# FINAL PROGRAM and BOOK OF ABSTRACTS

## 2023 IEEE 12th Data Driven Control and Learning Systems Conference (DDCLS'23)

## Xiangtan, Hunan, China

## May 12–14, 2023

### Organized by

Technical Committee on Data Driven Control, Learning and Optimization, Chinese Association of Automation

Qingdao University

### Locally Organized by

Hunan University of Science and Technology

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# CONTENTS

Organizing Committee……...1

Welcome Message from General Chairs……3

Message from Technical Program Chairs……...5

Keynote Address……7

Distinguished Lecture …… 11

Industrial Control Practice Forum …… 17

Pre-Conference Tutorial …… 19

Technical Program and Book of Abstracts……23

Program at a Glance……119

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# Welcome Message from General Chairs

Zhongsheng Hou
General Chair of DDCLS'23

Weijun Wang
General Chair of DDCLS'23

Dear Friends and Colleagues,

On behalf of the Organizing Committee, it is our greatest pleasure to welcome you to the 2023 IEEE 10th Data Driven Control and Learning Systems Conference (DDCLS'23), which is organized by Technical Committee on Data Driven Control, Learning and Optimization (DDCLO), Chinese Association of Automation and Qingdao University, locally organized by Technical Committee on Data Driven Control, Learning and Optimization, Chinese Association of Automation and Qingdao University, and sponsored by IEEE Beijing Section and Beijing Information Science and Technology University. The conference is held at Paragon Hotel, Xiangtan, Hunan Province, China, May 12–14, 2023.

Data driven control and learning systems, together with model-based control methods for the target of forming the complete control theory, is an emerging hot research area in the field of automation engineering and in systems & control. It focuses on all the issues of control, learning and optimization for the plants whose models are unavailable. Although the study on data driven control and learning is still in the embryonic stage, it has attracted a great amount of attention within the systems and control community, such as the special issues published in the top journals: *ACTA AUTOMATICA SINICA* (2009), *IEEE Transactions on Neural Networks* (2011), *Information Sciences* (2013), *IEEE Transactions on Industrial Informatics* (2013), *IEEE Transactions on Industrial Electronics* (2015, 2017), and *IET Control Theory & Applications* (2015, 2016). Further, the problems in the data driven control and learning systems would be fundamental challenges in the coming age of the *Internet of Things*, *Cyber-Physical Systems*, *Industry 4.0*, *China Manufacturing 2025*, and *Artificial Intelligence 2.0* under the big data environment, which is already on our road ahead but beyond the traditional systems & control methods.

As an inheritance of previous ten conferences, DDCLS'23 continues to attract broad interest throughout the world, with the submission of 431 papers. This reflects the increasing interest in our field, and meanwhile creates a difficult workload in evaluating the papers and organizing a cohesive program. We are fortunate to have an exceptional Technical Program Committee (TPC) that sorted through the evaluations and

integrated the individual submissions into the final technical program described in the proceedings. We want to thank our Organizing Committee for their invaluable assistance in arranging the diverse offerings at the conference, from registration and local arrangements to technical programs. Last but not least, we would like to express our deep appreciation to Hunan University of Science and Technology for their great support.

The Technical Program Committee has assembled a comprehensive technical program that covers a broad spectrum of topics in data driven control and learning systems. The DDCLS'23 technical program comprises 10 regular sessions, 32 invited sessions, 1 best paper award session and 2 poster sessions. Besides the technical sessions, the highlights of the DDCLS'23 are the keynote addresses given by world-class level scholars, Prof. Guangren Duan from China, Prof. Tariq Samad from America, Prof. Yongduan Song from China, and the distinguished lectures given by active young scholars. They are Prof. Lixian Zhang, Prof. Qinmin Yang, Prof. Zhi Quan, Prof. Ding Wang, Prof. Qiang Chen, Prof. Xuefang Li, all from China. During the conference, the other academic activities, including Industrial Control Practice Forum, Pre-Conference Tutorial are also held for various research interests of the conference participants. These activities provide high quality research and professional interactions with subject of data driven control such as mode-free adaptive control and iterative learning control, artificial intelligence, automation and industrial applications. We sincerely appreciate all the contributors, especially the keynote address speakers, distinguished lecture speakers, invited session organizers, and session chairs for their tremendous efforts towards a top-quality conference.

We also want to thank the young lovely volunteers who have made this conference possible. Without you, the monumental task ahead of us for organizing this conference would be significantly beyond our capabilities.

May you have a wonderful and fascinating stay in Xiangtan, Hunan Province, China, and enjoy the colorful scenery and magic foods.

Best wishes

Zhongsheng Hou
General Chair of DDCLS'23

Weijun Wang
General Chair of DDCLS'23

# Message from Technical Program Chairs

Mingxuan Sun
Technical Program Chair

Zengqiang Chen
Technical Program Chair

Dear Friends and Colleagues,

On behalf of the Technical Program Committee, it is our great honor to welcome you to the 2023 IEEE 12th Data Driven Control and Learning Systems Conference (DDCLS'23) in Xiangtan, China.

The annual event of DDCLS has proven to be one of the excellent forums for scientists, researchers, engineers, and industrial practitioners to present and discuss the latest technological advancements as well as future directions and trends in Data Driven Control, Learning and Optimization, and to set up useful links for their works. DDCLS'23 has received enthusiastic responses with a total of 431 submissions. All the submissions had been processed by the Technical Program Committee. All committee members worked professionally, responsibly, and diligently. Besides evaluations from reviewers, each member also provided his/her own assessments on the assigned papers, so as to ensure that only high-quality papers would be accepted. Their commitment and hard work have enabled us to put together a very solid proceeding for our conference. The proceeding includes 349 accepted papers which are divided into 43 oral sessions and 2 poster sessions for presentation. Moreover, 39 extended abstract papers are invited for presentation to show the latest academic development in data driven control and learning systems.

Ahead of the parallel technical sessions, we will have three keynote talks to be delivered by eminent scientists. These lectures will address the state-of-the-art developments and leading-edge research topics in both theory and applications in Data Driven Control, Learning and Optimization. We are most honored to have Prof. Guangren Duan (Southern University of Science and Technology/Harbin Institute of Technology), Prof. Tariq Samad (University of Minnesota), and Prof. Yongduan Song (Chongqing University) as the keynote address speakers. Besides, we are very fortunate to have the distinguished lectures given by the six outstanding young scholars, Prof. Lixian Zhang (Harbin Institute of Technology), Prof. Qinmin Yang (Zhejiang University), Prof. Zhi Quan (Shenzhen University), Prof. Ding Wang (Beijing University of Technology), Prof. Qiang Chen (Zhejiang University of Technology) and Prof. Xuefang Li (Sun Yat-sen University). DDCLS'23 is also rich in all kinds of academic activities, including Industrial Control Practice Forum, Pre-Conference Tutorial. More than eleven distinguished scholars will present their new research findings, in the field of data-driven automatic control and industrial applications. We are confident that their

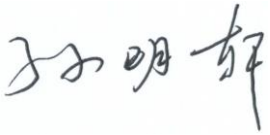
presence would undoubtedly act prestige to the conference. We would like to express our sincere appreciations to all of them for their enthusiastic contributions and strong supports to DDCLS'23.

To promote the development of the society of Data Driven Control, Learning and Optimization, the highest quality papers will be rewarded with the Best Paper Award at DDCLS'23. Based on reviewers' comments and nominations as well as the evaluations of Technical Program Committee members, 20 papers were selected for the consideration of the award by the Best Paper Award Committee. These papers were sent to some distinguished experts in the relevant areas for additional evaluations in a double-blind manner. Based on their comments and recommendations, five papers were shortlisted as the finalists for the award. During the conference, the oral presentations of the five finalists will be further assessed by the DDCLS'22 Best Paper Award Committee. The winner of the "DDCLS Best Paper Award" will be selected by the committee after assessing the oral presentations. Furthermore, the interactive presentations of 131 papers in 2 poster sessions will be assessed by the DDCLS'23 Best Poster Award Committee during the conference, and one or two papers will be conferred to the "DDCLS Best Poster Award" by the committee after assessing the interactive presentations.

A U-disk containing the PDF files of all papers scheduled in the program and an Abstract Book will be provided at the conference to each registered participant as part of the registration material. The official conference proceedings will be published by the IEEE and included in the IEEE Xplore Database.

On behalf of the Technical Program Committee, we would like to thank all reviewers for giving time and expertise to provide comments, which are contributive to the Committee in making a fair decision on the acceptance/rejection of each paper. Thanks also go to the dedication, diligence, and commitments of the Invited Session Chairs Prof. Dongbin Zhao, Prof. Senping Tian, Prof. Yanjun Liu, Prof. Ruizhuo Song, Prof. Li Wang, Prof. Qinglai Wei, Prof. Zhijian Ji, Prof. Weiwei Che, Prof. Ying Zheng, Prof. Tianjiang Hu, Prof. Xiangyang Li and Prof. Zhengguang Wu, Subject Session Chairs Prof. Zhihuan Song, Prof. Yongchun Fang and Prof. Xin Xu, and all the members of the Technical Program Committee. We would like to gladly acknowledge the technical sponsorship provided by the Organizing Committee of DDCLS'23 and Technical Committee on Data Driven Control, Learning and Optimization, Chinese Association of Automation. We also convey our heartfelt thanks to friends, colleagues, and families who have helped us in completing the technical program directly or indirectly. Last but not least, we are grateful for the strong and enthusiastic support of all delegates, especially those old faces around the world.

We do hope that you will find your participation in DDCLS'23 in Xiangtan is really stimulating, rewarding, enjoyable, and memorable.



Mingxuan Sun
Technical Program Chair

Zengqiang Chen
Technical Program Chair

# Keynote Address

## Keynote Address 1

### Fully Actuated System Approach and Data Driven Control

***Prof. Guangren Duan***
***Southern University of Science and Technology/Harbin Institute of Technology***

Saturday, May 13, 2023
08:30-09:20
The 1st Conference Hall / 壹号厅

## Abstract

Inspired by the practical mechanical fully actuated systems, the fully actuated system (FAS) approach, which is parallel to the well-known state-space one, has been recently proposed for general dynamical control system analysis and designs. The state-space models are convenient for obtaining the state vectors (state responses or estimates), but not the control vectors, while the FAS models are those from which the control vectors can be explicitly solved out, and thus can best perform the control. The FAS approach has found its great power in dealing with control of complicated nonlinear dynamical systems, including the time-varying nonlinear systems with time-varying delays, constrained systems and complex nonholonomic systems. In this talk, the backgrounds and the development of the FAS approach are briefly outlined, and applications of FAS approach in data driven control are also discussed.

## Biography

***Guang-Ren Duan*** received his Ph.D. degree in Control Systems Sciences from Harbin Institute of Technology, Harbin, P. R. China, in 1989. After a two-year post-doctoral experience at the same university, he became professor of control systems theory at that university in 1991. From December 1996 to October 2002, he visited the University of Hull, the University of Sheffield, and also the Queen's University of Belfast, UK. He is the founder and presently the Honorary Director of the Center for Control Theory and Guidance Technology at Harbin Institute of Technology. Recently, he has also established the Center for Control Science and Technology at the Southern University of Science and Technology (SUSTech) and is serving as the dean for the School of Automation and Intelligent Manufacturing at SUSTech. He is a Member of the Science and Technology Committee of the Chinese Ministry of Education, and has served as Vice President of the Control Theory and Applications Committee, Chinese Association of Automation (CAA), and Associate Editor of a few international journals. His main research interests include fully actuated system theories for nonlinear systems, parametric control systems design, descriptor systems, spacecraft control and magnetic bearing control, and he has published 5 books and over 450 SCI indexed publications. He is an Academician of the Chinese Academy of Sciences, and Fellow of CAA, IEEE and IET.

# Keynote Address 2

## The Relevance of Control Science and Engineering for Industry: Perspective, Messages, and Opportunities

***Prof. Tariq Samad***
***University of Minnesota, USA***

Saturday, May 13, 2023
10:00-10:50
The 1st Conference Hall / 壹号厅

## Abstract

Despite the enormous benefit that has accrued to society from control technology and the continued vitality of control science as a research field, there is broad consensus that the practitioners of control and the academic research community are insufficiently engaged with each other. This talk will explore this concern from an industry perspective. We will review results of surveys that indicate the extent of the problem and highlight specific issues. To emphasize the continuing relevance of control science to industry, several recent examples of successful, deployed advanced control solutions will be mentioned. The centerpiece of the talk will be a set of "messages," intended primarily for researchers interested in the practical impact of their work, that shed insight on the industry mindset. A concluding section will introduce an application domain outside of the realm of engineering systems—managerial decision making as a control system.

## Biography

***Tariq Samad*** holds the Honeywell/W.R. Sweatt Chair and is Senior Fellow at the Technological Leadership Institute at the University of Minnesota. He joined TLI in 2016 after a 30-year career with Honeywell, retiring as Corporate Fellow with Honeywell Automation and Control Solutions and the Global Innovation Leader for the business. During his career with Honeywell he led and contributed to automation and control technology developments for applications in clean energy, electric power systems, building management, he process industries, automotive engines, unmanned aircraft, and advanced manufacturing.

Dr. Samad is a past president of the American Automatic Control Council and IEEE Control Systems Society. He is a Fellow of IEEE, IFAC, and AAIA and the recipient of a few awards including the IEEE CSS Control Systems Technology Award, a Distinguished Member Award from IEEE CSS, and an IEEE Third Millennium Medal.. He is the founding chair of the IFAC Industry Committee and serves on the IFAC Council. Dr. Samad holds 20 patents and has authored or coauthored over 100 publications. His book publications include the Encyclopedia of Systems and Control (co-editor-in-chief, Springer, 2014; 2nd edition, 2020). He was editor-in-chief of IEEE Press and is currently the founding editor of the Wiley/IEEE Press Book Series on Technology Management, Innovation, and Leadership. He serves on the boards of Clean Energy Economy Minnesota and IEEE Technology and Engineering Management Society, where he is the Vice President for Publications. Dr. Samad holds a B.S. degree in Engineering and Applied Science from Yale University and M.S. and Ph.D. degrees in Electrical and Computer Engineering from Carnegie Mellon University.

# Keynote Address 3

## 预设时间控制理论的最新进展

***Prof. Yongduan Song***
***Chongqing University, China***

Saturday, May 13, 2023
10:50-11:40
The 1st Conference Hall / 壹号厅

## Abstract

预设时间控制具有收敛快且收敛时间不受初始条件和其它设计参数影响的特点，近几年受到广泛关注，并取得重要进展。本报告将梳理这些进展，并介绍几种典型的设计方法，包括：基于状态变换的鲁棒设计，基于时间变换的自适应设计，多输入多输出系统、多智能体系统的控制器设计等。同时讨论预设时间控制和有限时间控制的联系，以及几个可能的未来研究方向。

## Biography

***宋永端***，自动化及智能机器人领域知名学者，国家千人计划首批入选专家，欧亚科学院院士，IEEE Fellow，AAIA Fellow，中国自动化学会会士，重庆大学人工智能研究院院长，曾任重庆大学自动化学院院长。美国大学终身教授，注册职业工程师（美国），美国国家航空研究院六位Langley 杰出教授之一。承担并完成多项国家级重点研发任务，发表论文300余篇，专著12部，获包括中国、美国、日本在内的技术发明专利80余项。国际顶级期刊IEEE TNNLS主编，国际期刊Journal of Automation and Intelligence创始主编。

# Distinguished Lecture

## Distinguished Lecture 1

### Planning and Control for a Class of Rotor-Driven Hybrid Aerial and Terrestrial Vehicles

***Prof. Lixian Zhang***
***Harbin Institute of Technology, China***

Saturday, May 13, 2023
13:30-14:10
The 8th Conference Hall / 捌号厅

## Abstract

The hybrid aerial and terrestrial (HAT) vehicles possess mobility in the air and on the ground. Compared with UAVs, UGVs, and UAV-UGV collaborations, the HAT vehicles have shown significant advantages in accessibility and endurance, leading to great potential in large-range unknown environment exploration, long-distance delivery, etc. This talk will summarize the state-of-the-art of the rotor-driven HAT vehicles, present some progresses on configuration design, planning and smooth-transition control of two classes of rotor-driven HAT vehicles via multimodal design, NMPC, etc., and finally give the future works.

## Biography

***Lixian Zhang*** received the Ph.D. degree in control science and engineering from Harbin Institute of Technology, Harbin, China, in 2006. From January 2007 to September 2008, he was a Postdoctoral Fellow in the Department Mechanical Engineering at the Ecole Polytechnique de Montreal, Canada. He was a Visiting Professor at the Process Systems Engineering Laboratory, Massachusetts Institute of Technology (MIT), Cambridge, MA, USA, from February 2012 to March 2013. Since January 2009, he has been with Harbin Institute of Technology, where he is currently full professor and vice dean of School of Astronautics. His research interests include multimodal systems, model predictive control, and their applications in the field of specialized robots. Prof. Zhang serves as Senior Editor for IEEE Control Systems Letters, and served as Associate Editor for IEEE Transactions on Automatic Control, IEEE Transactions on Cybernetics, etc. He was named to the list of Clarivate Highly Cited Researchers in 2016–2021. He is a recipient of the NSFC for Outstanding Young Scholars. He is a Fellow of IEEE.

# Distinguished Lecture 2

## Industrial Data Intelligence Driven Technology for Operation of Off-Shore Wind Turbine Swarm

***Prof. Qinmin Yang***
***Zhejiang University, China***

Saturday, May 13, 2023
14:10-14:50
The 8th Conference Hall / 捌号厅

## Abstract

Wind energy has been considered to be a promising alternative to current fossil-based energies. Large-scale wind turbines have been widely deployed to substantiate the renewable energy strategy of various countries. In this talk, challenges faced by academic and industrial communities for high reliable and efficient exploitation of off-shore wind energy are discussed. Industrial data intelligence is introduced to (partially) overcome problems, such as uncertainty, intermittence, and intense dynamics. Theoretical results and attempts for practice are both present.

## Biography

***Qinmin Yang*** has been with the State Key Laboratory of Industrial Control Technology, the College of Control Science and Engineering, Zhejiang University, China, where he is currently a professor. He has also held visiting positions in University of Toronto and Lehigh University. He has been serving as an Associate Editor for IEEE Transactions on Systems, Man, and Cybernetics: Systems, IEEE Transactions on Neural Networks and Learning Systems, Transactions of the Institute of Measurement and Control, and Automatica Sinica. He has received five domestic Science and Technology Awards and a few conference paper awards. His research interests include intelligent control, renewable energy systems, smart grid, and industrial big data.

# Distinguished Lecture 3

## Efficient Learning and Intelligent Critic Control for Complex Nonlinear Systems

***Prof. Ding Wang***
***Beijing University of Technology, China***

Saturday, May 13, 2023
14:50-15:30
The 8th Conference Hall / 捌号厅

## Abstract

In recent years, with the wide popularity of networked techniques and the extension of computer control scales, more and more dynamical systems are encountered with the difficulty of building accurately mathematical models and are operated based on increasing communication resources. Due to the dynamics complexity, it is always difficult to achieve direct optimization design and the related control efficiencies are often low. Adaptive critic is an excellent kind of methods to address intelligent control problems for various complex systems. During the adaptive critic framework, reinforcement learning is combined with the neural network approximator to cope with complex optimization and advanced control problems approximately. This report displays some efficient learning and advanced control results with critic intelligence for complex discrete-time systems, which covers the novel control theory, advanced control methods, and typical applications for wastewater treatment systems. Therein, combining with artificial intelligence techniques, such as neural networks and reinforcement learning, the novel intelligent critic control theory as well as a series of advanced optimal regulation and trajectory tracking strategies are established for discrete-time nonlinear systems, followed by application verifications to complex wastewater treatment processes.

## Biography

***Ding Wang*** is a Full Professor with the Faculty of Information Technology, Beijing University of Technology. He has authored or co-authored over 120 journal and conference papers and four monographs. His current research interests include adaptive critic control with industrial applications, reinforcement learning, and intelligent systems. He chaired the Excellent Young Scientists Fund awarded by the National Natural Science Foundation of China and the Outstanding Young Scientists Fund awarded by the Beijing Natural Science Foundation. Dr. Wang was successively selected as a Clarivate Highly Cited Researcher from 2020 to 2022. He is a member of IEEE/CAA Journal of Automatica Sinica Early Career Advisory Board. He currently serves as an Associate Editor of IEEE Transactions on Systems, Man, and Cybernetics: Systems, Neural Networks, Engineering Applications of Artificial Intelligence, International Journal of Robust and Nonlinear Control, Neurocomputing, and Acta Automatica Sinica.

# Distinguished Lecture 4

## Data-Driven Calibration for Radio Frequency Communication Systems

***Prof. Zhi Quan***
***Shenzhen University, China***

Sunday, May 14, 2023
8:00-8:40
The 8th Conference Hall / 捌号厅

## Abstract

The radio frequency (RF) circuits of wireless communication systems assemble many analog devices, whose parameters have large deviation and could drift with temperature and over time. In large-scale manufacturing, it is difficult for the analog devices thus assembled to satisfy the performance requirements of wireless communication systems, such as power and frequency. Although it is possible to select high-end analog devices in RF circuit assembling to improve the whole system performance, the cost will increase dramatically. Because RF circuits are complex nonlinear systems, it is extremely difficult to model & control the RF circuitry. In this talk, we introduce data-driven methods to calibrate the RF communication systems precisely without modeling. We show that the RF communication system thus calibrated can reduce its transmit power error within 0.25 dB, and reduce its frequency error up to 3 orders.

## Biography

***Zhi Quan*** is a distinguished professor with the College of Electronic and Information Engineering, Shenzhen University, China. He received his Ph.D. in Electrical Engineering from University of California, Los Angeles (UCLA) with highest honors in 2009, and his B.E. in Communications Engineering from Beijing University of Posts and Telecommunications (BUPT), China in 1999. He worked as a Sr. System Engineer in Qualcomm Research Center (QRC) of Qualcomm Inc. (San Diego, CA) during 2008-2012, and as a RF System Architect with Apple Inc. (Cupertino, CA) during 2012-2015. Dr. Quan had contributed to IEEE 802.11ac/ah standards with over 30 U.S. issued patents and published over 60 papers in wireless communications and signal processing. Dr. Quan was the recipient of UCLA Outstanding Ph.D. Award in 2009, IEEE Signal Processing Society Best Paper Award in 2012, China National Excellent Young Scientist Foundation in 2016, and First Prize Technology Innovation Award by China Institute of Communications in 2020. His current research interests include wireless communication systems, RF system calibration and measurement, data-driven signal processing, and machine learning.

# Distinguished Lecture 5

## Intelligent Adaptive Control of Nonlinear Servo Systems

***Prof. Qiang Chen***
***Zhejiang University of Technology, China***

Sunday, May 14, 2023
8:40-9:20
The 8th Conference Hall / 捌号厅

## Abstract

The servo system is the core component of the motion control systems to achieve high-speed, high-precision and reliable operation. The modern servo system is developing towards complexity, modularization and intelligence, and it puts forward higher requirements for the rapidity, accuracy and reliability of the control system. However, the servo system has the characteristics of unknown parameters, inaccurate model and strong nonlinearity, which brings severe challenges to the control system design. The intelligent adaptive control, combining the advantages of intelligent learning and adaptive control, is considered to be one of the effective methods to solve the control problems of nonlinear uncertain systems, but the current intelligent adaptive control theory for servo systems has many challenges, such as the difficulty of precise compensation of nonlinear uncertainties and the difficulty of quantitative analysis of dynamic performance, etc. This report will briefly introduce the research work and preliminary results of the research group on intelligent adaptive control of nonlinear servo systems.

## Biography

***Qiang Chen*** received the Ph.D. degree in control science and engineering from Beijing Institute of Technology, Beijing, China, in 2012. Since 2012, He has been with the College of Information Engineering, Zhejiang University of Technology (ZJUT), Hangzhou, China. He is currently a Full Professor and the director of the institute of data-driven control and learning systems in ZJUT. He has presided over 3 National Natural Science Foundation of China (NSFC) projects including National Natural Science Fund for Excellent Young Scholars in 2022, and 1 Key Program of Natural Science Foundation of Zhejiang Province. He has published over 50 academic papers in IEEE Transactions and international journals, and has been authorized more than 40 invention patents, 12 of which were transferred. His research interests include adaptive control and learning control with applications to motion control systems.

# Distinguished Lecture 6

## Adaptive Iterative Learning Control for Nonlinear Systems

***Prof. Xuefang Li***
***Sun Yat-sen University, China***

Sunday, May 14, 2023
9:20-10:00
The 8th Conference Hall / 捌号厅

## Abstract

As a complementary method to traditional iterative learning control (ILC), adaptive ILC has been developed for more than 20 years and has achieved many important research results. In this talk, we will first introduce the developments of adaptive ILC, and then summarize the main difficulties and challenges we encounter in this area from both theoretical and practical aspects. In view of these difficulties, we will introduce some of our research progresses, including adaptive ILC for systems with unmeasurable states, adaptive ILC for underactuated nonlinear systems and its applications in autonomous driving. The proposed approaches provide new adaptive ILC design frameworks to break the original limitations, which might be able to refine the adaptive ILC theory and to widen its application scope.

## Biography

***Xuefang Li***, Associate Professor of the School of Intelligent Systems Engineering of Sun Yat-sen University. She received the B.Sc. and M.Sc. degrees from the Mathematical College, Sichuan University, Chengdu, China, in 2009 and 2012, respectively, and her PhD degree from the Department of Electrical and Computer Engineering, National University of Singapore in 2016. From 2016 to 2019, she was a Research Associate with the Department of Electrical and Electronic Engineering (EEE), Imperial College London, London, U.K. She was awarded by several best conference paper awards including IEEE 9th DDCLS, IEEE 13th ICCAS, 10th ASCC. She has published over 50 research papers and coauthored two research monographs. Her research interests include that learning and adaptive control theory as well as their applications to robotics, new energy vehicles and intelligent vehicles.

# Industrial Control Practice Forum

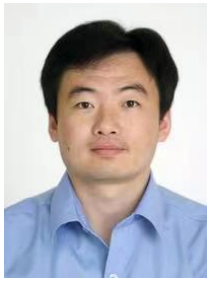
Industrial Control Practice Forum

Sunday, May 14, 2023
10:10-12:10
The 8th Conference Hall / 捌号厅

## Forum Abstract

本次论坛以“数据驱动控制与学习在高端装备可靠性中的应用”为主题，共同探讨数据驱动控制与学习应用于高端装备可靠性设计分析、健康管理、运维保障等的工程需求、应用现状、关键技术、新技术及发展趋势、产业化发展等方面内容。论坛邀请航空、航天、兵器、雷达、核领域的资深专家做论坛报告。

## Forum speaker



**Speaker 1**：周国强（中国航空工业集团公司）
**Title**：基于数据驱动的航空装备维修保障探索与思考
**Abstract**：立足航空武器装备，探讨数据驱动方法在维修保障领域的使用需求，分享应用探索的成果与经验，展望未来的发展趋势。包括：数据驱动方法的应用需求，分享课题与型号工作中的应用效果，展望用户紧迫需求等方面研判未来数据驱动方法在航空综合保障领域的结合方式与发展方向。
**Biography**：***周国强,*** 男，中国航空工业集团公司沈阳飞机设计研究所专业工程部部长，研究员，长期从事飞机综合保障、通用质量特性预先研究和型号研制工作，目前担任某型飞机通用质量特性、综合保障型号副总师，某型飞机保障能力预研课题所内负责人，同时还负责某型飞机背景预研课题综保技术研究、某型飞机通用质量特性论证。

**Speaker 2**：于英扬（航天科工集团三院三部）
**Title**：数据驱动在航天可靠性工程技术中的应用分析
**Abstract**：介绍数据驱动在航天可靠性工程技术中的应用分析，针对航空航天面临的部分可靠性问题，从系统健康管理的基本概念和内涵以及关键技术出发，结合案例讨论应用分析。
**Biography**：***于英扬***，男，航天科工集团三院三部，研究员，某海军重点型号总师助理，负责可靠性系统工程技术研究和工程应用。现任科工局质量与可靠性专家组专家；航天科工集团、三院质量与可靠性专家组成员；北京邮电大学兼职教授；中国现场统计研究会可靠性工程分会常务理事。

**Speaker 3**：柳月（中国北方车辆研究所总体技术部）
**Title**：数据驱动在装甲车辆健康管理技术的探索
**Abstract**：健康管理技术是充分利用各类在线、离线传感信息及自诊断信息，并借助各类模型和数据驱动算法，进行整车状态监控、故障诊断、综合评价，以牵引维修决策、维修帮助、伴随保障等工作的系统级技术。针对装甲车辆健康管理总体技术需求，分析数据驱动在装甲车辆健康管理系统研发中的需求，介绍在科研与装备中主要的应用方向与经验，分析目前面临的困难与未来的展望。
**Biography**：***柳月***，女，中国北方车辆研究所总体技术部人因与可靠性室主任。主要从事装甲车辆健康管理总体设计技术研究。承担了多项型号项目健康管理系统设计、开发、试验验证、条件保障能力建设，同时，承担多项国防科工局技术基础项目研究工作。

**Speaker 4**：张宇（中国船舶集团有限公司第八研究院）

**Title**：雷达设备寿命预测与健康管理应用案例

**Abstract**：介绍雷达设备组成、雷达设备寿命预测和健康管理技术体系架构、关键技术、雷达设备寿命预测和健康管理应用案例等内容。重点介绍数据驱动的方法和技术在雷达设备寿命预测和健康管理当中的现有应用情况以及未来发展前景。

**Biography**：***张宇***，男，中国船舶集团有限公司第八研究院质量安全环保部可靠性中心高级工程师。主要从事雷达设备质量和可靠性研究工作。承担了多项国防技术基础科研项目，以及舰载、岸基和军贸雷达产品可靠性设计、可靠性试验工作。

**Speaker 5**：湛力（中国核动力研究设计院反应堆工程研究所）

**Title**：基于数据驱动的核级设备可靠性研究

**Abstract**：核动力领域在役设备相较于传统工业设备而言，需面临更恶劣的服役环境、承担更重要的运行任务，这就对核级设备的可靠性应用提出了迫切需求和严格要求。基于上述需求，我单位以提升核级设备可靠性为研究目标，以泵、阀、驱动线、管道等核级设备为研究对象，开展了故障诊断、故障预测及可靠性评价等工作。当前已实现基于数据驱动的核级阀门故障诊断及预测，并完成了基于数据驱动的主泵故障诊断模型研究，获得了核动力系统基于故障树模型的故障定位方法，基于上述研究成果预期完成核动力装备健康管理系统，并聚焦能动设备健状态管理。

**Biography**：***湛力***，男，中国核动力研究设计院反应堆工程研究所反应堆设备可靠性及技术成熟度研究中心主任。主要从事核级设备鉴定和可靠性试验研究。承担了多项国防基础科研，多个型号的设备研制条件保障能力建设、鉴定和竞争性择优试验，以及核电设备鉴定服务。参与了能动阀门、驱动线等多个设备鉴定行业标准编制。

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# Pre-Conference Tutorial

## Pre-Conference Tutorial I

## Model Free Adaptive Control

Friday, May 12, 2023
14:00-16:00
The 3rd Conference Hall / 叁号厅

### Turtorial speaker

**Speaker** 1：Zhongsheng Hou

**Title**：The history and progress in MFAC theory

**Abstract**：This talk includes three parts. First parts will foucu on the history background of model free adaptive control (MFAC). The second is going to talk the MFAC progress both in theory and application, and the relationships between MFAC with traditional adaptive control, PID, and data-driven iterative learing control as well. The last is Conclusion.

**Biography**：***Zhongsheng Hou*** received the B.S. and M.S. degrees from Jilin University of Technology, Jilin, China, in 1983 and 1988, respectively, and the Ph.D. degree from Northeastern University, Shenyang, China, in 1994. From 1997 to 2018, he was with Beijing Jiaotong University, Beijing, China, where he was a Distinguished Professor and the Founding Director of Advanced Control Systems Lab, and the Head of the Department of Automatic Control. He is currently a Chair Professor with Qingdao University, Qingdao, China.

His research interests are in the fields of data-driven control, model-free adaptive control, learning control, and intelligent transportation systems. He has authored two monographs, *Nonparametric Model and its Adaptive Control Theory*, Science Press (in Chinese), 1999, and *Model Free Adaptive Control: Theory and Applications*, CRC Press, 2013. His pioneering work on model-free adaptive control has been verified in more than 200 different field applications, laboratory equipment and simulations with practical background, including wide-area power systems, lateral control of autonomous vehicles, temperature control of silicon rod.

Prof. Hou is the Founding Director of the Technical Committee on Data Driven Control, Learning and Optimization (DDCLO), Chinese Association of Automation (CAA), and is also a CAA Fellow, IEEE Fellow, AAIA Fellow. Dr. Hou was the Guest Editor for two Special Sections on the topic of data-driven control of the IEEE Transactions on Neural Networks in 2011, and the IEEE Transactions on Industrial Electronics in 2017.

**Speaker 2**：Dezhi Xu

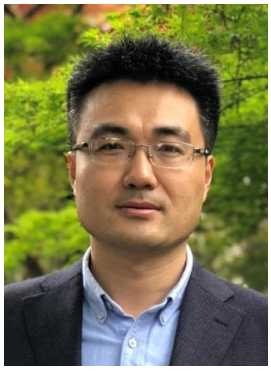
**Title**：Observer architecture-based model-free adaptive control

**Abstract**：The classical model-free adaptive control (MFAC) can solve the modeling and control problems of nonaffine nonlinear systems with unknown dynamics. On this basis, we propose an observer architecture-based MFAC strategy by using observer technique to dynamically reconstruct the system dynamics and prove the stability based on Lyapunov stability criterion, which enriches the theoretical research of MFAC. Specifically, the proposed strategy supports modular design, following the design concept of “observer - adaptive law - anti-windup compensator - advanced controller”, which is easy to implement. The proposed strategy addresses various

tracking control problems under actuator saturation, improving both dynamic and steady-state performance. Due to these advantages, the proposed control strategy has been widely applied to many fields such as smart grid, urban rail transit, chemical process and so on.

**Biography**：***Dezhi Xu*** (Senior Member, IEEE) received the Ph.D. degree in control theory and control engineering from Nanjing University of Aeronautics and Astronautics, China, in 2013. He was a Visiting Fellow with the Department of Biomedical Engineering, City University of Hong Kong, China, from 2018 to 2019. He is currently a Professor and Doctoral Supervisor with the Jiangnan University. His research interests include data-driven control, fault diagnosis and fault-tolerant control, multi-agent systems and cyber-physical systems, technologies of renewable energy, motor control, and smart grid.

Dr. Xu was supported by the National Natural Science Fund for Excellent Young Scientists Fund Program in 2022. He was a recipient of the First-Class Prize of Science and Technology Progression from the China General Chamber of Commerce in 2016, and the Best Young Scholar of Jiangnan University in 2022. He was a Guest Editor for the *International Journal of Innovative Computing, Information and Control* and the *Electric Power*. He currently serves as an Editorial Board Member for the *International Journal of Innovative Computing, Information and Control*, the *Electric Power*, the *Electrotechnical Application* and the *Electrical Engineering*. He is an Executive Director of China Energy Society, and a Committee Member of the Association of Energy Internet, and Trusted Control in Chinese Association of Automation, and the Energy Storage in China Renewable Energy Society.



**Speaker 3**：Zhonghua Pang

**Title**：Experimental Studies on MFAC with Application in Networked Systems

**Abstract**：As it is increasingly easy to obtain large amounts of input and output data of controlled plants, designing control laws directly from those data become important. Model-free adaptive control (MFAC), as a typical data-driven control approach, has attracted great attention in recent years, and has been widely applied in many practical systems. This talk is about the experimental studies of MFAC on several control test rigs by using NCSLab, a web-based 3D networked control laboratory, as well as the application of MFAC in predictive control of networked systems with random network-induced delays and packet dropouts.

**Biography**：***Zhonghua Pang*** received the Ph.D. degree in control theory and control engineering from the Institute of Automation, Chinese Academy of Sciences, China, in 2011. He was a Postdoctoral Research Fellow with the Tsinghua University, China, from Sept. 2011 to Feb. 2014, a Visiting Scholar at the University of South Wales, UK, from Nov. 2016 to Oct. 2017, and a Visiting Scholar at the Swinburne University of Technology, Australia, from Jul. 2019 to Aug. 2019 and from Jan. 2020 to Mar. 2020. Since 2014, he has been with the North China University of Technology, China, first as an Associate Professor and since 2017 as a Professor.

His research interests include networked control, data-driven control, and multi-agent systems. He is an author of 1 monograph in Springer, 3 Chinese edited books, over 110 journal and conference papers, and has 13 patents and 4 software copyrights. He has hosted more than 20 scientific research projects, including 3 projects funded by the Natural Science Foundation of China and 3 projects funded by the Beijing Natural Science Foundation projects. He serves as the early career advisory board member of IEEE/CAA Journal of Automatica Sinica. He is a senior member of IEEE, and a member of the Technical Committee on Data Driven Control, Learning and Optimization, Chinese Association of Automation (CAA), and the Technical Committee on Fault Diagnosis and Safety for Technical Processes, CAA.

# Pre-Conference Tutorial II

# Iteration Learning Control

Friday, May 12, 2023
16:00-18:00
The 3rd Conference Hall / 叁号厅

## Tutorial speaker

**Speaker 1**：孙明轩
**Title**：压缩映射迭代学习控制回顾与展望
**Abstract**：实际场合中存在诸多系统重复执行有限区间上的控制任务，基于压缩映射原理的迭代学习控制是重复作业方式下实现系统完全跟踪的控制技术，是一种数据驱动控制技术。本报告介绍迭代学习方法的基本原理，包括学习的表达、学习的不变量原理、迭代学习控制的基本概念与方法以及应用背景；简介这种控制系统分析与综合的主要方法；浅谈发展简史、管窥当前研究热点与发展趋势。
**Biography**：***孙明轩***, 浙江工业大学信息工程学院教授、博士生导师。1982 年毕业于西安理工大学自动控制专业，获工学学士学位，1987 年毕业于北京理工大学自动控制理论与应用专业，获工学硕士学位，2002 年获新加坡南洋理工大学哲学博士学位。曾任浙江省信号处理学会第一届理事会副理事长，现任中国自动化学会数据驱动控制学习与优化专业委员会副主任。 2004 年入选浙江省“新世纪 151 人才工程”；受聘为《数学评论》评论员。研究领域为迭代学习控制与重复控制、滑模控制与自适应控制，发表相关论文 200 余篇，1999 年由国防科技图书出版基金资助出版专著《迭代学习控制》；2003 年获 IEEE 控制系统学会北京分会奖；获省部级奖励 3 项。

**Speaker 2**：黄德青
**Title**：CEF 方法的前世今生
**Abstract**：本报告我们将首先简单介绍迭代学习控制（ILC）理论的发展历史，然后从理论和实际两个方面探讨传统 ILC 的局限性和所面临的挑战。进而，讨论研究自适应 ILC 理论的必要性，并详细介绍 CEF 方法的前世今生及理论框架。最后，我们将探讨当前自适应 ILC 领域已取得的重要进展、存在的问题及未来的研究方向。
**Biography**：***黄德青***，西南交通大学电气工程学院教授、博士生导师。2002 年毕业于四川大学数学学院数学专业，学士；2007 年毕业于四川大学数学学院应用数学专业，理学博士； 2011 年毕业于新加坡国立大学电气与计算机工程系控制理论及控制工程专业，工学博士； 2010-2013 年，新加坡国立大学，Research Fellow；2013-2016 年，英国伦敦帝国理工学院航空系，Research Associate；2016 年 1 月加入西南交通大学电气工程学院，任教授、博导、院长助理、国家一流专业负责人。四川省杰青、四川省千人计划专家、国家铁路局行业重点实验室副主任。目前主要从事学习控制理论及其应用研究。曾先后主持国家自然科学基金高铁联合基金等项目 20 余项。在 IEEE 汇刊等国际期刊杂志和会议上合作发表论文 200 余篇，出版专著 3 部，授权发明专利 35 项、软著 7 项，制定团体标准 3 项，获中国铁道学会科技进步一等奖 1 项、中国自动化学会科技进步二等奖 1 项、会议最佳论文奖或提名奖 5 次。

**Speaker 3**：刘杨

**Title**：迭代学习控制在高端光刻装备中的应用

**Abstract**：光刻机是半导体制造领域的核心装备，也是当今世界技术难度最大的尖端超精密制造装备。由于近年来国际社会的大力封锁，我国光刻机制造水平落后 ASML 等国际一流企业至少三代，使其成为了我国标志性的“卡脖子”装备，亟需突破以超精密运动控制为代表的一系列技术瓶颈。报告人将结合光刻机运动台的研发经历，汇报以迭代学习控制为代表的数据驱动控制方法在高动态亚纳米多自由度运动控制中的应用现状，为高端装备中兼顾高速度、高加速度和高定位精度的应用场景提供方法借鉴。

**Biography**：***刘杨***，哈尔滨工业大学教授，博士生导师，研究方向为超精密装备精度调控装置及方法，致力于解决光刻机等尖端超精密装备运动生成的核心共性问题。近 5 年来作为课题负责人主持国家十二五科技重大专项 02 专项项目等光刻机相关国家部委及行业领军企业委托重要项目 7 项，累计科研经费 5000 余万元。开发了超精密甚多轴强实时电控系统软硬件平台，提出了一整套数据与机理融合驱动的智能控制方法，实现了高动态亚纳米级多自由度运动台高速度、高加速度和高定位精度的兼顾。

# 2023 IEEE 12th Data Driven Control and Learning Systems Conference (DDCLS'23)

Technical Program
and
Book of Abstracts

# Technical Program

# Saturday, May 13, 2023

**SatA01** 13:30–15:30 2nd Conf. Hall
Regular Session: Iterative Learning Control

Chair: Shi, Jia — Xiamen Univ.
Co-Chair: Yu, Qiongxia — Henan Polytechnic Univ.

▶ SatA01-1 13:30–13:50
*An Improved Two-Dimensional Iterative Learning Control Scheme Based on Deep Reinforcement Learning for the Non-repetitive Uncertain Batch Processes*
Liu, Jianan — Xiamen Univ.
Hong, Wenjing — Xiamen Univ.
Shi, Jia — Xiamen Univ.

▶ SatA01-2 13:50–14:10
*Collaborative Learning Tracking for Networked Systems with Fading Communication*
Zhang, Zeyi — Renmin Univ. of China
Jiang, Hao — Renmin Univ. of China
Zeng, Kun — Beijing Univ. of Chemical Tech.
Shen, Dong — Renmin Univ. of China

▶ SatA01-3 14:10–14:30
*An Iterative Learning Control Research Based on RBF Neural Network and PSO Algorithm*
Wang, Shouqin — Xi'an Polytechnic Univ.
Geng, Yan — Xi'an Polytechnic Univ.
He, Xingshi — Xi'an Polytechnic Univ.

▶ SatA01-4 14:30–14:50
*Extended State Observer Based Iterative Learning Control for Systems with Nonrepetitive Disturbances*
Li, Shiyan — Sun Yat-sen Univ.
Li, Xuefang — Sun Yat-sen Univ.

▶ SatA01-5 14:50–15:10
*Data-driven-based Predictive Optimal for A Class of Iterative Learning Control by Q-learning Method*
Li, Jinze — South China Univ. of Tech.
Tian, Senping — South China Univ. of Tech.
Peng, Yunjian — South China Univ. of Tech.
Gu, Panpan — Hefei Univ. of Tech.

▶ SatA01-6 15:10–15:30
*Event-Triggered Based Data-Driven Predictive Iterative Learning Control*
Yu, Qiongxia — Henan Polytechnic Univ.
Fan, Zhihao — Henan Polytechnic Univ.
Tian, Fengchen — Henan Polytechnic Univ.
Hou, Zhongsheng — Beijing Jiaotong Univ.

**SatA02** 13:30–15:30 3rd Conf. Hall
Regular Session: Data-driven Fault Diagnosis and Health Maintenance I

Chair: Li, Yueyang — Univ. of Jinan
Co-Chair: Wang, Shenquan — Changchun Univ. of Tech.

▶ SatA02-1 13:30–13:50
*Remaining Useful Life Prediction for Multi-Component Stochastic Degrading Equipment under Competing Failure*
Li, Huiqin — Xi'an Inst. of Hi-Tech
Zhang, Zhengxin — Xi'an Inst. of High-Tech
Li, Tianmei — Xi'an Inst. of High-tech
Si, Xiaosheng — Xi'an Inst. of Hi-Tech

▶ SatA02-2 13:50–14:10
*Rolling Bearing Fault Diagnosis Based on ICEEMDAN-WTATD-DaSqueezeNet*
Geng, Zhiqiang — Beijing Univ. of Chemical Tech.
Yuan, Kui — Beijing Univ. of Chemical Tech.
Ma, Bo — Beijing Univ. of Chemical Tech., Diagnosis & Self-Recovery Engineering Research Center
Han, Yongming — Beijing Univ. of Chemical Tech.

