inductive method that employs data to model a system. However, it struggles in rigorous fields such as natural science and industrial applications, where deductive approaches like scientific computing are more commonly used. They can gain insights into the mathematical structures underlying systems and develop computational methods to preserve them. In this talk, I will introduce "geometric scientific machine learning," which incorporates such a deductive approach into artificial intelligence. This technique restricts the function space of deep learning to a subspace that guarantees adherence to the laws of physics while learning dynamics from data.

3. Ichiro Takeuchi, (Nagoya University, Japan / RIKEN)

Ichiro Takeuchi is a professor at Nagoya University in Japan and leads a team at the RIKEN Center for Advanced Intelligence Project. He earned his B.Eng., M.Eng., and D.Eng. degrees from Nagoya University in 1996, 1998, and 2000, respectively. After serving as a post-doctoral researcher under Prof. Yoshua Bengio in Montreal, Canada, he became a tenured assistant professor at Mie University in 2001. He later achieved associate and full professor positions at Nagoya Institute of Technology in 2008 and 2015, respectively, and finally a full professor position at Nagoya University in 2022. His research focuses on machine learning theory and algorithms and their applications in bio-medical and material sciences. He has published numerous studies in top machine learning and data mining conferences such as ICML, NIPS, and KDD, as well as high-impact journals in the respective fields.

Title: Data-driven Exploration and Generation of Scientific Hypotheses by Deep Generative Models

Abstract: Data-driven science is a rapidly growing field that aims to use data collection and analysis to drive scientific research. At the core of this field is the use of machine learning-based data analysis to explore and generate new hypotheses, which can lead to new scientific discoveries. In this tutorial, I will delve into the recent advances in hypothesis exploration and generation by effectively combining Bayesian experimental designs and deep generative models. These methods have been shown to be particularly promising in uncovering new insights and understanding complex systems. We will discuss the underlying principles of these methods and explore their applications in the field of chemical compound designs.

Program:

13:30–15:00	**A Tutorial how to Train Humanoid Robots with Artificial Super Intelligence. Are they the End or the Last Hope for Humans?** Matthias Rätsch (Reutlingen University, Germany)
15:00–15:10	Break
15:10–16:20	**Geometric Deep Learning for Modeling Dynamical Systems and Incorporating Laws of Physics** Takashi Matsubara (Osaka University, Japan)
16:20–16:30	Break
16:30–17:40	**Data-driven Exploration and Generation of Scientific Hypotheses by Deep Generative Models** Ichiro Takeuchi (Nagoya University, Japan)

Workshop 1

Tuesday September 6, 9:00-12:20 and 13:30-17:25, Room 24

Complex Networks on Time-Series for Process Analysis

Organizers:

Arun K. Tangirala, (Dept. of Chemical Engineering, IIT Madras)

Lakshminarayanan Samavedham, (Dept. of Chemical and Biomolecular Engineering, National University of Singapore)

Abstract:

Graphical representations or network models have found increasing applications in linear / non-linear complex dynamical systems, for the purposes of characterising and discovering changes in structural properties of signals / systems, causal discovery, analysis and control of complex systems, root-cause diagnosis, epidemic spread, brain connectivity, etc. Network models have a few key advantages: (i) a suite of simple (coarse) to fine-grained dynamical relationships can be constructed (ii) no prior distinction between causes and effects are required (iii) can be easily extended to accommodate univariate, multivariable signals and system of systems and (iv) the availability of a graph theory formalism.

The workshop aims to present a few well-established and emerging methods for reconstructing network models from time-series data. Specifically, we shall focus on identifying three different classes of networks or graphs: visibility graphs, correlation / coherence networks and causal networks for deterministic and stochastic processes. Applications of these network models in engineering and other domains shall be presented. Further, a brief discussion on experimental design for network identification is also included. The focus is on providing

the theory and tools for developing network models that (i) capture structural dependencies in non-linear time-series (ii) graphically represent directional and undirected dependencies and (iii) model non-linear dynamical systems.

Keywords:
Modeling, System Identification and Estimation; Computational Intelligence; Signal and/or Image Processing

Program:

Complex Networks on Time-Series for Process Analysis I	
9:00–10:05	**Network (Graphical) Models for Dynamical Systems Overview and Essentials** Arun K. Tangirala (Indian Institute of Technology Madras, India)
10:05–10:15	Break
10:15–11:00	**Correlation and Coherence Networks** Arun K. Tangirala (Indian Institute of Technology Madras, India)
11:00–12:00	**Granger Causality and GC Networks** Arun K. Tangirala (Indian Institute of Technology Madras, India)
12:00–13:30	Lunch break
Complex Networks on Time-Series for Process Analysis II	
13:30–14:15	**Deterministic Causal Networks using PCA** Arun K. Tangirala (Indian Institute of Technology Madras, India)
14:15–15:45	**CCM-Causal Networks for Non-linear Systems** Lakshminarayanan Samavedham (National University of Singapore) and Arun K. Tangirala (Indian Institute of Technology Madras, India)
15:45–15:55	Break
15:55–16:40	**Experimental Design for Network Identification** Lakshminarayanan Samavedham (National University of Singapore)
16:40–17:25	**Applications** Lakshminarayanan Samavedham (National University of Singapore) and Arun K. Tangirala (Indian Institute of Technology Madras, India)

Workshop 2

Tuesday September 6, 9:00-12:00, Room 25

Stochastic Configuration Networks for Industrial Data Analytics

Organizer:

Prof. Dianhui Wang, (China University of Mining and Technology, Northeastern University, China)

Abstract:

Recently, we developed a new randomized learning algorithm and ensure the resulting model, termed Stochastic Configuration Networks (SCNs), holds the universal approximation property. Such a milestone progress greatly contributes to both the advancement of knowledge on randomized learning theory and the development of lightweight computing technology for IoT-based industrial applications. This workshop aims to introduce the state-of-the-art of SCN models, algorithms and applications to the instrument and control community in Japan.