▶ SatA02-3 14:10–14:30
*An Improved Sparse Mode Decomposition Method for Pulse Signals*
Wu, Jialian — Univ. of Jinan
Li, Yueyang — Univ. of Jinan
Zhao, Dong — Beihang Univ.

▶ SatA02-4 14:30–14:50
*Event-triggered-based Subspace Identification Fault Detection with An Optimized Moving Window*
Zhang, Qi — Changchun Univ. of Tech.
Wang, Shenquan — Changchun Univ. of Tech.
Ji, Wenchengyu — Changchun Univ. of Tech.

▶ SatA02-5 14:50–15:10
*A Lightweight Pipeline Defect Detection Method via Structural Reparameterization Technique and Ghost Convolution*
Wen, Zhitao — Northeastern Univ.
Liu, Jinhai — Univ. of Northeastern
Shen, Xiangkai — Univ. of Northeastern
Lu, Senxiang — Northeastern Univ.
He, Zhao — Northeastern Univ.
Wang, Qiannan — Northeastern Univ.

▶ SatA02-6 15:10–15:30
*Tool Wear State Identification Based on Frequency Domain Denoising and Frequencies-separation Attention Networks*
Lai, Xuwei — Southwest Jiaotong Univ.
Zhang, Kai — Southwest Jiaotong Univ.
Li, Zhixuan — Southwest Jiaotong Univ.
Zheng, Qing — Southwest Jiaotong Univ.
Ding, Guofu — Southwest Jiaotong Univ.

**SatA03** 13:30–15:30 4th Conf. Hall
Invited Session: Process Monitoring and Control for Complex Industrial Systems

Chair: Luo, Hao — Harbin Inst. of Tech.
Co-Chair: Wang, Zhenhua — Harbin Inst. of Tech.

▶ SatA03-1 13:30–13:50
*Fault Detection for Satellite Gyroscope Using LSTM Networks*
Xu, Chi — Harbin Inst. of Tech.
Wang, Zhenhua — Harbin Inst. of Tech.

▶ SatA03-2 13:50–14:10
*Fault Detection for Rolling Bearings by Multi-sensor Information Fusion Method with Adaptive Weights*
Wu, Hao — Univ. of Sci. & Tech. Beijing
Zhao, Yinghao — Univ. of Sci. & Tech. Beijing
Yang, Xu — Univ. of Sci. & Tech. Beijing
Huang, Jian — Univ. of Sci. & Tech. Beijing
Cui, Jiarui — Univ. of Sci. & Tech. Beijing

▶ SatA03-3 14:10–14:30
*Data-driven Adaptive Control of CRAC in Data Center Based on Online Incremental RVFL*
Huang, Jiangyang — Univ. of Sci. & Tech. Beijing
Zhang, Zhengxuan — Univ. of Sci. & Tech. Beijing
Yang, Xu — Univ. of Sci. & Tech. Beijing
Tu, Rang — Univ. of Sci. & Tech.

▶ SatA03-4 14:30–14:50
*Emergency Vehicle Identification for Internet of Vehicles Based on Federated Learning and Homomorphic Encryption*
Zeng, Siyuan — Chongqing Jiaotong Univ.
Mi, Bo — Chongqing Jiaotong Univ.
Huang, Darong — Anhui Univ.

▶ SatA03-5 14:50–15:10
*Improved LeNet-5 Network for Equipment Fault Diagnosis of Ultra-supercritical Units*
Zhang, Xingfan — Zhejiang Univ. of Tech.
Wei, Chun — Zhejiang Univ. of Tech.
Cheng, Zhang — Zjut

▶ SatA03-6 15:10–15:30
*RAANet: Residual Aggregation Attention Network for Classification of Small Intestinal Endoscopic Images*
Cao, Bo — Zhejiang Univ. of Tech.
Li, Lei — Zhejiang Univ. of Tech.

Ma, Yue — Zhejiang Univ. of Tech.
Ye, Shufang — Lishui People Hospital
Li, Sheng — Zhejiang Univ. of Tech.
He, Xiongxiong — Zhejiang Univ. of Tech.

**SatA04** 13:30–15:30 5th Conf. Hall
Invited Session: Data-driven Control and Learning with Additive Decomposition

Chair: Qi, Guoyuan — Tiangong Univ.
Co-Chair: Quan, Quan — Beihang Univ.

▶ SatA04-1 13:30–13:50
*Model Compensation Control Based on Additive State Decomposition and Its Application in QUAV*
Li, Xia — Tiangong Univ.
Qi, Guoyuan — Tiangong Univ.

▶ SatA04-2 13:50–14:10
*Adaptive Output Regulation for Uncertain Nonlinear Systems: An Additive Decomposition-based Method*
Gong, Yizhou — ShanghaiTech Univ.
Wang, Yang — ShanghaiTech Univ.

▶ SatA04-3 14:10–14:30
*Two-Degree-of-Freedom Attitude Tracking Control for Bank-to-Turn Aerial Vehicles: An Additive-State-Decomposition-Based Method*
Ren, Jin-Rui — Xi'an Univ. of Posts & Telecommunications

▶ SatA04-4 14:30–14:50
*Robust Repetitive Control for A Class of Uncertain Nonlinear Systems*
Jia, Fengyi — Hunan Univ. of Sci. & Tech.
Zhou, Lan — Hunan Univ. of Sci. & Tech.
Wang, Xiaojuan — Hunan Univ. of Sci. & Technolog
Sun, Yongbo — Hunan Univ. of Sci. & Tech.

▶ SatA04-5 14:50–15:10
*Tube-based Distributed Model Predictive Control of Nonlinear Multi-agent Systems Based on Additive State Decomposition*
Li, Liya — Tiangong Univ.
Su, Peng Peng — Tiangong Univ.
Zhang, Xulong — TianGong Univ.

▶ SatA04-6 15:10–15:30
*Reinforcement Learning for Non-Affine Nonlinear Non-Minimum Phase System Tracking under Additive-State-Decomposition-Based Control Framework*
Chen, Lian — School of Automation Sci. & Electrical Engineering
Quan, Quan — Beihang Univ.

**SatA05** 13:30–15:30 6th Conf. Hall
Invited Session: Data Driven Information Processing and Intelligent Control

Chair: Xia, Chengyi — Tianjin Univ. of Tech.
Co-Chair: Dong, Na — Tianjin Univ.

▶ SatA05-1 13:30–13:50
*CGS-Net:Classification-guided Segmentation Network for Improved G-land Segmentation*
Tang, Xiaoheng — Zhejiang Univ. of Tech.
Peng, Yuyang — Zhejiang Univ. of Tech.
Ma, Yue — Zhejiang Univ. of Tech.
Chen, Jiani — Zhejiang Univ. of Tech.
Li, Sheng — Zhejiang Univ. of Tech.
He, Xiongxiong — Zhejiang Univ. of Tech.

▶ SatA05-2 13:50–14:10
*Tear Location Detection of Meniscus MRI Images Based on YOLOv5*
Wang, Zhuxin — Tianjin Univ. of Tech.
Wang, Juan — Tianjin Univ. of Tech.
Xia, Chengyi — Tianjin Univ. of Tech.

▶ SatA05-3 14:10–14:30
*Special Agents Policy Gradient in Value Decomposition-based Approach*
Kang, Qitong — Nankai Univ.
Wang, Fuyong — Nankai Univ.
Liu, Zhongxin — College of Artificial Intelligent, NanKai Univ.
Chen, Zengqiang — Nankai Univ.

▶ SatA05-4 14:30–14:50
*Multi-scale Learning Based Few-shot GAN for High-quality Art Paintings*
Guo, Zhendong — Tianjin Univ.
Dong, Na — Tianjin Univ.
Mai, Xiaoming — Tianjin Univ.

▶ SatA05-5 14:50–15:10
*An Improved Classification Method for Cervical Cancer Based on ResNet*
Guo, Jiajia — Tianjin Univ. of Tech.
Wang, Juan — Tianjin Univ. of Tech.
Xia, Chengyi — Tianjin Univ. of Tech.

▶ SatA05-6 15:10–15:30
*Flatness-based Trajectory Planning of An Under-actuated Quadrotor UAV*
Zhang, Chengxu — Jiangnan Univ.
Fang, Xing — Inst. of Automation, Jiangnan Univ.

**SatA06** 13:30–15:30 Yuetang Conf. Hall
Invited Session: Data Driven Control, Learning and Optimization

Chair: Hao, Li-Ying — Dalian Maritime Univ.
Co-Chair: Weng, Yongpeng — Dalian Maritime Univ.

▶ SatA06-1 13:30–13:50
*Research on Cooperative Control of Traffic Signals Based on Deep Reinforcement Learning*
Fan, Lingling — Beijing Information Sci. & Tech. Univ.
Yang, Yusong — Beijing Information Sci. & Tech. Univ.
Ji, Honghai — North China Univ. of Tech.
Xiong, Shuangshuang — Beijing Information Sci. & Tech. Universtiy

▶ SatA06-2 13:50–14:10
*Model Free Adaptive Fault-tolerant Control for Signalized Intersections with Detector Fault*
Ren, Ye — Beijing Jiaotong Univ.
Zhang, Dongxu — North China Univ. of Tech.
Wang, Li — North China Univ. of Tech.
Ji, Honghai — North China Univ. of Tech.

▶ SatA06-3 14:10–14:30
*Iterative Learning-Based Data-Driven Control for Unknown Unmanned Marine Vehicles with Actuator Faults*
Liu, Huiying — Dalian Maritime Univ.
Hao, Li-Ying — Dalian Maritime Univ.

▶ SatA06-4 14:30–14:50
*Tackling the Imbalance Biases in the Code Cloze Test*
Qi, Xuexin — Dalian Maritime Univ.
Zhao, Lingxiao — Dalian Maritime Univ.
Li, Hui — Dalian Maritime Univ.
Guo, Shikai — Dalian Maritime Univ.

▶ SatA06-5 14:50–15:10
*Line of Sight-based MFAC Path-following Control of Underactuated Surface Vessels with Exact Sideslip Compensation*
Liu, Zhuofu — Dalian Maritime Univ.
Zhang, Qiuxia — Dalian Maritime Univ.
Weng, Yongpeng — Dalian Maritime Univ.

▶ SatA06-6 15:10–15:30
*Adaptive Finite-Time Heading Control of Intelligent Ship with Asymmetric Output Constraints*
Liu, Yanli — Dalian Maritime Univ.
Sun, Yihua — Dalian Maritime Univ.
Hao, Li-Ying — Dalian Maritime Univ.

**SatA07** 13:30–15:30 Hongqi Conf. Hall
Invited Session: Deep Learning Based Soft Sensing and Iterative Learning Control

Chair: Zeng, Jiusun — Hangzhou Normal Univ.
Co-Chair: Yuan, Xiaofeng — Central South Univ.

▶ SatA07-1 13:30–13:50
*Iterative Learning Control for Moving Boundary Distributed Parameter Systems with Control Delays under Sensor/actuator Networks*
Gong, Weitai — Guangxi Univ. of Sci. & Tech.
Zhang, Jianxiang — Jiangnan Univ.
Dai, Xisheng — Guangxi Univ. of Sci. & Tech.,

▶ SatA07-2 13:50–14:10
*Self-Learning Temporal-Spatial Graph Model for Industrial Soft Sensing Application*
Zhang, Chiye — Zhejiang Univ.
Yao, Le — Hangzhou Normal Univ.
Chen, Zhichao — Zhejiang Univ.
Shen, Bingbing — Hangzhou Normal Univ.
Zeng, Jiusun — Hangzhou Normal Univ.

▶ SatA07-3 14:10–14:30

*Online Monitoring of Time-varying Process Using Probabilistic Principal Component Analysis*

Dong, Yuxuan — China Jiliang Univ.
Liu, Ying — China Tobacco Henan Industrial Co., Ltd
Liu, Suijun — China Tobacco Henan Industrial Co., Ltd
Lu, Cheng — China Jiliang Univ.
Luo, Shihua — Jiangxi Univ. of Finance & Economics
Zeng, Jiusun — Hangzhou Normal Univ.

► SatA07-4 14:30–14:50
*Time Series Data Augmentation Classifier for Industrial Process Imbalanced Fault Diagnosis*

Shen, Bingbing — Hangzhou Normal Univ.
Yao, Le — Hangzhou Normal Univ.
Jiang, Xiaoyu — Zhejiang Univ.
Yang, Zeyu — Huzhou Univ.
Zeng, Jiusun — Hangzhou Normal Univ.

► SatA07-5 14:50–15:10
*Industrial Soft Sensor Prediction Based on Multi-model Integrated Method*

Yuan, Xiaofeng — Central South Univ.
Jia, Zhenzhen — Central South Univ.
Ye, Lingjian — Huzhou Univ.
Wang, Kai — Central South Univ.
Wang, Yalin — Central South Univ.

► SatA07-6 15:10–15:30
*Gaussian Mixture Model and Double-Weighted Deep Neural Networks for Data Augmentation Soft Sensing*

Jiang, Xiaoyu — Zhejiang Univ.
Yao, Le — Hangzhou Normal Univ.
Yang, Zeyu — Huzhou Univ.
Song, Zhihuan — Zhejiang Univ.
Shen, Bingbing — Hangzhou Normal Univ.

**SatB00** 15:40–17:45 8th Conf. Hall
Award Session: Best Paper

Chair: SUN, Mingxuan — Zhejiang Univ. of Tech.

► SatB00-1 15:40–16:05
*A Shared Control Approach for Autonomous Vehicles via Driver Behaviors Learning*

Lang, Yilin — Zhejiang Univ.
Li, Zhaoyang — Zhejiang Univ.
Guo, Jiazhe — Zhejiang Univ.
Zhu, Wenxin — Zhejiang Univ.
Ren, Qinyuan — Zhejiang Univ.

► SatB00-2 16:05–16:30
*Adaptive Optimal Control for Discrete-Time Linear Systems via Hybrid Iteration*

Qasem, Omar — Florida Inst. of Tech.
Gao, Weinan — Northeastern Univ.
Gutierrez, Hector — Florida Inst. of Tech.

► SatB00-3 16:30–16:55
*Distributed Model Free Adaptive Iterative Learning Control of Multiple HSTs under DoS Attacks*

Yu, Wei — Southwest Jiaotong Univ.
Cheng, Junqiang — Europe-Aisa Hi-tech & Digital Tech. Company Limited
Huang, Deqing — Southwest Jiaotong Univ.

► SatB00-4 16:55–17:20
*Time-frequency Hypergraph Neural Network for Rotating Machinery Fault Diagnosis with Limited Data*

Ke, Haobin — Central South Univ.
Chen, Zhiwen — Central South Univ.
Xu, Jiamin — Central South Univ.
Fan, Xinyu — Central South Univ.
Yang, Chao — Central South Univ.
Peng, Tao — Central South Univ.

► SatB00-5 17:20–17:45
*Dual Observer-based Model-Free Adaptive I/O Constrained Control for MIMO Nonlinear Systems*

Zhang, Weiming — Jiangnan Univ.
Xu, Dezhi — Jiangnan Univ.
Yang, Weilin — Jiangnan Univ.
Liu, Jianxing — Harbin Inst. of Tech.
Hua, Fei — Jiangnan Univ.

**SatB01** 15:40–17:40 2nd Conf. Hall
Regular Session: Neural Networks, Fuzzy Systems Control in Data Driven Manner

Chair: Liu, Shan — Zhejiang Univ.
Co-Chair: Yang, Yong — Xihua Univ.

► SatB01-1 15:40–16:00
*Robust Fuzzy Adaptive Funnel Control of Flexible Exoskeleton Joints Based on Singular Perturbation Method*

Jin, Chengwu — XiHua Univ.
Yang, Yong — Xihua Univ.
Liu, Xia — Xihua Univ.
Shi, Xiaoyu — Xihua Univ.

► SatB01-2 16:00–16:20
*Prediction of Uterine Fibroid Outcomes Based on DenseNet and Multiple MRI Sequences*

Chen, Yuan — Southwest Jiaotong Univ.
Huang, Deqing — Southwest Jiaotong Univ.
Qin, Na — Southwest Jiaotong Univ.
Yin, Zijie — Southwest Jiaotong Univ.
You, Yiting — Southwest Jiaotong Univ.

► SatB01-3 16:20–16:40
*Improved Algorithm of Transient Chaotic Neural Network with Combinatorial Optimization*

Cong, Shuang — Univ. of Sci. & Tech. of China
Wang, Zhenning — Univ. of Sci. & Tech. of China

► SatB01-4 16:40–17:00
*Siamese Convolutional Neural Network Based Visual Servo for Manipulator*

Deng, Gaofeng — ZheJiang Univ.
Liu, Shan — Zhejiang Univ.

► SatB01-5 17:00–17:20
*Multi-Object Robot Visual Servo Based on YOLOv3*

Yang, Yulin — Zhejiang Univ.
Liu, Shan — Zhejiang Univ.

► SatB01-6 17:20–17:40
*A Novel Deep Belief Network Based on Shallow Feature Regression*

Cui, Jiarui — Univ. of Sci. & Tech. Beijing
Peng, Liu — Univ. of Sci. & Tech. Beijing
Yan, Qun — Univ. of Sci. & Tech. Beijing
Li, Qing — Univ. of Sci. & Tech. Beijing
Liu, Lingyi — Univ. of Sci. & Tech. Beijing

**SatB02** 15:40–17:40 3rd Conf. Hall
Regular Session: Deep Neural Network and Reinforcement Learning Control

Chair: Li, Dazi — Beijing Univ. of Chemical Tech.
Co-Chair: Li, Jinna — Liaoning Petrochemical Univ.

► SatB02-1 15:40–16:00
*Optimal Sensor Selection Self-Learning for Linear-Discrete System with Unknown Sensor Noise Covariance*

Wang, Xinru — Liaoning Petrochemical Univ.
Li, Jinna — Liaoning Petrochemical Univ.

► SatB02-2 16:00–16:20
*Two-dimensional Network Control Systems with Packet Loss Compensation for Batch Processes*

Xiao, Mohan — Liaoning Petrochemical Univ.
Yuan, Yidan — Liaoning Petrochemical Univ.
Bo, Guihua — Liaoning Petrochemical Univ.
Shi, Huiyuan — Liaoning Petrochemical Univ.
Su, Chengli — Liaoning Petrochemical Univ.

► SatB02-3 16:20–16:40
*Research on Intelligent Maneuvering Decision in Close Air Combat Based on Deep Q Network*

Zhang, Tingyu — Nankai Univ.
Zheng, Chen — Beijing Inst. of Astronautical Sys. Engineering
Sun, Mingwei — Nankai Univ.
Wang, Yongshuai — Nankai Univ.
Chen, Zengqiang — Nankai Univ.

► SatB02-4 16:40–17:00
*Neural-Learning-Based Finite-Time Trajectory Tracking Control for Robotic Manipulator with Input Friction*

Sun, Guofa — Qingdao Univ. of Tech.
Huang, Ming Yu — Qingdao Univ. of Tech.
Zhang, Guoju — Qingdao Univ. of Tech.

Zhao, Erquan Qingdao Univ. of Tech.

▶ SatB02-5 17:00–17:20
*Multi-agent Proximal Policy Optimization via Non-fixed Value Clipping*
Liu, Chiqiang Beijing Univ. of Chemical Tech.
Li, Dazi Beijing Univ. of Chemical Tech.

▶ SatB02-6 17:20–17:40
*Target Tracking and Path Planning of Mobile Sensor Based on Deep Reinforcement Learning*
Zhang, Kun Southwest Jiaotong Univ.
Hu, Yuanjiang Southwest Jiaotong Univ.
Huang, Deqing Southwest Jiaotong Univ.
Yin, Zijie Southwest Jiaotong Univ.

**SatB03** 15:40–17:40 4th Conf. Hall
Invited Session: Disturbance Compensation Based Control
Chair: Chen, Sen Shaanxi Normal Univ.
Co-Chair: Xue, Wenchao Chinese Acad. of Sci.

▶ SatB03-1 15:40–16:00
*Data-Driven Distributed Optimization Control for A Class of Networked Control Systems with Disturbances*
Yuan, Ruonan Shaanxi Normal Univ.
Zhao, Zhiliang Shaanxi Normal Univ.
Chen, Sen Shaanxi Normal Univ.

▶ SatB03-2 16:00–16:20
*Relation between Generalized Proportional Integral Observer and Linear Disturbance Observer Based Control*
Zhang, Shitong Shaanxi Normal Univ.
Huang, Meiqun Shaanxi Normal Univ.
Zhao, Zhiliang Shaanxi Normal Univ.
Chen, Sen Shaanxi Normal Univ.

▶ SatB03-3 16:20–16:40
*Predictive Finite-time ADRC Based Longitudinal Control for Hypersonic Aircraft with Parametric Uncertainties and Unmodeled Dynamics*
Yang, Jinwei China West Normal Univ.

▶ SatB03-4 16:40–17:00
*Predictive Active Disturbance Rejection Attitude Control for 2-DOF Unmanned Helicopter with Three Typical Uncertainti*
Yang, Jinwei China West Normal Univ.

▶ SatB03-5 17:00–17:20
*Intelligent Structure Control System Based on FPGA*
Qiu, Ruikang Yangzhou Univ.
Li, Shengquan Yangzhou Univ.
Cui, Ronghua Yangzhou Univ.
Zhang, Lujin Yangzhou Univ.
Li, Juan Southeast Univ.

▶ SatB03-6 17:20–17:40
*Improved BP Neural Network Based Active Disturbance Rejection Control for Magnetic Sensitivity Calibration System*
Wang, Minlin Beijing Inst. of Tech.
Dong, Xueming Department of Inertia
Ren, Xuemei Beijing Inst. of Tech.

**SatB04** 15:40–17:40 5th Conf. Hall
Invited Session: Data-driven Fault Diagnosis and Fault-tolerant Control
Chair: Chen, Hongtian Univ. of Alberta
Co-Chair: Jiang, Yuchen Harbin Inst. of Tech.

▶ SatB04-1 15:40–16:00
*Research on Privacy Protection of Internet of Vehicles Based on Elliptic Curve Ring Signature*
Mao, Weiqi Chongqing Jiaotong Univ.
Mi, Bo Chongqing Jiaotong Univ.
Huang, Darong Anhui Univ.
Ma, Haoyu Chongqing Jiaotong Univ.

▶ SatB04-2 16:00–16:20
*Privacy-Preserving PBFT Based on A New BFT Asynchronous Verifiable Secret Sharing*
Mi, Bo Chongqing Jiaotong Univ.
Mao, Yongyi Chongqing Jiaotong Univ.
Huang, Darong Chongqing Jiao-tong Univ.
Weng, Yuan Chongqing Jiaotong Univ.
Zou, Yongxing Chongqing Jiaotong Univ.

▶ SatB04-3 16:20–16:40
*FedVPS: Federated Learning for Privacy and Security of Internet of Vehicles on Non-IID Data*
Kuang, Hangdong Chongqing Jiaotong Univ.
Mi, Bo Chongqing Jiaotong Univ.
Huang, Darong Anhui Univ.
Deng, Zhaoyang Chongqing Jiaotong Univ.

▶ SatB04-4 16:40–17:00
*A Federated Learning Framework Based on CSP Homomorphic Encryption*
Zeng, Ran Chongqing Jiaotong Univ.
Mi, Bo Chongqing Jiaotong Univ.
Huang, Darong Anhui Univ.

▶ SatB04-5 17:00–17:20
*Hexapod Robot Gait Switching Based on Different Wild Terrains*
Fei, Shijie Soochow Univ.
Chen, Yiyang Soochow Univ.
Tao, Hong-Feng Jiangnan Univ.
Chen, Hongtian Univ. of Alberta

▶ SatB04-6 17:20–17:40
*Dynamic Path Planning of UAV Based on KF-RRT Algorithm*
Yan, Hang Beijing Information Sci. & Tech. Univ.
Fu, Xingjian Beijing Information Sci. & Tech. Univ.

**SatB05** 15:40–17:40 6th Conf. Hall
Invited Session: Adaptive Control for Nonlinear Servo Systems and Its Applications
Chair: Wang, Shubo Qingdao Univ.
Co-Chair: Zheng, Dongdong Beijing Inst. of Tech.

▶ SatB05-1 15:40–16:00
*A Fast Calibration Method of the Tool Frame for Industrial Robots*
Jiang, Lichen Kunming Univ. of Sci. & Tech.
Gao, Guanbin Kunming Univ. of Sci. & Tech.
Na, Jing Kunming Univ. of Sci. & Tech.
Xing, Yashan Kunming Univ. of Sci. & Tech.

▶ SatB05-2 16:00–16:20
*Adaptive Tracking and Synchronization Control of Dual-motor Driving Servo System*
Dang, Jiali Qingdao Univ.
Ding, Jiacheng Qingdao Univ.
Zhang, Nan Qingdao Univ.
Wang, Shubo Qingdao Univ.

▶ SatB05-3 16:20–16:40
*Adaptive Control-based on Adaptive Observer for Uncertain Nonlinear Servo Systems*
Song, Jiangchao Beijing Inst. of Tech.
Ren, Xuemei Beijing Inst. of Tech.
Na, Jing Kunming Univ. of Sci. & Tech.

▶ SatB05-4 16:40–17:00
*A Survey on Path Planning for Mobile Robot Systems*
Gao, Hejia Anhui Univ.
Liu, Dongliang Anhui Univ.
Hu, Juqi Anhui Univ.

▶ SatB05-5 17:00–17:20
*Design of An Adaptive Fuzzy Sliding Mode Controller for Hydraulic Position Servo System*
Tang, Guoqing Anhui Univ. of Tech.
Yang, Mingxing Anhui Univ. of Tech.
Liu, Qingyun Anhui Univ. of Tech.
Yang, Shuai Anhui Univ. of Tech.

▶ SatB05-6 17:20–17:40
*Neural Network-based Variable Impedance Control of Flexible Joint Robots*
Jiang, Minghao Beijing Inst. of Tech.
Zheng, Dongdong Beijing Inst. of Tech.

**SatB06** 15:40–17:40 Yuetang Conf. Hall
Invited Session: Data-driven Modeling and Adaptive Iterative Learning Control
Chair: Chen, Qiang Zhejiang Univ. of Tech.
Co-Chair: Kong, Ying Zhejiang Univ. of Tech.

▶ SatB06-1 15:40–16:00
*A Novel Distributed K-WTA Model for Communication-Limited Multi-Agent Networks*
Zhou, Junwen Zhejiang Univ. of Sci. & Tech.
Kong, Ying Zhejiang Univ. of Tech.

▶ SatB06-2 16:00–16:20
*A New Modification for Iterative Learning Control*
Zhu, Sheng — Hangzhou City Univ.
Liu, Hong — Hangzhou City Univ.

▶ SatB06-3 16:20–16:40
*A Robust Visual SLAM Based on Key Point Instantaneous Rate Identification in Dynamic Environments*
Dong, Xiangyu — Zhejiang Univ. of Tech.
Cheng, Chen — Zhejiang Univ. of Tech.
Zou, Peng — Zhejiang Univ. of Tech.
Ou, Xianhua — Zhejiang Univ. of Tech.
He, Xiongxiong — Zhejiang Univ. of Tech.

▶ SatB06-4 16:40–17:00
*Prescribed-Time Tracking Control for Robotic Systems with Uncertain Dynamics*
Yang, Hang — Kunming Univ. of Sci. & Tech.
Huang, Yingbo — Kunming Univ. of Sci. & Tech.
Na, Jing — Kunming Univ. of Sci. & Tech.
Chen, Qiang — Zhejiang Univ. of Tech.

▶ SatB06-5 17:00–17:20
*Robust Iterative Learning Control for Robot Manipulators with Input Deadzone*
Ji, Shuangjie — Zhejiang Univ. of Water Resources & Electric Power
Yan, Qiuzhen — Zhejiang Univ. of Water Resources & Electric Power
Chen, Qiang — Zhejiang Univ. of Tech.
Lin, Mingjun — Zhejiang Univ. of Water Resources & Electric Power

▶ SatB06-6 17:20–17:40
*Adaptive Iterative Learning Control of Nonparametric Systems Based on Inverse Deadzone Model*
Mo, Congcong — Zhejiang Univ. of Water Resources & Electric Power
Yan, Qiuzhen — Zhejiang Univ. of Water Resources & Electric Power
Lin, Mingjun — Zhejiang Univ. of Water Resources & Electric Power
Chen, Qiang — Zhejiang Univ. of Tech.

**SatB07** 15:40–17:40 Hongqi Conf. Hall
Invited Session: Identification and Learning Optimal Control for Nonlinear System
Chair: Lv, Yongfeng — Taiyuan Univ. of Tech.
Co-Chair: Li, Linwei — Zhengzhou Univ. of Light Industry

▶ SatB07-1 15:40–16:00
*Hammerstein System Identification Using Robust Estimator Based on Quantized Observation*
Li, Linwei — Zhengzhou Univ. of Light Industry
Wang, Fengxian — Zhengzhou Univ. of Light Industry

▶ SatB07-2 16:00–16:20
*Generalised Policy Learning Based Adaptive Optimal Tracking Control of Nonlinear Servomechanisms*
Zhao, Jun — Shandong Univ. of Sci. & Tech.

▶ SatB07-3 16:20–16:40
*Adaptive Robust Control of the Continuous-time Two-input Systems with Unknown Disturbance Based on Q-function*
Lv, Yongfeng — Taiyuan Univ. of Tech.

▶ SatB07-4 16:40–17:00
*Research on Dual Motor Drive System of Plug-in Hybrid Powertrain*
Zhao, Ziliang — Shandong Univ. of Sci. & Tech.

▶ SatB07-5 17:00–17:20
*Online Parameter Identification for Fractional Order Model of Lithium Ion Battery via Adaptive Genetic Algorithm*
Guo, Bin — Shandong Univ. of Sci. & Tech.

▶ SatB07-6 17:20–17:40
*Time-varying Formation Control for Second-order Nonlinear Multi-UAV System*
Li, Zhenyan — Kunming Univ. of Sci. & Tech.
Yang, Chunxi — Kunming Univ. of Sci. & Tech.
Zhang, Xiufeng — Yunnan International Joint Laboratory of Intelligent Control & Application of Advanced Equipment
Li, Yiming — Kunming Univ. of Sci. & Tech.
Yang, Jianquan — Kunming Univ. of Sci. & Tech.

# Sunday, May 14, 2023

**SunA01** 08:00–10:00 2nd Conf. Hall
Invited Session: Reinforcement Learning Theory and Its Applications

Chair: Xiang, Zhengrong — Nanjing Univ. of Sci. & Tech.
Co-Chair: Song, Ruizhuo — Univ. of Sci. & Tech. Beijing

▶ SunA01-1 08:00–08:20
*A New Deep Learning-based Food Recognition System for Mobile Terminal*
Chen, Wenze — School of Automation & Electrical Engineering
Song, Ruizhuo — Univ. of Sci. & Tech. Beijing

▶ SunA01-2 08:20–08:40
*YOLOv5 Detection Algorithm of Steel Defects Based on Introducing Light Convolution Network and DIOU Function*
Wu, Yinan — Nanjing Univ. of Sci. & Tech.
Zhu, Yun — Nanjing Univ. of Sci. & Tech.
Guo, Jia — Nanjing Univ. of Sci. & Tech.
Yin, Zhenyu — Nanjing Univ. of Sci. & Tech.

▶ SunA01-3 08:40–09:00
*Q-learning Based Optimal Tracking Control of Coal-fired Power Plants*
Liu, Xiaomin — China Univ. of Mining & Tech.
Yu, Mengjun — China Univ. of Mining & Tech.
Yang, Chunyu — China Univ. of Mining & Tech.
Zhou, Linna — China Univ. of Ming & Tech.

▶ SunA01-4 09:00–09:20
*Consensus Analysis for Multi-agent Systems with Markov Switching Hierarchical Network Topology*
Duan, Zhaoxia — Hohai Univ.
Dai, Jun — Hohai Univ.
Xiang, Zhengrong — Nanjing Univ. of Sci. & Tech.
Li, Xiankun — Beijing Jinghang Research Inst. of Computing & Communication
Wang, Shaoping — Hohai Univ.

▶ SunA01-5 09:20–09:40
*Event-triggered Finite-time Control Design for Positive Systems Based on Linear Programming Approach*
Li, Shuo — Hangzhou Dianzi Univ.
Li, Liang — Hangzhou-Dianzi-Univ.
Cui, Mingzhe — Hangzhou Dianzi Univ.
Tian, Yu-Ping — Hangzhou Dianzi Univ.
Wang, Jinling — Anhui Agricultural Univ.

▶ SunA01-6 09:40–10:00
*Physics-Informed LSTM Network-Based Nonlinear Model Predictive Control*
Chen, Yujing — Huazhong Univ. of Sci. & Tech.
Qu, Qilin — Huazhong Univ. of Sci. & Tech.
Zhang, Hong — Huazhong Univ. of Sci. & Tech.
Wang, Yanwei — Wuhan Inst. of Tech.
Zheng, Ying — Huazhong Univ. of Sci. & Tech.

**SunA02** 08:00–10:00 3rd Conf. Hall
Regular Session: Model-free Adaptive Control

Chair: Wang, Xin — Southwest Univ.
Co-Chair: Xiong, Shuangshuang — Beijing Information & Tech. Univ.

▶ SunA02-1 08:00–08:20
*A Novel Successive Updating Scheme of Iterative Learning Control for Networked Control System with Output Data Dropouts*
Zhang, Zhiyang — Beijing Inst. of Petrochemical Tech.
Li, Zhenxuan — Beijing Inst. of Petrochemical Tech.
Guo, Shuang — Beijing Inst. of Petrochemical Tech.
Yin, Chenkun — Beijing Jiaotong Univ.

▶ SunA02-2 08:20–08:40
*Consensus Control of Unknown Nonlinear Discrete-time Multi-agent Systems with Nonuniform Time-delays*
Xiong, Shuangshuang — Beijing Information & Tech. Univ.
Hou, Zhongsheng — Beijing Jiaotong Univ.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.

▶ SunA02-3 08:40–09:00
*Quantized Data Driven Model-Free Adaptive Predictive Control for A Class of Nonlinear Systems*
Liu, Genfeng — Henan Univ. of Tech.
Hou, Zhongsheng — Beijing Jiaotong Univ.

▶ SunA02-4 09:00–09:20
*Event-triggered Adaptive Cooperative Control for Nonstrict-Feedback Nonlinear Multiagent Systems*
Nie, Liduo — Southwest Univ.
Wang, Xin — Southwest Univ.

▶ SunA02-5 09:20–09:40
*Anti-sway Control for Bulk Terminal Gantry Cranes Based on MFAC*
Liu, Wangwang — Qingdao Univ. of Sci. & Tech.
Yao, Wen-Long — Qingdao Univ. of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.
Mu, Chenglin — Qingdao Univ. of Sci. & Tech.

▶ SunA02-6 09:40–10:00
*Adaptive Compensation FTC for Dynamic Nonlinear Systems Based on Data-Driven Theory*
Yang, Chen — Liaoning Petrochemical Univ.
Peng, Bo — Univ. of Sci. & Tech. Liaoning
Bo, Guihua — Liaoning Petrochemical Univ.
Shi, Huiyuan — Liaoning Petrochemical Univ.
Su, Chengli — Liaoning Petrochemical Univ.

**SunA03** 08:00–10:00 4th Conf. Hall
Invited Session: RL and ADP-based Adaptive Control

Chair: Zhao, Bo — Beijing Normal Univ.
Co-Chair: Bai, Weiwei — Dalian Maritime Univ.

▶ SunA03-1 08:00–08:20
*Adaptive Iterative Learning Control for Industry Batch Process with Time-Varying and Unknown Parameters*
Li, Peiyuan — Guangdong Univ. of Tech.
Li, Panshuo — Guangdong Univ. of Tech.

▶ SunA03-2 08:20–08:40
*An Overview of Optimal Control Methods for Singularly Perturbed Systems*
Nie, Hao — Liaoning Petrochemical Univ.
Li, Jinna — Liaoning Petrochemical Univ.

▶ SunA03-3 08:40–09:00
*Online Non-parametric Modeling for Ship Maneuvering Motion Using Local Weighted Projection Regression and Extended Kalman Filter*
Yue, Wancheng — Dalian Maritime Univ.
Ren, Junsheng — Dalian Maritime Univ.
Bai, Weiwei — Dalian Maritime Univ.

▶ SunA03-4 09:00–09:20
*Estimation of Ship Hydrodynamic Derivatives Using Numerical PMM Test with Trim Conditions*
Zhang, Guangbin — Dalian Maritime Univ.
Ren, Junsheng — Dalian Maritime Univ.
Tan, Xiaowei — Dalian Maritime Univ.

▶ SunA03-5 09:20–09:40
*Data-Based Approximate Optimal Control for Unknown Nonaffine Systems via Dynamic Feedback*
Lin, Jinquan — Guangdong Univ. of Tech.
Zhao, Bo — Beijing Normal Univ.
Liu, Derong — CASIA

▶ SunA03-6 09:40–10:00
*Classification of Motor Imagery EEG Signals Based on Channel Attention Mechanism*
Yu, Yue — Changchun Univ. of Tech.
Ji, Wenkai — Changchun Univ. of Tech.
Zhao, Liming — Changchun Univ. of Tech.
Sun, Zhongbo — Changchun Univ. of Tech.
Liu, Keping — Changchun Univ. of Tech.

**SunA04** 08:00–10:00 5th Conf. Hall
Invited Session: Reinforcement Learning and Its Applications in Decision-making and Control Systems

Chair: Zhang, Qichao — Chinese Acad. of Sci.
Co-Chair: Yang, Yongliang — Univ. of Sci. & Tech. Beijing

▶ SunA04-1 08:00–08:20
*Resilient Distributed Secondary Control Strategy for New Energy Shipboard Microgrid Against Bounded FDI Attacks*
Wang, Liangbin — Dalian Maritime Univ.
Yu, Renhai — Dalian Maritime Univ.

Lv, Jin — Port of Guangzhou Pilot Station
Zhang, Bo — Ningbo Pilot Station
Wang, Fuzhi — Dalian Maritime Univ.
Teng, Fei — Dalian Maritime Univ.

▶ SunA04-2 08:20–08:40
*Adaptive Input Shaping Control Based on RLS for Harvesting Mechanical Arm*
Sun, Mingming — Univ. of Sci. & Tech. Beijing
Liu, Dexin — Univ. of Sci. & Tech. Beijing

▶ SunA04-3 08:40–09:00
*Hybrid Variable Structure DBN Mission Decision-Making Method for UAV Swarm*
Liu, Bo Wei — Beijing Inst. of Tech., School of Aerospace
Sun, Jingliang — Beijing Inst. of Tech.
Long, Teng — Beijing Inst. of Tech.
Liu, Dawei — China Research Development Acad. of Machinery Equipment
Cao, Yan — Beijing Inst. of Tech.

▶ SunA04-4 09:00–09:20
*Adaptive Event-based Design of Nonlinear Systems with Unknown Control Directions*
Liu, Guilong — Univ. of Sicience & Tech.
Yang, Yongliang — Univ. of Sci. & Tech. Beijing

▶ SunA04-5 09:20–09:40
*Reinforcement Learning Driving Strategy Based on Auxiliary Task for Multi-Scenarios Autonomous Driving*
Sun, Jingbo — Beijing Inst. of Tech.
Fang, Xing — Chinese Acad. of Sci.
Zhang, Qichao — Chinese Acad. of Sci.

▶ SunA04-6 09:40–10:00
*Spectral Normalized Neural Networks Funnel Control for Servo System with Unknown Dynamics*
Zhang, Chao — Beijing Inst. of Tech.
Ren, Xuemei — Beijing Inst. of Tech.
Han, Ning — Beijing Inst. of Tech.
Zheng, Dongdong — Beijing Inst. of Tech.

**SunA05** 08:00–10:00 6th Conf. Hall
Invited Session: Intelligent and Adaptive Learning Control for Nonlinear Systems
Chair: Liu, Yang — Guangdong Univ. of Tech.
Co-Chair: Liu, Lei — Liaoning Univ. of Tech.

▶ SunA05-1 08:00–08:20
*Active Disturbance Rejection Based Containment Control of Stochastic Nonlinear Nonaffine Multiagent Systems*
Zhang, Pengchao — Bohai Univ.
Pan, Yingnan — Bohai Univ.

▶ SunA05-2 08:20–08:40
*Adaptive Quantized Consensus Control for Uncertain Nonlinear Multiagent Systems with Actuator Faults*
Xu, Haorui — Bohai Univ.
Cao, Liang — Bohai Univ.

▶ SunA05-3 08:40–09:00
*Synchronization of Complex Dynamic Networks with Time-varying Coupled Delays for Sampled Data Control*
Yan, Yuying — Linyi Univ.
Cheng, Long — Linyi Univ.
Sun, Jianqiang — Linyi Univ.
Chen, Xiangyong — Linyi Univ.
Liu, Yang — Guangdong Univ. of Tech.
Qiu, Jianlong — Linyi Univ.

▶ SunA05-4 09:00–09:20
*Design and Application of Workshop Production Scheduling Strategy Based on Manufacturing Big Data*
Wu, Bin — Guangdong Univ. of Tech.
Xiao, Yi — Guangdong Univ. of Tech.
Ren, Hongru — Guangdong Univ. of Tech.
Yang, Lan — Guangdong Univ. of Tech.
Lu, Renquan — Guangdong Univ. of Tech.

▶ SunA05-5 09:20–09:40
*Model Free Adaptive Consensus Control for Multiagent Systems with Actuator Faults*
Wang, Yuan — Northeastern Univ.
Du, Zhenbin — Yantai Univ.
Wu, Yanming — Northeastern Univ.

▶ SunA05-6 09:40–10:00
*Predefined-time Adaptive Repetitive Learning Control for Robot Manipulators*
Li, Yaqian — Zhejiang Univ. of Tech.
Shi, Huihui — Zhejiang Univ. of Tech.
Chen, Qiang — Zhejiang Univ. of Tech.

**SunA06** 08:00–10:00 Yuetang Conf. Hall
Invited Session: Repetitive Control for Uncertain Nonlinear Systems
Chair: Zhou, Lan — Hunan Univ. of Sci. & Tech.
Co-Chair: Huo, Xin — Harbin Inst. of Tech.

▶ SunA06-1 08:00–08:20
*Improved Repetitive Control with Frequency Adaptation in An LCL-type Grid-tied Inverter*
Zhang, Hongwei — Zhongyuan Univ. of Tech.
Zhao, Qiangsong — Zhongyuan Univ. of Tech.
Chen, Hao — Zhongyuan Univ. of Tech.

▶ SunA06-2 08:20–08:40
*Repetitive Control for Nonlinear Systems: An Actuator-focussed Design Method*
Quan, Quan — Beihang Univ.

▶ SunA06-3 08:40–09:00
*Fractional-order Multi-rate Repetitive Control for A Single-phase Grid-connected Inverter*
Liu, Kaiyue — Zhongyuan Univ. of Tech.
Zhao, Qiangsong — Zhongyuan Univ. of Tech.

▶ SunA06-4 09:00–09:20
*Adaptive Repetitive Control for A Class of Uncertain Nonlinear Systems with Input Delay*
Sun, Yongbo — Hunan Univ. of Sci. & Tech.
Zhou, Lan — Hunan Univ. of Sci. & Tech.
Li, Chengyang — Hunan Univ. of Sci. & Tech.
Yang, Qin — Hunan Univ. of Sci. & Tech.
Xiao, Wenbin — Hunan Univ. of Sci. & Tech.

▶ SunA06-5 09:20–09:40
*Multi-Frequency Selective Harmonic Repetitive Control of Programmable AC Power Sources*
Zhou, Keliang — Wuhan Univ. of Tech.

▶ SunA06-6 09:40–10:00
*Equivalent Circuit-based Modeling of Ultrasonic Motors for Hammerstein Systems*
Qian, Yihui — China Univ. of Mining & Tech.(Beijing)
Huo, Xin — Harbin Inst. of Tech.
Liu, Qingquan — Harbin Inst. of Tech.
Liu, Jingbo — Harbin Inst. of Tech.
Zhao, Hui — Harbin Inst. of Tech.

**SunA07** 08:00–10:00 Hongqi Conf. Hall
Invited Session: Equivalent-Input-Disturbance Approach for Disturbance Estimation and Rejection
Chair: Li, Feng — Jiangsu Univ. of Tech.
Co-Chair: Li, Meiliu — Hunan Univ. of Sci. & Tech.

▶ SunA07-1 08:00–08:20
*Robust Fixed-time Sliding Mode Control of Underactuated Furuta Pendulum System*
Wang, Zhujun — Linyi Univ.
Zhou, Xinhao — Linyi Univ.
Zhang, Ancai — Linyi Univ.
Liang, Xiao — Shandong Univ. of Sci. & Tech.
Pan, Guangyuan — Linyi Univ.

▶ SunA07-2 08:20–08:40
*Refined Disturbance Rejection for Permanent Magnet Synchronous Motors with Multi-Source Disturbances Using Equivalent Input Disturbance Approach*
Yang, Tao — Jiangsu Univ. of Tech.
Du, Youwu — China Univ. of GeoSci.
Zhu, Erlin — Jiangsu Univ. of Tech.
Li, Bo — Jiangsu Univ. of Tech.
Han, Zhenhua — Jiangsu Univ. of Tech.
Fang, Mingxing — Anhui Normal Univesity

▶ SunA07-3 08:40–09:00
*Further Enhancement for Disturbance-rejection Performance Based on*

*Modified Equivalent-Input-Disturbance Approach*
Wang, Zewen — China Univ. of GeoSci.
She, Jinhua — Tokyo Univ. of Tech.
Sato, Daiki — Tokyo Inst. of Tech.

▶ SunA07-4 09:00–09:20
*A Modified Equivalent-Input-Disturbance Method for Uncertain Networked Control Systems with Exogenous Disturbance*
Li, Meiliu — Hunan Univ. of Sci. & Tech.
Xiao, Wenbin — Hunan Univ. of Sci. & Tech.
Zhou, Lan — Hunan Univ. of Sci. & Tech.

▶ SunA07-5 09:20–09:40
*Command Filtered Backstepping Control of A Two-Link Flexible Joint Manipulator with Uncertainties Based on Reduced-Order ESO*
Fei, Xiangyin — Hunan Univ. of Sci. & Tech.
Pan, Changzhong — Hunan Univ. of Sci. & Tech.
Zhou, Lan — Hunan Univ. of Sci. & Tech.
Xiong, Peiyin — Hunan Univ. of Sci. & Tech.
Li, Meiliu — Hunan Univ. of Sci. & Tech.

▶ SunA07-6 09:40–10:00
*A Model-Predictive-Enabled Equivalent-Input-Disturbance Approach for Disturbance Rejection*
Zhou, Yujian — China Univ. of GeoSci.
She, Jinhua — Tokyo Univ. of Tech.
Wang, Feng — China Univ. of GeoSci.
Iwasaki, Makoto — Nagoya Inst. of Tech.

## Poster Session SunA08
May 14, 8:00–10:00
6th Conf. Hall

Chair: Sun, Mingwei — Nankai Univ.
Co-Chair: Cao, Rongmin — Beijing Information Sci. & Tech. of Univ.

▷ SunA08-01
*Data-driven Adaptive Tuning Method of Traditional Incremental Integral Control Law*
Bian, Yongming — Qingdao Univ. of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.

▷ SunA08-02
*Sliding-Mode Control Strategy for Dynamic Wireless Charging System with Long Guide Transmitting Coil for EV*
Guo, Yan — Shanghai Univ.
Song, Yang — Shanghai Univ.
Zhao, Wanqing — Univ. of East Anglia

▷ SunA08-03
*Fan Flue Gas Temperature Control System Based on Fuzzy PID Control*
Wang, Zihao — Beijing Univ. of Tech.
Li, Xiaoli — Beijing Univ. of Tech.
Wang, Kang — Beijing Univ. of Tech.
Li, Yang — Communication Univ. of China

▷ SunA08-04
*Active Fault-tolerant Predictive Control for Networked Multi-Agent Systems with Actuator Faults and Random Communication Constraints*
Li, Chao — North China Univ. of Tech.
Wang, Shitong — North China Univ. of Tech.
Pang, Zhonghua — North China Univ. of Tech.
Zheng, Changbing — Henan Univ. of Urban Construction
Sun, Dehui — North China Univ. of Tech.
Xu, Shu Wei — North China Univ. of Tech.

▷ SunA08-05
*Improved Model - Free Sliding Mode Control of PMSM Based on Finite-Time Generalized Proportional Integral Observer*
Wang, Dongdong — Qingdao Univ.
Liu, Shuguang — Shandong Luruan Digital Tech. Co. LTD
Liu, Xu Dong — Qingdao Univ.
Zhang, Zhixin — Qingdao Univ.
Chen, Yong Zhi — Qingdao Univ.

▷ SunA08-06
*Model - Free Adaptive Sliding Mode Predictive Control of Linear Ultrasonic Motor*
Li, Yifan — Beijing Information Sci. & Tech. Univ.
Cao, Rongmin — Beijing Information Sci. & Tech. of Univ.
Hou, Zhongsheng — Beijing Jiaotong Univ.
Zhou, Huixing — China Agricultural Univ.
Chang, Debiao — Beijing Information Sci. & Tech. Univ.
Jia, Jihui — Beijing Information Sci. Tech. Univ.

▷ SunA08-07
*High Order Sliding Mode Decoupling Control of Two-dimensional Linear Motor Based on Proportional Integral Model Free Adaptive Control*
Jia, Jihui — Beijing Information Sci. Tech. Univ.
Cao, Rongmin — Beijing Information Sci. & Tech. of Univ.
Hou, Zhongsheng — Beijing Jiaotong Univ.
Zhou, Huixing — China Agricultural Univ.
Chang, Debiao — Beijing Information Sci. & Tech. Univ.
Li, Yifan — Beijing Information Sci. & Tech. Univ.

▷ SunA08-08
*Distributed Bipartite Consensus for Multi-agent Systems via Data-driven Sliding Mode Scheme*
Zhao, Huarong — Jiangnan Univ.
Peng, Li — Jiangnan Univ.
Xie, Linbo — Jiangnan Univ.
Yang, Jielong — Xi'an Jiaotong Univ.
Xu, Ye — Jiangnan Univ.

▷ SunA08-09
*Reinforcement-learning-aided Adaptive Control for Autonomous Driving with Combined Lateral and Longitudinal Dynamics*
Wang, Yongshuai — Nankai Univ.
Zheng, Chen — Beijing Inst. of Astronautical Sys. Engineering
Sun, Mingwei — Nankai Univ.
Chen, Zengqiang — Nankai Univ.
Sun, Qinglin — Nankai Univ.

▷ SunA08-10
*DLinear Photovoltaic Power Generation Forecasting Based on Reversible Instance Normalization*
Wang, Gang — Hubei Minzu Univ.
Liao, Yu — Hubei Univ. for Nationalities
Guo, Li — Anhui Polytechnic Univ.
Geng, Jiahao — Hubei Minzu Univ.
Ma, Xianchao — Hubei Univ. for Nationalities

▷ SunA08-11
*A Semi-supervised Deep Learning Fault Diagnosis Method Based on Uncertainty Estimation and Weighted Labels*
Huang, Hanxin — Shanghai Maritime Univ.
Zhou, Funa — Shanghai Maritime Univ.
Jia, Pengpeng — Shanghai Maritime Univ.
Wen, Yanqi — Shanghai Maritime Univ.

▷ SunA08-12
*Interpretable Bearing Stage Division Based on Shapelet and SVM*
Li, Xinye — Huazhong Univ. of Sci. & Tech.
Yang, Xiaoyu — Huazhong Univ. of Sci. & Tech.
Zhang, Hong — Huazhong Univ. of Sci. & Tech.
Wang, Yanwei — Wuhan Inst. of Tech.
Zheng, Ying — Huazhong Univ. of Sci. & Tech.

▷ SunA08-13
*Study on Fault Identification Method of Transmission Lines Based on An Improved CNN*
Li, Rui — Beijing Information Sci. & Tech. of Univ.
Li, Qingkui — Beijing Information Sci. & Tech. Univ., Beijing
Yu, Di — Beijing Information Sci. & Tech. Univ.

▷ SunA08-14
*Study on Genetic Algorithm Optimization of Ultrasonic Echo Peak Value Thickness Measurement Algorithm*
Wang, Zenan — Sichuan Univ. of Sci. & Engineering
Li, Zhaofei — Sichuan Univ. of Sci. & Engineering
Hou, Jin — Sichuan Univ. of Sci. & Engineering
Huang, Zhenghong — Sichuan Huaqi Detection & Tech.
Zhong, Mingshan — Sichuan Univ. of Sci. & Engineering

▷ SunA08-15
*Anomaly Root Cause Analysis for Wind Turbines Based on Denoising Autoencoder and Sparse Estimation*
Du, Songtao — Huazhong Univ. of Sci. & Tech.
Wan, Yiming — Huazhong Univ. of Sci. & Tech.
Zhang, Cong — Beijing Inst. of Control Engineering
Zhang, Sihang — China Acad. of Space Tech.

▷ SunA08-16
*A Novel Fault Diagnosis Approach Integrated LRKPCA with AdaBoost.M2 for Industrial Process*
Xu, Yuan — Beijing Univ. of Chemical Tech.
Jiang, Xue — Beijing Univ. of Chemical Tech.

Zhu, Qunxiong Beijing Univ. of Chemical Tech.
He, Yan-Lin Beijing Univ. of Chemical Tech.
Zhang, Yang Beijing Univ. of Chemical Tech.
Zhang, Ming-Qing Beijing Univ. of Chemical Tech.

▷ SunA08-17
*Abnormal Sound Detection of Electrical Equipment Based on Time-spectrum Information Fusion*
Ma, Xianchao Hubei Univ. for Nationalities
Liao, Yu Hubei Univ. for Nationalities
Guo, Li Anhui Polytechnic Univ.
Geng, Jiahao Hubei Minzu Univ.
Wang, Gang Hubei Minzu Univ.

▷ SunA08-18
*SRUH-GNN: Social Recommendation of User Homophily based on Graph Neural Network*
Gao, Shuai Bohai Univ.
Xing, Xing Bohai Univ.

▷ SunA08-19
*Iterative Learning Control for Linear Systems with Random Actuator Faults*
He, Xun Renmin Univ. of China
Jiang, Hao Renmin Univ. of China
Shen, Dong Renmin Univ. of China

▷ SunA08-20
*Fault Estimation and Accommodation for Networked Systems Based on Intermediate Variable with Intermittent DoS Attacks*
Zhao, Yuezhou Univ. of Electronic Sci. & Tech. of China
Li, Tieshan Dalian Maritime Univ.
Long, Yue Univ. of Electronic Sci. & Tech. of China

▷ SunA08-21
*Intelligent Fault Diagnosis of Nuclear Grade Electric Equipment Based on Quantum Genetic Support Vector Machine*
Liu, Zhilong Nuclear Power Inst. of China

▷ SunA08-22
*Model-free Adaptive Cluster Consensus Control for Nonlinear Multi-agent Systems under DoS Attack*
Li, Yuhan Henan Polytechnic Univ.
Bu, Xuhui Henan Polytechnic Univ.
Guo, Jinli Henan Polytechnic Univ.

▷ SunA08-23
*Iterative Learning Containment Control under Fading Communication*
Zeng, Kun Beijing Univ. of Chemical Tech.
Zhang, Zeyi Renmin Univ. of China
Shen, Dong Renmin Univ. of China

▷ SunA08-24
*Gradient-Based Iterative Learning Control for Signal Quantization with Encoding-Decoding Mechanism*
Tao, Yujuan Jiangnan Univ.
Huang, Yande Jiangnan Univ.
Tao, Hong-Feng Jiangnan Univ.
Chen, Yiyang Soochow Univ.

▷ SunA08-25
*Group Consensus for Discrete-time Multi-agent Systems Based on Iterative Learning Control*
Gao, Qianhui Xidian Univ.
Li, Jinsha Xidian Univ.

▷ SunA08-26
*Analysis and Identification of Ancient Glass Relics Based on Clustering Algorithm and Random Forest*
Xu, Yiming Zhengzhou Univ.
Zhi, Weimei Zhengzhou Univ.

▷ SunA08-27
*LTV System Identification via Kernel-based Regularization Method under Savitzky-Golay Filtering*
Yu, Xian The Chinese Univ. of Hong Kong, Shenzhen
Ji, Xiaoqiang The Chinese Univ. of Hong Kong, Shenzhen

▷ SunA08-28
*Separated Model for Stopping Point Prediction of Autoregressive Sequence*
Liu, Tingzhen Tencent IEG
Zhang, Shengxi Shangdong Univ. at Weihai
Xiong, Qianqian Shandong Univ.

▷ SunA08-29
*Photovoltaic Power Generation Forecasting Based on Weighted Copula Model and Pattern Analysis*
Zhao, Yilin Shanghai Univ.
Zhou, Yang Shanghai Univ.
Jia, Li Shanghai Univ.
Li, Yan Shanghai Univ.

▷ SunA08-30
*Industrial Fault Detection Based on C-Vine Copula Model and Transfer Learning Strategy*
Li, Yan Shanghai Univ.
Zhou, Yang Shanghai Univ.
Jia, Li Shanghai Univ.
Zhao, Yilin Shanghai Univ.

▷ SunA08-31
*Water Supply Network Optimization Based on Improved Sparrow Search Algorithm*
Huang, Xiaoyi Beijing Univ. of Chemical Tech.
Wang, Yungan Beijing Univ. of Chemical Tech.
Chu, Jizheng Beijing Univ. of Chemical Tech.

▷ SunA08-32
*A Novel Lazy Learning-based Data Driven Fault Diagnosis Method for Public Transport Vehicles*
Fu, Xiaotian North China Univ. of Tech.
Wang, Li North China Univ. of Tech.
Liu, Shida Beijing Jiaotong Univ.
Ji, Honghai North China Univ. of Tech.

▷ SunA08-33
*Associated Modal Transfer Network of International Crude Oil Futures and Domestic Major Crop Prices' Fluctuation and Its High Order Knots Analysis*
Liu, Jie Wuhan Textile Univ.

▷ SunA08-34
*A Constructive Density Function Path Leading to Global Coverage Strategy for A Gaussian Random Field*
Yang, Yuxing Huazhong Univ. of Sci. & Tech.
Su, Mao Designing Institude of Hubei Space Tech. Acad.
Fan, Huijin Huazhong Univ. of Sci. & Tech.
Liu, Lei Huazhong Univ. of Sci. & Tech.
Wang, Bo Huazhong Univ. of Sci. & TTech.

▷ SunA08-35
*Remaining Useful Life Prediction Method for Rolling Bearings Based on CBAM-CNN-BiLSTM*
Zhou, Honggen Jiangsu Univ. of Sci. & Tech.
Ren, Xiaodie Jiangsu Univ. of Sci. & Tech.
Sun, Li Jiangsu Univ. of Sci. & Tech.
Li, Guochao Jiangsu Univ. of Sci. & Tech.
Liu, Yinfei Jiangsu Univ. of Sci. & Tech.

▷ SunA08-36
*A Robust Variable Projection Algorithm for RBF-AR Model*
She, Yuexin Fuzhou Univ.
Chen, Guangyong Fuzhou Univ.
Gan, Min Fuzhou Univ.

▷ SunA08-37
*Optimized Mutation of Grey-box Fuzzing: A Deep RL-based Approach*
Shao, Jiawei Southeast Univ.
Zhou, Yan Southeast Univ.
Liu, Guohua Southeast Univ.
Zheng, Dezhi Beijing Inst. of Tech.

▷ SunA08-38
*Wind Speed Prediction Based on ARMA and SVR*
Jiao, Xuguo Qingdao Univ. of Tech.
Zhang, Daoyuan Qingdao Univ. of Tech.
Yang, Qinmin Zhejiang Univ.
Zhang, Zhenyong Guizhou Univ.
Liu, Wenfeng Qingdao Univ. of Tech.

▷ SunA08-39
*A Review of the Current Status and Future Directions of Research on Subspace Clustering Feature Selection*
Song, Xinyu Beijing Univ. of Tech.
Wang, Xiujuan Beijing Univ. of Tech.

▷ SunA08-40
*A Separable Training Algorithm Based on Nonmonotone Trust-region*

*Method for Neural ODE*

Wang, Yaping — Fuzhou Univ.
Chen, Guangyong — Fuzhou Univ.
Gan, Min — Fuzhou Univ.

▷ SunA08-41
*Identification Approach of the Hammerstein-Wiener Model Applying Combined Signals*

Zhou, Shibo — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

▷ SunA08-42
*General Decay Synchronization of Delayed Complex-valued Neural Networks with Discontinuous Neuron Activations*

Han, Xiaofang — Xinjiang Univ.
Abdurahman, Abdujelil — Xinjiang Univ.

▷ SunA08-43
*Subway Short-term Passenger Flow Prediction Based on Improved LSTM*

Yao, Yajuan — Beijing Jiaotong Univ.
Jin, Shangtai — Beijing Jiaotong Univ.
Qian, Wang — Beijing Jiaotong Univ.

▷ SunA08-44
*Ship Adaptive RBF Neural Network Course Keeping Control Considering System Uncertainty*

Zhang, Sihang — Shandongjiaotong Univ.
Zhang, Qiang — Shandong Jiaotong Univ.
Su, Wenxue — Qingdao Harbour Vocation & Technical College
Li, Haoyang — School of Navigation & Shipping, Shandong Jiaotong Univ.
Gai, Xudong — Shandong Jiaotong Univ.

▷ SunA08-45
*Hierarchical Label Text Classification Method with Deep-Level Label-Assisted Classification*

Cao, Yukun — Shanghai Univ. of Electric Power
Wei, Ziyue — Shanghai Univ. of Electric Power, Shanghai
Tang, Yijia — Shanghai Univ. of Electric Power
Jin, Chengkun — Shanghai Univ. of Electric Power, Shanghai

▷ SunA08-46
*Identification of MISO Hammerstein Nonlinear Model with Moving Average Noise Based on Hybrid Signal*

Zhao, Caiting — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

▷ SunA08-47
*Coordinated Voltage Regulation of Microgrid Clusters Based on Deep Reinforcement Learning Approach*

Xue, Xiaozhe — Nanjing Normal Univ.
Ge, Hui — Nanjing Univ. of Posts & Telecommunicaiton

▷ SunA08-48
*Industrial Time Series Prediction Based on Incremental DBSCAN-KNN with Self-learning Scheme*

Zhong, Xueyan — Dalian Univ. of Tech., Dalian
Chen, Long — Dalian Univ. of Tech., Dalian
Han, Zhongyang — Dalian Univ. of Tech.
Zhao, Jun — Dalian Univ. of Tech.
Wang, Wei — Dalian Univ. of Tech.

▷ SunA08-49
*Flotation Condition Recognition Based on HGNN and Forth Image Dynamic Feature*

Fan, Zunguan — Beijing Univ. of Tech.
Wang, Kang — Beijing Univ. of Tech.
Li, Xiaoli — Beijing Univ. of Tech.

▷ SunA08-50
*A Multi-objective Optimal Scheduling Method by Considering Energy and Production for Integrated Energy System in Steel Industry*

Wang, Jichen — Dalian Univ. of Tech.
Jin, Feng — Dalian Univ. of Tech.
Zhao, Jun — Dalian Univ. of Tech.
Wang, Wei — Dalian Univ. of Tech.

▷ SunA08-51
*A Multi-Head Self-Attention-based on GRU Encoder-Decoder Framework for Predicting Molten Iron Silicon Content*

Cai, Yu — Zhejiang Univ.
Yang, Chunjie — Zhejiang Univ.
Lou, Siwei — Zhejiang Univ.
Zeng, Zhenyu — Alibaba Cloud
Liao, Huanyu — Alibaba Cloud
Zhang, Bing — Alibaba Group

▷ SunA08-52
*Data Driven Strip Crown Prediction for A Hot Strip Rolling Mill Process*

Zhang, Yanyan — Univ. of Sci. & Tech. Beijing
Zhang, Kai — Univ. of Sci. & Tech. Beijing
Yang, Pengcheng — Univ. of Sci. & Tech. Beijing
Peng, Kaixiang — Univ. of Sci. & Tech. Beijing

▷ SunA08-53
*Researching on Signal Transmission Performance of LoRa Technology in Urban Environment*

Wu, Zhaobin — Guangxi Univ. of Sci. & Tech.
Shen, Qiguang — Guangxi Univ. of Sci. & Tech.
Wang, Junhui — Guangxi Univ. of Sci. & Tech.

▷ SunA08-54
*An Improved Industrial Process Soft Sensor Method Based on LSTM*

He, Yan-Lin — Beijing Univ. of Chemical Tech.
Wang, Pengfei — Beijing Univ. of Chemical Tech.
Xu, Yuan — BEIJING Univ. OF CHEMICAL Tech.
Zhu, Qunxiong — Beijing Univ. of Chemical Tech.

▷ SunA08-55
*A Comparison of LS-based Steel Thickness Prediction Methods for A Hot Rolling Mill Process*

Zhang, Xiaowen — Univ. of Sci. & Tech. of Beijing
Zhang, Kai — Univ. of Sci. & Tech. Beijing
Peng, Kaixiang — Univ. of Sci. & Tech. Beijing

▷ SunA08-56
*Event-Triggered Mechanism-Based Adaptive Cooperative Tracking Control for MHSTs System with Uncertain Dynamics*

Zhang, Yusha — Southwest Jiaotong Univ.
Ma, Junjie — Southwest Jiaotong Univ.
Huang, Deqing — Southwest Jiaotong Univ.
Wu, Yue — Southwest Jiaotong Univ.
Wang, Jiaxin — Southwest Jiaotong Univ.

▷ SunA08-57
*Formation Control Based on Active Compensation for Multi-Agent System under Communication Attack*

Wang, Jing — North China Univ. of Tech., China
Wang, Siyuan — North China Univ. of Tech.
Meng, Zhou — North China Univ. of Tech.

▷ SunA08-58
*Model-free Active Disturbance Rejection Control of Two-dimensional Linear Motor Based on Multi-parameter Genetic Optimization*

Chang, Debiao — Beijing Information Sci. & Tech. Univ.
Cao, Rongmin — Beijing Information Sci. & Tech. of Univ.
Hou, Zhongsheng — Beijing Jiaotong Univ.
Jia, Jihui — Beijing Information Sci. Tech. Univ.
Li, Yifan — Beijing Information Sci. & Tech. Univ.

▷ SunA08-59
*Adaptive Sliding Mode Control of Suppressing Quadrotor Payload Swing with Variable-Length Cable*

Wang, Yikun — Beijing Univ. of Chemical Tech.
Li, Dazi — Beijing Univ. of Chemical Tech.
Huang, Jingwen — Beijing Univ. of Chemical Tech.

▷ SunA08-60
*GLSUR: POI Recommendations Based on Similar Users and Current Geographic Location*

Jia, Zhichun — Bohai Univ.

▷ SunA08-61
*Comparison of Different Domain Randomization Methods for Policy Transfer in Reinforcement Learning*

Ma, Mingjun — Chinese Acad. of Sci.
Li, Haoran — Univ. of Chinese Acad. of Sci.
Hu, Guangzheng — Beijing Inst. of Tech.
Liu, Shasha — Univ. of Chinese Acad. of Sci.
Zhao, Dong-Bin — Inst. of Automation

▷ SunA08-62
*Research of Intelligent Analysis Based on 12328 Transportation Service Supervision Hotline Data*

Chen, Bangju Beijing Inst. of Tech.
Xue, Guangyue China Transport Telecommunications & Information Center

▷ SunA08-63
*Stabilization of Port-Controlled Hamiltonian Systems Subject to Exogenous Disturbances via Compensation Control Approach*
Fu, Baozeng Qingdao Univ.
Wang, Qingzhi Qingdao Univ.
Liu, Yongchao Qingdao Univ.

▷ SunA08-64
*Graph Context Target Attention Graph Neural Network for Session-based Recommendation*
Xing, Xing Bohai Univ.

▷ SunA08-65
*Fault-tolerant Tracking Control for Mobile Robots Based on the Framework of Intermediate Estimator and MPC*
Ying, Liang-Huan Zhejiang Univ. of Tech.
Zhu, Jun-Wei Zhejiang Univ. of Tech.

## SunB01 10:10–12:10 2nd Conf. Hall
Regular Session: Data Driven Control

Chair: Wang, Zhu China Univ. of Petroleum (Beijing)
Co-Chair: Peng, Yunjian South China Univ. of Tech.

▶ SunB01-1 10:10–10:30
*Real-time Observability of Smooth Continuous Systems and Corresponding Data-based Observability Determination and Observer Design Method*
Liu, Zehua Beihang Univ.
Wang, Zhuo Beijing Univ. of Aeronautics & Astronautics
Wang, Ruigang Beijing Univ. of Aeronautics & Astronautics
Qin, Bodong Beijing Univ. of Aeronautics & Astronautics
Li, Feng Beijing Univ. of Aeronautics & Astronautics
Yan, Yifan Beihang Univ.

▶ SunB01-2 10:30–10:50
*Interval Observer Based Extended Predictive Controller for Heavy Duty Gas Turbine*
Liu, Ke School of Control Sci. & Engineering
Liu, Yang School of Control Sci. & Engineering
Zhao, Jun Dalian Univ. of Tech.
Wang, Wei Dalian Univ. of Tech.

▶ SunB01-3 10:50–11:10
*Q-Learning-based Finite Control Set Model Predictive Control for LCL-Coupled Inverters with Deviated Parameters*
Zhang, Lei South China Univ. of Tech.
Peng, Yunjian South China Univ. of Tech.
Sun, Weijie South China Univ. of Tech.
Li, Jinze South China Univ. of Tech.

▶ SunB01-4 11:10–11:30
*Outlier Detection of Traction Energy Consumption Based on Local Density and Cluster for Time Series Data*
Zhang, Chengxi Beijing Jiaotong Univ.
Xun, Jing Beijing Jiaotong Univ.
Ji, Zhihui Beijing Jiaotong Univ.
Yin, Chenkun Beijing Jiaotong Univ.
Cao, Jiang CRRC Qingdao Sifang Rolling Stock Co., Ltd

▶ SunB01-5 11:30–11:50
*DDPG-based Path Planning Approach for Autonomous Driving*
Li, Yimin Sun Yat-sen Univ.
Chen, Yanfang Sun Yat-sen Univ.
Lao, Jingtao Sun Yat-sen Univ.
Li, Tianru Sun Yat-sen Univ.
Li, Xuefang Sun Yat-sen Univ.

▶ SunB01-6 11:50–12:10
*Set-membership Identification Recursive Algorithm Based on Adaptive Noise Bounding*
Wang, Zhu China Univ. of Petroleum (Beijing)
Wang, Qian China Univ. of Petroleum (Beijing)
Wang, Shao Xian China Univ. of Petroleum (Beijing)

## SunB02 10:10–12:10 3rd Conf. Hall
Invited Session: Recent Advances for Control-theoretic Iterative Methods

Chair: Li, Juntao Henan Normal Univ.
Co-Chair: Meng, Deyuan Beihang Univ. (BUAA)

▶ SunB02-1 10:10–10:30
*Robust $H_infty$ Control for Switched Stochastic Nonlinear Systems under Periodic Sampling*
Zhao, Hongpeng Henan Normal Univ.
Xiong, Jiandong Henan Normal Univ.
Mu, Xiaoxia Henan Normal Univ.

▶ SunB02-2 10:30–10:50
*Chattering-Free Adaptive Iterative Learning for Attitude Tracking Control of Uncertain Spacecraft*
Zhang, Fan Beihang Univ.
Meng, Deyuan Beihang Univ. (BUAA)
Li, Xuefang Sun Yat-sen Univ.

▶ SunB02-3 10:50–11:10
*Fixed-time Synchronization of Nonlinear Non-affine System*
Liu, Dandan Qilu Univ. of Tech.
Lv, Hui Qilu Univ. of Tech. (Shandong Acad. of Sci.)
Zhao, Fuyu Qilu Univ. of Tech.
Han, Andong Qilu Univ. of Tech.
Du, Mingjun Qilu Univ. of Tech. (Shandong Acad. of Sci.)

▶ SunB02-4 11:10–11:30
*Distributed Algorithm for Solving Sylvester Matrix Equation via Iterative Learning Control*
Liang, Cong Henan Normal Univ.
Huo, Xuanmin State Grid Henan Electric Power Company Xinxiang Power Supply Company
Xu, Shizhou Henan Normal Univ.
Wang, Lei Henan Normal Univ.
Li, Juntao Henan Normal Univ.

▶ SunB02-5 11:30–11:50
*Average Bipartite Consensus Problems over Directed Signed Networks Subject to Saturation Constraints*
Yan, Zhiguo Qilu Univ. of Tech.
Chen, Baicheng Qilu Univ. of Tech.
Du, Mingjun Qilu Univ. of Tech. (Shandong Acad. of Sci.)
Lv, Hui Qilu Univ. of Tech. (Shandong Acad. of Sci.)

▶ SunB02-6 11:50–12:10
*A Distributed Patrol Algorithm for Multi-robot Systems Based on Discrete-time Consensus Theory*
Zhang, Pengchao Lanzhou Jiaotong Univ.
Li, Zonggang Lanzhou Jiaotong Univ.

## SunB03 10:10–12:10 4th Conf. Hall
Invited Session: Advanced Motion Control Methods for Modern Mechatronics Systems

Chair: Wang, Junxiao Zhejiang Univ. of Techology
Co-Chair: Chen, Qiang Zhejiang Univ. of Tech.

▶ SunB03-1 10:10–10:30
*Extended RVR Based Degradation Modeling for RUL Prediction of DC-Link Capacitors in High-Speed Trains*
Wang, Xiuli Zhejiang Univ. of Tech.
Li, Zhongxin Zhejiang Univ. of Tech.
Li, Yang Shanghai Univ.

▶ SunB03-2 10:30–10:50
*High Precision Position Control of Magnetic Levitation Ball System Based on Generalized Disturbance Estimation*
Lu, Qinkun Zhejiang Univ. of Tech.
Wang, Junxiao Zhejiang Univ. of Techology

▶ SunB03-3 10:50–11:10
*A Novel Predefined - Time Control Strategy for Attitude Stabilization of Rigid Spacecraft*
Xie, Shuzong College of Information Engineering, Zhejiang Univ. of Tech.
Yang, Qinmin Zhejiang Univ.
Chen, Qiang Zhejiang Univ. of Tech.

▶ SunB03-4 11:10–11:30
*Fuzzy Adaptive Nonsingular Predefined-Time Attitude Tracking Control of Quadrotor UAVs*
Tao, Meiling Anhui Polytechnic Univ.
Chen, Qiang Zhejiang Univ. of Tech.

▶ SunB03-5 11:30–11:50
*Position Sensorless Control of Permanent Magnet Synchronous Motor at Standstill and Low Speed*
Hu, Kailin Zhejiang Univ. of Tech.

Wang, Junxiao — Zhejiang Univ. of Techology

▶ SunB03-6 11:50–12:10
*Spatial Adaptive Iterative Learning Control for Nonparametric Uncertain Systems*
Su, Yang — Zhejiang Univ. of Tech.
Shi, Huihui — Zhejiang Univ. of Tech.
Chen, Qiang — Zhejiang Univ. of Tech.
Zhang, Zhihao — Zhejiang Univ. of Tech.

**SunB04** 10:10–12:10 5th Conf. Hall
Invited Session: Intelligent Cooperative Control for Multiagent Systems
Chair: Liang, Hongjing — Univ. of Electronic Sci. & Tech. of China
Co-Chair: Pan, Yingnan — Bohai Univ.

▶ SunB04-1 10:10–10:30
*Observer-based Data-driven Sliding Mode Control for A Discrete-time Nonlinear Multiagent Systems*
Yin, Caiyun — Guangdong Univ. of Tech.
Lin, Guohuai — Guangdong Univ. of Tech.
Chen, Guangdeng — Guangdong Univ. of Tech.
Ma, Hui — Guangdong Univ. of Tech.
Li, Hongyi — Guangdong Univ. of Tech.

▶ SunB04-2 10:30–10:50
*Event-Triggered Optimal Tracking Control for Multiplayer Non-Zero-Sum Games of Nonlinear Systems via Concurrent Learning*
Qin, Yi — Bohai Univ.
Wang, Lijie — Qingdao Univ.

▶ SunB04-3 10:50–11:10
*Manufacturing Big Data Modeling Algorithm Based on GM (1,1)-LSTM and Its Application in Sales Forecasting*
Long, Yinren — Guangdong Univ. of Tech.
Xiao, Yi — Guangdong Univ. of Tech.
Ren, Hongru — Guangdong Univ. of Tech.
Lu, Renquan — Guangdong Univ. of Tech.

▶ SunB04-4 11:10–11:30
*A Parameter Optimized Variational Mode Decomposition Method for Harmonic and Inter-harmonic Detection*
Xi, Xinze — N/A
Sun, Pengqi — Kunming Univ. of Sci. & Tech.
Xing, Chao — Electric Power Research Inst.
Li, Shengnan — Electric Power Research Inst.
Tian, Xincui — Kunming Univ. of Sci. & Tech.

▶ SunB04-5 11:30–11:50
*Backstepping Sliding Mode Control of Dual-motor Servo System Based on Improved Double Power Reaching Law*
Xu, Sha Man — Anhui Polytechnic Univ.
Tao, Liang — Anhui Polytechnic Univ.
Tao, Meiling — Zhejiang Univ. of Tech.
Xu, Binzi — Anhui Polytechnic Univ.
Deng, Xiongfeng — Anhui Polytechnic Univ.
Shi, Linlin — Zhejiang Univ. of Tech.

▶ SunB04-6 11:50–12:10
*Capsule Endoscopes Actuated with Permanent Magnet:A Model-Free Adaptive Control Approach*
Li, Yijia — Zhejiang Univ. of Tech.
Chen, Jiashu — Zhejiang Univ.
Chen, Peng — Zhejiang Univ. of Tech.
Ou, Xianhua — Zhejiang Univ. of Tech.
He, Xiongxiong — Zhejiang Univ. of Tech.

**SunB05** 10:10–12:10 6th Conf. Hall
Invited Session: Data-driven Based Complex Network Learning and Security Analysis
Chair: Zhang, Guangchen — North Minzu Univ.
Co-Chair: He, Shuping — Anhui Univ.

▶ SunB05-1 10:10–10:30
*A Novel Data-Driven Fault-Tolerant Control Method Based on Convex Optimization*
Wang, Siqing — Northwestern Polytechnical Univ.
Fan, Quan-Yong — Northwestern Polytechnical Univ.
Li, Jiaxuan — Northwestern Polytechnical Univ.
Zhang, Naizong — Northwestern Polytechnical Univ.

▶ SunB05-2 10:30–10:50
*Distributed Pneumatic Physiotherapy Robot for Human Acupoints*
Wan, Xiao — Wuhan Inst. of Tech.
Huang, Zixin — Wuhan Inst. of Tech.
Li, Yun — Hubei Provincial Hospital of Traditional Chinese Medicine
Wang, Wei — Zhongnan Univ. of Economics & Law
Yang, Zhixuan — Wuhan Inst. of Tech.
Wang, Liheng — Wuhan Inst. of Tech.

▶ SunB05-3 10:50–11:10
*Secure Control for the Discrete-time CPSs under DoS Attacks via A Switching Strategy*
Zhang, Ruifeng — Shandong Univ.
Li, Guitong — Shandong Univ.
Yang, Rongni — Shandong Univ.

▶ SunB05-4 11:10–11:30
*Iterative Learning Control for 2-D Discrete Systems in Frequency Domain*
Wan, Kai — Huizhou Univ.
Xu, Qing-Yuan — Guangdong Polytechnic Normal Univ.

▶ SunB05-5 11:30–11:50
*Speed and Heading Control of An Unmanned Surface Vehicle Using Deep Reinforcement Learning*
Wu, Ting — Jiangsu Univ. of Sci. & Tech.
Ye, Hui — Jiangsu Univ. of Sci. & Tech.
Xiang, Zhengrong — Nanjing Univ. of Sci. & Tech.
Yang, Xiao-Fei — Jiangsu Univ. of Sci. & Tech.

▶ SunB05-6 11:50–12:10
*Dynamic Route Planning Method Based on Deep Reinforcement Learning and Velocity Obstacle*
Lou, Mengmeng — Jiangsu Univ. of Sci. & Tech.
Yang, Xiao-Fei — Jiangsu Univ. of Sci. & Tech.
Xiang, Zhengrong — Nanjing Univ. of Sci. & Tech.
Wang, Qi — Jiangsu Univ. of Sci. & Tech.
Hu, Jiabao — Jiangsu Univ. of Sci. & Tech.

**SunB06** 10:10–12:10 Yuetang Conf. Hall
Regular Session: Active Disturbance Rejection Control and Applications
Chair: Pang, Zhonghua — North China Univ. of Tech.
Co-Chair: Ai, Wei — South China Univ. of Tech.

▶ SunB06-1 10:10–10:30
*Cascaded Generalized Extended State Observer-Based Control for Servo Systems with Matched and Mismatched Disturbances*
Jiang, Fuxi — Key Laboratory of Image Processing & Intelligent Control, School of Artificial Intelligence & Automation, Huazhong Univ. of Sci. & Tech.
Ye, Jie — Huazhong Univ. of Sci. & Tech.
Cheng, Shanmei — Key Laboratory of Image Processing & Intelligent Control, School of Artificial Intelligence & Automation, Huazhong Univ. of Sci. & Tech.

▶ SunB06-2 10:30–10:50
*Disturbance Rejection Based Adaptive Fast Terminal Sliding Mode Control for Ship Course Control*
Qin, Huayang — Nankai Univ.
Zheng, Chen — Beijing Inst. of Astronautical Sys. Engineering
Tan, Panlong — Nankai Univ.
Sun, Mingwei — Nankai Univ.
Chen, Zengqiang — Nankai Univ.
Sun, Qinglin — Nankai Univ.

▶ SunB06-3 10:50–11:10
*Changed Extended State Observer Based Position Control for Autonomous Underwater Vehicle*
Song, Wanping — Nankai Univ.
Zheng, Chen — Beijing Inst. of Astronautical Sys. Engineering
Chen, Zengqiang — Nankai Univ.
Sun, Mingwei — Nankai Univ.
Sun, Qinglin — Nankai Univ.

▶ SunB06-4 11:10–11:30
*Fixed-time Nonsingular Terminal Sliding Mode Control for Vehicle Platoon with Disturbance Observer*
Wang, Yan-Bo — Jiangnan Univ.
Li, Yu-Ling — Jiangnan Univ.
Liu, Cheng-Lin — Jiangnan Univ.

▶ SunB06-5 11:30–11:50
*ADRC with Built-in RLC Control Scheme for Uncertain Systems with Periodic Reference Input*
Li, Xiangyang — South China Uni. of Tech

Huang, Jian — Kunming Shipborne Equipment Research & Test Center
Tian, Senping — South China Univ. of Tech.
Ai, Wei — South China Univ. of Tech.

▶ SunB06-6 11:50–12:10
*Speed Tracking Control of PMSM Using Adaptive Extended Harmonic State Observer*
Wang, Xianyu — North China Univ. of Tech.
Pang, Zhonghua — North China Univ. of Tech.
Guo, Haibin — Beijing Inst. of Tech.
Gao, Shengnan — Dalian Maritime Univ.

**SunB07** 10:10–12:10 Hongqi Conf. Hall
Invited Session: Data-driven Intelligent Control and Public Security of Traffic Network System

Chair: Ji, Honghai — North China Univ. of Tech.
Co-Chair: Liu, Shida — Beijing Jiaotong Univ.

▶ SunB07-1 10:10–10:30
*Adaptive Feedforward Feedback Iterative Learning Control Method and Its Application to Autonomous Bus*
Liu, Shida — Beijing Jiaotong Univ.
Huang, Wei — North China Univ. of Tech.
Ji, Honghai — North China Univ. of Tech.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.

▶ SunB07-2 10:30–10:50
*Parameter Optimization Design of MFAC Based on Reinforcement Learning*
Liu, Shida — Beijing Jiaotong Univ.
Jia, Xiongbo — North China Univ. of Tech.
Ji, Honghai — North China Univ. of Tech.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.

▶ SunB07-3 10:50–11:10
*Interpretable Diagnosis of Glaucoma Based on Attention Mechanism and Embedded Class Activation Map*
Liu, Bao — Xi'an Univ. of Sci. & Tech.
Li, Shuqi — College of Electrical & Control Engineering
He, Ruilong — Xi 'an Univ. of Sci. & Tech.
Zhao, Yu-Ge — College of Electrical & Control Engineering

▶ SunB07-4 11:10–11:30
*Global-Local Attention Mechanism Based Small Object Detection*
Liu, Bao — Xi'an Univ. of Sci. & Tech.
Huang, Jinlei — Xi'an Univ. of Sci. & Tech.

▶ SunB07-5 11:30–11:50
*A Modified Data-driven Distributed Information-Weighted Kalman Consensus Filtering with Switching Topology and Packet Loss*
Ji, Honghai — North China Univ. of Tech.
Wu, Yuxin — North China Univ.of Tech.
Liu, Shida — Beijing Jiaotong Univ.
Wang, Li — North China Univ. of Tech.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.
Xiong, Shuangshuang — Beijing Information Sci. & Tech. Universtiy

▶ SunB07-6 11:50–12:10
*Deep Knowledge Tracing Model with An Evolved Transformer Structure*
Li, Zhijun — North China Univ. of Tech.
Xue, Zixiao — North China Univ. of Tech.
Liu, Chen — North China Univ. of Tech.
Feng, Yanzhang — Beijing AIKANG Medical

Poster Session SunB08
May 14, 10:10–12:10
6th Conf. Hall

Chair: Wang, Xianghua — Shandong Univ. of Sci. & Tech.
Co-Chair: Hui, Yu — Beihang Univ. (BUAA)

▷ SunB08-01
*Global Self-optimizing Control of A Solid Oxide Fuel Cell*
Fu, Shengdong — Zhejiang Univ.
Ye, Lingjian — Huzhou Univ.

▷ SunB08-02
*Prediction of Aeration Quantity of Biochemical Tank Based on Ensemble Learning Algorithm*
Tao, Yuxin — North China Univ. of Tech.
Yang, Bin — Beijing KingTrol Data Tech. Co., Ltd
Pang, Zhonghua — North China Univ. of Tech.
Fan, Lanzhi — North China Univ. of Tech.

▷ SunB08-03
*PH Nonlinear Process Control Method Based on Lyapunov Stability Theory*
Chen, Juan — Beijing Univ. of Chemical Tech.
Ou, Baoming — Beijing Univ. of Chemical Tech.

▷ SunB08-04
*Model Predictive Control of Permanent Magnet Synchronous Motor Based on Recursive Least Square Parameter Identification*
Yang, Dandan — North China Univ. of Tech.
Yang, Bin — Beijing KingTrol Data Tech. Co., Ltd
Pang, Zhonghua — North China Univ. of Tech.
Zheng, Changbing — Henan Univ. of Urban Construction

▷ SunB08-05
*Group Consensus for Second-order Linear Multi-agent Systems with Intermittent Control*
Wu, Zhaoqin — Tianjin Univ. of Tech. & Educatuon
Li, Weixun — Tianjin Univ. of Tech. & Education
Du, Xiangyang — Tianjin Univ. of Tech. & Education
Xiao, Jingyu — Tianjin Uinversity of Tech. & Education
Zhang, Limin — Zhongyuan Univ. of Tech.

▷ SunB08-06
*Research on UAV Formation Obstacle Avoidance Based on Consistency Control*
Liu, Ruoyang — Zhongyuan Univ. of Tech.
Qu, Boyang — Zhongyuan Univ. of Tech.
Wei, Tao — Henan Univ. of Engineering
Zhang, Limin — Zhongyuan Univ. of Tech.
Yan, Li — Zhongyuan Univ. of Tech.
Chai, Xuzhao — Zhongyuan Univ. of Tech.

▷ SunB08-07
*Non-parametric Model Adaptive Control Based on Gaussian Process Regression*
Lin, Chenxu — Yunnan Univ.
Li, Mingyao — Yunnan Univ.
Zhu, Juanping — Yunnan Univ.

▷ SunB08-08
*Model-free Adaptive Tension Control of New Energy Vehicle Winding Machine*
Mu, Chenglin — Qingdao Univ. of Sci. & Tech.
Yao, Wen-Long — Qingdao Univ. of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.
Yan, Chengyang — Qingdao Univ. of Sci. & Tech.
Liu, Wangwang — Qingdao Univ. of Sci. & Tech.

▷ SunB08-09
*Collaborative Multi-vehicle Trajectory Tracking Control Based on Model-free Adaptive Iterative Learning under Data Loss*
Zhang, Wen Yi — Shandong Univ. of Sci. & Tech.
Wang, Xianghua — Shandong Univ. of Sci. & Tech.