Speakers:

Dr Wang was awarded a Ph.D. from Northeastern University, Shenyang, China, in 1995. From 1995 to 2001, he worked as a Postdoctoral Fellow at Nanyang Technological University, Singapore, and a Researcher at The Hong Kong Polytechnic University, Hong Kong, China. From July 2001 to December 2020, he worked as a Reader in the Department of Computer Science and Information Technology, La Trobe University, Australia, and with adjunct appointment from 2021. Since 2017, Dr Wang has been a visiting Professor at State Key Laboratory of Synthetical Automation of Process Industries, also Industrial AI Research Institute, Northeastern University, China. In July 2021, He joined AI Research Institute at China University of Mining and Technology, working as a Dean, Professor, and Director of Research Center for Stochastic Configuration Machines. His current research focuses on industrial artificial intelligence, specifically on Deep Stochastic Configuration Networks (http://www.deepscn.com/) for data analytics in process industries, intelligent sensing, and control systems, prediction of significant and small probability events. Dr Wang published more than 240 technical papers on applied mathematics, control engineering and computer sciences. Dr Wang is a Senior Member of IEEE, serving as an Associate Editor for IEEE Transactions on Cybernetics, IEEE Transactions on Fuzzy Systems, Information Sciences, Artificial Intelligence Review and WIREs Data Ming and Knowledge Discovery.

Dr. Qiao received the B.E. and M.E. degrees in control engineering from Liaoning Technical University, Fuxin, China, in 1992 and 1995, respectively, and the Ph.D. degree from Northeast University, Shenyang, China, in 1998. From 1998 to 2000, he was a Postdoctoral Fellow with the School of Automatics, Tianjin University, Tianjin, China. He joined the Beijing University of Technology, Beijing, China, where he is currently a professor. He is also the Director of the Intelligence Systems Laboratory, Beijing. His current research interests include neural networks, intelligent systems, self-adaptive learning systems, and process control systems. Prof. Qiao is a member of the IEEE Computational Intelligence Society.

Dr Ding received the B. E., M.E. and Ph.D. degrees in Control Theory and Control Engineering from Northeastern University, Shenyang, China. He is a Professor of the State Key Laboratory of Synthetical Automation for Process Industry, Northeastern University. He has authored or co-authored over 200 refereed journal papers and refereed papers at international conferences. He has also invented or co-invented over 50 patents. His research interests include modeling, plant-wide control and optimization for the complex industrial systems, machine learning, industrial artificial intelligence, and computational intelligence and application. Prof. Ding was a recipient of the Young Scholars Science and Technology Award of China in 2016, the National Science Fund for Distinguished Young Scholars in 2015, the National Technological Invention Award in 2013, and three First-Prize of Science and Technology Awards of the Ministry of Education in 2006, 2012, and 2018, respectively.

Dr Dai received his master's and Ph.D. degrees in control theory and control engineering from Northeastern University, China, in 2009 and 2015, respectively. He is working as a Professor of the Artificial Intelligence Research Institute, China University of Mining and Technology (CUMT), China. His research focuses on industrial big data analytics, industrial artificial intelligence, and knowledge discovery for complex industrial processes. He has been awarded with the National Youth Talent Support Program, and has received the First Prize of Liaoning Province Patent Award in 2022, the Youth Science and Technology Award of China Coal Industry in 2022. Prof. Dai is an Associate Editor of Industrial Artificial Intelligence and an Editorial board member of the Frontiers in Control Engineering.

Dr Zhang received the B.Sc. degree in applied mathematics, the M.S. degree in control theory and control engineering, and the Ph.D. degree in control theory and control engineering from Northeastern University, China, in 1989, 2004, and 2008, respectively, where he is currently with the College of Sciences. He has published more than 60 SCI journal papers and 150 EI papers and 3 books (including Fundamentals of control theory in Higher Education Press, National Eleventh Five Year Plan textbook). His research interests include fuzzy control, fractional order control systems and singular systems. He won the First prize of teaching achievement of Liaoning Province and the excellent teacher of Northeastern University. Prof. Zhang is an Associate Editors of IEEE Access and IET Electronic Letters.

Program:

9:00–9:40	**Stochastic Configuration Networks for Industrial Artificial Intelligence** Dianhui Wang, (CUMT (Xuzhou) and NEU (Shenyang) China
9:40–10:20	**Dynamic Stochastic Configuration Networks with Lifelong Learning for Industrial Data Stream Modelling** Junfei Qiao, Beijing University of Technology, Beijing, China
10:20–10:30	Break
10:30–11:00	**Stochastic Configuration Networks for Prediction of Industrial Production Indices** Prof. Jinliang Ding, Northeastern University, Shenyang, China
11:00–11:30	**Stochastic Configuration Networks for Human Activity Recognition** Prof. Wei Dai, China University of Mining and Technology, China
11:30–12:00	**Universal Approximation Property of Stochastic Configuration Networks for Time Series** Prof. Xuefeng Zhang, Northeastern University, Shenyang, China