▷ SunB08-10
*Data-driven Temperature Control of Internal Mixers*
Zhou, Zhihao — Qingdao Univ. of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.

▷ SunB08-11
*Active Disturbance Rejection Control of Diesel Engine Air System Based on Online Optimization of Observation Bandwidth and Control Gain*
Liu, Xingyi — Weichai Power
Ren, Yuru — Tianjin Univ.

▷ SunB08-12
*Design of Neutral Mixed Delay Multi Stochastic Systems with Event Triggering*
Yi, Shuai — Qilu Univ. of Tech.
Lu, Hong Qian — Qilu Univ. of Tech.
Wang, Renren — Qilu Univ. of Tech.,Jinan
Feng, Xin — Qilu Univ. of Tech.

▷ SunB08-13
*Indirect Prediction Method for Remaining Useful Life of Lithium-ion Battery Based on Gray Wolf Optimized Extreme Learning Machine*
Ding, Miaomiao — Shandong Univ. of Sci. & Tech.
Wang, Xianghua — Shandong Univ. of Sci. & Tech.

▷ SunB08-14
*Insulator Defect Detection Based on Improved YOLOv5 Algorithm*
Wang, Yongheng — Hubei Minzu Univ.
Li, Qin — Hubei Minzu Univ.

Liu, Yachong — Hubei Minzu Univ.
Wang, Chao — Hubei Minzu Univ.

▷ SunB08-15
*A Remaining Useful Life Prediction Method for Rolling Bearing Based on Multi-channel Fusion Hierarchical Vision Transformer*
Li, Zhixuan — Southwest Jiaotong Univ.
Zhang, Kai — Southwest Jiaotong Univ.
Lai, Xuwei — Southwest Jiaotong Univ.
Zheng, Qing — Southwest Jiaotong Univ.
Ding, Guofu — Southwest Jiaotong Univ.

▷ SunB08-16
*A Graph Convolutional Shrinkage Network-based Fault Diagnosis Method for Industrial Process*
Xu, Yuan — Beijing Univ. of Chemical Tech.
Zou, Xun — BUCT
Ke, Wei — Macao Polytechnic Inst.
Zhu, Qunxiong — Beijing Univ. of Chemical Tech.
He, Yan-Lin — Beijing Univ. of Chemical Tech.
Zhang, Ming-Qing — Beijing Univ. of Chemical Tech.
Zhang, Yang — Beijing Univ. of Chemical Tech.

▷ SunB08-17
*Intelligent Fault Diagnosis for Unknown Faults of Rotating Machinery Based on the CNN and the DCGAN*
Yu, Gongye — Beijing Univ. of Chemical Tech.
You, Yapeng — Beijing Univ. of Chemical Tech.
Ma, Bo — Beijing Univ. of Chemical Tech., Diagnosis & Self-Recovery Engineering Research Center
Han, Yongming — Beijing Univ. of Chemical Tech.

▷ SunB08-18
*A Variational Bayesian Dictionary Learning for Process Monitoring*
Zhang, Qi — Zhejiang Univ.
Xie, Lei — Zhejiang Univ.
Xu, Weihua — Zhejiang Univ.
Su, Hongye — Zhejiang Univ., China

▷ SunB08-19
*Fault Diagnosis of Bearings Based on An Improved Lightweight Convolution Neural Network*
Li, Qiankun — Beijing Univ. of Chemical Tech.
Cui, Mingliang — Beijing Univ. of Chemical Tech.
Wang, Youqing — Beijing Univ. of Chemical Tech.

▷ SunB08-20
*The Internal Mixers Temperature Iterative Learning Control*
Zhou, Zhihao — Qingdao Univ. of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.

▷ SunB08-21
*ILC for Discrete Linear Switched Systems with Varying Trial Lengths*
Kong, Ying — Sun Yat-sen Univ.
Li, Xiao-Dong — Sun Yat-sen Univ.

▷ SunB08-22
*Error Tracking Learning Control for Nonlinearly Parameterized Systems with Input Deadzone*
Fan, Longwei — Zhejiang Univ. of Water Resources & Electric Power
Yan, Qiuzhen — Zhejiang Univ. of Water Resources & Electric Power
Chen, Qiang — Zhejiang Univ. of Tech.

▷ SunB08-23
*Terminal Iterative Learning Control for Nonaffine Nonlinear Systems with Nonrepetitive Uncertainties*
Hui, Yu — Beihang Univ. (BUAA)
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.

▷ SunB08-24
*Optimized Statistical Model for Complex Chemical Processes Monitoring*
Zhang, Jian — Datang East China Electric Power Test & Research Inst.
Qu, Xiaohe — Datang East China Electric Power Test & Research Inst.
Lei, Zhiwei — Datang East China Electric Power Test & Research Inst.
Zhang, Haifeng — Anhui Univ.
Zhong, Kai — Anhui Univerisity

▷ SunB08-25
*Dual Quantized Iterative Learning Control over Random Fading Channel*
Liu, Taojun — Renmin Univ. of China
Shen, Dong — Renmin Univ. of China

▷ SunB08-26
*Iterative Learning Control Based on First-order Accelerated Gradient Method*
Qian, Jiaxi — Jilin Univ.
Jiang, Hao — Renmin Univ. of China
Shen, Dong — Renmin Univ. of China

▷ SunB08-27
*Improved Mixed Discrete Particle Swarms Based Multi-task Assignment for UAVs*
Jia, Zhenshuai — Northwestern Polytechnical Univ.
Xiao, Bing — Harbin Inst. of Tech.
Qian, Hanyu — Northwestern Polytechnical Univ.

▷ SunB08-28
*Optimal Dispatch of An Integrated Energy System Based on Deep Reinforcement Learning Considering New Energy Uncertainty*
Zhou, Yang — Shanghai Univ.
Jia, Li — Shanghai Univ.
Zhao, Yilin — Shanghai Univ.
Zhan, Zhiyong — Shanghai Univ.

▷ SunB08-29
*A Salp Swarm Algorithm-based Model-free Adaptive Control Method and Its Application in Transformer Constant Temperature System*
Li, Zhen — North China Univ. of Tech.
Jin, Lei — TBEA Tianjin Transformers CO., Ltd
Ma, Guangjuan — TBEA Tianjin Transformers CO., Ltd
Liu, Shida — Beijing Jiaotong Univ.

▷ SunB08-30
*An AGV Task Scheduling Method Based on Multi-Agent Reinforcement Learning*
Zhao, Yuxin — Zhejiang Univ.
Zhu, Ke — Zhejiang Univ.
Song, Xueming — Zhejiang Univ.
Zhang, Jianming — Institution of Cyber-Sys. & Control

▷ SunB08-31
*Prediction of HVAC Energy Consumption Using PSO Optimized Deep Neural Network*
Du, Linhui — Beijing Univ. of Tech.
Li, Xiaoli — Beijing Univ. of Tech.
Wang, Kang — Beijing Univ. of Tech.
Li, Yang — Communication Univ. of China

▷ SunB08-32
*Contrastive Representation Learning for Time Series via Compound Consistency and Hierarchical Contrasting*
Zheng, Teng — DongHua Univ.
Cao, Guanghao — Donghua Univ.
Chen, Lei — The Engineering Research Center of Digitized Textile & Apparel Tech., Ministry of Education
Hao, Kuangrong — Donghua Univ.

▷ SunB08-33
*Feature Extraction Method of Sludge Bulking Using Multi-KPCA*
Yang, Hongyan — Beijing Inst. of Tech.
Ding, Yingfan — Beijing Univ. of Tech.
Han, Honggui — Beijing Univ. of Tech.

▷ SunB08-34
*Long Short-term Memory Modeling Method with Monotonicity Analysis as Constraints Base on Spearman Coefficient*
Zhan, Zhiyong — Shanghai Univ.
Zhou, Yang — Shanghai Univ.
Jia, Li — Shanghai Univ.
Zhao, Yilin — Shanghai Univ.

▷ SunB08-35
*Establishment and Analysis of Carbon Sequestration Model by Using Grey Correlation Analysis Method*
Yu, Xiyu — Qingdao Univ. of Sci. & Tech.
Li, Junhao — Qingdao Univ. of Sci. & Tech.
Li, Xin — Qingdao Univ. of Sci. & Tech.
Zhang, Ruikun — Qingdao Univ. of Sci. & Tech.

▷ SunB08-36
*Novel Virtual Sample Generation Using Gibbs Sampling Integrated with GRNN for Handling Small Data in Soft Sensing*

Zhu, Qunxiong Beijing Univ. of Chemical Tech.
Zhao, Qiqian Beijing Univ. of Chemical Tech.
Xu, Yuan Beijing Univ. of Chemical Tech.
He, Yan-Lin Beijing Univ. of Chemical Tech.

▷ SunB08-37
*Cultivation of Students' Language Production Ability by Blend Learning*
Wu, Liping Shenyang Aerospace Univ.
Wang, Yan Shenyang Aerospace Univ.

▷ SunB08-38
*An RGB-D Semantic Map Building and Global Localization Method*
Fu, Tianqi Southwest Jiaotong Univ.
Tian, Facun Southwest Jiaotong Univ.
Ma, Lei Southwest Jiaotong Univ.
Sun, Yongkui Southwest Jiaotong Univ.

▷ SunB08-39
*A Data-Driven Residual Life Prediction Method for Rolling Bearings*
Li, Shangrui Univ. of Electronic Sci. & Tech. of China
Li, Meng Univ. of Electronic Sci. & Tech. of China
Liu, Zhilong Nuclear Power Inst. of China

▷ SunB08-40
*Analysis and Prediction of Glass Product Composition by Using Control Variable Method*
Li, Xin Qingdao Univ. of Sci. & Tech.
Li, Junhao Qingdao Univ. of Sci. & Tech.
Yu, Xiyu Qingdao Univ. of Sci. & Tech.
Zhang, Ruikun Qingdao Univ. of Sci. & Tech.

▷ SunB08-41
*YOLO-Log: A Light-weight Object Detector for Logistics Safe Driving*
Ye, Linhua Chinese Acad. of Sci.
Chen, Songhang Chinese Acad. of Sci.
Lai, Zhiqing Chinese Acad. of Sci.

▷ SunB08-42
*Substation Helmet Detection Based on Improved YOLOX-S Algorithm*
Tong, Xiaodong Sichuan Univ. of Sci. & Engineering
Li, Zhaofei Sichuan Univ. of Sci. & Engineering

▷ SunB08-43
*Chiller Load Prediction Based on CEEMDAN-BiLSTM-Attention Model for Sufficient Data and Small Sample Data Cases*
Zhang, Xu Wuhan Univ. of Tech.
Li, Xiangshun Huazhong Univ. of Sci. & Tech.

▷ SunB08-44
*An Optimization Algorithm with Hausdorff-like Derivative in GRU for SOC Estimation of Lithium-ion Battery*
Jia, Kai Liaoning Univ.
Gao, Zhe Liaoning Univ.
Li, Mingdi Liaoning Univ.
Chai, Haoyu Liaoning Univ.

▷ SunB08-45
*Event-based Object Detection Using Graph Neural Networks*
Sun, Daobo Univ. of Sci. & Tech. of China
Ji, Haibo Univ. of Sci. & Tech. of China

▷ SunB08-46
*Fuzzy Adaptive Sliding Mode Attitude Control of Quaternion Model for Aircraft Based on Back-stepping Method*
Zhuang, Huixuan Nankai Univ.
Zhang, Xuefeng Northeastern Univ.
Sun, Qinglin Nankai Univ.
Chen, Zengqiang Nankai Univ.

▷ SunB08-47
*Research on Dissolved Oxygen Fuzzy Controller in Sewage Treatment Process*
Lv, Zhiguo Shaoyang Univ.

▷ SunB08-48
*A LSTM Model with Attention Mechanism for Soft Sensor of SO2 Conversion Rate in Flue Gas Acid Production Process*
Zhang, Yongzheng Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.
Wang, Kang Beijing Univ. of Tech.
Li, Yang Communication Univ. of China

▷ SunB08-49
*Optimized SAC Deep Reinforcement Learning Control for Electro-hydraulic Servo Systems*
Yu, Zhen Xiamen Univ.
Hu, Huiteng Xiamen Univ.
Jiang, Mengman Xiamen Univ.
Tang, Yifan Xiamen Univ.
Qian, Rongrong AECC Commercial Aircraft Engine Company LTD
Liu, Lijun Xiamen Univ.

▷ SunB08-50
*Reinforcement Q-Learning and Non-Zero-Sum Games Optimal Tracking Control for Discrete-Time Linear Multi-Input Systems*
Zhao, Jin-Gang Weifang Univ.

▷ SunB08-51
*Transfer Reinforcement Learning of Robotic Grasping Training Using Neural Networks with Lateral Connections*
Wang, Wenxiao Xidian Univ.
Wang, Xiaojuan Xidian Univ.
Li, Renqiang Xidian Univ.
Jiang, Haosheng Xidian Univ.
Liu, Ding Xidian Univ.
Ping, Xubin Xidian Univ.

▷ SunB08-52
*Composite Multi-Vector Model Predictive Control for Permanent Magnet Synchronous Motor*
Gao, Lin AnHui Univ.
Pan, Tian-Hong Anhui Univ.

▷ SunB08-53
*Non-cooperative Target Localization and Grasp Based on Visual Closed Loop*
Tian, Miaomiao China Acad. of Space Tech.
Yu, Jiyang China Acad. of Space Tech.

▷ SunB08-54
*Multi-objective Optimization Control of Flotation Process Based on Policy Iteration*
Xu, Hang Beijing Univ. of Tech., Beijing 100124, China
Wang, Kang Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.

▷ SunB08-55
*Generalized Predictive Control of Converter Inlet Temperature in the Process of Acid Production with Flue Gas*
Liu, Minghua Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.
Wang, Kang Beijing Univ. of Tech.

▷ SunB08-56
*Soft Sensor Based on JITL-SVR for Ultrasonic Chinese Medicine Extraction*
Chen, Juan Beijing Univ. of Chemical Tech.
Xue, Zepeng Beijing Univ. of Chemical Tech.

▷ SunB08-57
*Model Free Adaptive Control for Air-Conditioning System in Office Buildings Based on Improved NSGA-II Algorithm*
Chen, Pan Univ. of Sci. & Tech. Beijing
Gao, Jingjing Univ. of Sci. & Tech. Beijing
Yang, Xu Univ. of Sci. & Tech. Beijing
Zhang, Tao Univ. of Sci. & Tech. Beijing

▷ SunB08-58
*Safe Sliding Mode Control Design with Its Application to Mobile Robot Path Tracking*
Zhao, Gan Beijing Jiaotong Univ.
Liu, Xiangbin Beijing Jiaotong Univ.
Lu, Shan Shenzhen Polytechnic
Lou, Zhijiang Shenzhen Polytechnic

▷ SunB08-59
*Two-stage Anaerobic Digestion Process Optimal Control Study Based on Extremum-seeking Control and Self-optimizing Control*
Li, Hongxuan Nanjing Univ. of Sci. & Tech.
Wang, Haoping Nanjing Univ. of Sci. & Tech.
Tian, Yang Nanjing Univ. of Sci. & Tech.

▷ SunB08-60
*Multi-attribute Decision Web Service Selection Based on Optimal Ant Colony Algorithm*
Jia, Zhichun Bohai Univ.

▷ SunB08-61
*Research on Virtual Widening of Power Information Acquisition Channel Based on LoRa and Data Compression*

Jiang, Jing — Shandong Foreign Trade Vocational College
Wang, Mingjia — Qingdao Univ. of Sci. & Tech.

▷ SunB08-62
*Modeling and Estimation of Train Traction Characteristics under Emergency Traction Considering On-board Energy Storage Devices*
Wang, Jiaxin — Southwest Jiaotong Univ.
Hu, Yuanjiang — Southwest Jiaotong Univ.
Huang, Deqing — Southwest Jiaotong Univ.
Zhang, Yusha — Southwest Jiaotong Univ.
Fang, Jiaxin — Southwest Jiaotong Univ.

▷ SunB08-63
*Reinforcement Learning Based Data-driven Optimal Control Strategy for Systems with Disturbance*
Fan, Zhong-Xin — Southeast Univ.
Li, Shihua — Southeast Univ., China
Liu, Rongjie — Florida State Univ.

▷ SunB08-64
*Fault Estimation for Nonlinear Systems with Time Delay Based on Iterative Learning Scheme*
Xu, Shuiqing — Chongqing Univ.
Dai, Haosong — Hefei Univ. of Tech.
Huang, Darong — Anhui Univ.
Tao, Songbing — Chongqing Univ.
Hu, Chong — Chongqing Micro Standard Tech. Co. Ltd

▷ SunB08-65
*Dynamical Linearization Based PLS Modeling and Model-free Adaptive Control*
Lin, Mingming — Qingdao Universtiy of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.
Lin, Na — Qingdao Univ. of Sci. & Tech.
Liu, Zhiqing — Qingdao Univ. of Sci. & Tech.

▷ SunB08-66
*Trajectory Tracking by An Adaptive Controller for High-Speed Train Based on Neural Network and Sliding Mode Control*
Zhou, Cen — Southwest Jiaotong Univ.
Li, Zhi — Southwest Jiaotong Univ.
Wang, Qingyuan — Southwest Jiaotong Univ.
Sun, Pengfei — Southwest Jiaotong Univ.
Guo, Youxing — Southwest Jiaotong Univ.

## SunC01 13:30–15:30 2nd Conf. Hall
Invited Session: In-depth Exploration and Learning of Industrial Data I

Chair: Liu, Yi — Zhejiang Univ. of Tech.
Co-Chair: Yao, Yuan — National Tsing Hua Univ.

▶ SunC01-1 13:30–13:50
*Dynamic Graph Learning Soft Sensor in Process Industry*
Jia, Mingwei — Zhejiang Univ. of Tech.
Xu, Danya — Northeastern Univ.
Yang, Tao — Northeastern Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Yi — Zhejiang Univ. of Tech.

▶ SunC01-2 13:50–14:10
*Short-term Load Forecasting of CCHP System Based on PSO-LSTM*
Zhu, Yu-Rong — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Sun, Yuqian — Shanghai Univ.
Wu, Jia Jun — Shanghai Univ.
Zhao, Guoqiang — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Jianlong — Shanghai Minghua Power Tech. Co., Ltd
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

▶ SunC01-3 14:10–14:30
*Operation Optimization of CCHP System Based on Improved PSO Algorithm*
Yu, Guo-Yuan — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Deng, Dai-Shihao — Shanghai Univ.
Wu, Jia Jun — Shanghai Univ.
Zhao, Guoqiang — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Jianlong — Shanghai Minghua Power Tech. Co., Ltd
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

▶ SunC01-4 14:30–14:50
*Features Masked Auto-Encoder-Based Anomaly Detection in Process Industry*
Hu, Junhao — Zhejiang Univ. of Tech.
Jia, Mingwei — Zhejiang Univ. of Tech.
Yang, Qinmin — Zhejiang Univ.
Liu, Yi — Zhejiang Univ. of Tech.

▶ SunC01-5 14:50–15:10
*Orthogonal Feature Separation Autoencoder for Process Monitoring*
Yang, Chao — Northeastern Univ.
Zhang, Congcong — Northeastern Univ.
Liu, Qiang — Northeastern Univiersity

▶ SunC01-6 15:10–15:30
*Gated Recurrent Unit Neural Networks for Wind Power Forecasting Based on Surrogate-Assisted Evolutionary Neural Architecture Search*
Zhang, Kehao — Faculty of Information Engineering & Automation, Kunming Univ. of Sci. & Tech.
Jin, Huaiping — Kunming Univ. of Sci. & Tech.
Jin, Huaikang — Huaneng Renewables Co.,Ltd.Yunnan Branch
Wang, Bin — Kunming Univ. of Sci. & Tech.
Yu, Wangyang — Wuhan Maritime Communication Research Inst.

## SunC02 13:30–15:30 3rd Conf. Hall
Invited Session: Modeling, Optimization and Control of Data-driven Energy Internet Systems I

Chair: Gao, Zhe — Liaoning Univ.
Co-Chair: Li, Shengquan — Yangzhou Univ.

▶ SunC02-1 13:30–13:50
*Detecting False Data Injection Attacks Using Spatial-temporal Graph Neural Network*
Wei, Xingshen — NARI
Liu, Wei — State Grid Electric Power Research Inst.
Zhou, Jian — State Grid Electric Power Research Inst.
Zhou, Xiaoming — State Grid Liaoning Electric Power Supply Co
Zhang, Wenjie — State Grid Liaoning Electric Power Supply Co
Cao, Yongjian — Nanjing Nari Information Communication Tech.

▶ SunC02-2 13:50–14:10
*Active Disturbance Rejection Vibration Control Based on Delay Compensator for An All-clamped Plate with Inertial Actuator*
Zhang, Lujin — Yangzhou Univ.
Li, Juan — Southeast Univ.
Qiu, Ruikang — Yangzhou Univ.
Li, Shengquan — Yangzhou Univ.
Cao, Wei — Yangzhou Univ.

▶ SunC02-3 14:10–14:30
*Hidden Markov model based finite-time $H_\infty$ guaranteed cost control for singular discrete-time Markov jump delay systems*
Chen, Zhiwen — Jiangsu Univ. of Tech.
Li, Bo — Jiangsu Univ. of Tech.
Zhao, Junjie — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.
Du, Youwu — China Univ. of GeoSci.

▶ SunC02-4 14:30–14:50
*Two-dimensional Iterative Learning Model Predictive Control Based on Just-in-Time Learning Method for Batch Processes*
Zheng, Chuangkai — Yangzhou Univ.
Zhou, Liuming — Yangzhou Univ.
Li, Feng — Jiangsu Univ. of Tech.

▶ SunC02-5 14:50–15:10
*Optimal Control of Stochastic Power System Based on Braking Resistance*
Lin, Xue — Jiangsu Univ. of Tech.
Wang, Qi — Jiangsu Univ.
Luo, Yinsheng — Jiangsu Teachers Univ. of Tech.
Cai, Changchun — Hohai Univ.

▶ SunC02-6 15:10–15:30
*Tuning Method for Parameters in Fractional-Order PID Controllers Based on Neural Networks with Improved Borges Derivative*
Li, Mingdi — Liaoning Univ.
Gao, Zhe — Liaoning Univ.
Jia, Kai — Liaoning Univ.
Xiao, Shasha — Liaoning Univ.

**SunC03** 13:30–15:30 4th Conf. Hall
Invited Session: Intelligent Control of Nonlinear Networked Systems

Chair: Li, Yuan Xin — Liaoning Univ. of Tech.
Co-Chair: Che, Wei-Wei — Qingdao Univ.

► SunC03-1 13:30–13:50
*A Fault Diagnosis Method Based on Wavelet Denoising and 2DCNN under Background Noise*
Liu, Kexin — Hunan Univ.
Li, Zhe — Hunan Univ.
He, Wenbin — Hunan Univ.
Peng, Jia — State Grid Hunan Electric Power Company Limited
Wang, Xudong — Hunan Univ.
Wang, Yaonan — Hunan Univ.

► SunC03-2 13:50–14:10
*Tracking Control of High-Speed Trains Based on An Improved Disturbance Observer*
Zhang, Jian-Ping — East China Jiaotong Univ.
Deng, Lin-Bao — East China Jiao Tong Univ.
Xie, Chun-Hua — East China Jiaotong Univ.

► SunC03-3 14:10–14:30
*Model-Free Adaptive Control for SISO Nonlinear Systems under Sparse Sensor Attacks*
Chen, Yifan — Shenyang Aerospace Univ.
Liu, Dong — Shenyang Aerospace Univ.

► SunC03-4 14:30–14:50
*Finite-Time Adaptive Fuzzy Control for MIMO Nonlinear Multi-Agent Systems*
Sui, Shuai — Liaoning Univ. of Tech.

► SunC03-5 14:50–15:10
*Dynamic Observer-based Controllers for Fractional-order Linear Systems with Positive Real Uncertainty*
He, Li — Shenyang Aerospace Univ.
Liu, Shuo — Shenyang Aerospace Univ.

► SunC03-6 15:10–15:30
*Active Iterative Learning Control Based on Big Data*
Lin, Mingming — Qingdao Universtiy of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.
Lin, Na — Qingdao Univ. of Sci. & Tech.
Liu, Zhiqing — Qingdao Univ. of Sci. & Tech.

**SunC04** 13:30–15:30 5th Conf. Hall
Regular Session: Data-driven Modeling, Optimization and Scheduling

Chair: Zhang, Jianming — Institution of Cyber-Sys. & Control
Co-Chair: Han, Weixin — Northwestern Polytechnical Univ.

► SunC04-1 13:30–13:50
*Heterogeneous AGVs Scheduling in Hospital Using ALNS-based Metaheuristic Algorithm*
Song, Xueming — Zhejiang Univ.
Zhu, Ke — Zhejiang Univ.
Zhao, Yuxin — Zhejiang Univ.
Zhang, Jianming — Institution of Cyber-Sys. & Control

► SunC04-2 13:50–14:10
*Optimal Scheduling of Distribution Network Maintenance Personnel Based on the Northern Cthulhu Algorithm*
Liu, Chengwei — Hunan Univ. of Sci. & Tech.
Chen, Chao-Yang — Hunan Univ. of Sci. & Tech.
Chen, Zuguo — Hunan Univ. of Sci. & Tech.
Li, Pei — Hunan Univ. of Sci. & Tech.

► SunC04-3 14:10–14:30
*On Consistent Filter Design for Angle of Attack Estimation with Airspeed Rate Measurement*
Huang, Shuyan — AMSS, CAS
Xiang, Feiyu — Univ. of Chinese Acad. of Sci.
Xue, Wenchao — Chinese Acad. of Sci.
Fang, Hai-Tao — Chinese Acad. of Sci.

► SunC04-4 14:30–14:50
*A Data-driven Physical Mechanism Modeling Method for the Spin-Exchange Relaxation-Free Comagnetometer*
Li, Feng — Beijing Univ. of Aeronautics & Astronautics
Wang, Zhuo — Beijing Univ. of Aeronautics & Astronautics
Zhang, Min — Beijing Univ. of Aeronautics & Astronautics
Wang, Ruigang — Beijing Univ. of Aeronautics & Astronautics
Qin, Bodong — Beijing Univ. of Aeronautics & Astronautics
Chai, Yanchao — Beijing Univ. of Aeronautics & Astronautics

► SunC04-5 14:50–15:10
*Chiller System Modeling Using PSO Optimization Based NARX Approach*
Song, Zilong — Beijing Univ. of Tech.
Li, Xiaoli — Beijing Univ. of Tech.
Wang, Kang — Beijing Univ. of Tech.
Li, Yang — Communication Univ. of China

► SunC04-6 15:10–15:30
*Safety Predefined-Time Tracking Control of Second-Order Nonlinear Systems*
Xu, Yang — Soochow Univ.
Sun, Yuan — Soochow Univ.
Chen, Yiyang — Soochow Univ.
Tao, Hong-Feng — Jiangnan Univ.

**SunC05** 13:30–15:30 6th Conf. Hall
Invited Session: Adaptive Control for Nonlinear Mechanical System

Chair: Huang, Yingbo — Kunming Univ. of Sci. & Tech.
Co-Chair: Zhang, Menghua — Shandong Univ.

► SunC05-1 13:30–13:50
*Periodic SMC Method for 4-DOF Tower Crane Systems under Unknown Control Direction*
Zhang, Menghua — Shandong Univ.

► SunC05-2 13:50–14:10
*Prediction of Matte Grade in the Oxygen-rich Top Blown Smelting Based on WD-SSA-SVM Algorithm*
Li, Xincai — Kunming Univ. of Sci. & Tech.
Yang, Chunxi — Kunming Univ. of Sci. & Tech.
Zhang, Xiufeng — Yunnan International Joint Laboratory of Intelligent Control & Application of Advanced Equipment
Li, Gengen — Kunming Univ. of Sci. & Tech.

► SunC05-3 14:10–14:30
*GSC-YOLOv5: An Algorithm Based on Improved Attention Mechanism for Road Creak Detection*
Wang, Jianhao — Shandong Univ. of Sci. & Tech.
Gao, Xuehui — Shandong Univ. of Sci. & Tech.
Liu, Zhen — Shandong Univ. of Sci. & Tech.
Wan, Yu — Shandong Univ. of Sci. & Tech.

► SunC05-4 14:30–14:50
*Cogging Torque Compensation in PMSM with Spatial Repetitive Learning Control*
Li, Mingyu — Zhejiang Univ. of Tech.
Shi, Huihui — Zhejiang Univ. of Tech.
Chen, Qiang — Zhejiang Univ. of Tech.
Ji, Qianzhen — Zheiiang Univ. of Tech.

► SunC05-5 14:50–15:10
*PD Control with Gravity Compensation for 3-RPS Parallel Manipulator*
Lv, Zhiyuan — Ocean Univ. of China
Ning, Donghong — Ocean Univ. of China
Liu, Pengfei — Ocean Univ. of China
Liao, Peng — Ocean Univ. of China

► SunC05-6 15:10–15:30
*USDE-based Synchronization Control for Bilateral Teleoperation System Subject to Time-Varying Delay*
Bai, Zhiqiang — Kunming Univ. of Sci. & Tech.
Wang, Xian — Kunming Univ. of Sci. & Tech.
Hao, Duan — Kunming Univ. of Sci. & Tech.
Huang, Yingbo — Kunming Univ. of Sci. & Tech.

**SunC06** 13:30–15:30 Yuetang Conf. Hall
Invited Session: Networked Control System Simulation and Engineering

Chair: Guo, Shenghui — Suzhou Univ. of Sci. & Tech.
Co-Chair: Meng, Zhou — North China Univ. of Tech.

► SunC06-1 13:30–13:50
*Signal Reconstruction of Output Attacks on Autonomous Vehicles*
Chen, Li — Suzhou Univ. of Sci. & Tech.
Guo, Shenghui — Suzhou Univ. of Sci. & Tech.

► SunC06-2 13:50–14:10
*Minimal Detectable and Isolable Faults of Active Fault Diagnosis*
Xu, Feng — Tsinghua Univ.

► SunC06-3 14:10–14:30
*In-distribution Stability Analysis for Neural Markovian Jump Systems: A Delay-feedback Control Method*
Li, Xiaohang — Shanghai Univ. of Engineering Sci.

▶ SunC06-4 14:30–14:50
*Sludge Bulking Prediction Method for Sewage Treatment Plant Based on GWO-CPSO Algorithm*
Xue, Tong Lai — North China Univ. of Tech.
Gao, Yutao — North China Univ. of Tech.
Meng, Zhou — North China Univ. of Tech.
Han, Fei — Hebei Univ. of Sci. & Tech.
Liu, Chun — Hebei Univ. of Sci. & Tech.

▶ SunC06-5 14:50–15:10
*Research on Target Grab of Leg-arm Cooperative Robot Based on Vision*
Xia, Haichuang — NUAA
Zhang, Xiaoping — North China Univ. of Tech.

▶ SunC06-6 15:10–15:30
*A Review of Sound Source Localization Research in Three-Dimensional Space*
Yang, Fan — Beijing Univ. of Sci. & Tech.
Song, Ruizhuo — Univ. of Sci. & Tech. Beijing

**SunC07** 13:30–15:30 Hongqi Conf. Hall
Invited Session: Distributed Learning, Optimization and Control
Chair: Liu, Yang — Beihang Univ. (BUAA)
Co-Chair: Mo, Lipo — Beijing Tech. & Business Univ.

▶ SunC07-1 13:30–13:50
*Distributed Online Convex Optimization with Adaptive Event-triggered Scheme*
Suo, Wei — Beihang Univ.
Li, Wenling — Beihang Univ.

▶ SunC07-2 13:50–14:10
*Differential Dynamic Programming for Finite-Horizon Multi-Player Non-Zero-Sum Differential Games of Nonlinear Systems*
Zhang, Yuqi — Beijing Univ. of Posts & Telecommunications
Zhang, Bin — Beijing Univ. of Posts & Telecommunications (BUPT)

▶ SunC07-3 14:10–14:30
*Event-Triggered Adaptive Gain-Varying Finite-Time Consensus Tracking Control for Multi-Manipulator Systems*
Zhao, Lin — Qingdao Univ.

▶ SunC07-4 14:30–14:50
*Distributed Containment Control for Nonlinear HOFA-MASs*
Liu, Yang — Beihang Univ. (BUAA)
Zhang, Jiaming — Beihang Univ.

▶ SunC07-5 14:50–15:10
*LMS Algorithms Based on Fractional Order Gradient and Difference*
Mo, Lipo — Beijing Tech. & Business Univ.
Zhang, Haozhe — Beijing Tech. & Business Univ.

▶ SunC07-6 15:10–15:30
*Almost Sure Stability Analysis of Dual Switching Continuous-time Nonlinear System*
Mu, Qianqian — Guizhou Univ.
Long, Fei — Guizhou Univ.
Mo, Lipo — Beijing Tech. & Business Univ.

**SunD01** 15:40–17:40 2nd Conf. Hall
Invited Session: In-depth Exploration and Learning of Industrial Data II
Chair: Liu, Yi — Zhejiang Univ. of Tech.
Co-Chair: Yao, Yuan — National Tsing Hua Univ.

▶ SunD01-1 15:40–16:00
*An Adaptive Soft Sensor Method Based on Online Deep Evolving Fuzzy System for Industrial Process Data Streams*
Gao, Yu — Kunming Univ. of Sci. & Tech.
Jin, Huaiping — Kunming Univ. of Sci. & Tech.
Wang, Bin — Kunming Univ. of Sci. & Tech.
Yang, Biao — Kunming Univ. of Sciecnce & T
Yu, Wangyang — Wuhan Maritime Communication Research Inst.

▶ SunD01-2 16:00–16:20
*A Soft Sensor Method Based on Unsupervised Multi-layer Domain Adaptation for Batch Processes*
Xiong, Qin — Kunming Univ. of Sci. & Tech.
Jin, Huaiping — Kunming Univ. of Sci. & Tech.
Wang, Bin — Kunming Univ. of Sci. & Tech.
Liu, Haipeng — Kunming Univ. of Sci. & Tech.
Yu, Wangyang — Wuhan Maritime Communication Research Inst.

▶ SunD01-3 16:20–16:40
*Multi-objective Optimization for CCHP System Operation Based on NSGA-II Algorithm*
Zhu, Kai-Kai — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Wang, Yixin — Shanghai Univ.
Zhao, Guoqiang — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Jianlong — Shanghai Minghua Power Tech. Co., Ltd
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

▶ SunD01-4 16:40–17:00
*Choquet Integral-based Multimodal Fusion Strategy in the Application of Atherosclerosis Risk Prediction*
Xue, Yihang — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Chen, Rui — Shang Hai Univ.
Chang, Daoduo — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

▶ SunD01-5 17:00–17:20
*Granger-Based Root Cause Diagnosis with Improved Backward-in-Time Selection*
Xue, Yihang — Shanghai Univ.
Chen, Rui — Shang Hai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Liu, Wei — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Jianlong — Shanghai Minghua Power Tech. Co., Ltd
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

▶ SunD01-6 17:20–17:40
*A Granger Causality Analysis Method Based on GRBF Network*
Chen, Huang — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Ding, Pang-Bin — Shanghai Univ.
Ye, Xiangyun — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

**SunD02** 15:40–17:40 3rd Conf. Hall
Invited Session: Modeling, Optimization and Control of Data-Driven Energy Internet Systems II
Chair: Li, Shengquan — Yangzhou Univ.
Co-Chair: Li, Feng — Jiangsu Univ. of Tech.

▶ SunD02-1 15:40–16:00
*Optimization Scheduling Strategy of Integrated Energy System Based on Improved Particle Swarm Optimization Algorithm*
Liu, Shiheng — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

▶ SunD02-2 16:00–16:20
*Multi-objective Optimization of Electric-gas-thermal Integrated Energy System Based on Non-dominant Sorting Genetic Algorithm*
Liu, Lei — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.
Cao, Qingfeng — Yangzhou Univ.

▶ SunD02-3 16:20–16:40
*Intermittent Semi-global Containment Control of Descriptor Multi-agent Systems with Input Saturation*
Li, Xiaofang — Lanzhou Univ. of Tech.
Wang, Zhiwen — Lanzhou Univ. of Tech.
Lu, Yanrong — Lanzhou Univ. of Tech.
Sun, Hongtao — Qufu Normal Univ.
Wang, Yuying — Lanzhou Univ. of Tech.

▶ SunD02-4 16:40–17:00
*Bettering Iterative Solution Methods for Nonlinear Equations: A Control-Theoretic Perspective*
Ding, Shufen — Beihang Univ.
Meng, Deyuan — Beihang Univ. (BUAA)

▶ SunD02-5 17:00–17:20

*Dynamic Event-triggered Fixed-time Average Consensus for Multi-agent Systems under Switching Topologies*
Ning, Xiaogang — Lanzhou Jiaotong Univ.
Li, Zonggang — Lanzhou Jiaotong Univ.

▶ SunD02-6 17:20–17:40
*Estimation of Wiener Model Based on Neural Fuzzy Network*
Qian, Shengyi — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

**SunD03** 15:40–17:40 4th Conf. Hall
Regular Session: Data-driven Fault Diagnosis and Health Maintenance II
Chair: Zhang, Xinmin — Zhejiang Univ.
Co-Chair: He, Yan-Lin — Beijing Univ. of Chemical Tech.

▶ SunD03-1 15:40–16:00
*Quality Control and Feature Restoration of High-Speed Magnetic Flux Leakage Signals Based on Signal Compensation Method*
Xiao, Qi — Northeastern Univ.
Feng, Jian — Northeastern Univ.
Wang, Lei — Northeastern Univ.
Li, Qiangxin — Northeastern Univ.
Xu, Hang — Northeastern Univ.

▶ SunD03-2 16:00–16:20
*Rolling Bearing Fault Diagnosis Based on Time-frequency Transform-assisted CNN: A Comparison Study*
Song, Baoye — Shandong Univ. of Sci. & Tech.
Liu, Yiyan — Shandong Univ. of Sci. & Tech.
Lu, Peng — Shangdong Univ. of Sci. & Tech.
Bai, Xingzhen — Shandong Univ. of Sci. & Tech.

▶ SunD03-3 16:20–16:40
*A Remaining Useful Life Prediction Method with Degradation Model Calibration*
Ren, Chao — Xi'an Inst. of Hi-Tech
Li, Huiqin — Xi'an Inst. of Hi-Tech
Zhang, Zhengxin — Xi'an Inst. of High-Tech
Si, Xiaosheng — Xi'an Inst. of Hi-Tech

▶ SunD03-4 16:40–17:00
*Novel Autoencoder Based on Variable Correlation Analysis for Industrial Soft Sensing*
He, Yan-Lin — Beijing Univ. of Chemical Tech.
Guo, Shuaifeng — Beijing Univ. of Chemical Tech.
Xu, Yuan — BEIJING Univ. OF CHEMICAL Tech.
Zhu, Qunxiong — Beijing Univ. of Chemical Tech.

▶ SunD03-5 17:00–17:20
*Fault Diagnosis for Rolling Bearings Based on Novel Visibility Graph and GCN Scheme*
Gao, Shoupeng — Univ. of Jinan
Li, Yueyang — Univ. of Jinan
Zhao, Dong — Beihang Univ.

▶ SunD03-6 17:20–17:40
*Inference Attack and Privacy Security of Data-driven Industrial Process Monitoring Systems*
Zhang, Xinmin — Zhejiang Univ.
Zhang, Xuerui — Zhejiang Univ.
Song, Zhihuan — Zhejiang Univ.
Ren, Qinyuan — Zhejiang Univ.
Wei, Chihang — Hangzhou Normal Univ.

**SunD04** 15:40–17:40 5th Conf. Hall
Regular Session: Statistical Learning and Machine Learning in Automation Field
Chair: Zhang, Hongwei — Zhejiang Univ.
Co-Chair: Han, Yongming — Beijing Univ. of Chemical Tech.

▶ SunD04-1 15:40–16:00
*Network Intrusion Detection Method Based on Conditional Generative Adversarial Network Integrating Multi-scale CNN*
Geng, Zhiqiang — Beijing Univ. of Chemical Tech.
Xi, Xiang — Beijing Univ. of Chemical Tech.
Hu, Xuan — Beijing Univ. of Chemical Tech.
Han, Yongming — Beijing Univ. of Chemical Tech.

▶ SunD04-2 16:00–16:20
*A Variable Projection-based Parameter Estimation Algorithm for the Non-smooth Separable Nonlinear Problems*
Cheng, Siqing — Fuzhou Univ.
She, Yuexin — Fuzhou Univ.
Wang, Yaping — Fuzhou Univ.

▶ SunD04-3 16:20–16:40
*Time Series Generator Adversarial Network with Stochastic Process for the Degradation Generation and Prediction*
Shangguan, Anqi — Xi'an Univ. of Tech.
Feng, Nan — Xi'an Univ. of Tech.
Mu, Lingxia — Xi'an Univ. of Tech.
Fei, Rong — Xi'an Univ. of Tech.
Hei, Xinhong — Xi'an Univ. of Tech.
Xie, Guo — Xi'an Univ. of Tech.

▶ SunD04-4 16:40–17:00
*Comparative Study on Segmentation Methods of Fundus Images*
Cao, Juan — Chongqing Jiaotong Univ.
Liu, Jinjia — Chongqing Jiaotong Univ.

▶ SunD04-5 17:00–17:20
*Dual Attention Embedded Reconstruction Distillation for Unsupervised Yarn-dyed Fabric Defect Detection*
Zhang, Hongwei — Zhejiang Univ.
Liu, Shuaibo — Xi 'an Polytechnic Univ.
Meng, Liping — Xi'an Polytechnic Univ.
Lu, Shuai — Beijing Univ. of Chemical Tech.
Li, Pengfei — Xi'an Polytechnic Univ.

▶ SunD04-6 17:20–17:40
*Adaptive Quasi-Newton Algorithm for Remote Sensing*
Wang, Jun — Soochow Univ.
Yu, Wenbo — Soochow Univ.
Huang, He — Soochow Univ.

**SunD05** 15:40–17:40 6th Conf. Hall
Invited Session: Model-free Control, Optimization and Their Applications
Chair: Xu, Dezhi — Jiangnan Univ.
Co-Chair: Mao, Zehui — Nanjing Univ. of Aeronautics & Astronautics

▶ SunD05-1 15:40–16:00
*Frequent Real-time Optimization Using Dynamical Disturbance Observers*
Ye, Lingjian — Huzhou Univ.
Shen, Feifan — Ningbo Inst. of Tech., Zhejiang Univ.
Zhou, Zhe — Huzhou Univ.
Yang, Zeyu — Huzhou Univ.

▶ SunD05-2 16:00–16:20
*Fractional Order Terminal Sliding Mode Observer for State of Charge Estimation of Lithium-Ion Battery*
Ma, Yunchen — Jiangnan Univ.
Xu, Dezhi — Jiangnan Univ.
Yang, Weilin — Jiangnan Univ.
Pan, Tinglong — Jiangnan Univ.
Ding, Yueheng — Univ. of Kent

▶ SunD05-3 16:20–16:40
*Multi-agent Adaptive Virtual Inertia Cooperative Control of AC/DC Microgrid Based on Virtual Synchronous Generators*
Dou, Zhenlan — State Net Overseas Integrated Energy Service Co., Ltd
Tang, Lianqing — Jiangnan Univ.
Zhang, Chunyan — State Grid Shanghai Municipal Electric Power Company
Yang, Haitao — STATE GRID SHANGHAI SHIBEI ELECTRIC POWER SUPPLY COMPANY
Han, Dong — State Grid Shanghai Municipal Electric Power Company
Jiang, Jingjing — STATE GRID SHANGHAI SHIBEI ELECTRIC POWER SUPPLY COMPANY
Xu, Dezhi — Jiangnan Univ.

▶ SunD05-4 16:40–17:00
*Data-driven Fault-tolerant Controller Design for Hypersonic Vehicles with Sensor Fault*
Han, Jingtian — Huazhong Univ. of Sci. & Tech.
Fan, Huijin — Huazhong Univ. of Sci. & Tech.
Liu, Lei — Huazhong Univ. of Sci. & Tech.
Wang, Bo — Huazhong Univ. of Sci. & TTech.

▶ SunD05-5 17:00–17:20
*Observer Based Model-Free Adaptive Iterative Learning Constrained*

*Control for Nonlinear Systems*

Hua, Fei — Jiangnan Univ.
Zhang, Weiming — Jiangnan Univ.
Lu, Wenzhou — Jiangnan Univ.
Xu, Dezhi — Jiangnan Univ.

▶ SunD05-6 17:20–17:40

*Formation Control Method Based on Guidance and LADRC for Under-actuated USVs*

Ma, Yuhe — Tianjin Univ.
Hu, Chaofang — Tianjin Univ.
Xiang, Yiyi — Tianjin Univ.

**SunD06** 15:40–17:40 Yuetang Conf. Hall

Invited Session: Model Predictive Control of Cyber-physical Systems

Chair: He, Ning — Xi'an Univ. of Architecture & Tech.
Co-Chair: Wang, Xin — Heilongjiang Univ.

▶ SunD06-1 15:40–16:00

*Distributed Model-Free Adaptive Command-Filter-Backstepping Sliding Mode Control for High-Order Multi-Agent Systems Consensus Tracking*

Chen, Mingchao — Shenyang Aerospace Univ.
Liu, Dong — Shenyang Aerospace Univ.

▶ SunD06-2 16:00–16:20

*Nonlinear Large Maneuver Control of Thrust Vector UAV for Flying-Wing Layout*

Chen, Zhuoying — Northwestern Polytechnical Univ.
Li, Huiping — Northwestern Polytechnical Univ.
Chen, Huaimin — Northwestern Polytechnical Univ.,
Zhou, Shaobo — Northwestern Polytechnical Univ.

▶ SunD06-3 16:20–16:40

*Fault-Tolerant Intermediate Estimator-Based Output Feedback Control for A Class of Interconnected Systems with Nonlinear Coupling Interconnections*

Ma, Zhijuan — Heilongjiang Univ.
Yu, Tingting — Heilongjiang Univ.
Wang, Xin — Heilongjiang Univ.

▶ SunD06-4 16:40–17:00

*A Cyber-security Framework for ST-MPC of State and Input Constrained CPS under False Data Injection Attacks*

He, Ning — Xi'an Univ. of Architecture & Tech.
Li, Yuxiang — Xi'an Univ. of Architecture & Tech.
Ma, Kai — Xi'an Univ. of Architecture & Tech.

▶ SunD06-5 17:00–17:20

*An Improved Method for Calculating the Meshing Clearance of Cycloidal Pin Wheel*

Zhou, Shidong — Jiangsu Univ. of Tech.
Han, Zhenhua — Jiangsu Univ. of Tech.
Li, Rirong — Jiangsu Univ. of Tech.
Du, Youwu — China Univ. of GeoSci.
Wang, Hao — Jiangsu Univ. of Tech.

▶ SunD06-6 17:20–17:40

*Dynamic Modeling and Transmission Error Analysis of Cycloid Drive Based on Variable Clearance*

Zhou, Yunchen — Jiangsu Univ. of Tech.
Han, Zhenhua — Jiangsu Univ. of Tech.
Wang, Hao — Jiangsu Univ. of Tech.
Du, Youwu — China Univ. of GeoSci.
Li, Rirong — Jiangsu Univ. of Tech.

**SunD07** 15:40–17:40 Hongqi Conf. Hall

Invited Session: Data-driven Motion and Vibration Control for Micro/Nano Scale Positioning Systems

Chair: Liu, Yang — Harbin Inst. of Tech.
Co-Chair: Song, Fazhi — Harbin Inst. of Tech.

▶ SunD07-1 15:40–16:00

*Position Control of X-Y Precision Planar Motion Stage Based on Iterative Learning and Cross-coupling*

Fang, Jingzhe — Shenyang Univ. of Tech.
Zhang, Tao — Shenyang Inst. of Automation Chinese Acad. of Sci.
Chen, Xi-You — Dalian Univ. of Tech.
Qi, Chen — Dalian Univ. of Tech.
Zhang, Guopeng — Shenyang Univ. of Tech.
Zhang, Hualiang — Chinese Acad. of Sci.
Yan, Hongyu — Shenyang Univ. of Tech.

▶ SunD07-2 16:00–16:20

*Data-driven Feedforward Tuning Algorithm Based on Self-adaptive Hybrid Self-learning TLBO*

Chen, Siwen — Harbin Inst. of Tech.
Liu, Yang — Harbin Inst. of Tech.
Song, Fazhi — Harbin Inst. of Tech.

▶ SunD07-3 16:20–16:40

*Adaptive Learning Control with Extended Bandwidth for Synchronization Motion Stages*

Sun, Pengyu — Harbin Inst. of Tech.
Song, Fazhi — Harbin Inst. of Tech.
Chen, Shuaiqi — Harbin Inst. of Tech.
Liu, Yang — Harbin Inst. of Tech.

▶ SunD07-4 16:40–17:00

*Iterative Control Decoupling Tuning by Feedforward Compensation for Precision Motion Stage*

Zhao, Hongyang — Harbin Inst. of Tech.
Li, Li — Harbin Inst. of Tech.
Liu, Yang — Harbin Inst. of Tech.

▶ SunD07-5 17:00–17:20

*Event-triggered Extended Kalman Filter for UAV Monitoring System*

Zang, Yunge — Beijing Aerospace Automatic Control Inst.
Li, Yan — Beijing Aerospace Automatic Control Inst.
Duan, Yuting — Beijing Aerospace Automatic Control Inst.
Li, Xiangyu — Beijing Aerospace Automatic Control Inst.
Chang, Xi — Beijing Aerospace Inst. for Metrology & Measurement Tech.
Li, Zhen — Beijing Inst. of Tech.

▶ SunD07-6 17:20–17:40

*Load Tooth Contact Analysis of Composite Cycloidal Planetary Transmission with Small Tooth Difference*

Zhou, Shuhan — Jiangsu Univ. of Tech.
Han, Zhenhua — Jiangsu Univ. of Tech.
Zhou, Yunchen — Jiangsu Univ. of Tech.
Zhao, Yunda — Jiangsu Univ. of Tech.
Wang, Hao — Jiangsu Univ. of Tech.
Du, Youwu — China Univ. of GeoSci.

# Book of Abstracts

# Saturday, May 13, 2023

**SatA01** 13:30–15:30 2nd Conf. Hall

Regular Session: Iterative Learning Control

Chair: Shi, Jia — Xiamen Univ.

Co-Chair: Yu, Qiongxia — Henan Polytechnic Univ.

▶ SatA01-1 13:30–13:50

*An Improved Two-Dimensional Iterative Learning Control Scheme Based on Deep Reinforcement Learning for the Non-repetitive Uncertain Batch Processes*

Liu, Jianan — Xiamen Univ.
Hong, Wenjing — Xiamen Univ.
Shi, Jia — Xiamen Univ.

Iterative learning control is (ILC) an advantage control strategy that is widely used in periodic/repetitive/batch systems. Nevertheless, in the face of complex batch processes with system uncertainty and non-repetitive nature, designing an effective iterative learning control scheme is still a critical problem in theoretical research and practical application. By virtue of the self-learning ability and good robustness of deep reinforcement learning (DRL) through the interaction with the controlled system, in this paper, we propose a two-dimensional iterative learning control-reinforcement learning (2D ILC-RL) control scheme, which is composed of a two-dimensional ILC controller and a DRL compensator. The 2D ILC controller ensures the primary control performance for the batch system. Meanwhile, the DRL compensator counteracts the negative impact of the system uncertainty and the non-repetitive nature. Finally, simulation results demonstrate the proposed control method' s effectiveness, significant control performance, and strong robustness.

▶ SatA01-2 13:50–14:10

*Collaborative Learning Tracking for Networked Systems with Fading Communication*

Zhang, Zeyi — Renmin Univ. of China
Jiang, Hao — Renmin Univ. of China
Zeng, Kun — Beijing Univ. of Chemical Tech.
Shen, Dong — Renmin Univ. of China

Using a networked structure, many subsystems can communicate and collaborate to accomplish a global objective. With collaborative learning control, the system enables high-precision tracking of repetitive tasks. However, the transmitted signal generally suffers damage in the network. The fading problem is one of the concerns being addressed. To this end, this article investigates collaborative learning control systems in fading channels. We propose a control algorithm equipped with decreasing learning gain. Then, we prove that the reference trajectory can be accurately realized in the mean square sense. Finally, we provide numerical simulations to verify our method.

▶ SatA01-3 14:10–14:30

*An Iterative Learning Control Research Based on RBF Neural Network and PSO Algorithm*

Wang, Shouqin — Xi'an Polytechnic Univ.
Geng, Yan — Xi'an Polytechnic Univ.
He, Xingshi — Xi'an Polytechnic Univ.

In order to solve the problem of trajectory shift, a PSO-DRBFNNILC strategy is designed. The first RBFNN is introduced to estimate the output of the ILC system; second RBFNN is built to adaptively adjust the learning gain matrix in the input update law. PSO algorithm is used to find the optimal search step for the update of the weight, center and radius of the activation function. Convergence analysis shows that the estimation error of the weight of the network and the tracking error of the ILC system are bounded. The effectiveness of the control strategy is verified by numerical simulation.

▶ SatA01-4 14:30–14:50

*Extended State Observer Based Iterative Learning Control for Systems with Nonrepetitive Disturbances*

Li, Shiyan — Sun Yat-sen Univ.
Li, Xuefang — Sun Yat-sen Univ.

A novel extended state observer (ESO) based iterative learning control (ILC) scheme is investigated, including three channels, namely, feedforward, feedback, and disturbance rejection channels. The goal of this work is to achieve high-accuracy tracking of nonlinear systems in the presence of nonrepetitive disturbances under repetitive operating conditions. The ESO is used to estimate and offset the nonrepetitive disturbance in real time, which reduces the sensitivity of the controller to system parameters and operating environments. The convergence of control scheme are analyzed, and the estimation accuracy of the observer for disturbances with different frequencies is demonstrated. Finally,an implementation to an automatic guided vehicle (AGV) is illustrated to verify the effectiveness of the proposed control scheme.

▶ SatA01-5 14:50–15:10

*Data-driven-based Predictive Optimal for A Class of Iterative Learning Control by Q-learning Method*

Li, Jinze — South China Univ. of Tech.
Tian, Senping — South China Univ. of Tech.
Peng, Yunjian — South China Univ. of Tech.
Gu, Panpan — Hefei Univ. of Tech.

The paper investigates predictive optimal for P-type iterative learning control (ILC) under unknown system's dynamic. First, with an $\triangle$u(k+1)-based discounted linear quadratic cost function of control errors in ILC, we formulate the predictive optimal problem for P-type ILC and present a solution for such a problem in a discrete algebraic Riccati equation (DARE) with known system's dynamic, by which a predictive optimal algorithm can be established. Second, a reinforcement Q-learning method is proposed to find predictive optimal solution for P-type ILC under unknown system's dynamic, which is intended to develop a model-free and iterative learning algorithm to implement ILC with a higher convergence speed only by utilizing the input and output data of ILC. Based on the performance function, a Q-function is elaborately chosen in an iterative formulation with trials of $\triangle$u(k+1) and control errors for critic P-type ILC performance with its updated converge rated. Third, the convergence of the algorithm is proved and discussed with it conditions. Last, An illustrative digital simulation at MATLAB verifies the effectiveness of the proposed algorithm and shows its advantages over the traditional method.

▶ SatA01-6 15:10–15:30

*Event-Triggered Based Data-Driven Predictive Iterative Learning Control*

Yu, Qiongxia — Henan Polytechnic Univ.
Fan, Zhihao — Henan Polytechnic Univ.
Tian, Fengchen — Henan Polytechnic Univ.
Hou, Zhongsheng — Beijing Jiaotong Univ.

In this paper, a novel event-triggered data-driven predictive iterative learning control (ET-DDPILC) scheme is proposed for a class of discrete-time nonlinear networked control systems (NCSs). Firstly, by using dynamic linearization technique (DLT) to transform the nonlinear NCSs into a virtual linear data model with an introduced unknown pseudo partial derivative (PPD) parameter, we established a data-driven predictive iterative learning control framework. Secondly, in order to reduce the number of ineffective updates during the iterative process, an event-triggered mechanism is designed, and the controller updates data only when the event-triggered condition is satisfied, saving network communication resources. Finally, the monotonic convergence properties of tracking error are explored through a rigorous theoretical analysis, and the effectiveness of the proposed ET-DDPILC algorithm is verified by simulation.

**SatA02** 13:30–15:30 3rd Conf. Hall

Regular Session: Data-driven Fault Diagnosis and Health Maintenance I

Chair: Li, Yueyang — Univ. of Jinan

Co-Chair: Wang, Shenquan — Changchun Univ. of Tech.

▶ SatA02-1 13:30–13:50

*Remaining Useful Life Prediction for Multi-Component Stochastic Degrading Equipment under Competing Failure*

Li, Huiqin — Xi'an Inst. of Hi-Tech
Zhang, Zhengxin — Xi'an Inst. of High-Tech
Li, Tianmei — Xi'an Inst. of High-tech
Si, Xiaosheng — Xi'an Inst. of Hi-Tech

Remaining useful life (RUL) prediction is the key to prognostics and

health management (PHM). This paper addresses the multi-component competing failure problem and proposes a multi-component RUL prediction method based on the time-varying Copula function. In the proposed method, the dependent time-varying multi-component degradation model is built by the time-varying Copula function and the joint RUL distribution function of multi-component stochastic degrading equipment is accordingly derived. To implement the proposed method, the maximum likelihood estimation method is used to estimate the model' s unknown parameters. Finally, the effectiveness of the multi-component RUL prediction method is demonstrated by the practical case of the gyroscope.

▶ SatA02-2 13:50–14:10

*Rolling Bearing Fault Diagnosis Based on ICEEMDAN-WTATD-DaSqueezeNet*

Geng, Zhiqiang — Beijing Univ. of Chemical Tech.
Yuan, Kui — Beijing Univ. of Chemical Tech.
Ma, Bo — Beijing Univ. of Chemical Tech., Diagnosis & Self-Recovery Engineering Research Center
Han, Yongming — Beijing Univ. of Chemical Tech.

Rolling bearing is a mechanical part of industrial scenarios which is extensively used. The working environment of the bearing is complex including high load, high pressure, and high temperature, so the failure probability is high. So the vibration signals of bearings are often accompanied by a large amount of noise, leading to unstable signal data characteristics. Aiming at the characteristics of data instability and a large number of complex noises, an adaptive threshold denoising (WTAT) method based on improved complete ensemble empirical mode decomposition with adaptive noise (ICEEMDAN) combined with wavelet transform is proposed. Then combined with an improved SqueezeNet model, an accurate diagnosis of rolling bearing fault was achieved. Firstly, the ICEEMDAN is used for mode decomposition to obtain a sequence of intrinsic mode functions (IMFs), which effectively solves the mode aliasing and pseudo-mode problems of traditional empirical mode decomposition. Moreover, the WTAT noise reduction is carried out for several IMFs with the least correlation, which effectively solves the problem of overstrangling and over-retention of traditional wavelet denoising. Then, in order to better integrate local features and global dependencies, the dual attention convolutional module is embedded in the fire module of SqueezeNet and a lightweight model named dasqueeezenet is built for bearing fault diagnosis. Finally, compared with common convolutional neural networks such as VGG16, ResNet and Xception, the presented method achieves remarkable results in terms of the accuracy with 96.17%, the precision with 96.3%, the recall rate with 96.42% and the F1-Score with 96.26%, and the presented model's effectiveness in diagnosing rolling bearing faults has been demonstrated.

▶ SatA02-3 14:10–14:30

*An Improved Sparse Mode Decomposition Method for Pulse Signals*

Wu, Jialian — Univ. of Jinan
Li, Yueyang — Univ. of Jinan
Zhao, Dong — Beihang Univ.

In signal processing field, mode decomposition is one of the most important branches. Many existing decomposition methods are mainly used to deal with narrow-band signals. If the analyzed signal is composed of bandwidth components, such as periodic pulse signals, traditional mode decomposition algorithms may have a performance deterioration. In order to overcome this problem, this paper proposes an improved sparse decomposition based on the group-sparse mode decomposition (GSMD) algorithm. The idea of the algorithm can be divided into two parts. First, the least square curve fitting technique is used to replace the average energy in GSMD algorithm with the fitted signal energy curve. Second, the bandwidth of each mode is adaptively reconstructed by the 3dB bandwidth criterion. The feasibility and superiority of the proposed method are verified by processing a set of actual bearing fault signal data and comparing with some existing methods.

▶ SatA02-4 14:30–14:50

*Event-triggered-based Subspace Identification Fault Detection with An Optimized Moving Window*

Zhang, Qi — Changchun Univ. of Tech.
Wang, Shenquan — Changchun Univ. of Tech.
Ji, Wenchengyu — Changchun Univ. of Tech.

In this paper, a fault detection (FD) method with moving window subspace identification method (MW-SIM) is proposed for the problem of difficult detection of incipient faults. Since the size of the window length has a direct relationship with the fault detection rate, the optimal window length is found by the sparrow search algorithm (SSA) to obtain the maximum fault detection rate. Furthermore, applying event-triggered strategy to subspace identification algorithms can effectively reduce data transmission. Finally, the effectiveness of the designed strategy is verified by the Tennessee Eastman (TE) process simulation.

▶ SatA02-5 14:50–15:10

*A Lightweight Pipeline Defect Detection Method via Structural Reparameterization Technique and Ghost Convolution*

Wen, Zhitao — Northeastern Univ.
Liu, Jinhai — Univ. of Northeastern
Shen, Xiangkai — Univ. of Northeastern
Lu, Senxiang — Northeastern Univ.
He, Zhao — Northeastern Univ.
Wang, Qiannan — Northeastern Univ.

To address the inference speed problem of pipeline defect detection, this paper proposes a single-stage lightweight pipeline defect detection method based on the reparameterization technique and ghost convolution. Initially, the baseline model selected for this study is You Only Look Once (YOLO)v5. To further enhance the learning ability without increasing model inference time, the reparameterization convolution (RepConv) is used instead of the 3×3 convolution of the original model. Subsequently, the ghost convolution (GhostConv) is utilized to build the ghost module, which substantially reduces the model's complexity to achieve the trade-off between accuracy and speed. Finally, an efficient channel attention (ECA) is employed in the backbone network and feature fusion stages to improve the model's feature extraction and aggregation capability. After actual experimental tests, the proposed improvement method reduces about 30% in parameters, reduces about 34% in floating point operations (FLOPs), and improves about 1% in accuracy.

▶ SatA02-6 15:10–15:30

*Tool Wear State Identification Based on Frequency Domain Denoising and Frequencies-separation Attention Networks*

Lai, Xuwei — Southwest Jiaotong Univ.
Zhang, Kai — Southwest Jiaotong Univ.
Li, Zhixuan — Southwest Jiaotong Univ.
Zheng, Qing — Southwest Jiaotong Univ.
Ding, Guofu — Southwest Jiaotong Univ.

Real-time and accurate monitoring of tool wear is an important link to realizing intelligent manufacturing, which has an important impact on product quality and production cost. Due to its convenience and strong nonlinear mapping capability, deep learning has attracted extensive attention in the field of tool wear monitoring. However, the monitoring signal in the machining process will inevitably be interfered with by the noise from the machine tool, which will affect the models' reliability and optimization. In this work, the effectiveness of monitoring signals is analyzed, and a machine tool inherent characteristic frequency interception method and a time-frequency domain decoupling technique based on wavelet transform with tunable Q-factor are introduced to perform targeted noise removal during machining. The method is naturally interpretable. Meanwhile, a frequency-separation attention mechanism is proposed to weigh the frequency at different stages adaptively. The validity of the proposed method is verified by using real machining data. And the interpretability of the model is briefly analyzed.

## SatA03 13:30–15:30 4th Conf. Hall

Invited Session: Process Monitoring and Control for Complex Industrial Systems

Chair: Luo, Hao — Harbin Inst. of Tech.
Co-Chair: Wang, Zhenhua — Harbin Inst. of Tech.

▶ SatA03-1 13:30–13:50

*Fault Detection for Satellite Gyroscope Using LSTM Networks*

Xu, Chi — Harbin Inst. of Tech.
Wang, Zhenhua — Harbin Inst. of Tech.

To handle the interference of attitude maneuver and measurement noise in gyroscope fault detection, a data-driven time series model based on long short-term memory (LSTM) with residual smoothing is proposed. First, a LSTM network is used to build a time series model, which achieves effective mining of attitude system data and tracking gyroscope output. And a sliding window mechanism is involved for better prediction. Then, the residuals between estimation data and real data are smoothed by exponentially weighted moving average (EWMA) to reduce the effect of measurement noise on fault detection. Finally, the fault is determined by comparing the smoothed residuals with the threshold. Simulation results show that the model proposed in this paper is effective in both fault

scenarios of gyroscopes and has higher accuracy than traditional fault detection models such as BP and RBF neural networks.

▶ SatA03-2 13:50–14:10

*Fault Detection for Rolling Bearings by Multi-sensor Information Fusion Method with Adaptive Weights*


| | |
|---|---|
| Wu, Hao | Univ. of Sci. & Tech. Beijing |
| Zhao, Yinghao | Univ. of Sci. & Tech. Beijing |
| Yang, Xu | Univ. of Sci. & Tech. Beijing |
| Huang, Jian | Univ. of Sci. & Tech. Beijing |
| Cui, Jiarui | Univ. of Sci. & Tech. Beijing |


Driven by the increasing needs for production safety, a fault detection method based on multi-sensor fusion with adaptive weight coefficients is proposed in this paper to make full use of multi-measuring points information. To this end, considering the different information among multi-measuring points, the variance contribution rate (VCR) of vibration signals are used to design adaptive weight coefficients for data fusion to fully utilize the information contained in each vibration signal. On this basis, the least atoms contain time domain and frequency domain are extracted based on dictionary sparse representation (DSR) algorithm to represent the feature information of the original signal to weaken the influence of the curse of dimensionality. Finally, K-nearest neighbor distance is used in sparse residual space (SRS) for fault detection (K-SRS). The effectiveness of the proposed method is demonstrated by the rolling bearings data, results show the advantage of our proposed approach.

▶ SatA03-3 14:10–14:30

*Data-driven Adaptive Control of CRAC in Data Center Based on Online Incremental RVFL*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|---|---|
| Huang, Jiangyang | Univ. of Sci. & Tech. Beijing |
| Zhang, Zhengxuan | Univ. of Sci. & Tech. Beijing |
| Yang, Xu | Univ. of Sci. & Tech. Beijing |
| Tu, Rang | Univ. of Sci. & Tech. |


An adaptive control method based on online identification of controller parameters is proposed for the cooling process of Computer Room Air Conditioning(CRAC) in data centers with complex nonlinear and dynamic characteristics. Firstly, the nonlinear system is divided into low-order linear part and high-order unmodeled dynamic term. The random vector functional link network is used to identify the controller parameters. The unmodeled dynamic compensator is introduced into the control strategy to offset the influence of uncertain dynamic term on the closed-loop control system of CRAC-Cabinet system. Then, in order to solve the problem that the identification ability of the offline model is reduced due to the changes of the location layout of the cabinet, the number and placement of electronic devices and other factors in the data center, the online addition of hidden layer nodes is added, and the output weight of the original hidden layer is recalculated and updated when new nodes are added. Through simulation experiments, it is proved that the control and tracking ability of the nonlinear adaptive controller with unmodeled dynamic compensation is better than that of the adaptive controller based on linear model, and the experimental results show that the incremental learning network model has faster response speed and higher tracking accuracy than the original model.

▶ SatA03-4 14:30–14:50

*Emergency Vehicle Identification for Internet of Vehicles Based on Federated Learning and Homomorphic Encryption*


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|---|---|
| Zeng, Siyuan | Chongqing Jiaotong Univ. |
| Mi, Bo | Chongqing Jiaotong Univ. |
| Huang, Darong | Anhui Univ. |


With the development of the Internet of Vehicles (IoV), its application has attracted wide attention. Emergency vehicles often have trouble moving in traffic. Therefore, the classification of vehicles into emergency and non-emergency categories is conducive to the development of IoV applications such as emergency rescue services, intelligent traffic management and autonomous driving systems. At the same time, its data is very sensitive in terms of data privacy and security issues. Federated learning, as a framework of machine learning, can be used to improve the privacy and security of data. The trained data is distributed on multiple machines to cooperate with each other for learning. In the process of federated learning, the model needs to be uploaded and downloaded. In order to ensure that the information of the model is not leaked, homomorphic encryption is used to encrypt the model to protect the information of the model. This paper presents a federated learning algorithm for IoV data privacy protection based on homomorphic encryption.

▶ SatA03-5 14:50–15:10

*Improved LeNet-5 Network for Equipment Fault Diagnosis of Ultra-supercritical Units*


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|---|---|
| Zhang, Xingfan | Zhejiang Univ. of Tech. |
| Wei, Chun | Zhejiang Univ. of Tech. |
| Cheng, Zhang | Zjut |


Abstract: In order to improve the reliability of the power generation system of ultra-supercritical units, a fault diagnosis algorithm based on the improved LeNet-5 network is proposed to address the problems of difficult feature extraction, low accuracy and reliance on manual experience of traditional fault diagnosis methods. Firstly, multi-scale convolutional kernels in parallel are used to extract more details of the fault features. By using the improved inception V2 network and residual neural network, more complete and accurate features can be extracted while avoiding the degradation of the model due to too deep layers. Then a combination of 1*1 convolution and global average pooling is used instead of partial fully connected layers, which greatly reduces the parameters of the model and prevents model overfitting. The test shows that the fault identification rate of this method can be 98.42%.

▶ SatA03-6 15:10–15:30

*RAANet: Residual Aggregation Attention Network for Classification of Small Intestinal Endoscopic Images*


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|---|---|
| Cao, Bo | Zhejiang Univ. of Tech. |
| Li, Lei | Zhejiang Univ. of Tech. |
| Ma, Yue | Zhejiang Univ. of Tech. |
| Ye, Shufang | Lishui People Hospital |
| Li, Sheng | Zhejiang Univ. of Tech. |
| He, Xiongxiong | Zhejiang Univ. of Tech. |


Due to blurred boundaries between lesions and normal tissues, different intra-class scales, and high inter-class similarities, it is very challenging to accurately classify small intestinal lesions. In this paper, a residual aggregation attention network (RAANet) is proposed for multi-classification of small intestinal lesions with wireless capsule endoscopy (WCE) images. A relative position sensing encoding (RPSE) module is developed to attack the boundary blurring problem between lesion areas and normal tissue. By learning important information between different lesion categories, the characterization ability of obscure lesion areas is greatly enhanced. Then, a Non-local attention (NLA) module is introduced to collect multi-scale information to reduce the impact of high inter-class similarity and large intra-class differences. In addition, a dataset with five common small intestinal lesions is generated. By evaluating the proposed RAANet in the five-class dataset, it is verified that better classification results can be achieved compared with some existing state-of-art classification algorithms.

**SatA04** 13:30–15:30 5th Conf. Hall

Invited Session: Data-driven Control and Learning with Additive Decomposition

Chair: Qi, Guoyuan Tiangong Univ.

Co-Chair: Quan, Quan Beihang Univ.

▶ SatA04-1 13:30–13:50

*Model Compensation Control Based on Additive State Decomposition and Its Application in QUAV*


| | |
|---|---|
| Li, Xia | Tiangong Univ. |
| Qi, Guoyuan | Tiangong Univ. |


The Quadrotor unmanned aerial vehicle (QUAV) is a strongly nonlinear system with multivariate coupling, uncertainty and sensitivity to disturbances. However, most of the controllers designed for QUAV are for the linearized design model. The design model with Jacobian linearization ignores more nonlinearities in the system. And the controller designed according to the Jacobian linearization model can only achieve local convergence of the closed-loop system. In contrast, the state-compensated linearization uses the idea of additive decomposition, which decomposes the nonlinear system into a linear time-invariant system and a nonlinear system. Among them, the linear time-invariant system is completely known as the primary system, and its controller implementation is relatively easy. However, as a secondary system, the nonlinear system is more complex and contains not only matched but also unmatched disturbances, and these disturbances are unknown. The compensation function observer (CFO) proposed by Qi. et al is a novel high precision unknown model or disturbance observer. But the existing CFO can only handle matched disturbances and are powerless against unmatched disturbances. Therefore, the system variables are redefined in this paper to transform the nonlinear system in non-affine form into affine form. Thus, the original CFO works for unmatched disturbances. Based on the

estimation of the CFO for different disturbances, a model compensation control is designed to stabilize the nonlinear system. Finally, the controller is composed of two parts, one is a simple proportional-differential (PD) control algorithm designed for linear primary system, the other is a model compensation controller developed for nonlinear secondary system. The feasibility of the method on the QUAV attitude system is tested by simulation.

▶ SatA04-2 13:50–14:10

*Adaptive Output Regulation for Uncertain Nonlinear Systems: An Additive Decomposition-based Method*

Gong, Yizhou ShanghaiTech Univ.
Wang, Yang ShanghaiTech Univ.

This paper investigates the robust output regulation problem for a class of nonlinear MIMO systems affected by a periodic disturbance with known frequency information. The system in question is assumed to be minimum phase but largely uncertain. To this end, a novel internal model-based control protocol is proposed under the framework of additive state decomposition, i.e., decomposing the original output regulation problem into a more tractable disturbance rejection problem for a LTI system, and a tracking problem for a known system with the nonlinear term. Thanks to the decomposition, the proposed method mitigates the design difficulty of the output regulation problem for nonlinear MIMO systems. Finally, a numerical experiment is conducted to show the effectiveness of the presented method.

▶ SatA04-3 14:10–14:30

*Two-Degree-of-Freedom Attitude Tracking Control for Bank-to-Turn Aerial Vehicles: An Additive-State-Decomposition-Based Method*

Ren, Jin-Rui Xi'an Univ. of Posts & Telecommunications

This paper presents an additive-state-decomposition-based attitude tracking control method for a class of bank-to-turn (BTT) aerial vehicles subject to unknown disturbances and nonlinear coupling. This method 'additively' decomposes the original tracking problem into two more tractable problems, namely a tracking problem for a deterministic nonlinear 'primary' system, and a disturbance rejection problem for a linear time-invariant 'secondary' system. Based on the decomposition, a backstepping controller is designed for the primary system to track the reference attitude signal, and a proportional-integral controller is applied to the secondary system to compensate for the disturbances. Finally, the two designed controllers are combined to achieve the original control objective. By using additive state decomposition (ASD), the proposed control method with two degrees of freedom can consider tracking task and disturbance rejection task respectively. Simulation results illustrate that the proposed controller can track the reference attitude signal and compensate for disturbances meanwhile. Additionally, the ASD-based controller outperforms the traditional backstepping controller in the presence of unknown disturbances and input delay.

▶ SatA04-4 14:30–14:50

*Robust Repetitive Control for A Class of Uncertain Nonlinear Systems*

Jia, Fengyi Hunan Univ. of Sci. & Tech.
Zhou, Lan Hunan Univ. of Sci. & Tech.
Wang, Xiaojuan Hunan Univ. of Sci. & Technolog
Sun, Yongbo Hunan Univ. of Sci. & Tech.

This paper presents an output-feedback repetitive control method for a class of systems with nonlinearities, unknown state-dependent uncertainties, and external disturbances. An additive-state-decomposition approach is used to decompose the system under study into a primary linear periodic system in charge of repetitive-control tracking task and a secondary linearized system in charge of robustly stabilization task. Thus, a periodic term from the nonlinearity in the plant is extracted to be treated in the primary system and the known plant information is used to design controller parameters, which greatly improves the disturbance rejection ability of the system. Finally, a case study on the tracking control of a chuck-piece system demonstrates the validity of the proposed method.

▶ SatA04-5 14:50–15:10

*Tube-based Distributed Model Predictive Control of Nonlinear Multi-agent Systems Based on Additive State Decomposition*

Li, Liya Tiangong Univ.
Su, Peng Peng Tiangong Univ.
Zhang, Xulong TianGong Univ.

For nonlinear leader-following stochastic multi-agent system, a tube-based distributed model predictive control (MPC) algorithm of followers is proposed in this paper to achieve containment control. Considering that nonlinear may greatly increase the complexity of the optimization problems, some scholars pay attention to linearization method, in which the model error may lead bad system performance. In order to compensate the model error between nonlinear system and linear system, additive state decomposition is utilized to separate the original nonlinear system into two parts: primary linear system and secondary nonlinear system. Based on pole assignment, the feedback control algorithm for the secondary nonlinear system is proposed, ensuring primary state convergence. To ensure the satisfaction of system constraints, the tightened constraints are constructed involving the disturbance and linearity error. Based on the constraints, the distributed tube-based MPC optimization problem is established for the primary system. Then in the combined action of the two controllers, all followers are steered to the convex hull of leaders under interference. Finally, the effectiveness of the proposed method is verified for the nonlinear system by numerical simulation.

▶ SatA04-6 15:10–15:30

*Reinforcement Learning for Non-Affine Nonlinear Non-Minimum Phase System Tracking under Additive-State-Decomposition-Based Control Framework*

Chen, Lian School of Automation Sci. & Electrical Engineering
Quan, Quan Beihang Univ.

This paper proposes a reinforcement-learning additive-state-decomposition-based tracking controller for a class of non-affine nonlinear non-minimum phase systems. Because the tracking performance is not satisfied with the model-based additive-state-decomposition tracking control with an approximate ideal internal model, two reinforcement learning schemes are introduced to improve the performance under the proposed additive-state-decomposition-based control framework. One is used to generate control commands, and the other is used to generate tracking reference commands. Finally, numerical simulations show the effectiveness of the proposed controller.

**SatA05** 13:30–15:30 6th Conf. Hall

Invited Session: Data Driven Information Processing and Intelligent Control

Chair: Xia, Chengyi Tianjin Univ. of Tech.
Co-Chair: Dong, Na Tianjin Univ.

▶ SatA05-1 13:30–13:50

*CGS-Net:Classification-guided Segmentation Network for Improved Gland Segmentation*

Tang, Xiaoheng Zhejiang Univ. of Tech.
Peng, Yuyang Zhejiang Univ. of Tech.
Ma, Yue Zhejiang Univ. of Tech.
Chen, Jiani Zhejiang Univ. of Tech.
Li, Sheng Zhejiang Univ. of Tech.
He, Xiongxiong Zhejiang Univ. of Tech.

The diagnosis of colorectal cancer depends on the analysis of pathological images, and it is of great significance to accurately segment the shape of glands in pathological images. Accurate gland segmentation is extremely challenging, such as adhesion between adjacent glands, huge morphological differences between benign and malignant glands and so on. This paper proposes a classification-guided segmentation network (CGS-NET), which uses the characteristics related to benign and malignant glands after classification to improve the segmentation accuracy of glands. A local feature attention module and a multi-feature fusion module are introduced to enhance the encoder features and fuse the outputs of different scales, respectively. Experiments show that the proposed method can segment different types of glands well, and its performance on the 2015 MICCAI Gland Challenge is better than some existing methods compared in this paper.

▶ SatA05-2 13:50–14:10

*Tear Location Detection of Meniscus MRI Images Based on YOLOv5*

Wang, Zhuxin Tianjin Univ. of Tech.
Wang, Juan Tianjin Univ. of Tech.
Xia, Chengyi Tianjin Univ. of Tech.

Knee meniscus tear is a common joint disorder that is usually diagnosed with the help of MRI imaging. However, the diagnosis of a meniscal tear places high technical demands on physicians, and the results of the diagnosis are also inconsistent. In this paper, a me-niscal tear detection method based on YOLOv5 target detection network is developed to help physicians make more accurate diagnoses. To begin, a channel and space parallel attention module is designed and integrated into the feature fusion part of the network to improve the network's attention to the tear area. Then, ConvNeXt is used in the backbone network part to im-

prove the C3 module to obtain the ConvC3 module, which strengthens the ability of the backbone network to extract the features of the meniscal tear lesion area. After labelling and creating the dataset, the improved YOLOv5 network is trained to obtain the target model. The experimental results show that compared with the original model, the improved YOLOv5 model has an increased mAP from 82.5% to 84.8%. Although there exists a slight decrease in GFLOPs, our model presents an overall considerable improvement. The current results can help clinicians to perform the diagnosis of meniscal tears more accurately.

► SatA05-3 14:10–14:30

*Special Agents Policy Gradient in Value Decomposition-based Approach*

Kang, Qitong Nankai Univ.
Wang, Fuyong Nankai Univ.
Liu, Zhongxin College of Artificial Intelligent, NanKai Univ.
Chen, Zengqiang Nankai Univ.

In many real-world environments, such as soldiers and general in a battlefield, or teammates and goalkeeper in a soccer field, the "general" has a significantly stronger role than the "soldier", so that it is logical to assign higher "intelligence" and "flexibility" to the "general", we define it as special agent. Here, we propose a multi-agent reinforcement learning algorithm that provides stronger intelligence to special agent in a fully cooperative heterogeneous multi-agent environment. Similar to QMIX, we design a common monotonicity critic for all agents, but a separate actor network to improve its "intelligence" for the special agent. In this way we can improve the group's ability to cooperate by giving special agent greater ability, while ensuring that the group remains cooperative. We evaluate the above algorithm on two sets of StarCraft 2 micromanagement tasks, and the experimental results show that the algorithm has a significant advantage over baseline algorithms for tasks with significant heterogeneity.

► SatA05-4 14:30–14:50

*Multi-scale Learning Based Few-shot GAN for High-quality Art Paintings*

Guo, Zhendong Tianjin Univ.
Dong, Na Tianjin Univ.
Mai, Xiaoming Tianjin Univ.

The rise and development of Generative Adversarial Networks (GAN) has led to the widespread use of computer image generation techniques in many fields in the direction of art making, and the use of GAN algorithms to realize the generation of high-quality art paintings with rich features has gradually become a trend. There is, however, a drawback in art painting generation research: the dominant image generation methods for GANs rely on a large amount of data, and a large amount of data must be input to the model for training, severely imiting the conditions for generating GAN images. Dedicated to solving the aforementioned problems, we improve the structure of GANs in order to generate high quality fused multi-style art painting images.

► SatA05-5 14:50–15:10

*An Improved Classification Method for Cervical Cancer Based on ResNet*

Guo, Jiajia Tianjin Univ. of Tech.
Wang, Juan Tianjin Univ. of Tech.
Xia, Chengyi Tianjin Univ. of Tech.

An improved model named HDA-ResNet, which combines the improved residual network with the dual attention mechanism, was proposed to perform the cervical cancer grade classification based on colposcopy images. Firstly, the maximum pooling layer of the residual network is replaced by a hybrid dilated convolution. Then, the dual attention mechanism is embedded into the improved residual network. Finally, the model is trained and verified on the clinical real dataset provided by the First Affiliated Hospital of Science and Technology of China. The accuracy and precision of experimental classification are up to 93.40% and 94.30%, and the sensitivity and specificity are 95.13% and 96.80%, respectively. The proposed model can be used to improve the prediction of cervical cancer and assist clinicians in making preliminary judgments.

► SatA05-6 15:10–15:30

*Flatness-based Trajectory Planning of An Under-actuated Quadrotor UAV*

Zhang, Chengxu Jiangnan Univ.
Fang, Xing Inst. of Automation, Jiangnan Univ.

The quadrotor UAV is a typical under-actuated and nonlinear system, which brings challenges to the design of the UAV controller and trajectory planning. In addition, the trajectory planning of the UAV is different from the path planning. The trajectory planning considers performance indicators such as time and dynamic constraints of the system, and uses the optimal control idea to generate the optimal reference trajectory in real time. The traditional trajectory planning optimal problem is designed based on the input and state space, and the quadrotor UAV is a typical nonlinear model. Therefore, the planning directly in the state space will bring huge calculations, and even affect the real-time trajectory planning of the UAV. Hence, how to solve the calculation problems brought by trajectory planning is also very important.

**SatA06** 13:30–15:30 Yuetang Conf. Hall

Invited Session: Data Driven Control, Learning and Optimization

Chair: Hao, Li-Ying Dalian Maritime Univ.
Co-Chair: Weng, Yongpeng Dalian Maritime Univ.

► SatA06-1 13:30–13:50

*Research on Cooperative Control of Traffic Signals Based on Deep Reinforcement Learning*

Fan, Lingling Beijing Information Sci. & Tech. Univ.
Yang, Yusong Beijing Information Sci. & Tech. Univ.
Ji, Honghai North China Univ. of Tech.
Xiong, Shuangshuang Beijing Information Sci. & Tech. Universtiy

With the increasing traffic pressure, the problem of road congestion needs to be solved urgently. In recent years, many researchers have used deep reinforcement learning to solve traffic signal control problems, but most of them are based on the situation of single intersection or adjacent intersection, with limitations. This paper proposes an index to evaluate the regional traffic performance, and uses this index to design a traffic signal coordination control algorithm based on deep Q network. The experimental results on the SUMO simulation platform show that the proposed algorithm has better performance in terms of average waiting time and average time loss compared with the other three signal control algorithms.

► SatA06-2 13:50–14:10

*Model Free Adaptive Fault-tolerant Control for Signalized Intersections with Detector Fault*

Ren, Ye Beijing Jiaotong Univ.
Zhang, Dongxu North China Univ. of Tech.
Wang, Li North China Univ. of Tech.
Ji, Honghai North China Univ. of Tech.

In the paper, a data-driven model free adaptive fault tolerant control method designed for signalized intersection with detector fault. First, the RBFNN is used to estimate the queue length in the case of detector fault. Then, the dynamic linearization is applied to construct the data relationship of intersection input and output. Then, based on the idea of queue length equalization, the estimated queue length is introduced into the algorithm to obtain a fault-tolerant signal control algorithm. Finally, the numerical simulation is carried out, in which superiority of the proposed method is validated.

► SatA06-3 14:10–14:30

*Iterative Learning-Based Data-Driven Control for Unknown Unmanned Marine Vehicles with Actuator Faults*

Liu, Huiying Dalian Maritime Univ.
Hao, Li-Ying Dalian Maritime Univ.

This paper researches the iterative learning-based data-driven control for unknown unmanned marine vehicles with actuator faults. And the trajectory tracking problem was considered with external disturbances. Based on the partial form dynamic linearization technique, an equivalent dynamic linearization data model with independent disturbance of unmanned marine vehicles is established. The disturbance and input data have different pseudo partial derivative matrices, and it increases the immunity of the UMVs to disturbance in the environment. Furthermore, an equivalent data model with the unknown pseudo partial derivative matrices including the actuator faults and the UMVs dynamics information is proposed. And, an iterative learning-based fault-tolerant trajectory tracking data-driven control scheme is developed such that the error of trajectory tracking is convergent under external disturbance and actuator faults. Finally, the examples are provided to validate the effectiveness of the proposed iterative learning trajectory tracking control scheme in this paper.

► SatA06-4 14:30–14:50

*Tackling the Imbalance Biases in the Code Cloze Test*

Qi, Xuexin Dalian Maritime Univ.
Zhao, Lingxiao Dalian Maritime Univ.
Li, Hui Dalian Maritime Univ.

Guo, Shikai Dalian Maritime Univ.

Code automation aims to semi-automatically or automatically generate source code of software according to the needs of users. However, existing methods fail to tackle the imbalance bias problem. To solve this problem, we propose a model that uses Gradient Harmonizing Mechanism (GHM) technology to alleviate the difference in the amount of data of different categories in the data. The proposed model first calculates the gradient of each sample, that is, the difference between the classification result and the label value, which is used to indicate the difficulty of classification, and then calculates the gradient density. Finally, take the reciprocal of the gradient density as the weight of the loss value calculation function, reconstruct the loss value calculation function, so as to reduce the influence of the data with too large gradient density on model training, so as to alleviating the data imbalance in the dataset. The proposed method is evaluated through four experiments on our dataset. The results show that the results obtained by the Code Cloze model (C-CM) outperforms the traditional model and the recurrent neural network. Compared with RNN, NBM and SVM models, the average accuracy in all programming languages is improved by 32.9%, 224.7% and 517.9%, respectively.

▶ SatA06-5 14:50–15:10

*Line of Sight-based MFAC Path-following Control of Underactuated Surface Vessels with Exact Sideslip Compensation*

Liu, Zhuofu Dalian Maritime Univ.
Zhang, Qiuxia Dalian Maritime Univ.
Weng, Yongpeng Dalian Maritime Univ.

In this paper, a novel discrete-time reduced-order extended state observer (ESO) sideslip observer-based mode-free adaptive control (ELOS-MFAC) scheme is developed for underactuated unmanned vehicles. The main contributions are as follows: 1) the time-varying sideslip angle is exactly estimated by a reduced-order ESO, thus achieving a high-precision estimation of the sideslip angle and laying the groundwork for sideslip angle compensation; 2) an ESO-based Line of Sight (ELOS) guidance law is proposed to enhance the generalis ability of the LOS guidance law in the case of unknown side slip angles; 3) with estimated surge speed and heading guidance, MFAC technology is adopted in the design of speed controllers. The simulation study conclusively demonstrates the efficacy and superiority of the proposed ELOS-MFAC framework.

▶ SatA06-6 15:10–15:30

*Adaptive Finite-Time Heading Control of Intelligent Ship with Asymmetric Output Constraints*

Liu, Yanli Dalian Maritime Univ.
Sun, Yihua Dalian Maritime Univ.
Hao, Li-Ying Dalian Maritime Univ.

A command filter based finite-time heading control scheme of intelligent ship with asymmetric output constraints is developed. Firstly, asymmetric output constraints are handled via the nonlinear state-dependent function. Then, the finite-time command filters are utilized to filter the immediate control function. This method can solve the issue of calculating burden with good effect. Subsequently, the finite-time error compensate signals are established to make up for the filtering error. Under the constructed tactic, system output does not violate the constraint conditions. Additionally, by analysis of the Lyapunov function and immediate control function, all closed-loop signals are bounded, the heading tracking error can converge to zero in finite time. And the validity of the tactic is confirmed on the simulations in the end.

**SatA07** 13:30–15:30 Hongqi Conf. Hall

Invited Session: Deep Learning Based Soft Sensing and Iterative Learning Control

Chair: Zeng, Jiusun Hangzhou Normal Univ.
Co-Chair: Yuan, Xiaofeng Central South Univ.

▶ SatA07-1 13:30–13:50

*Iterative Learning Control for Moving Boundary Distributed Parameter Systems with Control Delays under Sensor/actuator Networks*

Gong, Weitai Guangxi Univ. of Sci. & Tech.
Zhang, Jianxiang Jiangnan Univ.
Dai, Xisheng Guangxi Univ. of Sci. & Tech.,

The iterative learning control problem of moving boundary distributed parameter systems with control delay under sensor/actuator networks is studied. A P-type iterative learning algorithm with known delays is proposed. The convergence of linear systems with sensor/actuator networks is proved by using compression mapping principle. In order to meet the actual needs of industrial production, the nonlinear system with control delay is also considered, and its convergence is proved by strict mathematical analysis. Through strict mathematical analysis, the condition of convergence of output error is obtained. Numerical results show the effectiveness of the proposed method.

▶ SatA07-2 13:50–14:10

*Self-Learning Temporal-Spatial Graph Model for Industrial Soft Sensing Application*

Zhang, Chiye Zhejiang Univ.
Yao, Le Hangzhou Normal Univ.
Chen, Zhichao Zhejiang Univ.
Shen, Bingbing Hangzhou Normal Univ.
Zeng, Jiusun Hangzhou Normal Univ.

In recent years, deep learning (DL) has been widely studied in soft sensing due to its advantages in feature extraction and nonlinear fitting. However, DL models are black-box models, which are difficult to explain. It is difficult to introduce the prior knowledge about the process into the model, and these shortcomings hinder its application in the actual industrial processes. In this paper, a Self-Learning Temporal-Spatial Graph (SLTSG) deep learning model is proposed and applied to the soft sensor modeling of complex dynamic industrial processes. It uses the graph attention network to construct the explicit nonlinear relationship between variables, and uses its ability to aggregate information to complete the feature extraction from the graph for each time step. Then, the spatio-temporal convolutional network is utilized to extract local nonlinear dynamic features for the prediction of quality variables. Since it is difficult and subjective to obtain graph structure by relying on prior knowledge such as process mechanism, a self-learning method of graph structure is adopted in this paper. To verify the effectiveness of the proposed method, the soft sensing case study of carbon monoxide content in the process of High-Low Transformer is presented. The experimental results show that the model not only has high accuracy, but also has certain knowledge discovery ability.

▶ SatA07-3 14:10–14:30

*Online Monitoring of Time-varying Process Using Probabilistic Principal Component Analysis*

Dong, Yuxuan China Jiliang Univ.
Liu, Ying China Tobacco Henan Industrial Co., Ltd
Liu, Suijun China Tobacco Henan Industrial Co., Ltd
Lu, Cheng China Jiliang Univ.
Luo, Shihua Jiangxi Univ. of Finance & Economics
Zeng, Jiusun Hangzhou Normal Univ.

This paper develops a moving window probabilistic PCA(MW PPCA) online process monitoring method for monitoring time-varying industrial process. First, PPCA model and the method of iteratively solving the parameters of PPCA model by variational inference are introduced. On the basis of the PPCA model, three monitoring statistic, T2, SPE and Var, are introducedalso. In order to solve the time-varying trend, this paper further utilizes a sequential update procedure for PPCA model which is based on a moving window, and uses the streaming variational inference method to recursively update the parameters of PPCA model in each window. Then, the non central chi square distribution approximation is used to solve the control limits of the three statistics under the confidence limits in order to adapt to the process changes more effectively, so as to update the control limits. Finally, the effectiveness of the distillation process is verified.

▶ SatA07-4 14:30–14:50

*Time Series Data Augmentation Classifier for Industrial Process Imbalanced Fault Diagnosis*

Shen, Bingbing Hangzhou Normal Univ.
Yao, Le Hangzhou Normal Univ.
Jiang, Xiaoyu Zhejiang Univ.
Yang, Zeyu Huzhou Univ.
Zeng, Jiusun Hangzhou Normal Univ.

Fault classification is a common problem in industrial fault diagnosis. Usually, classifiers are built assuming an equal amount of data across different classes. However, the amount of normal data and fault data collected from industrial processes is often imbalanced. Intrinsically, the fault classification is also an imbalanced data classification problem. To address this issue, data augmentation methods can be used to effectively generate more data and achieve data balance. While the performance of classification is greatly influenced by the generated data. The quality of the generated data can greatly impact the classification performance. To ensure the stability of the generated data, this paper extends the gen-

eration of single data to the generation of time series data using a time variational autoencoder. Using the generated time series data, a new classifier called the Time Series Data Augmentation Classifier (TSDAC) is proposed to solve the imbalanced fault classification problem. After that, the TSDAC is applied to Tennessee Eastman (TE) benchmark process. The results show that the TSDAC is recommended for imbalanced fault classification.

▶ SatA07-5 14:50–15:10

*Industrial Soft Sensor Prediction Based on Multi-model Integrated Method*


Yuan, Xiaofeng Central South Univ.
Jia, Zhenzhen Central South Univ.
Ye, Lingjian Huzhou Univ.
Wang, Kai Central South Univ.
Wang, Yalin Central South Univ.


The industrial processes are commonly characterized by nonlinearities and dynamics. Therefore, long short-term memory (LSTM) networks are often adopted to extract the nonlinear dynamic features for the prediction of industrial quality indicators. However, traditional LSTM only captures the temporal characteristics of input variables but ignores the output variables. Therefore, a multi-model integrated method (MMIM) is proposed for simultaneously extracting the input and output temporal characteristics in this study. In the MMIM, a LSTM and other static models are used to collect the temporal and static characteristics for the inputs, while a RNN is applied to predict the output variable. The effectiveness and performance are verified on an industrial hydrocracking plant for the prediction of light naphtha isopentane and heavy naphtha quality.

▶ SatA07-6 15:10–15:30

*Gaussian Mixture Model and Double-Weighted Deep Neural Networks for Data Augmentation Soft Sensing*


Jiang, Xiaoyu Zhejiang Univ.
Yao, Le Hangzhou Normal Univ.
Yang, Zeyu Huzhou Univ.
Song, Zhihuan Zhejiang Univ.
Shen, Bingbing Hangzhou Normal Univ.


In practice, data-driven soft sensors often face data shortages in modeling. Although data augmentation technology offers a feasible solution for this problem in recent years. How to make better use of virtual data for data augmentation is still an open topic. In this paper, a novel data augmentation soft sensing method is proposed. It uses Gaussian mixture models (GMMs) to generate virtual data for the training dataset, and developed a double weighted neural network (dwDNN) for weighted regression modeling. On top of that, Bayesian optimization algorithm is applied to the hyperparameter selection of dwDNN to further enhance the efficiency and effectiveness of GMM-dwDNN on virtual data. In the end, a real industrial case is used to illustrate the superiority of the proposed approach in soft sensing.

**SatB00** 15:40–17:45 8th Conf. Hall

Award Session: Best Paper

Chair: SUN, Mingxuan Zhejiang Univ. of Tech.

▶ SatB00-1 15:40–16:05

*A Shared Control Approach for Autonomous Vehicles via Driver Behaviors Learning*


Lang, Yilin Zhejiang Univ.
Li, Zhaoyang Zhejiang Univ.
Guo, Jiazhe Zhejiang Univ.
Zhu, Wenxin Zhejiang Univ.
Ren, Qinyuan Zhejiang Univ.


Vehicles today are in a phase between human control and full autonomy. A reliable and stable approach that shares the decisions of both human and autonomous controllers is needed. This paper introduces a shared control approach to offer control signal from autonomous controller to complement commands of drivers to reduce driving risks and improve driving performance. Knowing future actions of drivers is essential in final decision making. To predict the behavior of driver, Gaussian process regression is adopted to model the driver with the data gathered in the driving process. Utilizing the drivers model and vehicles model, autonomous signal is provided by Model Predictive Controller (MPC) and combined with commands of drivers in certain proportion constituting the final outputs. With the shared control algorithm, both tracking and heading errors are significantly eliminated.

▶ SatB00-2 16:05–16:30

*Adaptive Optimal Control for Discrete-Time Linear Systems via Hybrid Iteration*


Qasem, Omar Florida Inst. of Tech.
Gao, Weinan Northeastern Univ.
Gutierrez, Hector Florida Inst. of Tech.


In this paper, a novel dynamic programming (DP) and adaptive dynamic programming (ADP) algorithms are proposed, namely hybrid iteration (HI), for discrete-time linear systems. The proposed HI approach fill up the performance gap of two well-known DP algorithms, i.e., policy iteration (PI) and value iteration (VI). In particular, HI drops the need of the prior knowledge of an initial stabilizing control policy required in PI, and at the same time it maintains a fast quadratic convergence rate compared with VI. A data-driven adaptive optimal controller design is also proposed based on the proposed HI algorithm. Simulation results for randomly generated discrete-time linear systems with different system orders demonstrate that the proposed HI approach can significantly save CPU time and reduce the number of learning iterations to converge to the optimal solution comparing with the VI approach. The data-driven HI method is implemented to an application of turbocharged diesel engine with exhaust gas recirculation, and the simulation results illustrate the efficacy of the proposed HI method.

▶ SatB00-3 16:30–16:55

*Distributed Model Free Adaptive Iterative Learning Control of Multiple HSTs under DoS Attacks*


Yu, Wei Southwest Jiaotong Univ.
Cheng, Junqiang Europe-Aisa Hi-tech & Digital Tech. Company Limited
Huang, Deqing Southwest Jiaotong Univ.


This paper studies the distributed model free adaptive iterative learning control (MFAILC) of multiple high-speed trains (MHSTs) under malicious denial-of-service (DoS) attacks. By using the equivalent linearization technique, the discrete-time dynamic model of MHSTs is firstly converted into a linear data-based one. Then, the strategy of DoS attacker is introduced, which is represented by a Bernoulli variable with unknown mathematical expectation. Next, the distributed MFAILC scheme is conducted, which belongs to the scope of data-driven approach. Finally, the stability of MHSTs is studied and the validity of the MFAILC is confirmed by a numerical test.

▶ SatB00-4 16:55–17:20

*Time-frequency Hypergraph Neural Network for Rotating Machinery Fault Diagnosis with Limited Data*


Ke, Haobin Central South Univ.
Chen, Zhiwen Central South Univ.
Xu, Jiamin Central South Univ.
Fan, Xinyu Central South Univ.
Yang, Chao Central South Univ.
Peng, Tao Central South Univ.


Due to the scarcity of fault samples and the weakness of processing higher-order interactive information, the most existing intelligence methods fail to achieve the optimal effect in fault diagnosis. To address these problems, a time-frequency hypergraph neural network-based fault diagnosis method is proposed. In the proposed network, the limited data is initially segmented using the sliding window mechanism to obtain a set of time-domain signal instances. Additionally, the Fast Fourier Transform (FFT) is applied to each signal instance to extract corresponding frequency-domain signals, so as to capture more fault-sensitive features. Subsequently, a two-layer convolutional neural network is used to extract fault-attention features from both the time and frequency domain signals. Also, in order to reduce computational complexity, the time-frequency domain features are adaptively stacked based on a self-attention mechanism. Furthermore, a feature similarity graph is constructed for the time-frequency domain features using a k-nearest neighbor algorithm. This graph is then input into the hypergraph neural network (HGNN) to obtain the final diagnosis results. One comparative experiment shows that the proposed method not only mitigates the performance degradation caused by limited samples and noisy environments, but also effectively leverages the higher-order interaction information among nodes in the hypergraph.

▶ SatB00-5 17:20–17:45

*Dual Observer-based Model-Free Adaptive I/O Constrained Control for MIMO Nonlinear Systems*


Zhang, Weiming Jiangnan Univ.
Xu, Dezhi Jiangnan Univ.
Yang, Weilin Jiangnan Univ.

Liu, Jianxing Harbin Inst. of Tech.
Hua, Fei Jiangnan Univ.

In this paper, a dual observer based model-free adaptive control strategy is designed for multiple input multiple output (MIMO) nonlinear systems with disturbances and input/output (I/O) constraints. The dual observers consists of an adaptive observer and a discrete extended state observer, in which the former is designed to realize the dynamic reconfiguration of the system and devise the Lyapunov stability criterion-based estimation algorithm for time-varying parameters, and the latter is explored for composite disturbance estimation. Based on the information from dual observers, a dynamic anti-windup compensator along with an improved prescribed performance control method are proposed in the sliding mode controller to solve the I/O constraint problem. Finally, the stability analysis and simulation are supplied for performance verification.

**SatB01** 15:40–17:40 2nd Conf. Hall
Regular Session: Neural Networks, Fuzzy Systems Control in Data Driven Manner

Chair: Liu, Shan Zhejiang Univ.
Co-Chair: Yang, Yong Xihua Univ.

▶ SatB01-1 15:40–16:00
*Robust Fuzzy Adaptive Funnel Control of Flexible Exoskeleton Joints Based on Singular Perturbation Method*

Jin, Chengwu XiHua Univ.
Yang, Yong Xihua Univ.
Liu, Xia Xihua Univ.
Shi, Xiaoyu Xihua Univ.

This paper focuses on the adaptive funnel control of a flexible exoskeleton joint based on the singular perturbation method. The singular perturbation is used to find the asymptotic solution of a differential equation by decomposing the system into two subsystems. For the fast subsystem, a torque-feedback-based subcontroller is proposed to ensure the suppression of flexible vibration. For the remaining slow subsystem, an improved funnel error transformation is introduced and integrated into the controller design to achieve a specified tracking error performance. Fuzzy logic systems are employed to deal with the nonlinear uncertainties, and an adaptive fuzzy funnel controller is constructed by backstepping method. The simulation results verify the feasibility of the proposed control scheme.

▶ SatB01-2 16:00–16:20
*Prediction of Uterine Fibroid Outcomes Based on DenseNet and Multiple MRI Sequences*

Chen, Yuan Southwest Jiaotong Univ.
Huang, Deqing Southwest Jiaotong Univ.
Qin, Na Southwest Jiaotong Univ.
Yin, Zijie Southwest Jiaotong Univ.
You, Yiting Southwest Jiaotong Univ.

High-intensity focused ultrasound (HIFU) is a surgical method commonly used to treat uterine fibroids, but not all patients are suitable for this treatment. Therefore, effective postoperative outcome prediction can improve surgical success rate. In this study, a data-driven prediction model for HIFU treatment outcome was developed based on patients' MRI sequences and DenseNet network. We used N4 bias correction, SimpleITK intensity normalization, image registration and other preprocessing methods to improve image quality. We also introduced data augmentation and transfer learning methods to solve the problem of small dataset and integrated multimodal information through feature fusion method. In conclusion, the fusion model's Accuracy was 0.769, AUC value was 0.806, which was better than the prediction accuracy of single sequence, and the experimental results showed that the model had good predictive performance.

▶ SatB01-3 16:20–16:40
*Improved Algorithm of Transient Chaotic Neural Network with Combinatorial Optimization*

Cong, Shuang Univ. of Sci. & Tech. of China
Wang, Zhenning Univ. of Sci. & Tech. of China

Transiently chaotic neural networks (TCNN) and its improved versions have been proven to have search abilities for combinatorial optimization problem (COP). However, the TCNN may be able to maintain its solving ability while the chaotic dynamics are cut. In this paper, the mechanism of the continuous-time Hopfield neural network (CHNN) and the TCNN for COP are analyzed qualitatively from the view of the energy function. It is believed that the "annealing" progress, i.e., the dynamic relaxation of the energy function, helps the improvement of the TCNN over the CHNN. Another Hopfield network with a linear activation function and annealing strategy for the COP is proposed in this paper. Simulations on the TSP show that the improved network performs as well as TCNN but is much more efficient. The performance of the TCNN is improved when linear activation functions are used. Compared with the traditional sigmoid activation function, the improved network is more suitable for hardware implementation.

▶ SatB01-4 16:40–17:00
*Siamese Convolutional Neural Network Based Visual Servo for Manipulator*

Deng, Gaofeng ZheJiang Univ.
Liu, Shan Zhejiang Univ.

A visual servo algorithm based on Siamese Convolution Neural Network is proposed for the manipulator to avoid the requirement of feature extraction and feature matching in the traditional image-based visual servo (IBVS). The algorithm feeds the current image and the desired image into the network at the same time, and outputs the relative pose difference between the two images. A closed-loop control system is constructed through the pose difference, and control the end-effector of the manipulator to reach the desired position to grasp the target workpiece. Meanwhile, in order to meet the large amount of data needed in training the neural network, an algorithm to automatically generate the data set is proposed, which can avoid manual collection and labeling of the data set and greatly save the cost. The simulations show the effectiveness and accuracy of the proposed method by comparing with the traditional feature point based IBVS, and the grasping experiment shows the feasibility of the proposed method in actual practice.

▶ SatB01-5 17:00–17:20
*Multi-Object Robot Visual Servo Based on YOLOv3*

Yang, Yulin Zhejiang Univ.
Liu, Shan Zhejiang Univ.

Aiming at the low robustness of image feature extractor in Image-Based Visual Servo (IBVS), a robot visual servo method based on object detection neural network YOLOv3 is proposed. By improving the output layer of YOLOv3 and adding attitude angle of camera, the pixel coordinate and depth information of feature points, the robustness of the IBVS system based on point features is improved while it can cope with multi-type and multi-instance objects, and the problem of the image Jacoby matrix falling into singularity caused by excessive rotation angle error of the optical axis is avoided. The visual servo convergence is accelerated. Meanwhile, the network training data generation algorithm of the desired image is used to replace the traditional manual data annotation, which reduces the cost of data acquisition, and the data enhancement method ensures the generalization performance of the training model.

▶ SatB01-6 17:20–17:40
*A Novel Deep Belief Network Based on Shallow Feature Regression*

Cui, Jiarui Univ. of Sci. & Tech. Beijing
Peng, Liu Univ. of Sci. & Tech. Beijing
Yan, Qun Univ. of Sci. & Tech. Beijing
Li, Qing Univ. of Sci. & Tech. Beijing
Liu, Lingyi Univ. of Sci. & Tech. Beijing

To address the problem that deep belief network (DBN) does not fully utilize the feature information of hidden layer in the application process, which leads to the degradation of model prediction accuracy. A novel DBN based on shallow feature regression (SDBN) is proposed in this paper. Firstly, the initial parameters of SDBN are obtained by unsupervised pre-training. All hidden layers are added to the fully connected layer for regression, and the final prediction output is obtained by linear weighted summation of the hidden layer outputs. Then, backpropagation algorithm (BP) is applied to the supervised fine-tuning process of SDBN. Finally, experimental testing in the debutanizer column validates the validity of the SDBN model. The experimental results show that the prediction accuracy of the SDBN model is reduced by 0.053and 0.071 compared with DBN and PLSR, respectively, under the premise of guaranteeing the model speed.

**SatB02** 15:40–17:40 3rd Conf. Hall
Regular Session: Deep Neural Network and Reinforcement Learning Control

Chair: Li, Dazi Beijing Univ. of Chemical Tech.
Co-Chair: Li, Jinna Liaoning Petrochemical Univ.

▶ SatB02-1 15:40–16:00
*Optimal Sensor Selection Self-Learning for Linear-Discrete System with Unknown Sensor Noise Covariance*

Wang, Xinru Liaoning Petrochemical Univ.
Li, Jinna Liaoning Petrochemical Univ.

This paper focuses on an optimal sensor selection problem with unknown sensor noise covariance for the linear discrete system. Noisy sensor measurements may result in the inaccurate system information and the deteriorating system quadratic performance. A multi-armed bandit formulation based on the optimal sensor selection is presented first. Then, several action-value methods of reinforcement learning are proposed to evaluate the performance of sensor selection and to find the sensor with the smallest noise covariance by minimizing the quadratic performance. To this end, a statistical method is developed to estimate the unknown sensor noise covariance and its convergence is proved. Simulation results of a linear quadratic control example are given to illustrate the effectiveness of the proposed methods.

► SatB02-2 16:00–16:20

*Two-dimensional Network Control Systems with Packet Loss Compensation for Batch Processes*

Xiao, Mohan Liaoning Petrochemical Univ.
Yuan, Yidan Liaoning Petrochemical Univ.
Bo, Guihua Liaoning Petrochemical Univ.
Shi, Huiyuan Liaoning Petrochemical Univ.
Su, Chengli Liaoning Petrochemical Univ.

Aiming at two-dimensional (2D) batch processes with unknown parameters and packet loss under the network transmission, a novel data-dependent 2D off-policy algorithm with compensation of packet loss is developed for realizing the precise and timely control. First, in order to better compensate for the negative impact of data loss on the system performance, a Smith predictor combined with preceding 2D data is introduced into the design of the controller. Second, an optimization performance index is defined and a 2D optimal tracking control problem for the batch process with data loss is constructed. Furthermore, a completely data-driven 2D off-policy Q-learning algorithm is derived by taking into account the reinforcement learning theory and the dynamic programming method. Only the data in time and batch directions is used to acquire the optimal controller gains, and the data-driven optimal tracking control of batch processes with data loss can also be realized. Ultimately, the unbiasedness and convergence of the proposed algorithm are demonstrated by a strict proof process, and its effectiveness is verified by simulation experiments.

► SatB02-3 16:20–16:40

*Research on Intelligent Maneuvering Decision in Close Air Combat Based on Deep Q Network*

Zhang, Tingyu Nankai Univ.
Zheng, Chen Beijing Inst. of Astronautical Sys. Engineering
Sun, Mingwei Nankai Univ.
Wang, Yongshuai Nankai Univ.
Chen, Zengqiang Nankai Univ.

For the Unmanned Combat Aerial Vehicle(UCAV)maneuvering decision in close air combat, the design of reinforcement learning(RL) reward function and the selection of hyperparameters are studied based on the deep Q network algorithm. Considering the angle, range, altitude, and speed factors, an auxiliary reward function is proposed to solve the sparse reward problem of RL. Meanwhile, aiming at the issue of hyperparameter selection in RL, the influence of learning rate, the number of network nodes, and layers on the decision-making system is explored, and a suitable range of parameters is given, which provides a reference for the subsequent research on parameter selection. In addition, the simulation results show that the trained agent can obtain the optimal maneuver strategy in different air combat situations, but it is sensitive to RL hyperparameters.

► SatB02-4 16:40–17:00

*Neural-Learning-Based Finite-Time Trajectory Tracking Control for Robotic Manipulator with Input Friction*

Sun, Guofa Qingdao Univ. of Tech.
Huang, Ming Yu Qingdao Univ. of Tech.
Zhang, Guoju Qingdao Univ. of Tech.
Zhao, Erquan Qingdao Univ. of Tech.

Due to the unknown nonlinear friction, there was a barricade preventing the precision of manipulators from further improvement. To overcome this challenge, the dynamic model of 2-degrees of freedom robot manipulator based on LuGre friction is established in this paper. The adaptive sliding mode observer is used to estimate the immeasurable states, meanwhile the neural network to approximate the friction. On this foundation, a neural-learning-based finite-time trajectory tracking control is designed to improve robustness. In particular, the closed-loop system stability is investigated by the Lyapunov theorem and computed the finite convergence rate thereafter. Finally, simulation results show that the control scheme has a better control effect of the manipulators.

► SatB02-5 17:00–17:20

*Multi-agent Proximal Policy Optimization via Non-fixed Value Clipping*

Liu, Chiqiang Beijing Univ. of Chemical Tech.
Li, Dazi Beijing Univ. of Chemical Tech.

With the wide application of multi-intelligent reinforcement learning (MARL), its development becomes more and more mature. Multi-agent Proximal Policy Optimization (MAPPO) extended by Proximal Policy Optimization (PPO) algorithm has attracted the attention of researchers with its superior performance. However, the increase in the number of agents in multi-agent cooperation tasks leads to overfitting problems and suboptimal policies due to the fixed clip range that limits the step size of updates. In this paper, MAPPO via Non-fixed Value Clipping (NVC-MAPPO) algorithm is proposed based on MAPPO, and Gaussian noise is introduced in the value function and the clipping function, respectively, and rewriting the clipping function into a form called non-fixed value clipping function. In the end, experiments are conducted on StarCraftII Multi-Agent Challenge (SMAC) to verify that the algorithm can effectively prevent the step size from changing too much while enhancing the exploration ability of the agents, which has improved the performance compared with MAPPO.

► SatB02-6 17:20–17:40

*Target Tracking and Path Planning of Mobile Sensor Based on Deep Reinforcement Learning*

Zhang, Kun Southwest Jiaotong Univ.
Hu, Yuanjiang Southwest Jiaotong Univ.
Huang, Deqing Southwest Jiaotong Univ.
Yin, Zijie Southwest Jiaotong Univ.

One of classic issues in the field of artificial intelligence is Path planning, which is widely used in many fields such as national defense military, road traffic, robot simulation, etc. However, most of the existing path planning algorithms have the problems of single environment, discrete action space, and manual modeling. As a machine learning method that does not require artificially providing training data to interact with the environment, the deep reinforcement learning obtained by reinforcement learning is further enhanced the ability to solve practical problems. This paper proposes the application of DDPG (Deep Deterministic Policy Gradient) algorithm on the mobile sensor to achieve path planning on the target. The DDPG algorithm combines DQN, Actor-Critic, PolicyGrient and other strategies. The problem of continuous space adopting the method of deep reinforcement learning has further realized decision-making and judgment on continuous and complex environment.

## SatB03 15:40–17:40 4th Conf. Hall

Invited Session: Disturbance Compensation Based Control

Chair: Chen, Sen Shaanxi Normal Univ.
Co-Chair: Xue, Wenchao Chinese Acad. of Sci.

► SatB03-1 15:40–16:00

*Data-Driven Distributed Optimization Control for A Class of Networked Control Systems with Disturbances*

Yuan, Ruonan Shaanxi Normal Univ.
Zhao, Zhiliang Shaanxi Normal Univ.
Chen, Sen Shaanxi Normal Univ.

This paper investigates the distributed optimization control for a class of first-order multi-agent networked continuous-time control systems. The aim is to design a distributed feedback controller for each agent to make their states converge to the optimal point of the global cost function, which is the sum of local cost functions assigned to each agent. However, in complicated environment, exact mathematical models of external disturbances are always hard to be established. How to design an appropriate feedback controller such that control performance does not be affected by external disturbances is an important, not yet satisfactorily solved issue. This paper proposes a sampled-data-driven disturbance compensation distributed optimization control design method for a class of multi-agent dynamic control systems with disturbances. In this optimization controller design, only the sampled data of each agent and its neighbors is utilized for the convenience of information communication and physical implementation. Besides, a true value of the disturbance at some time instant in the last sampling interval is calculated by using the sampled data, which is used to compensate the disturbance in the

current sampling interval. Through Lyapunov method, it is proved that when disturbance and its derivative are bounded, the states of all agents converge to an arbitrarily small neighborhood of the optimal point of the global cost function. Numerical simulations illustrate the effectiveness of the proposed method.

▶ SatB03-2 16:00–16:20

*Relation between Generalized Proportional Integral Observer and Linear Disturbance Observer Based Control*

Zhang, Shitong — Shaanxi Normal Univ.
Huang, Meiqun — Shaanxi Normal Univ.
Zhao, Zhiliang — Shaanxi Normal Univ.
Chen, Sen — Shaanxi Normal Univ.

Among different disturbance compensation based control methods, the way of estimating disturbances is the core. This paper studies the relationship between two frequently used observer, i.e., generalized proportional integral observer (GPIO) and linear disturbance observer (DOB). By rigorously calculating the transfer function of GPIO, it is revealed that GPIO is exactly an optimal linear DOB. In details, by carefully designing the order and parameters of Q-filter in DOB, the estimating performance of GPIO and linear DOB is the same. The presented theoretical result further shows the relationship between extended state observer and linear DOB, which generalizes the existing results.

▶ SatB03-3 16:20–16:40

*Predictive Finite-time ADRC Based Longitudinal Control for Hypersonic Aircraft with Parametric Uncertainties and Unmodeled Dynamics*

Yang, Jinwei — China West Normal Univ.

It is a significant issue to achieve the fast maneuverability and the strong robustness of hypersonic aircraft. Based on the thoughts of finite-time control and active disturbance rejection control (ADRC), this paper proposes a finite-time ADRC for controlling the longitudinal dynamics of hypersonic aircraft. The proposed design consists of three parts: finite-time feedback, finite-time estimation and estimating predictive modules. To avoid discontinuously changing of control input, the presented finite-time design is in a continuous form. Moreover, to overcome the delay phenomenon of estimation in the conventional ADRC, the predictive values of total disturbance and angular velocity are calculated based on Taylor expansion. The simulations for nonlinear uncertainties validate the effectiveness of the proposed method.

▶ SatB03-4 16:40–17:00

*Predictive Active Disturbance Rejection Attitude Control for 2-DOF Unmanned Helicopter with Three Typical Uncertainti*

Yang, Jinwei — China West Normal Univ.

This paper considers the attitude control for 2-DOF unmanned helicopter. To handle the nonlinear uncertainties in helicopter system, active disturbance rejection control (ADRC) based attitude controller is designed. Compared with the conventional ADRC, the proposed ADRC design contains an additional predictive part for the estimated value from ESO. By utilizing the estimated value and its derivative, the predictive values of total disturbance and unmeasured angular velocity are calculated based on Taylor expansion. The presented predictive design can cancel the hysteresis phenomenon of estimation in ESO, which results in the more accurate estimation. Due to the precise estimation for total disturbance and unmeasured angular velocity, the satisfied tracking performance of presented method is validated. In simulations, the estimating and tracking performance of the presented method is shown for three typical uncertainties: step disturbances, ramp disturbances and nonlinear uncertainties.

▶ SatB03-5 17:00–17:20

*Intelligent Structure Control System Based on FPGA*

Qiu, Ruikang — Yangzhou Univ.
Li, Shengquan — Yangzhou Univ.
Cui, Ronghua — Yangzhou Univ.
Zhang, Lujin — Yangzhou Univ.
Li, Juan — Southeast Univ.

A linear active disturbance rejection control (LADRC) strategy is proposed to suppress the structural vibration caused by external excitations and internal uncertainties in intelligent structures under complex working conditions via an Anlu EG4S20B256 chip. First, the electromechanical coupling model of the whole vibration control system is obtained based on the dynamic equations of the all-clamped plate structure and the electromagnetic equations of the inertial actuator. Second, based on the system model, a third-order extended state observer (ESO) is designed to estimate the internal modelling errors and external excitation perturbations of the system in real time. In addition, the influence of internal and external disturbances on the control effect in the experiment is offset by a feedforward compensation. Finally, a vibration control platform based on the Anlu FPGA chip is built to verify the control effect of the proposed vibration active control strategy through physical real-time simulation.

▶ SatB03-6 17:20–17:40

*Improved BP Neural Network Based Active Disturbance Rejection Control for Magnetic Sensitivity Calibration System*

Wang, Minlin — Beijing Inst. of Tech.
Dong, Xueming — Department of Inertia
Ren, Xuemei — Beijing Inst. of Tech.

In the magnetic sensitivity calibration system, the calibration accuracy of inertial sensor is directly related to the control accuracy of the magnetic induction intensity. Since the helmholtz coils in the calibration system have large parameter uncertainties and the magnetic field sensor has some time-delay, the traditional PID controller cannot satisfy the accuracy requirement of the magnetic induction intensity. Therefore, an improved neural network based active disturbance rejection controller (ADRC) is proposed, which utilizes the conjugate gradient algorithm and Fletcher-Reeves linear search method to adjust the parameters of ADRC for achieving the optimal control efforts. Moreover, the extended state observer of ADRC can compensate for the parameter uncertainties and time-delay exactly such that the control accuracy of the magnetic induction intensity can be largely improved. The simulations are conducted to show the effectiveness and superiority of the proposed control algorithm.

## SatB04 15:40–17:40 5th Conf. Hall

Invited Session: Data-driven Fault Diagnosis and Fault-tolerant Control

Chair: Chen, Hongtian — Univ. of Alberta
Co-Chair: Jiang, Yuchen — Harbin Inst. of Tech.

▶ SatB04-1 15:40–16:00

*Research on Privacy Protection of Internet of Vehicles Based on Elliptic Curve Ring Signature*

Mao, Weiqi — Chongqing Jiaotong Univ.
Mi, Bo — Chongqing Jiaotong Univ.
Huang, Darong — Anhui Univ.
Ma, Haoyu — Chongqing Jiaotong Univ.

With the continuous development of new energy vehicles in recent years, the application of the Internet of Vehicles has also been rapidly expanded. However, behind the development of this series of technologies, there will also be many security issues. has happened. In response to this phenomenon, this paper uses elliptic curve ring signature technology to protect the privacy of messages signed by vehicle users. By hiding their public key in a user group, the other party will not find the information through the signed message. source. Prevent the disclosure of identity and privacy of vehicle users in the process of anonymous voting. The simulation results show that our method is feasible in the Internet of Vehicles (IoV) because it is completely sufficient to support this scheme from the perspective of time.

▶ SatB04-2 16:00–16:20

*Privacy-Preserving PBFT Based on A New BFT Asynchronous Verifiable Secret Sharing*

Mi, Bo — Chongqing Jiaotong Univ.
Mao, Yongyi — Chongqing Jiaotong Univ.
Huang, Darong — Chongqing Jiao-tong Univ.
Weng, Yuan — Chongqing Jiaotong Univ.
Zou, Yongxing — Chongqing Jiaotong Univ.

Many researches on PBFT in the past focused on improving the efficiency of the algorithm, but with the development of the times, people have higher requirements for data privacy, which poses new challenges to the design of the PBFT algorithm. Considering the issue of data privacy, a natural idea is to use the method of secret sharing to let each node only store the secret share locally, and use the binding between the secret share and the polynomial to ensure the consistency of the system. In this line, integrating VSS into the BFT algorithm is a common method, but we found that when the traditional VSS is integrated into the BFT algorithm, there is a problem that the misbehavior of data writer cannot be identified. To solve this problem, we design a new BFT AVSS based on ZKIPCP. Our scheme itself is not excellent, but it is a good choice when integrated into the BFT algorithm, and it can solve the problem that traditional schemes cannot identify malicious data writers. We describe how to integrate our BFT AVSS scheme into the PBFT algorithm for data privacy protection. Finally, we implemented our privacy-preserving PBFT, and proves through experiments that it can meet our original purpose,

that is, privacy protection and malicious data writer identification.

▶ SatB04-3 16:20–16:40

*FedVPS: Federated Learning for Privacy and Security of Internet of Vehicles on Non-IID Data*

Kuang, Hangdong Chongqing Jiaotong Univ.
Mi, Bo Chongqing Jiaotong Univ.
Huang, Darong Anhui Univ.
Deng, Zhaoyang Chongqing Jiaotong Univ.

There are the advantages of fast transmission rate, low delay, and ultra-dense network in 6th generation mobile networks (6G). It solves the problem of communication in the Internet of Vehicles (IoV). However, In the Internet of Vehicles, automobiles as terminals will generate Non-Independent Identically Distribution (Non-IID) data during driving. The Internet of Vehicles as a vehicle network that integrates intelligent computing and vehicle networking, needs to introduce distributed machine learning. In this paper, we propose a heterogeneous Federated Learning scheme that addresses Non-IID of local data and the heterogeneity of local models. According to the distributed architecture (Terminal - Edge device - Cloud) in the Internet of Vehicles, we designed a privacy protection scheme based on Secure Multi-Party Computation (SMPC). It ensures that the terminals participating in the Federated Learning get correct calculation results, without revealing useful information. Thus the privacy of local datasets is preserved. The privacy and security of the Internet of Vehicles based on Federated Learning (FedVPS) not only protects the privacy of the terminals but also improves communication efficiency, enabling accurate and efficient distributed machine learning. The aggregation method of Federated Learning is a prototype-based scheme. This scheme utilizes the effective information stored in local datasets. In the test of the BIT-Vehicle dataset, FedVPS is not only more robust but also has excellent prediction accuracy. Compared with FedAvg, FedVPS has advantages in communication efficiency and model prediction accuracy.

▶ SatB04-4 16:40–17:00

*A Federated Learning Framework Based on CSP Homomorphic Encryption*

Zeng, Ran Chongqing Jiaotong Univ.
Mi, Bo Chongqing Jiaotong Univ.
Huang, Darong Anhui Univ.

In the era of big data, the field of deep learning is developing rapidly. Deep learning model algorithms and a large amount of data make deep learning an effective tool to solve practical problems. However, in the current centralized deep learning model of a large number of client-server models, when we upload our data for training on the server side, there is a risk of leaking privacy. Federated Learning is a type of distributed machine learning that allows multiple institutions or individuals to learn collaboratively without exchanging data. Users only upload their model parameters, and the server aggregates the model parameters of each user into a global model and returns it to the client, and the client updates its local model according to the global model to achieve the global optimal solution, avoiding leakage of private data. However, attackers can still restore user data by obtaining uploaded model parameters from users, which leads to the fact that only transmitting model parameters cannot protect user privacy. Therefore, the issue of privacy protection has become the focus of federated learning. In this paper, the CSP fully homomorphic encryption algorithm is used to encrypt the user model parameters. The CSP algorithm will not cause the loss of model performance, and at the same time has the characteristics of fast encryption speed, which is very suitable for application in the field of machine learning.

▶ SatB04-5 17:00–17:20

*Hexapod Robot Gait Switching Based on Different Wild Terrains*

Fei, Shijie Soochow Univ.
Chen, Yiyang Soochow Univ.
Tao, Hong-Feng Jiangnan Univ.
Chen, Hongtian Univ. of Alberta

Hexapod robots have become an indispensable part of legged robots due to their excellent stability and traversability, and have recently become a hot research topic. In complex outdoor environments, the ability of the hexapod robot to switch its motion strategy according to the terrain is crucial for improving its mobility. This paper presents a terrain recognition network that enables our hexapod robot to switch its forward gait based on the different types of outdoor terrain. This method provides better stability for the hexapod robot than traditional single-gait walking through different terrains.

▶ SatB04-6 17:20–17:40

*Dynamic Path Planning of UAV Based on KF-RRT Algorithm*

Yan, Hang Beijing Information Sci. & Tech. Univ.
Fu, Xingjian Beijing Information Sci. & Tech. Univ.

For the dynamic path planning of UAV, an algorithm based on Kalman Filter and improved Rapid-exploration Random Tree (KF-RRT) is proposed. Firstly, on the basis of the RRT algorithm, the weight coefficient of the target area trend is added, which reduces the time of UAV path planning. Secondly, the prediction function of Kalman Filter is added to predict the motion trajectory of dynamic obstacles in advance. Then, B-spline curve is used for smoothing to plan the feasible path of UAV. Finally, the KF-RRT algorithm in this paper is compared with other RRT algorithms by simulation, which shows that the proposed algorithm is more suitable for the dynamic path planning of UAV.

**SatB05** 15:40–17:40 6th Conf. Hall

Invited Session: Adaptive Control for Nonlinear Servo Systems and Its Applications

Chair: Wang, Shubo Qingdao Univ.
Co-Chair: Zheng, Dongdong Beijing Inst. of Tech.

▶ SatB05-1 15:40–16:00

*A Fast Calibration Method of the Tool Frame for Industrial Robots*

Jiang, Lichen Kunming Univ. of Sci. & Tech.
Gao, Guanbin Kunming Univ. of Sci. & Tech.
Na, Jing Kunming Univ. of Sci. & Tech.
Xing, Yashan Kunming Univ. of Sci. & Tech.

Industrial robots perform tasks through tools installed on the end flange. The position and orientation of the tools are essential factors that affect the motion accuracy of industrial robots. However, existing calibration methods for the tool frame mainly de-pend on manual observation. To solve this problem, this paper proposes an automatic calibration method of the tool frame based on the fact that the accurate position and orientation of the tools relative to the flange can be obtained through the calibration of the tool frame. First, the tool carried by the robot moves in a uniform circle at different heights. The origin and orientation calibration models of the tool frame are established respectively based on the similarity of the motion track of each point on a rigid body. Through two pairs of vertically mounted laser beam sensors, the time when the tool passes through the laser beam and the posi-tion of the corresponding robot flange are obtained. Second, the simulation platform with the robot and sensors is built in a 3-dimensional software to simulate the motion and measurement of the tool. The data required for calibration are acquired, by which the parameters of the origin and orientation of the tool frame are identified and compensated in the motion controller of the robot. Finally, the accuracy of the tool frame before and after calibration is tested in the simulation platform, and the simulation results verify the effectiveness of the proposed model and method.

▶ SatB05-2 16:00–16:20

*Adaptive Tracking and Synchronization Control of Dual-motor Driving Servo System*

Dang, Jiali Qingdao Univ.
Ding, Jiacheng Qingdao Univ.
Zhang, Nan Qingdao Univ.
Wang, Shubo Qingdao Univ.

This paper proposes an adaptive tracking and synchronization control scheme for dual-motor driving servo systems with nonlinear dead-zone. To achieve the tracking performance, the neural network is used to approximate the unknown dynamics, and the approximation is incorporated into the control design to compensate the unknown dynamics. Then, adaptive dynamics surface controller is designed to improve the tracking performance. Moreover, a robust controller is presented based on the mean deviation coupling strategy to guarantee the synchronous operation of dual motors. Simulation results illustrate the performance of the proposed control strategy.

▶ SatB05-3 16:20–16:40

*Adaptive Control-based on Adaptive Observer for Uncertain Nonlinear Servo Systems*

Song, Jiangchao Beijing Inst. of Tech.
Ren, Xuemei Beijing Inst. of Tech.
Na, Jing Kunming Univ. of Sci. & Tech.

A new adaptive observer algorithm and the corresponding controller are designed for nonlinear servo mechanisms containing unknown system states and parameters in this paper. The most innovative point of this paper is that by defining the auxiliary matrix to extract the unknown pa-

rameter estimation error of the system to design the adaptive law, the system state and parameters can be estimated online simultaneously and its convergence is demonstrated. The persistent excitation condition of the system was then verified online. Moreover, based on the estimated values of the adaptive observer, the adaptive controller is designed, and proved the convergence and stability of the overall system. Finally, numerical simulations are designed to verify the effectiveness of the proposed observer framework.

▶ SatB05-4 16:40–17:00

*A Survey on Path Planning for Mobile Robot Systems*

Gao, Hejia Anhui Univ.
Liu, Dongliang Anhui Univ.
Hu, Juqi Anhui Univ.

During the past three decades, it is witnessed that a lot of intense interests and quick advancements have been poured down to the field of robot vehicles. Multiple types of robots, like sweeping robots, greeting robots and robotic toys have become more and more common in people' s daily life. As a core part of robot technology, path planning is to find a fast and safe route from the initial position to the target destination. Motivated by making convenience for scholars who are ambitious to study the path planning technologies, this paper has conducted a round review on this topic. Throughout this paper, the path planning technologies of robot vehicles have been divided into three categories, namely, traditional, intelligent and other approaches. After the main concerns of path planning are concluded for the mobile robot vehicles, the future research directions are subsequently discussed.

▶ SatB05-5 17:00–17:20

*Design of An Adaptive Fuzzy Sliding Mode Controller for Hydraulic Position Servo System*

Tang, Guoqing Anhui Univ. of Tech.
Yang, Mingxing Anhui Univ. of Tech.
Liu, Qingyun Anhui Univ. of Tech.
Yang, Shuai Anhui Univ. of Tech.

In this paper, a novel fuzzy self-tuning mechanism-based adaptive sliding mode controller has been proposed to realize precise position tracking of a hydraulic position servo system with time-varying parameters. To ensure the robustness of the designed system, an adaptive sliding-mode control has been designed. It can also deal with the uncertainties in the dynamics of the hydraulic system. Meanwhile, a fuzzy self-tuning mechanism has been developed to regulate the proportional and switching gains of the reaching control term, which can minimize the chattering problem caused by discontinuous control action of the sliding mode controller. The stability of the controlled system is proven by the Lyapunov stability principle. Finally, a real-time control platform is established, and the effectiveness of the proposed controller for the specified tracking task is demonstrated by preliminary experiments.

▶ SatB05-6 17:20–17:40

*Neural Network-based Variable Impedance Control of Flexible Joint Robots*

Jiang, Minghao Beijing Inst. of Tech.
Zheng, Dongdong Beijing Inst. of Tech.

In this paper, a novel adaptive impedance control strategy for the flexible joint robot (FJR) is proposed. To simplify the controller design process, the singular perturbation technique is used to decompose the original high-order system into low-order subsystems. To reduce the mismatch of the system model, the neural network is used to estimate the friction and unknown system dynamic, where an improved optimal bounded ellipsoid (IOBE) algorithm is adopted to optimize the weight matrix of the neural network, which can fix the learning gain matrix vanishing or unbounded growth in traditional OBE algorithm. Different from traditional impedance controllers with fixed impedance parameters, in this paper, the variable stiffness and damping coefficients are used, which can maintain a fast response speed when the FJR is moving freely and can show more compliance characteristics when the FJR is interacting with the environment. The stability of the closed-loop system is proved via the Lyapunov approach and the effectiveness of the algorithm is verified by simulations.

## **SatB06** 15:40–17:40 Yuetang Conf. Hall

Invited Session: Data-driven Modeling and Adaptive Iterative Learning Control

Chair: Chen, Qiang Zhejiang Univ. of Tech.
Co-Chair: Kong, Ying Zhejiang Univ. of Tech.

▶ SatB06-1 15:40–16:00

*A Novel Distributed K-WTA Model for Communication-Limited Multi-Agent Networks*

Zhou, Junwen Zhejiang Univ. of Sci. & Tech.
Kong, Ying Zhejiang Univ. of Tech.

The aim of the k-winner-take-all (k-WTA) strategy is to address the discovery of the k maximum outputs from s inputs in a competitive manner. In this manuscript, a general distributed k-WTA based on quadratic programming is proposed, for which no center command is needed to identify the k winners. Theoretical analyses shows the generalized superiorities of the distributed model, such as asymptotically convergence, robustness and intelligence. In addition, a numerical examples with dynamic inputs under a limited communication agreement are conducted to showcase the performance of the distributed k-WTA model.

▶ SatB06-2 16:00–16:20

*A New Modification for Iterative Learning Control*

Zhu, Sheng Hangzhou City Univ.
Liu, Hong Hangzhou City Univ.

In this paper, we propose a novel robust adaptive iterative learning control (RAILC) method with switching $sigma$ modifications for a class of nonlinear systems. Different from the existed works, the switching $sigma$ modification instead of the saturation modification, is introduced to guarantee the robustness of the system parametric estimations.

▶ SatB06-3 16:20–16:40

*A Robust Visual SLAM Based on Key Point Instantaneous Rate Identification in Dynamic Environments*

Dong, Xiangyu Zhejiang Univ. of Tech.
Cheng, Chen Zhejiang Univ. of Tech.
Zou, Peng Zhejiang Univ. of Tech.
Ou, Xianhua Zhejiang Univ. of Tech.
He, Xiongxiong Zhejiang Univ. of Tech.

This paper proposes a new motion segmentation and keypoint motion detection method, which can improve the localization accuracy of RGB-D SLAM in dynamic environments. First, we adopt the lightweight semantic segmentation network TopFormer to extract semantic information more quickly, and propose a semantic mask inpainting method based on the depth geometric information obtained by RGB-D sensor, which can make up for the deficiency of the original segmentation mask. Then, based on the inconsistency of the optical flow vector between the moving target and the static background, we propose a keypoint motion state detection method based on two-stage motion estimation, so as to ensure the reliability of this method. Finally, the experimental results show that our method has good performance in dynamic environment.

▶ SatB06-4 16:40–17:00

*Prescribed-Time Tracking Control for Robotic Systems with Uncertain Dynamics*

Yang, Hang Kunming Univ. of Sci. & Tech.
Huang, Yingbo Kunming Univ. of Sci. & Tech.
Na, Jing Kunming Univ. of Sci. & Tech.
Chen, Qiang Zhejiang Univ. of Tech.

This paper presents a prescribed-time tracking control scheme for robotic systems with unknown dynamics. One salient feature is that the robotic systems can achieve prescribed-time stability with the prescribed transient performance, which is different with the traditional work that achieves uniformly ultimately bounded (UUB) and/or asymptotic stability. To realize this purpose, the prescribed performance dynamics (PPD) instead of the traditional prescribed performance function (PPF) is suggested, by which both the transient and steady-state tracking performance can be guaranteed within a specified region inpriori. To avoid using the function approximators (i.e., neural networks (NNs), fuzzy logic systems (FLSs)), an approximationfree- based prescribed-time controller is established with the inertial matrix of robotic systems and the finite-time function merely, which can not only address the system unknown uncertainties but also regulate the control error to zero in a prescribed-time. Furthermore, the Lyapunov-based theoretical analysis is conducted to prove the prescribed-time stability of the closed-loop system. Finally, comparative numerical simulation results are provided to demonstrate the effectiveness of the proposed method

▶ SatB06-5 17:00–17:20

*Robust Iterative Learning Control for Robot Manipulators with Input Deadzone*

Ji, Shuangjie Zhejiang Univ. of Water Resources & Electric Power
Yan, Qiuzhen Zhejiang Univ. of Water Resources & Electric Power

Chen, Qiang Zhejiang Univ. of Tech.
Lin, Mingjun Zhejiang Univ. of Water Resources & Electric Power

This work studies the angle tracking problem of robot manipulators with input deadzone and nonzero initial errors. An robust initial-rectification adaptive iterative learning control scheme is proposed to solve this problem. First, the rectification reference trajectory is constructed for dealing with nonzero initial errors during ILC design. Then, based on system parameterization of robot manipulators, by developing Lyapunov function candidate, together with reasonable dealing with the deadzone nonlinearity, a novel robust adaptive iterative learning control scheme is proposed for uncertain robotic system with unknown input deadzone. All closed closed-loop signals are proved to be bounded, with the desired tracking performance achieved. At the end, a numerical simulation is carried out to verify the effective of the proposed robust adaptive iterative learning control scheme.

▶ SatB06-6 17:20–17:40

*Adaptive Iterative Learning Control of Nonparametric Systems Based on Inverse Deadzone Model*

Mo, Congcong Zhejiang Univ. of Water Resources & Electric Power
Yan, Qiuzhen Zhejiang Univ. of Water Resources & Electric Power
Lin, Mingjun Zhejiang Univ. of Water Resources & Electric Power
Chen, Qiang Zhejiang Univ. of Tech.

In this work, a robust adaptive iterative learning control approach is proposed to solve the tracking control problem for a class of nonparametric systems with input deadzone. An adaptive learning deadzone inverse model is constructed to handle the unknown deadzone nonlinearity. Lyapunov synthesis is used to design a robust adaptive ILC law. High precision tracking performance may be obtained over the whole time interval as the iteration cycle increases. The boundedness of all closed-loop signals can be guaranteed. At last, a simulation result is given to demonstrate the effectiveness of the proposed robust adaptive iterative learning control scheme.

**SatB07** 15:40–17:40 Hongqi Conf. Hall

Invited Session: Identification and Learning Optimal Control for Nonlinear System

Chair: Lv, Yongfeng Taiyuan Univ. of Tech.
Co-Chair: Li, Linwei Zhengzhou Univ. of Light Industry

▶ SatB07-1 15:40–16:00

*Hammerstein System Identification Using Robust Estimator Based on Quantized Observation*

Li, Linwei Zhengzhou Univ. of Light Industry
Wang, Fengxian Zhengzhou Univ. of Light Industry

Hammerstein system is the most popular block-oriented model, which can represent a large number of nonlinear model features. With the rapid development of science and technology, quantization communication has become a hot topic in data transmission field based on quantized sensor. Because Hammerstein system can describe an actuator in series with linear system, the quantized Hammerstein system are receiving more and more attention. In this context, this work discusses the identification of the Hammerstein system in the presence of quantitative observation. To obtain the effective system data, a constant filter gain is used to filter the system input and output data. Then, the multi innovation theory is introduced to expand the prediction error data into matrix form. Based on the above matrices, the augmented parameter error data can be gained. Right after, the robust estimator is given by using the augmented parameter error data. Finally, we apply the quantized example to examine the performance of the proposed estimator.

▶ SatB07-2 16:00–16:20

*Generalised Policy Learning Based Adaptive Optimal Tracking Control of Nonlinear Servomechanisms*

Zhao, Jun Shandong Univ. of Sci. & Tech.

This paper develops an optimal tracking control strategy for nonlinear servomechanisms via generalised policy learning (GPL) algorithm, where the actor neural network (ANN) and an initial stabilising control policy are avoided. To this end, we first design a steady-state control to guarantee the tracking performance, while an optimal control is derived to further regulate the tracking error via minimizing the cost function. Then, a critic neural network (CNN) is used to reformulate the defined optimal cost function, this contributes to updating the critic with Bellman approach. To obtain CNN weights with guaranteed convergence, a novel adaptive law is designed via adopting the sliding mode technique. Because of its strong online learning ability, the adaptive critic and the control action update each other continuously and simultaneously without any iterative steps. Finally, simulation results are performed to verify the effectiveness of presented control method.

▶ SatB07-3 16:20–16:40

*Adaptive Robust Control of the Continuous-time Two-input Systems with Unknown Disturbance Based on Q-function*

Lv, Yongfeng Taiyuan Univ. of Tech.

Considering overshoot and chatter of the multi-input system with unknown interference, this paper solved the adaptive robust optimal controls of continuous-time two-input systems with an approximate dynamic programming (ADP) based Q-function scheme. A complex Hamilton-Jacobi-Issacs (HJI) equation is constructed with the two-input system and the zero-game-based value function. To solve the HJI equation is a challenging task. Thus, an ADP based Q-function with neural network is constructed to learn the saddle point of the HJI equation. Simultaneously, an integral reinforcement signal of the critic networks is introduced such that the system drift and input dynamics in HJI equation are relaxed when studying the saddle-point intractable solution. Then, the adaptive robust optimal actor and worst disturbance are approximated with another three networks. Finally, an F-16 aircraft plant is used to verify the proposed ADP based Q-function.

▶ SatB07-4 16:40–17:00

*Research on Dual Motor Drive System of Plug-in Hybrid Powertrain*

Zhao, Ziliang Shandong Univ. of Sci. & Tech.

The power performance and economic performance of the vehicle are very affected by hybrid powertrain system. The intelligent Dual motor System (iDD) configuration scheme is proposed in this paper, which is mainly composed of an engine, drive motor, generator, transmission mechanism, and so on, which is mainly driven by electric motor, which can achieve all of the hybrid function. On this basis, the dynamic characteristics and basic control strategies of the plug-in hybrid power are analyzed in the CD (Charge Depleting) phase and the CS (Charge Sustaining) phase. The iDD and P2 configuration characteristics are compared in detail take the A-class model as an example, parameter matching of components is carried out respectively, and the DC phase and the CS phase performance simulation comparative analysis are completed. The results show that the iDD performance is better than P2 in CD phase; the four factors are analyzed in the CS phase, such as transmission efficiency, brake energy recovery, series and parallel efficiency, and different vehicle speed conditions, iDD economy performance is better than P2, but the cost and versatility of P2 are better than iDD. From above analysis, it can be concluded that P2 is suitable for the current product development application, iDD is more powerful, and has the advantages of simple structure, compact layout, and high system efficiency et al. It is one of the development directions for electric vehicle power system.

▶ SatB07-5 17:00–17:20

*Online Parameter Identification for Fractional Order Model of Lithium Ion Battery via Adaptive Genetic Algorithm*

Guo, Bin Shandong Univ. of Sci. & Tech.

In order to overcome the shortcomings of the equivalent circuit model and the electrochemical model, a fractional impedance model is established based on the electrochemical impedance spectrum data, and the polarization effect is described in a simple and meaningful way using fractional elements. In this paper, we propose an online parameter identification method for fractional order model (FOM) of lithium ion battery, where an adaptive genetic algorithm is designed to estimation unknown parameters. To this end, an FOM is constructed by using the Grünwald-Letnikov (GL) definition. Then, a unscented kalman filter (UKF) method is adopted to estimate the internal model states. Based on the obtained states, an adaptive genetic algorithm (AGA) is designed to online identify the unknown parameters. Finally, comprehensive experimental verification results are provided to show the effectiveness of the proposed methods.

▶ SatB07-6 17:20–17:40

*Time-varying Formation Control for Second-order Nonlinear Multi-UAV System*

Li, Zhenyan Kunming Univ. of Sci. & Tech.
Yang, Chunxi Kunming Univ. of Sci. & Tech.
Zhang, Xiufeng Yunnan International Joint Laboratory of Intelligent Control & Application of Advanced Equipment

Li, Yiming Kunming Univ. of Sci. & Tech.
Yang, Jianquan Kunming Univ. of Sci. & Tech.

The problem of time-varying formation analysis and control protocol design for a multi-UAV system with a nonlinear term is considered. Firstly, a formation control protocol for multi-UAV system is proposed for a predefined time-varying formation. Then, the multi-UAV formation problem is transformed into a consensus problem through the formation reference function. The condition for the multi-UAV system to reach time-varying formation is proposed. And the reference function expression is given. Moreover, the stability of the system is proved by the partial stability method. In addition, the design process of time-varying formation control protocol for multi-UAV system with nonlinear term is given. Finally, a multi-UAV system composed of five UAVs is utilized to verify the feasibility of the method by simulink. Simulation results show that the proposed time-varying formation control method is effective.

# Sunday, May 14, 2023

**SunA01** 08:00–10:00 2nd Conf. Hall
Invited Session: Reinforcement Learning Theory and Its Applications
Chair: Xiang, Zhengrong Nanjing Univ. of Sci. & Tech.
Co-Chair: Song, Ruizhuo Univ. of Sci. & Tech. Beijing

► SunA01-1 08:00–08:20
*A New Deep Learning-based Food Recognition System for Mobile Terminal*
Chen, Wenze School of Automation & Electrical Engineering
Song, Ruizhuo Univ. of Sci. & Tech. Beijing

With the improvement of people's health awareness, people pay more attention to their health. In recent years, the intelligent health management system based on food recognition technology has become popular, which can help users maintain healthy eating habits. However, applying the current deep learning method in mobile phones and other terminal devices is difficult, mainly because the terminal devices have the low computing power and the network needs to perform many calculations during operation. In this paper, we have adopted the methods of parameter reconstruction and calculation graph fusion to reduce the network computing load so that it can run in real-time in terminal devices, and the detection speed on Snapdragon 778G SOC exceeds 7 FPS. Besides, experiments on the VIPER-FoodNet (VFN) dataset show that our model has a high mean average precision (mAP) of 9.17% compared with the current advanced model.

► SunA01-2 08:20–08:40
*YOLOv5 Detection Algorithm of Steel Defects Based on Introducing Light Convolution Network and DIOU Function*
Wu, Yinan Nanjing Univ. of Sci. & Tech.
Zhu, Yun Nanjing Univ. of Sci. & Tech.
Guo, Jia Nanjing Univ. of Sci. & Tech.
Yin, Zhenyu Nanjing Univ. of Sci. & Tech.

During production and use, the steel surface will produce cracks, rolling scale, patches, pitting surfaces, inclusions, scratches, etc. These defects will damage the physical structure of the steel and have a great impact on the quality of the steel. Aiming at the problem that the detection accuracy of steel surface defects needs to be improved, an improved algorithm based on YOLOv5 is proposed to identify the surface defects of steel. First, the improved lightweight ShuffleNet V2 is introduced to replace the convolution layer in some backbone networks, so as to enhance the feature extraction capability of the backbone networks; Then DIoU loss function is selected to replace GIoU loss function in YOLO to optimize the training model to improve the recognition accuracy of the network model. The improved algorithm has obvious improvement in accuracy P (Precision), recall R (Recall), and average precision MAP (Mean Average Precision), which verifies the feasibility of this method.

► SunA01-3 08:40–09:00
*Q-learning Based Optimal Tracking Control of Coal-fired Power Plants*
Liu, Xiaomin China Univ. of Mining & Tech.
Yu, Mengjun China Univ. of Mining & Tech.
Yang, Chunyu China Univ. of Mining & Tech.
Zhou, Linna China Univ. of Ming & Tech.

With ever increasing energy consumption, "new energy, thermal power and energy storage" become the main developing direction of future energy source. Coal-fired power generation is the main controllable and storable energy source, and its flexible optimal control plays an important role in the safe and stable operation of power grids. However, coal-fired power generation faces many challenges, such as the difficulty in accurately constructing mathematical models and asymmetric input constraints. To this end, in this paper, we propose a Q-learning algorithm based on critic-only structure to solve the optimal tracking control problem of model-free non-affine nonlinear discrete systems with asymmetric input constraints, and thus realize the adaptive set-point tracking control of coal-fired power plants. Firstly, the coal-fired boiler-turbine system tracking problem can be converted into a state feedback regulation problem of an augmented error system. Then, by introducing a continuous monotone bounded odd function as a symmetric constraint function, the asymmetric input is constrained to be symmetric around the median of the control range. A performance index function without additional penalty term is designed to satisfy the optimal performance index, and then the constrained control problem is transformed into an unconstrained control problem. Experience replay technology is introduced to priority sample data near the set value and store them in the experience pool, so as to improve the efficiency of data exploration and accelerate the convergence speed of the algorithm. Next, Q-learning algorithm is proposed by updating state-action value function with information obtained from sampling. A single critic neural network is introduced to approximation Q function whose weights are updated by least-square method, and an adaptive controller is designed by policy gradient descent method. It is proved by mathematical induction that the Q function converges monotonically to the optimal value function in the iterative process. Finally, the feasibility and effectiveness of the proposed control method is verified through the boiler-turbine system numerical simulation.

► SunA01-4 09:00–09:20
*Consensus Analysis for Multi-agent Systems with Markov Switching Hierarchical Network Topology*
Duan, Zhaoxia Hohai Univ.
Dai, Jun Hohai Univ.
Xiang, Zhengrong Nanjing Univ. of Sci. & Tech.
Li, Xiankun Beijing Jinghang Research Inst. of Computing & Communication
Wang, Shaoping Hohai Univ.

In this paper, we study the state consensus problem of multi-agent systems with Markov switching in hierarchical network topology and interlayer communication delay. The statistical property of Markov process and a mode-dependent Lyapunov-Krasovskii functional is used to derive the sufficient conditions of hierarchical consensus in form of linear matrix inequalities. An illustrative example is provided to verify the effectiveness of the proposed approach.

► SunA01-5 09:20–09:40
*Event-triggered Finite-time Control Design for Positive Systems Based on Linear Programming Approach*
Li, Shuo Hangzhou Dianzi Univ.
Li, Liang Hangzhou-Dianzi-Univ.
Cui, Mingzhe Hangzhou Dianzi Univ.
Tian, Yu-Ping Hangzhou Dianzi Univ.
Wang, Jinling Anhui Agricultural Univ.

This paper addresses the finite-time control design for a class of positive systems based on event-triggered mechanisms via a linear programming(LP) approach. Firstly, a new event-triggering condition in the form of vector 1 norm is proposed for positive systems. Then, sufficient conditions of positivity, finite-time stability and finite-time boundedness are provided for the closed-loop system under the designed LP-based event-triggered finite-time control law by applying the matrix decomposition technology. Finally, an example with comparison is given to illustrate the validity of the results.

► SunA01-6 09:40–10:00
*Physics-Informed LSTM Network-Based Nonlinear Model Predictive Control*
Chen, Yujing Huazhong Univ. of Sci. & Tech.
Qu, Qilin Huazhong Univ. of Sci. & Tech.
Zhang, Hong Huazhong Univ. of Sci. & Tech.
Wang, Yanwei Wuhan Inst. of Tech.
Zheng, Ying Huazhong Univ. of Sci. & Tech.

To address the problems of poor physical interpretability and huge sample size requirement when using neural networks to fit nonlinear control system models for state prediction, this paper proposes a model predictive control algorithm based on a physics-informed long short-term memory(LSTM) network. Firstly, the neural network incorporating physical information is extended to model the ordinary differential equations with variable initial states and external control quantities, which makes the network adaptable to the control task and makes the training model physically interpretable. Secondly, a network structure with a mixture of fully connected layers and LSTM layers is built by using the good learning ability of LSTM for time-series data, and the loss function is designed according to the system characteristics and prediction requirements. The trained neural network model is then used as an internal prediction model to construct a nonlinear model predictive control algorithm. Finally, taking the continuous stirring reactor system as an example, the method is verified to be able to fit the system model highly and reduce the time to reach the steady state with a small number of samples.

**SunA02** 08:00–10:00 3rd Conf. Hall
Regular Session: Model-free Adaptive Control

Chair: Wang, Xin Southwest Univ.
Co-Chair: Xiong, Shuangshuang Beijing Information & Tech. Univ.

▶ SunA02-1 08:00–08:20
*A Novel Successive Updating Scheme of Iterative Learning Control for Networked Control System with Output Data Dropouts*
Zhang, Zhiyang Beijing Inst. of Petrochemical Tech.
Li, Zhenxuan Beijing Inst. of Petrochemical Tech.
Guo, Shuang Beijing Inst. of Petrochemical Tech.
Yin, Chenkun Beijing Jiaotong Univ.

This paper explores the problem of random successive data loss at output side of stochastic linear systems and proposes a novel successive updating scheme (SUS) based on iterative learning control (ILC) to refrain from deteriorating of the control performance due to the data loss. Specifically, the successively dropped output data in current iteration is compensated by predictive information which the multi-step predictive model estimated correctly with the same time instant label in the latest iteration. The convergence of the proposed ILC scheme is proved by mathematical induction. Finally, a simulation example is given to corroborate the theoretical analysis.

▶ SunA02-2 08:20–08:40
*Consensus Control of Unknown Nonlinear Discrete-time Multi-agent Systems with Nonuniform Time-delays*
Xiong, Shuangshuang Beijing Information & Tech. Univ.
Hou, Zhongsheng Beijing Jiaotong Univ.
Fan, Lingling Beijing Information Sci. & Tech. Univ.

This note investigates the data-driven consensus control for a class of unknown heterogeneous nonlinear multi-agent systems with nonuniform communication delay by using modelfree adaptive control (MFAC) method. The designed controller is distributed and data-driven with only using the agent itself and its neighbors data information without any model information. The consensus of the multi-agent system is rigorously presented based on the proposed control protocol. The effectiveness of the proposed algorithm is test by the simulation of two different topologies.

▶ SunA02-3 08:40–09:00
*Quantized Data Driven Model-Free Adaptive Predictive Control for A Class of Nonlinear Systems*
Liu, Genfeng Henan Univ. of Tech.
Hou, Zhongsheng Beijing Jiaotong Univ.

In this paper, a quantized data driven model-free adaptive predictive control algorithm is presented for a class of nonlinear systems to deal with the limited network transmission capacity. Firstly, a uniform quantizer is designed to handle the network bandwidth limitation and an encoding–decoding mechanism is introduced to reduce the effects of quantization errors. Secondly, based on compact form dynamic linearization method, by only utilizing the input and output data of the control system, a quantized data driven control scheme is designed. Finally, a simulation is given to show the effectiveness and robustness of the presented control algorithm.

▶ SunA02-4 09:00–09:20
*Event-triggered Adaptive Cooperative Control for Nonstrict-Feedback Nonlinear Multiagent Systems*
Nie, Liduo Southwest Univ.
Wang, Xin Southwest Univ.

This study examines the leader-follower consistency issue in a particular class of multiagent systems and provides an event-triggered adaptive control approach. The event-triggered mechanism designed in this paper dramatically reduces the communication load and data transmission, which can better serve practical production applications. It is shown that the suggested control method prevents Zeno behavior and ensures that all signals in a closed-loop system are bounded. The effectiveness of the suggested control method is confirmed by the simulation results.

▶ SunA02-5 09:20–09:40
*Anti-sway Control for Bulk Terminal Gantry Cranes Based on MFAC*
Liu, Wangwang Qingdao Univ. of Sci. & Tech.
Yao, Wen-Long Qingdao Univ. of Sci. & Tech.
Chi, Ronghu Qingdao Univ. of Sci. & Tech.
Mu, Chenglin Qingdao Univ. of Sci. & Tech.

To address the problem of lifting weight sway generated by underdriven gantry cranes during operation, considering the load diversity of the portal machine and other disturbance effects, this paper proposes a control method that does not rely on an exact model. Firstly, a simple kinematic model of the gantry cranes is established and dynamically analyzed, then a compact form dynamic linearization is performed to obtain the data model, a pseudo-partial derivative estimation law is computed online, a model-free adaptive control based gantry cranes anti-sway controller is designed, and finally a simulation analysis is performed. The simulation results show that the load swing angle amplitude is effectively suppressed and quickly dissipated, while it has strong robustness to external unknown disturbances. Compared with the PID control simulation analysis, this control algorithm has more effective anti-sway control effect and can reach the stable state faster.

▶ SunA02-6 09:40–10:00
*Adaptive Compensation FTC for Dynamic Nonlinear Systems Based on Data-Driven Theory*
Yang, Chen Liaoning Petrochemical Univ.
Peng, Bo Univ. of Sci. & Tech. Liaoning
Bo, Guihua Liaoning Petrochemical Univ.
Shi, Huiyuan Liaoning Petrochemical Univ.
Su, Chengli Liaoning Petrochemical Univ.

Since modern industrial processes often have characteristics of parameter uncertainty, strong nonlinearity and partial actuator failure, an adaptive compensation fault-tolerant control for dynamic nonlinear systems based on data-driven theory. First, a controlled object is represented as an incremental state space model consisting of an identifiable linear part with a failure coefficient and a lumped dynamic nonlinear term. Second, the lumped dynamic nonlinear term is divided into a nonlinear term of the previous time and a nonlinear incremental term. An adaptive compensation fault-tolerant controller based on data-driven theory is constructed, including a linear controller and two nonlinear compensators. Among the rest, a conventional robust fault-tolerant controller is designed based on the linear part of the incremental model, and a nonlinear fault-tolerant compensator is designed for the nonlinear term of the previous time. Then, taking the tracking error of the closed-loop system as an input, a feedforward fault-tolerant compensator for the nonlinear incremental term is designed with the one-step optimal feedforward idea. Third, the corresponding stability and convergence of the system are analyzed by proving that the input, output and tracking error of the closed-loop system are bounded. Finally, the simulation and experiment results show that the proposed method can make the output has excellent tracking effect and little fluctuation.

**SunA03** 08:00–10:00 4th Conf. Hall
Invited Session: RL and ADP-based Adaptive Control

Chair: Zhao, Bo Beijing Normal Univ.
Co-Chair: Bai, Weiwei Dalian Maritime Univ.

▶ SunA03-1 08:00–08:20
*Adaptive Iterative Learning Control for Industry Batch Process with Time-Varying and Unknown Parameters*
Li, Peiyuan Guangdong Univ. of Tech.
Li, Panshuo Guangdong Univ. of Tech.

The batch process is a typical manufacturing mode in industry. In this article, an adaptive ILC method is proposed for the batch process with time-varying and unknown parameters. The proposed method involves merging an adaptive updating law that utilizes the steepest descent method to estimate unknown parameters with a controller that adjusts the estimated system. The proposed condition ensures that the estimated parameter error remains bounded and that the estimated state error is stabilized. The controller utilizes the estimated results to steer the estimated system to track the reference trajectory. A numerical experiment is presented to demonstrate the efficiency of the proposed method.

▶ SunA03-2 08:20–08:40
*An Overview of Optimal Control Methods for Singularly Perturbed Systems*
Nie, Hao Liaoning Petrochemical Univ.
Li, Jinna Liaoning Petrochemical Univ.

Optimal control design methods for multiple time-scale systems are a hot research topic in recent years. In this paper, a comprehensive overview of the design methods for optimal control of multiple time-scale systems is presented. Firstly, the mathematical model of the optimal control problem of multiple time-scale systems is given, and the key difficulties of the related research are analysed. Secondly, the design methods for optimal control of multiple time-scale systems based on the model and reinforcement learning (RL) methods are given respectively. Thirdly, the performance analysis and practical application of the multi-time scale system

are analyzed. Finally, the current problems in solving the optimization of multiple time-scale systems are analysed, and the research directions of optimal control of multiple time-scale systems are prospected.

▶ SunA03-3 08:40–09:00

*Online Non-parametric Modeling for Ship Maneuvering Motion Using Local Weighted Projection Regression and Extended Kalman Filter*

Yue, Wancheng Dalian Maritime Univ.
Ren, Junsheng Dalian Maritime Univ.
Bai, Weiwei Dalian Maritime Univ.

This paper proposed a method of online non-parameter identification of nonlinear ship motion systems.Firstly, we use Mariner to generate a certain amount of ship motion data to train the LWPR model. Then the ship travels along a set track. During this process, the sensors continuously obtain the distance, radial velocity and azimuth of the ship relative to the ship, and then completes the construction of simulation data. Next, the performance of the algorithm is verified which uses the Kalman filtering framework. Finally, the estimated value is further used for updating the LWPR model to achieve the purpose of online learning, and the updated model will be used for the next prediction. The experimental results show that the online modeling and tracking method proposed in this paper has higher tracking accuracy than the parameter estimation techniques.

▶ SunA03-4 09:00–09:20

*Estimation of Ship Hydrodynamic Derivatives Using Numerical PMM Test with Trim Conditions*

Zhang, Guangbin Dalian Maritime Univ.
Ren, Junsheng Dalian Maritime Univ.
Tan, Xiaowei Dalian Maritime Univ.

Based on planar motion mechanism and overlapping mesh technique, the maneuverability hydrodynamic derivative of KVLCC2 ship model in viscous flow field is calculated. By numerical simulation of oblique shipping motion, pure sway motion and pure yaw motion, the calculated hydrodynamic force is compared with the experimental value under corresponding conditions. The calculated hydrodynamic derivative is in good agreement with the experimental value, and the accuracy of the calculated hydrodynamic derivative is high. On this basis, the trim is added to the ship to study the variation law of hydrodynamic derivative of ship maneuverability under the condition of trim.

▶ SunA03-5 09:20–09:40

*Data-Based Approximate Optimal Control for Unknown Nonaffine Systems via Dynamic Feedback*

Lin, Jinquan Guangdong Univ. of Tech.
Zhao, Bo Beijing Normal Univ.
Liu, Derong CASIA

In this paper, an integral reinforcement learning (IRL)-based approximate optimal conrtol (AOC) method for unknown nonaffine systems is developed by using dynamic feedback. For optimal control problems of nonaffine systems, optimal control policy cannot be expressed explicitly since the input gain matrix is unknown. Therefore, the nonaffine system is transformed into an augmented affine system by introducing a dynamic feedback signal as the virtual control input. Moreover, by designing an appropriate value function for the augmented affine system, the optimal control of augmented affine system is formulated as the approximate optimal control for unknown nonaffine systems. Moreover, the integral reinforcement learning method is adopted to derive the approximate solution of Hamilton-Jacobi-Bellman equation via the critic-only structure. Theoretical analysis concludes that the developed IRL-based AOC scheme guarantees the closed-loop system to be uniformly ultimately bounded. Finally, a simulation example is utilized to illustrate the effectiveness of the present approach.

▶ SunA03-6 09:40–10:00

*Classification of Motor Imagery EEG Signals Based on Channel Attention Mechanism*

Yu, Yue Changchun Univ. of Tech.
Ji, Wenkai Changchun Univ. of Tech.
Zhao, Liming Changchun Univ. of Tech.
Sun, Zhongbo Changchun Univ. of Tech.
Liu, Keping Changchun Univ. of Tech.

Brain-computer interface (BCI) technology establishes communication between the brain and external devices by decoding EEG signals. BCI technology based on motor imagery (MI) has great application potential. There are many different methods to extract motor intention from electroencephalogram (EEG) based on motor imagery (MI).These methods rely on extracting the unique features of EEG in the process of imaginary movement, which directly affect the performance of neural decoding algorithm of BCI. Convolutional neural network (CNN) shows outstanding advantages in automatic extraction of image features. In this paper, an image representation method based on the EEG is proposed as the input of the network. Then, a CNN and a CNN based on Channel Attention Mechanism (CAM) are built as the classifier, convolution layers and activation functions of different sizes are validated. The performance of the method is evaluated. A CNN framework based on CAM, which contained three convolution layers (3-L) is better than the other state-of-the-art approaches. The accuracy on dataset IV from BCI competition II reaches 72.6%.

## SunA04 08:00–10:00 5th Conf. Hall

Invited Session: Reinforcement Learning and Its Applications in Decision-making and Control Systems

Chair: Zhang, Qichao Chinese Acad. of Sci.
Co-Chair: Yang, Yongliang Univ. of Sci. & Tech. Beijing

▶ SunA04-1 08:00–08:20

*Resilient Distributed Secondary Control Strategy for New Energy Shipboard Microgrid Against Bounded FDI Attacks*

Wang, Liangbin Dalian Maritime Univ.
Yu, Renhai Dalian Maritime Univ.
Lv, Jin Port of Guangzhou Pilot Station
Zhang, Bo Ningbo Pilot Station
Wang, Fuzhi Dalian Maritime Univ.
Teng, Fei Dalian Maritime Univ.

The application of shipboard microgrids (SMGs) makes it possible to effectively use renewable new energy on the shipboard platform. As renewable energy sources are connected to SMGs in the form of distributed generators (DGs), the openness of the system increases and so does the risk of exposure to cyber attacks. In this paper, a resilient distributed secondary frequency control strategy for SMGs is constructed to resist false data injection (FDI) attacks. An attacker can tamper with the information in the communication links between the DGs of a SMG to prevent the DGs from outputting stable power, thereby causing oscillations in the entire SMG. To increase resilience to FDI attacks, the proposed resilient control strategy introduces a control network layer interconnected with the original data transmission layer to form a hierarchical communication network. By setting the SMG parameters, the proposed strategy can well reduce the negative effects of FDI attacks on DGs and ensure the stable operation of SMGs. Finally, the simulation results verify the effectiveness of the strategy.

▶ SunA04-2 08:20–08:40

*Adaptive Input Shaping Control Based on RLS for Harvesting Mechanical Arm*

Sun, Mingming Univ. of Sci. & Tech. Beijing
Liu, Dexin Univ. of Sci. & Tech. Beijing

In this paper, a direct method of adaptive input shaping algorithm for a harvesting mechanical arm clamps the tomato bunches is proposed to achieved zero residual vibration. The traditional input shaping would lose its vibration suppressing function when the system parameter changed during mechanical arm’ s load varied. The adaptive input shaping algorithm based on recursive least square method (RLS) requires no system identification. The residual vibration of output signal is used as the input of the algorithm to calculate the impulse time and amplitude of shaper. An adaptive forgetting factor updating algorithm is proposed to improve the control performance in variable load condition. The experimental results show that the adaptive forgetting factor input shaper greatly reduces the residual vibration.

▶ SunA04-3 08:40–09:00

*Hybrid Variable Structure DBN Mission Decision-Making Method for UAV Swarm*

Liu, Bo Wei Beijing Inst. of Tech., School of Aerospace
Sun, Jingliang Beijing Inst. of Tech.
Long, Teng Beijing Inst. of Tech.
Liu, Dawei China Research Development Acad. of Machinery Equipment
Cao, Yan Beijing Inst. of Tech.

To cope with the dynamic mission decision-making issue in complex environments for UAV swarm, a hybrid variable structure-based dynamic Bayesian network (HVSDBN) inference decision-making method is proposed. Firstly, the UAV swarm mission decision-making model is established to assess the UAV swarm state and threat state accurately. To further improve the accuracy of decision-making, the threat assessmen-

t model and swarm state assessment model are built by using mixed continuous and discrete variables, respectively. Furthermore, a dynamic HVSDBN decision-making algorithm based on hybrid performance-capability parameters is proposed, which can adjust the structure of the decision model according to the priori information and observation data to improve the adaptability of the solution strategy. Simulation results demonstrate that, the HVSDBN method can im-prove the variance of decision results by 25.03% compared with traditional method, which effectively improves the accuracy of UAV swarm mission decision-making under complex dynamic environment.

▶ SunA04-4 09:00–09:20

*Adaptive Event-based Design of Nonlinear Systems with Unknown Control Directions*

Liu, Guilong — Univ. of Sicience & Tech.
Yang, Yongliang — Univ. of Sci. & Tech. Beijing

This paper provides an adaptive design based on event-based control with unknown control directions. Nussbaum-type functions are used to address the problems associated with nonlinear systems' unknown control directions. An event-triggered mechanism, which is based on the measurement error defined by the control signal, is presented to reduce the number of controller updates and save transmission resources. The dynamic surface control is incorporated into the controller architecture to prevent the complexity explosion. Finally, the effectiveness of the designed strategy is assessed using the simulation.

▶ SunA04-5 09:20–09:40

*Reinforcement Learning Driving Strategy Based on Auxiliary Task for Multi-Scenarios Autonomous Driving*

Sun, Jingbo — Beijing Inst. of Tech.
Fang, Xing — Chinese Acad. of Sci.
Zhang, Qichao — Chinese Acad. of Sci.

Reinforcement learning (RL) has made great progress in the field of autonomous driving. However, using one RL based driving policy for multi-scenarios autonomous driving is still challenging. There are different observations and reward measurements in different scenarios. At the same time, there is also the problem of low data efficiency in reinforcement learning. To address above problems, we propose a reinforcement learning framework based on auxiliary task. Firstly, we designed a reward function to enable vehicles to learn safe and efficient strategies. Further, an auxiliary task is designed to learn the characteristics of different scenarios, so that the ego agent can adopt different strategies for different scenarios. Finally, in order to handle the driving problem in multiple scenarios, we propose a representation network based on MLP, CNN and Transformer networks to learn multi-source heterogeneous state. The multi-source heterogeneous state consists of ego vehicle state, bev state and neighbour vehicle states. Experiments show that our method achieved a higher success rate compared with the popular reinforcement learning algorithm.

▶ SunA04-6 09:40–10:00

*Spectral Normalized Neural Networks Funnel Control for Servo System with Unknown Dynamics*

Zhang, Chao — Beijing Inst. of Tech.
Ren, Xuemei — Beijing Inst. of Tech.
Han, Ning — Beijing Inst. of Tech.
Zheng, Dongdong — Beijing Inst. of Tech.

This paper proposes a novel spectral normalized neural networks funnel control approach for servo system with unknown dynamics. To address the challenge posed by the unknown dynamics, spectral normalization technology is introduced into the funnel controller design. Spectral normalization techniques can be employed to restrict the spectral norm of the weight matrices of the neural networks, leading to a more stable and robust network. Moreover, the spectral normalized neural network exhibits a strong generalization ability and can adapt to offline learning strategies, which significantly reduces the computation cost of the system. By implementing the funnel control architecture, the output of the system is constrained to remain within an acceptable boundary, optimizing transient performance and guaranteeing satisfactory control performance. The stability of the closed-loop system is established using the Lyapunov method. Finally, the results of the simulations demonstrate that this approach provides commendable tracking performance and superior generalization capabilities.

**SunA05** 08:00–10:00 6th Conf. Hall

Invited Session: Intelligent and Adaptive Learning Control for Nonlinear Systems

Chair: Liu, Yang — Guangdong Univ. of Tech.
Co-Chair: Liu, Lei — Liaoning Univ. of Tech.

▶ SunA05-1 08:00–08:20

*Active Disturbance Rejection Based Containment Control of Stochastic Nonlinear Nonaffine Multiagent Systems*

Zhang, Pengchao — Bohai Univ.
Pan, Yingnan — Bohai Univ.

This paper investigates the containment control problem for stochastic nonlinear nonaffine multiagent systems. First, the stochastic nonlinear nonaffine multiagent systems are transformed into the affine systems with unknown dynamics through the idea of active disturbance rejection control and differential homeomorphism transformation. Then, the compensations for completely unknown stochastic and uncertain terms are achieved by using two filters that are designed in the extended states of each follower. Moreover, in light of Lyapunov theory, the proposed containment control strategy ensures that containment errors for all followers are converged to a small neighbourhood of the origin. In the end, the validity of the proposed control scheme is demonstrated by simulation data.

▶ SunA05-2 08:20–08:40

*Adaptive Quantized Consensus Control for Uncertain Nonlinear Multiagent Systems with Actuator Faults*

Xu, Haorui — Bohai Univ.
Cao, Liang — Bohai Univ.

This paper studies the adaptive fault-tolerant quantized consensus control problem for a class of nonlinear multiagent systems with time-varying parameters and disturbances. With parameters compensation technique, a distributed adaptive consensus control scheme is developed, where the bound of the actuator fault parameters is estimated. Then a robust distributed adaptive quantized consensus tracking controller is designed to compensate the effect of unknown time-varying parameters and external disturbances. Based on Lyapunov stability theory, it is proven that the control strategy can guarantee the stability of the closed-loop systems, which is demonstrated by simulation results.

▶ SunA05-3 08:40–09:00

*Synchronization of Complex Dynamic Networks with Time-varying Coupled Delays for Sampled Data Control*

Yan, Yuying — Linyi Univ.
Cheng, Long — Linyi Univ.
Sun, Jianqiang — Linyi Univ.
Chen, Xiangyong — Linyi Univ.
Liu, Yang — Guangdong Univ. of Tech.
Qiu, Jianlong — Linyi Univ.

This paper researches the synchronisation problem of complex dynamic networks with time-varying coupling delays based on sampled data control. First, a new Lyapunov-Krasovskii function (LKF) is constructed and then linear matrix inequality (LMI) is gained using Wirtinger' s inequality. Then, by solving the LMI, the unconservative condition for guaranteeing the synchronisation of a time-varying coupled time delay complex network for the control of sampled data is obtained. Finally, the example of numerical simulations shows that has broad application prospects.

▶ SunA05-4 09:00–09:20

*Design and Application of Workshop Production Scheduling Strategy Based on Manufacturing Big Data*

Wu, Bin — Guangdong Univ. of Tech.
Xiao, Yi — Guangdong Univ. of Tech.
Ren, Hongru — Guangdong Univ. of Tech.
Yang, Lan — Guangdong Univ. of Tech.
Lu, Renquan — Guangdong Univ. of Tech.

A multi-objective flexible workshop production scheduling optimization model is established for a series of workshop data in manufacturing enterprises, such as delivery time, processing time, and machine energy consumption, with the goal of minimizing total weighted lead and delay time, minimizing maximum completion time, and minimizing total machine energy consumption. On the basis of the NSGA-II algorithm, a combination of random generation and heuristic generation is used to initialize the population, while introducing dynamic crossover, mutation probability, and an improved elite retention strategy based on dynamic update crowding operator to optimize the NSGA-II algorithm, and solving the scheduling model to obtain the optimal set of scheduling so-

lutions. Compared with the original NSGA-II algorithm, the improved NSGA-II (INSGA-II) algorithm improves population diversity, accelerates convergence speed, avoids falling into local optima, and can obtain better scheduling schemes. Finally, the feasibility and effectiveness of the INSGA-II algorithm were verified through simulation experiments.

► SunA05-5 09:20–09:40

*Model Free Adaptive Consensus Control for Multiagent Systems with Actuator Faults*

Wang, Yuan Northeastern Univ.
Du, Zhenbin Yantai Univ.
Wu, Yanming Northeastern Univ.

The model free consensus control problem of multiagent systems with actuator faults is investigated in this paper. In order to address the actuator faults, an adaptive estimation law is developed adaptively to estimate the fault information online on the basis of the neighboring output tracking error. Then, a distributed model free adaptive fault-tolerant consensus control algorithm is constructed for multiagent systems to achieve consensus tracking. Compared with previous methods, the dependence on constructing RBFNN to handle faults is avoided. Moreover, only the input/output data information are employed instead of the known system model. Finally, a simulation is provided to prove the effectivenss of the developed scheme.

► SunA05-6 09:40–10:00

*Predefined-time Adaptive Repetitive Learning Control for Robot Manipulators*

Li, Yaqian Zhejiang Univ. of Tech.
Shi, Huihui Zhejiang Univ. of Tech.
Chen, Qiang Zhejiang Univ. of Tech.

The predefined-time adaptive repetitive learning controller is developed for the robot manipulators angular position stabilization, and the main contributions are summarized as follows. 1) By following backstepping recursive design procedures, the possible singularity problem is directly avoided by designing quadratic functions in the controllers without using any filters or piecewise continuous functions, such that the stability analysis becomes more concise and straightforward. 2) In controller design, predefined-time control can ensure fast transient performance, and repetitive learning control can ensure high steady-state tracking accuracy of the system, thus it can enable that the angular position of the robot manipulators can track the desired trajectory quickly and have high tracking accuracy. 3) A predefined-time parameter update law is constructed to acquire the information on parameter estimation errors indirectly, such that the gain of robust controller can converge to some constants in predefined time.

**SunA06** 08:00–10:00 Yuetang Conf. Hall

Invited Session: Repetitive Control for Uncertain Nonlinear Systems

Chair: Zhou, Lan Hunan Univ. of Sci. & Tech.
Co-Chair: Huo, Xin Harbin Inst. of Tech.

► SunA06-1 08:00–08:20

*Improved Repetitive Control with Frequency Adaptation in An LCL-type Grid-tied Inverter*

Zhang, Hongwei Zhongyuan Univ. of Tech.
Zhao, Qiangsong Zhongyuan Univ. of Tech.
Chen, Hao Zhongyuan Univ. of Tech.

The paper introduces a frequency adaptive improved repetitive control (FA-IRC) for grid-tied inverters that can handle fluctuating grid frequencies. The FA-IRC has two key enhancements over the conventional repetitive control (CRC). Firstly, the FA-IRC uses an improved internal model filter, which generates a higher open-loop control gain than CRC. This enhancement is expected to improve the transient response. Secondly, the FA-IRC implements a finite impulse response (FIR) filter to make its frequency adaptive. By using the FIR filter, the characteristic frequency of the inverter follows the grid frequency, thus improving the inverter's performance under different grid conditions. Therefore, an innovative solution to enhance the performance of gridtied inverters operating under non-uniform grid cases is achieved. Finally, the validity and benefits of the proposed strategy are verified through simulation.

► SunA06-2 08:20–08:40

*Repetitive Control for Nonlinear Systems: An Actuator-focussed Design Method*

Quan, Quan Beihang Univ.

There exist at least two viewpoints on the internal model principle (IMP), namely the cancelation viewpoint and the geometrical viewpoint. However, neither of them is applicable to repetitive control (RC, or repetitive controller, also designated RC) of nonlinear systems directly. Because of this, error dynamics are often derived to transform a periodic signal tracking problem into a rejection problem. This not only fails to represent the special feature of periodic signals but also restricts the applications of RC. In view of this, this paper proposes a new viewpoint on IMP, namely the actuator-focussed viewpoint. With this, the periodic signal tracking problem can be converted into a stability problem without deriving error dynamics for linear periodic systems and nonlinear systems. In order to demonstrate its effectiveness, the proposed design approach is applied to RC problems for a linear periodic system, a minimum-phase, nonlinear system and a nonminimum-phase nonlinear system.

► SunA06-3 08:40–09:00

*Fractional-order Multi-rate Repetitive Control for A Single-phase Grid-connected Inverter*

Liu, Kaiyue Zhongyuan Univ. of Tech.
Zhao, Qiangsong Zhongyuan Univ. of Tech.

In order to improve the harmonic suppression ability of traditional repetitive control (CRC) when the grid frequency fluctuates and reduce the computational burden of digital systems, a fractional order multi-rate repetitive control (FOMRC) scheme is proposed in this paper. FOMRC is composed of a multi-rate repetitive control (MRC) with low sampling rate and a Farrow structure fractional delay (FD) filter based on Taylor series expansion. Through the stability analysis of the system, FOMRC can accurately approximate the FD generated when the grid fundamental frequency fluctuates, and achieve good frequency adaptation. Simulation verifies the effectiveness of the proposed strategy.

► SunA06-4 09:00–09:20

*Adaptive Repetitive Control for A Class of Uncertain Nonlinear Systems with Input Delay*

Sun, Yongbo Hunan Univ. of Sci. & Tech.
Zhou, Lan Hunan Univ. of Sci. & Tech.
Li, Chengyang Hunan Univ. of Sci. & Tech.
Yang, Qin Hunan Univ. of Sci. & Tech.
Xiao, Wenbin Hunan Univ. of Sci. & Tech.

This paper presents an adaptive repetitive control method for a class of uncertain nonlinear systems with mismatched disturbances and input delay. The original tracking problem for the uncertain nonlinear system is decomposed into two subproblems: repetitive control problem for a primary linear time-invariant (LTI) system and robust stabilization problem for a secondary nonlinear system with mismatched disturbances and input delay. For the primary LTI system, repetitive control is used to deal with periodic signals, where a slight correction to amount of the time delay of the repetitive controller is introduced, leading to a significant improvement in steady-state tracking performance. For the secondary nonlinear system, adaptive backstepping control is used to deal with structural uncertainties and external disturbances, where an integral term is introduced to handle the time-delay input, and a first-order filter is used to estimate the derivative of the virtual control input. Both the controller design and the stability criteria are provided. Simulation results show that the proposed method achieves both satisfactory tracking and disturbance-rejection performance.

► SunA06-5 09:20–09:40

*Multi-Frequency Selective Harmonic Repetitive Control of Programmable AC Power Sources*

Zhou, Keliang Wuhan Univ. of Tech.

The Selective Harmonic (SH) Repetitive Control (RC) provides an efficient generic RC solution to tackling selected harmonics of periodic signals with a known fundamental frequency. Whether the sampling rate is variable or fixed, the multiple SH-RC controllers in parallel would fail to achieve exact tracking of multi-frequency signals, because it is impossible that every ratio of the sampling frequency to each signal frequency is integer. In this paper, a fractional-order multi-frequency SH-RC scheme is proposed to exactly compensate multi-frequency periodic signals. The stability criteria are given. An example of SH-RC of programmable AC power sources is provided.

► SunA06-6 09:40–10:00

*Equivalent Circuit-based Modeling of Ultrasonic Motors for Hammerstein Systems*

Qian, Yihui China Univ. of Mining & Tech.(Beijing)
Huo, Xin Harbin Inst. of Tech.
Liu, Qingquan Harbin Inst. of Tech.
Liu, Jingbo Harbin Inst. of Tech.

Zhao, Hui Harbin Inst. of Tech.

In order to analyze and design an ultrasonic motor (USM) control system, an accurate and reliable mathematical model should be established. Due to the nonlinear characteristics of the motor, which are resulted from special structure and complicated working principle, traditional modeling methods are no longer applicable. Nonlinear Hammerstein model structure is proved to be a better choice for describing nonlinearities in operation after years of study and practice. The Hammerstein model of the equivalent circuit model can be established to simulate the process of modeling the actual motor since both of the two models are in a one-to-one correspondence with the motor. In this paper, following the establishment of the quivalent circuit model, a model based on this idea is established with two-phase driving voltage as its inputs. The complete modeling process is given and the method is applied to an actual ultrasonic motor, which verifies the effectiveness of the proposed method.

**SunA07** 08:00–10:00 Hongqi Conf. Hall
Invited Session: Equivalent-Input-Disturbance Approach for Disturbance Estimation and Rejection

Chair: Li, Feng Jiangsu Univ. of Tech.
Co-Chair: Li, Meiliu Hunan Univ. of Sci. & Tech.

▶ SunA07-1 08:00–08:20
*Robust Fixed-time Sliding Mode Control of Underactuated Furuta Pendulum System*
Wang, Zhujun Linyi Univ.
Zhou, Xinhao Linyi Univ.
Zhang, Ancai Linyi Univ.
Liang, Xiao Shandong Univ. of Sci. & Tech.
Pan, Guangyuan Linyi Univ.

A Furuta pendulum is a typical underactuated mechanical system with two degrees of freedom (DOF) and only one input. We address the robust stabilization control problem for this 2-DOF underactuated system with a matched external disturbance. A fixed-time sliding mode control method is presented. First, the dynamic motion model of the system is established using the Euler-Lagrange modeling method. And then, we get the approximate linearization model of the system around the origin equilibrium point and construct a homeomorphic coordinate transformation for this model. After that, a sliding mode surface and a fixed-time robust controller are designed for the transformed system. The developed controller ensures the system's state variables to reach the sliding mode surface in a fixed time. This guarantees the fixed-time robust stabilization control objective to be achieved. Finally, two numerical examples demonstrate the validity of our presented control strategy.

▶ SunA07-2 08:20–08:40
*Refined Disturbance Rejection for Permanent Magnet Synchronous Motors with Multi-Source Disturbances Using Equivalent Input Disturbance Approach*
Yang, Tao Jiangsu Univ. of Tech.
Du, Youwu China Univ. of GeoSci.
Zhu, Erlin Jiangsu Univ. of Tech.
Li, Bo Jiangsu Univ. of Tech.
Han, Zhenhua Jiangsu Univ. of Tech.
Fang, Mingxing Anhui Normal Univesity

This paper presents a control strategy to reject disturbances for a permanent magnet synchronous motor (PMSM) system based on the equivalent-input-disturbance (EID) approach. Two EID estimators are devised to handle disturbances imposed on a current loop: one is used to estimate low-frequency components of disturbances, while the other is employed to estimate medium- and high-frequency components of disturbances. Another EID estimator is developed to estimate disturbances imposed on a speed loop of the motor. The estimates of disturbances are used for compensation on the control input channel of the current loop and the speed loop. It shows that disturbances are estimated separately and suppressed effectively for both loops. Simulation results demonstrate the validity and the superiority of the method.

▶ SunA07-3 08:40–09:00
*Further Enhancement for Disturbance-rejection Performance Based on Modified Equivalent-Input-Disturbance Approach*
Wang, Zewen China Univ. of GeoSci.
She, Jinhua Tokyo Univ. of Tech.
Sato, Daiki Tokyo Inst. of Tech.

This paper presents a modified equivalent-input-disturbance (MEID) approach that enhances the ability of the control system to reject the exogenous disturbances. Since the disturbance-compensation error of the conventional equivalent-input-disturbance (EID) approach contains a state-estimation error, as long as the state-estimation error does not converge to zero, there is a large disturbance-compensation error. The MEID approach obtains the state-estimation error by analyzing the characteristics of the conventional equivalent-input-disturbance (EID) approach and rejects it on the input channel. A comparison with the conventional EID approach demonstrates the validity of the new method.

▶ SunA07-4 09:00–09:20
*A Modified Equivalent-Input-Disturbance Method for Uncertain Networked Control Systems with Exogenous Disturbance*
Li, Meiliu Hunan Univ. of Sci. & Tech.
Xiao, Wenbin Hunan Univ. of Sci. & Tech.
Zhou, Lan Hunan Univ. of Sci. & Tech.

In a networked control system (NCS), time delays, uncertainties, and exogenous disturbances seriously affect the control performance. To solve these problems, a modified disturbance suppression configuration of NCS was built. In the configuration, a proportional–integral observer (PIO) reproduces the state of a plant and reduces the observation error; an equivalent input disturbance (EID) estimator estimates and compensates for the disturbance in the control input channel. The stability conditions of the NCS are given by using a linear matrix inequality, and the gains of the PIO and state feedback controller are obtained.

▶ SunA07-5 09:20–09:40
*Command Filtered Backstepping Control of A Two-Link Flexible Joint Manipulator with Uncertainties Based on Reduced-Order ESO*
Fei, Xiangyin Hunan Univ. of Sci. & Tech.
Pan, Changzhong Hunan Univ. of Sci. & Tech.
Zhou, Lan Hunan Univ. of Sci. & Tech.
Xiong, Peiyin Hunan Univ. of Sci. & Tech.
Li, Meiliu Hunan Univ. of Sci. & Tech.

The motion control of flexible joint manipulators (FJMs) is a hot topic in the field of robot control, and the uncertainties including parameter perturbations and disturbances are the key challenges in the development of control strategies for FJMs. In this paper, we take a two-link FJM with complex uncertainties as the object, and present a command filtered backstepping control approach based on reduced-order extended state observer (RESO) for the trajectory tracking control of the two-link FJM with high precision. To enhance the robustness of the control system, an RESO which takes parameter perturbations, friction term and external disturbances as the lumped disturbances is constructed to estimate and compensate for the disturbances. The second-order command filter technique is introduced to eliminate the "explosion of complexity" problem of the conventional backstepping method, and an error compensation dynamic system is developed to reduce the potential filtering errors. All signals of the closed-loop system are proved to be uniformly ultimately bounded by Lyapunov theorem. Simulation reaults are shown to demonstrate the effectiveness and efficiency of the proposed control method.

▶ SunA07-6 09:40–10:00
*A Model-Predictive-Enabled Equivalent-Input-Disturbance Approach for Disturbance Rejection*
Zhou, Yujian China Univ. of GeoSci.
She, Jinhua Tokyo Univ. of Tech.
Wang, Feng China Univ. of GeoSci.
Iwasaki, Makoto Nagoya Inst. of Tech.

This paper presents a model-predictive-control (MPC)-enabled equivalent-input-disturbance (EID) method for disturbance rejection. An EID estimator with a state observer estimates the effect of disturbances in a system. The disturbance estimation will not be directly added to the input channel for disturbance rejection. A cost function that considers the disturbance estimation is designed. An MPC controller calculates an optimal control input by minimizing the cost function. The stability condition of the closed-loop system is analyzed based on the Lyapunov stability theory.

Poster Session SunA08
May 14, 8:00–10:00
6th Conf. Hall

Chair: Sun, Mingwei Nankai Univ.
Co-Chair: Cao, Rongmin Beijing Information Sci. & Tech. of Univ.

▷ SunA08-01
*Data-driven Adaptive Tuning Method of Traditional Incremental Integral Control Law*
Bian, Yongming Qingdao Univ. of Sci. & Tech.

Chi, Ronghu Qingdao Univ. of Sci. & Tech.

In this paper, we propose a data-driven adaptive tuning (DDAT) methods for nonlinear non-affine systems with traditional incremental integral control laws. Firstly, for nonlinear and non-affine systems, we use compact form dynamic linearization (CFDL) method to transform the original nonlinear system into an equivalent linear data model and design an objective function to dynamically adjust the learning gain of the integral control law. Then DDAT method based on CFDL is proposed by optimizing the objective function of the design. This method only uses the input and output data of the system and does not rely on any model information of the original system. Finally, the validity of the method is verified by rigorous mathematical verification and simulation.

▷ SunA08-02

*Sliding-Mode Control Strategy for Dynamic Wireless Charging System with Long Guide Transmitting Coil for EV*

Guo, Yan Shanghai Univ.
Song, Yang Shanghai Univ.
Zhao, Wanqing Univ. of East Anglia

One of the main problems of dynamic wireless charging systems for electric vehicles (EVs) proposed in recent years is the variation of mutual inductance caused by the motion of EVs, which leads to the fluctuation of system output voltage. In this paper, the output voltage control problem of EV long guide dynamic wireless charging (DWC) system is studied. Firstly, the compensation circuit suitable for the system is determined. Secondly, the linear variable parameter model of DWC system is established by considering mutual inductance time varying and combining circuit theory and control theory. Finally, the sliding mode control is applied to the output voltage control of DWC system and the sliding mode controller is designed, so that the output voltage can quickly track the expected reference voltage and improve the anti-position migration ability of the charging system. The simulation results show that the receiver output voltage can track the reference signal well even if the receiver coil has transverse and longitudinal displacement.

▷ SunA08-03

*Fan Flue Gas Temperature Control System Based on Fuzzy PID Control*

Wang, Zihao Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.
Wang, Kang Beijing Univ. of Tech.
Li, Yang Communication Univ. of China

Due to the complex process of flue gas acid production and numerous processes, the controlled objects in the whole process have the characteristics of time-variation, randomness, nonlinearity and large lag. For SO2 fan, because the traditional PID control adopts the parameters set in advance, it is difficult to play an effective role in the complex flue gas acid production system, therefore, a fuzzy PID control method is proposed. The two-dimensional structure fuzzy controller model with two inputs and three outputs can adaptively adjust the parameters of the PID controller. After establishing the transfer function model for the factory temperature data, the fuzzy PID control is compared with the traditional PID controller. The results show that the designed fuzzy PID controller has strong anti-interference ability, shorter adjustment time and small overshoot volume, which can control the fan outlet temperature more effectively.

▷ SunA08-04

*Active Fault-tolerant Predictive Control for Networked Multi-Agent Systems with Actuator Faults and Random Communication Constraints*

Li, Chao North China Univ. of Tech.
Wang, Shitong North China Univ. of Tech.
Pang, Zhonghua North China Univ. of Tech.
Zheng, Changbing Henan Univ. of Urban Construction
Sun, Dehui North China Univ. of Tech.
Xu, Shu Wei North China Univ. of Tech.

The fault-tolerant tracking control problem for linear dynamic networked multi-agent systems with the leader-following structure is studied. A networked active fault-tolerant predictive control method is proposed. The control method is designed to enable the output of each agent to track the reference signal and maintain the desired deviation in the networked multi-agent systems with actuator faults and two-channel random communication constraints. We derive a necessary and sufficient condition for the stability of the closed-loop system. The results show that this condition is independent of actuator faults and random communication constraints. Finally, numerical simulations validate the effectiveness of the proposed control method.

▷ SunA08-05

*Improved Model - Free Sliding Mode Control of PMSM Based on Finite-Time Generalized Proportional Integral Observer*

Wang, Dongdong Qingdao Univ.
Liu, Shuguang Shandong Luruan Digital Tech. Co. LTD
Liu, Xu Dong Qingdao Univ.
Zhang, Zhixin Qingdao Univ.
Chen, Yong Zhi Qingdao Univ.

A novel speed control method with improved model-free sliding mode control is proposed for permanent magnet synchronous motor control system with external load disturbance, model and parameter uncertainties. Firstly, the ultra-local model of permanent magnet synchronous motor system without considering motor parameters is established. Then, a sliding mode single-loop strategy is proposed with a fast nonsingular terminal sliding mode surface, The controller adopts the speed-current single-loop sliding mode control strategy instead of the traditional speed-current cascade control, which simplifies the control system structure. Furthermore, to improve the anti-disturbance ability, the finite-time generalized proportional integral observer (FT-GPIO) is used to estimate the unknown disturbance of the system and used for feedforward compensation. Finally, compared with the traditional control method, the simulation results show that the proposed control method has good dynamic performance, anti-interference ability and steady-state control accuracy.

▷ SunA08-06

*Model - Free Adaptive Sliding Mode Predictive Control of Linear Ultrasonic Motor*

Li, Yifan Beijing Information Sci. & Tech. Univ.
Cao, Rongmin Beijing Information Sci. & Tech. of Univ.
Hou, Zhongsheng Beijing Jiaotong Univ.
Zhou, Huixing China Agricultural Univ.
Chang, Debiao Beijing Information Sci. & Tech. Univ.
Jia, Jihui Beijing Information Sci. Tech. Univ.

Because the linear ultrasonic motor system has obvious nonlinearity and time-varying. In the process of operation, the tracking error, mechanical delay and other factors will have a great impact on the position tracking accuracy. To reduce the linear ultrasonic motor position steady - state error. Sliding mode control (SMC) is invariant to system disturbance and model - free adaptive predictive control (MFAPC) can realize adaptive control only by input and output data of controlled system, this paper designed a model free adaptive sliding mode predictive controller (MFASMPC) and proved its stability and convergence Finally, the position control of linear ultrasonic motor based on model-free adaptive sliding mode predictive control method is simulated and analyzed. Theoretical proof and simulation results show that, such an algorithm can effectively reduce the steady-state error to meet the control accuracy requirements.

▷ SunA08-07

*High Order Sliding Mode Decoupling Control of Two-dimensional Linear Motor Based on Proportional Integral Model Free Adaptive Control*

Jia, Jihui Beijing Information Sci. Tech. Univ.
Cao, Rongmin Beijing Information Sci. & Tech. of Univ.
Hou, Zhongsheng Beijing Jiaotong Univ.
Zhou, Huixing China Agricultural Univ.
Chang, Debiao Beijing Information Sci. & Tech. Univ.
Li, Yifan Beijing Information Sci. & Tech. Univ.

Two-dimensional linear motor motion systems are nonlinear, multivariate, uncertain and strongly coupled, and easy to be affected by external disturbances. Based on the characteristics of model free adaptive control (MFAC) does not depend on the controlled system accurate mathematical model and that sliding mode control (SMC) can suppress external disturbances and is insensitive to bounded disturbances, a composite control scheme combining multiple input multiple output proportional integral model free adaptive control (MIMO-PIMFAC) and high order sliding mode control (HOSMC) is proposed. A proportional control term is added to the model free adaptive control to further improve the response speed of the two-dimensional linear motor. High order sliding mode controller compensates for system errors, and the two methods are closely combined to improve the position tracking accuracy of the two-dimensional linear motor and improve the system robustness. An adaptive decoupling control strategy is also used to further decouple the system by designing a discrete expansion state observer (DESO) to estimate and compensate for the coupling between the two axes, unmodelled dynamics and unknown external disturbances. The simulation experimental results show that the proposed scheme can effectively im-

prove the position control accuracy of the two-dimensional linear motor.

▷ SunA08-08

*Distributed Bipartite Consensus for Multi-agent Systems via Data-driven Sliding Mode Scheme*


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|---|---|
| Zhao, Huarong | Jiangnan Univ. |
| Peng, Li | Jiangnan Univ. |
| Xie, Linbo | Jiangnan Univ. |
| Yang, Jielong | Xi'an Jiaotong Univ. |
| Xu, Ye | Jiangnan Univ. |


This paper investigates a fully distributed bipartite consensus tracking problem for nonlinear discrete-time Multi-agent systems (MASs) with unknown dynamics and antagonistic interactions. A fully distributed data-driven sliding mode bipartite consensus (DSMBC) approach is proposed. The convergence of the proposed method is no longer related to the format of the reference trajectory, including time-varying and time-invariant trajectories. Moreover, the strongly connected requirement is no longer needed. Firstly, a bipartite combined measurement error function is formulated to transfer the bipartite consensus issue into the consensus issue. Then, an enhanced compact form dynamic linearization data mode is established by employing the input/output data of the MASs. After that, the DSMBC is constructed, and the proposed algorithm's convergence is proved, showing that the bipartite consensus tracking errors of each agent are cut to a small region around the origin. Finally, two examples are presented, and the results further illustrate the effectiveness of the proposed scheme, where the MASs can tackle both time-varying and time-invariant tracking tasks.

▷ SunA08-09

*Reinforcement-learning-aided Adaptive Control for Autonomous Driving with Combined Lateral and Longitudinal Dynamics*


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|---|---|
| Wang, Yongshuai | Nankai Univ. |
| Zheng, Chen | Beijing Inst. of Astronautical Sys. Engineering |
| Sun, Mingwei | Nankai Univ. |
| Chen, Zengqiang | Nankai Univ. |
| Sun, Qinglin | Nankai Univ. |


This paper presents a deep reinforcement learning-aided controller for a 3-DOF autonomous vehicle with combined lateral and longitudinal dynamics. In this scheme, the active disturbance rejection control (ADRC) gives full play to its advantages of being model-free and being able to estimate and compensate for internal uncertainties and external disturbances in real-time, and deep deterministic policy gradient (DDPG) fully considers safety, comfort, economy, and combines driving demand with state, action, reward to achieve real-time adaptive adjustment of control parameters. Thus, the adaptive controller can better deal with uncertainties from modeling, parameters, and driving environment, and self-learning and adaptation ability is obtained simultaneously. Moreover, simulation results illustrate that the adaptive controller performs satisfactorily for different driving operations and environments due to the online tuning and optimization of control parameters.

▷ SunA08-10

*DLinear Photovoltaic Power Generation Forecasting Based on Reversible Instance Normalization*


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|---|---|
| Wang, Gang | Hubei Minzu Univ. |
| Liao, Yu | Hubei Univ. for Nationalities |
| Guo, Li | Anhui Polytechnic Univ. |
| Geng, Jiahao | Hubei Minzu Univ. |
| Ma, Xianchao | Hubei Univ. for Nationalities |


Accurate and timely PV power generation forecasting is of great significance for maintaining the stability of the power system. In order to improve the forecasting accuracy and forecasting speed of PV power generation, this paper proposes a DLinear PV power generation forecasting model based on reversible instance normalization - RevIN-DLinear. The model firstly uses normalization and denormalization to alleviate the distribution shift problem of PV data over time; and secondly combines the advantages of the DLinear network model: the time series analysis method of seasonal-trend decomposition improves the predictability of PV data; the linear network to directly performs multi-step forecasting to avoid error accumulation. The experimental results show that the forecasting accuracy of the model is higher than that of the original DLinear and the advanced Transformer series models, and the speed is much better than that of the Transformer series models.

▷ SunA08-11

*A Semi-supervised Deep Learning Fault Diagnosis Method Based on Uncertainty Estimation and Weighted Labels*


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| Huang, Hanxin | Shanghai Maritime Univ. |
| Zhou, Funa | Shanghai Maritime Univ. |
| Jia, Pengpeng | Shanghai Maritime Univ. |
| Wen, Yanqi | Shanghai Maritime Univ. |


Abstract: The fault diagnosis method based on deep learning has been widely used due to its powerful feature extraction ability. However, its excellent performance relies on sufficient labeled data participating in model training. Semi-supervised learning is a very effective method to address the issue of low diagnosis accuracy caused by insufficient labeled data.FixMatch, which combines consistent regularization and pseudo-labels, has recently performed well on semi-supervised learning. However, the pseudo-labels of unlabelled samples obtained in FixMatch by high and fixed thresholds can lead to slow model convergence, and such pseudo-labels obtained using pre-defined high thresholds may still be incorrect, and guided by these incorrect pseudo-labels can lead to significant degradation in model performance. Also it is obviously unreasonable to use the same weight for the consistency loss of all unlabelled samples in FixMatch without considering the differences between samples. To address the above issues, a semi-supervised deep learning fault diagnosis method based on uncertainty estimation and weighted labels is designed and experimentally validated using the Case Western Reserve University bearing dataset. Experimental results show that when there are only 2 labels per class, the accuracy of the test set reaches 90.59% and the fault diagnosis accuracy of our proposed method is improved by 9.08% compared to FixMatch.

▷ SunA08-12

*Interpretable Bearing Stage Division Based on Shapelet and SVM*


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| Li, Xinye | Huazhong Univ. of Sci. & Tech. |
| Yang, Xiaoyu | Huazhong Univ. of Sci. & Tech. |
| Zhang, Hong | Huazhong Univ. of Sci. & Tech. |
| Wang, Yanwei | Wuhan Inst. of Tech. |
| Zheng, Ying | Huazhong Univ. of Sci. & Tech. |


The stage division of bearings is of great significance to ensure the safe operation of heavy machinery. By dividing bearing stages, early degradation points can be identified for bearing remaining useful life (RUL) prediction, and the accuracy of RUL prediction can be improved. Although the existing stage division methods can effectively divide the stages of bearings, most of the methods lack interpretability. In this paper, an interpretable rolling bearing stage division method based on shapelet and Support vector machine (SVM) is proposed. Firstly, a Manhattan distance-based shapelet is used to extract the bearing degradation features, which better discriminates the difference of bearing signals in different health states. Then, SVM is utilized to stage the degradation features. Finally, shapelet evolution diagrams are constructed to characterize the rolling bearing vibration signals at different stages, visually interpreting the bearing stage classification results. Based on the experimental study on the PRONOSTIA platform, the effectiveness and interpretability of the proposed method are verified. The results show that the proposed method can effectively classify the bearing health stages and visualize the interpretation of the stage classification results.

▷ SunA08-13

*Study on Fault Identification Method of Transmission Lines Based on An Improved CNN*


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|---|---|
| Li, Rui | Beijing Information Sci. & Tech. of Univ. |
| Li, Qingkui | Beijing Information Sci. & Tech. Univ., Beijing |
| Yu, Di | Beijing Information Sci. & Tech. Univ. |


When a transmission line fault occurs, the fault traveling wave data contains the occurrence location information of the fault point, which implies the characteristics of different fault reasons rise from specify location. Fast and accurate positioning and identification of the variable and random faults is difficult and complicated. According to this requirement developing fault identification system just as objective of this study. Firstly, applying wavelet transform analysis for the fault in current data, the data preprocessing filters most of the additive interference burr signals, and afford clean data to realizes fast fault positioning. Then, on the basis of data cleaning and filtering processing, this paper studies the characteristics and main reasons of ten typical faults related to thunder lightning and common sources of high voltage transmission lines. The improved . The test results show that the improved CNN based on batch normalization and hierarchical standardization can effectively handle the nonlinear fault waveforms, and achieve higher recognition speed and identification accuracy in common cases.

▷ SunA08-14

*Study on Genetic Algorithm Optimization of Ultrasonic Echo Peak Value Thickness Measurement Algorithm*


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|---|---|
| Wang, Zenan | Sichuan Univ. of Sci. & Engineering |
| Li, Zhaofei | Sichuan Univ. of Sci. & Engineering |
| Hou, Jin | Sichuan Univ. of Sci. & Engineering |
| Huang, Zhenghong | Sichuan Huaqi Detection & Tech. |
| Zhong, Mingshan | Sichuan Univ. of Sci. & Engineering |


This paper presents a genetic algorithm-based ultrasonic echo peak combination method for detecting the wall thickness of a gas storage well. The method first identifies internal echo and wall echo according to the characteristics of ultrasonic waves and the characteristics of gas storage wells, then optimizes the search for the optimal peak combination through genetic algorithms, and finally calculates the accurate wall thickness measurement value. Experimental studies show that the method can effectively reduce the computational cost, reduce the calculation time by about three times, can better implement the automatic measurement of the wall thickness of the gas storage well, and has a high practical application value.

▷ SunA08-15

*Anomaly Root Cause Analysis for Wind Turbines Based on Denoising Autoencoder and Sparse Estimation*


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| Du, Songtao | Huazhong Univ. of Sci. & Tech. |
| Wan, Yiming | Huazhong Univ. of Sci. & Tech. |
| Zhang, Cong | Beijing Inst. of Control Engineering |
| Zhang, Sihang | China Acad. of Space Tech. |


Wind turbine condition monitoring has been extensively studied to reduce maintenance costs. Although there exist a vast amount of literature on anomaly detection for wind turbine, anomaly root cause analysis has not been fully addressed so far. To cope with this problem, we propose a denoising autoencoder (DAE) based anomaly detector and performs anomaly root cause analysis using sparse estimation. For anomaly detection, deep denoising autoencoder is learned with normal history data, with enhanced robustness compared to the conventional autoencoder. The reconstruction error from the DAE is further evaluated by the exponentially weighted moving average control chart to reduce the false positive rate. After anomaly detection, root cause analysis performs sparse fault estimation, with the assumption that a small number of observed variables are affected under the abnormal condition. The fault estimates are then leveraged to identify the variables most relevant to the underlying anomaly root causes. Real cases on a public dataset demonstrate the effectiveness of the proposed method.

▷ SunA08-16

*A Novel Fault Diagnosis Approach Integrated LRKPCA with AdaBoost.M2 for Industrial Process*


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| Xu, Yuan | Beijing Univ. of Chemical Tech. |
| Jiang, Xue | Beijing Univ. of Chemical Tech. |
| Zhu, Qunxiong | Beijing Univ. of Chemical Tech. |
| He, Yan-Lin | Beijing Univ. of Chemical Tech. |
| Zhang, Yang | Beijing Univ. of Chemical Tech. |
| Zhang, Ming-Qing | Beijing Univ. of Chemical Tech. |


Facing the safety problems in industrial process, how to effectively diagnose process faults has become quite necessary and important. In this paper, a novel fault diagnosis approach integrated local reconstructed kernel principal component analysis(LRKPCA) with AdaBoost.M2 is proposed. Firstly, kernel principal component analysis(KPCA) is adopted to extract the global features through non-linear projection transformation. And local feature extraction based on t-distributed stochastic neighbor embedding(TSNE) is realized by minimizing the similarity of probability distribution of samples in high-dimensional space and low-dimensional space. Secondly, LRKPCA-based feature extraction method is proposed, in which the reconstruction error is calculated based on local features and mapped to the global feature space so that data dimension is reduced through coordinate reconstruction. Thirdly, AdaBoost.M2 is adopted to establish multi-classification model to realize fault diagnosis. Finally, the experimental results based on Tennessee Eastman process(TEP) show that the proposed method has higher diagnosis accuracy.

▷ SunA08-17

*Abnormal Sound Detection of Electrical Equipment Based on Time-spectrum Information Fusion*


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| Ma, Xianchao | Hubei Univ. for Nationalities |
| Liao, Yu | Hubei Univ. for Nationalities |
| Guo, Li | Anhui Polytechnic Univ. |
| Geng, Jiahao | Hubei Minzu Univ. |
| Wang, Gang | Hubei Minzu Univ. |


In the daily monitoring and maintenance of electrical equipment, the detection of abnormal sound is a very important part, and the high accuracy and efficiency of sound to distinguish the abnormal state of the equipment is more conducive to the troubleshooting of the equipment. At present, the research of algorithms for identifying the working status of electrical equipment operation sound based on machine learning and deep learning has been more widely used, but many algorithms are mainly based on frequency domain sequence modeling, ignoring the information of time sequence. Since the time-domain information in abnormal sounds is difficult to capture compared with the frequency-domain information, a time-domain information feature extraction network is designed by combining the commonly used frequency-domain analysis methods. In this paper, we propose a time-spectrum fusion-based anomaly detection optimization model that combines frequency-domain and time-domain feature fusion to improve the detection performance of anomalous sounds. Our method is experimentally validated on the DCASE 2020 Challenge Task 2 dataset, with an average AUC improvement of 1.31% and an average pAUC improvement of 1.35% compared to the current best method.

▷ SunA08-18

*SRUH-GNN: Social Recommendation of User Homophily based on Graph Neural Network*


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| Gao, Shuai | Bohai Univ. |
| Xing, Xing | Bohai Univ. |


Social recommendation is an effective method to improve recommendation accuracy and recommendation system performance in recommender systems, attempting to combine user-item interactions with social links to reduce data sparsity and cold-start problems. Previous research approaches on social recommendation model the fusion of social information and user-item interactions, however, they ignore the problem of inconsistent social relationships, which affects the accuracy of recommendations. To consider the consistency of user social relationships, this paper proposes a graph neural network-based social recommendation model for user homogeneity, which obtains consistent embeddings of users at the contextual and relational levels through graph neural networks and relational attention. In social recommendation, through experiments on two mainstream datasets, we can demonstrate that our model outperforms the comparison model.

▷ SunA08-19

*Iterative Learning Control for Linear Systems with Random Actuator Faults*


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| He, Xun | Renmin Univ. of China |
| Jiang, Hao | Renmin Univ. of China |
| Shen, Dong | Renmin Univ. of China |


This paper investigates fault-tolerant control for linear systems with random actuator faults. The random actuator faults are modeled by random variables multiplied by the actual input. Before the actual input is transmitted to the actuator, a pre-correction mechanism is used to cope with the occurrence of actuator faults. Moreover, a P-type iterative learning control algorithm is proposed to deal with the effect of actuator faults, where the system uncertainty is eliminated by decreasing learning gain sequences. The input errors are shown convergent to zero in the mean-square sense, and the mean-square of output errors converges to a finite limit. In the end, numerical results are presented to verify the effectiveness of the proposed algorithm.

▷ SunA08-20

*Fault Estimation and Accommodation for Networked Systems Based on Intermediate Variable with Intermittent DoS Attacks*


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|---|---|
| Zhao, Yuezhou | Univ. of Electronic Sci. & Tech. of China |
| Li, Tieshan | Dalian Maritime Univ. |
| Long, Yue | Univ. of Electronic Sci. & Tech. of China |


In this paper, the problem of fault estimation(FE) and fault-tolerant control is considered for networked systems under intermittent denial-of-service(DoS) attacks. Under the influence of DoS attacks, some measurement information via the communication network is unavailable, which makes some existing FE methods unusable. By introducing an intermediate variable containing the system state information and fault information, the observer to accurately estimate the fault and state of the system is proposed. By introducing a switching FE design method, the information that cannot be updated due to DoS attacks is discarded. The gain matrices of the FE observer and fault-tolerant controller are calcu-

lated simultaneously by solving two linear matrix inequalities. Compared with the existing results, the proposed FE strategy does not require the system to match observer matching conditions. Finally, the simulation example shows the effectiveness of the proposed method.

▷ SunA08-21

*Intelligent Fault Diagnosis of Nuclear Grade Electric Equipment Based on Quantum Genetic Support Vector Machine*

Liu, Zhilong — Nuclear Power Inst. of China

Abstract: Nuclear grade electric equipment is the key operating equipment of reactors in nuclear islands, and its reliable operation is a prerequisite to guarantee the operation of nuclear reactors. In order to effectively diagnose the faults of nuclear grade electric equipment, an intelligent fault diagnosis method based on QGA-SVM (Quantum Genetic Support Vector Machine) for nuclear grade electric equipment is proposed. Firstly, EEMD (Ensemble Empirical Mode Decomposition) and vibration eigenvalues calculation are carried out for the vibration signals collected under normal operation state and different fault degrees of nuclear grade equipment. Secondly, power eigenvalues calculation is carried out for the power signals collected under normal operation state and different fault degrees of nuclear grade equipment. Then, QGA((Quantum Genetic algorithm) and SVM (Support Vector Machine) are established to build an intelligent fault diagnosis model for nuclear grade electric equipment, and the operation eigenvalues is used as model input parameters. The results show that the proposed algorithm can efficiently and intelligently diagnose the faults of nuclear grade electric equipment, and the proposed method has certain significance for the fault diagnosis of electric equipment in other fields.

▷ SunA08-22

*Model-free Adaptive Cluster Consensus Control for Nonlinear Multi-agent Systems under DoS Attack*

Li, Yuhan — Henan Polytechnic Univ.
Bu, Xuhui — Henan Polytechnic Univ.
Guo, Jinli — Henan Polytechnic Univ.

Aiming at the cluster consensus problem for a class of unknown discrete time nonlinear multi-agent systems with denial of service(DoS) attacks, a model-free adaptive control algorithm is proposed. It is assumed that the system has a fixed topology and only part of the agents in each cluster can receive the leader information. Firstly, the dynamic linearization strategy is used to construct the data relation model of the multi-agent system, and the periodic DoS attack model conform to Bernoulli distribution is constructed by limiting the corresponding attack time and frequency. A data-driven cluster tracking control protocol is designed by combining the cluster consensus error under the coupling effect among agents. Then, the sufficient conditions to ensure the convergence of tracking error under the expectation are given by the method of compression mapping, and the convergence of the proposed algorithm is analyzed theoretically. Finally, simulation results verify the effectiveness of the proposed algorithm.

▷ SunA08-23

*Iterative Learning Containment Control under Fading Communication*

Zeng, Kun — Beijing Univ. of Chemical Tech.
Zhang, Zeyi — Renmin Univ. of China
Shen, Dong — Renmin Univ. of China

This paper studies containment control problems with fading channels for linear time-variant multi-agent systems (MASs). The fading channels are modeled by multiplicative and additive random variables. An Iterative Learning Containment Control (ILCC) algorithm is proposed to solve the containment control problem. By designing a decreasing stepsize and an appropriate learning gain, the fading problem is asymptotically eliminated along the iteration axis. As a result, all followers are driven into the convex hull spanned by the leaders, and the containment errors approach zero in the mean square sense. The simulation experiment verifies the effectiveness of the control law.

▷ SunA08-24

*Gradient-Based Iterative Learning Control for Signal Quantization with Encoding-Decoding Mechanism*

Tao, Yujuan — Jiangnan Univ.
Huang, Yande — Jiangnan Univ.
Tao, Hong-Feng — Jiangnan Univ.
Chen, Yiyang — Soochow Univ.

This paper addresses the optimization problem of quantized iterative learning control (ILC) for networked control systems (NCSs) with limited bandwidth. For linear time-invariant systems with quantized input signals, a mathematical cost function is constructed to obtain a gradient-based ILC law that rests with the system model, and the learning gain is updated in the trial domain. By combining the infinite logarithmic quantizer with the encoding and decoding mechanism to encode and decode the signals, the quantization accuracy is enhanced and the system tracking capability is improved. Compared with the traditional gradient descent method with fixed learning gain, the gradient-based ILC law can obtain faster error convergence. Simulation based on industrial robot system is given to substantiate the suggested method.

▷ SunA08-25

*Group Consensus for Discrete-time Multi-agent Systems Based on Iterative Learning Control*

Gao, Qianhui — Xidian Univ.
Li, Jinsha — Xidian Univ.

In this paper, the problem of perfect group consensus tracking is discussed for first-order discrete-time multi-agent systems with linear and nonlinear dynamic under directed communication topology. First of all, for first-order discrete-time linear and nonlinear multi-agent systems with two subgroups, distributed control protocols are constructed using iterative learning control method, based on matrix theory and compression mapping principle, sufficient conditions are derived to achieve perfect group consensus tracking under the proposed control protocol. The novel initial state learning laws are proposed, which can make each follower agent with arbitrary initial state and track the corresponding leader as iteration number approaches infinity. Secondly, we extend the corresponding results to the case of multiple subgroups. Then the formation control with multiple subgroups is also considered. Finally, three numerical examples are given to demonstrate the validity of the results.

▷ SunA08-26

*Analysis and Identification of Ancient Glass Relics Based on Clustering Algorithm and Random Forest*

Xu, Yiming — Zhengzhou Univ.
Zhi, Weimei — Zhengzhou Univ.

Glass is valuable evidence of cultural exchanges between my country and the West through the Silk Road, and ancient glass is extremely susceptible to weathering due to the impact of the burial environment. During the weathering process, internal elements undergo a substantial exchange with environmental elements, resulting in changes in their compositional proportions that affect the correct judgment of their category. In order to improve the accuracy of glass classification, this paper conducts statistical analysis based on the given glass data to summarize the statistical laws of chemical composition and weathering, and establishes a machine learning model to analyze and identify glass cultural relics. First, the chi-square test was used to confirm the correlation between whether the glass was weathered and various factors, and a descriptive statistical analysis was performed on the change law of the chemical composition before and after weathering. Then, according to the weathering situation, the glass cultural relics were divided into high-potassium or lead-barium categories, and the system clustering model and random forest model were respectively established to obtain the classification results; In this case, the cluster analysis is carried out, and the significant difference value of the clustering results is used as the basis for the selection of the appropriate chemical composition, and the subcategories are divided by comparing the Euclidean distance between the samples; finally, the correlation analysis is carried out on the classified glass cultural relics, and the correlation Coefficient heatmaps show chemical composition correlations and differences for different classes of glasses. The validity of the proposed method is verified on a batch of detection data of ancient glass products in my country, and the perturbation experiments with different intervals are set for each chemical composition, which proves that the model has good robustness.

▷ SunA08-27

*LTV System Identification via Kernel-based Regularization Method under Savitzky-Golay Filtering*

Yu, Xian — The Chinese Univ. of Hong Kong, Shenzhen
Ji, Xiaoqiang — The Chinese Univ. of Hong Kong, Shenzhen

An important task in the identification community for time-varying systems is to track the possible changes in system dynamics as well as possible. For the currently applied identification techniques, this task is usually implemented at the cost of increasing the computational quantity as the time increases, or of adding a forgetting factor that requires to be determined a priori. In this paper we develop an estimation approach for linear time-varying systems with additive disturbances, which achieves

a major computational advantage without determining the additional factor. In particular, we integrate the idea behind Savitaky-Golay filtering into the kernel-based regularization method under the framework of regularized least squares. It is found that the developed approach remains the same computational quantity during the whole time interval in the estimating procedure. A numerical example is simulated to validate the effectiveness of the developed approach.

▷ SunA08-28

*Separated Model for Stopping Point Prediction of Autoregressive Sequence*

Liu, Tingzhen — Tencent IEG
Zhang, Shengxi — Shangdong Univ. at Weihai
Xiong, Qianqian — Shandong Univ.

While the language model using the stop sign as an independent token has been widely used to decide when the model should stop, it may lead to the growth of vocabulary dimensions and further problems. Similarly, present research on game algorithms usually estimate stopping point related problems based on the evaluation of the winning rate. However, information redundancy may also exist in such models, thus increasing the training difficulty. Above two types of tasks (and similar autoregressive tasks) show a common problem of stopping point prediction. In this paper, we describe a design of separated model, trying to separate the complexity of stopping point prediction from the main task model, so that the information used for estimating stopping point can be reduced. On this basis, in order to verify the rationality of using separated model, we propose a model-free test method. It judges the separability of transformed data based on point difference and sequence difference metrics. In this way, it can predict the credibility of the separated model inference.

▷ SunA08-29

*Photovoltaic Power Generation Forecasting Based on Weighted Copula Model and Pattern Analysis*

Zhao, Yilin — Shanghai Univ.
Zhou, Yang — Shanghai Univ.
Jia, Li — Shanghai Univ.
Li, Yan — Shanghai Univ.

Accurate solar power generation forecasting can help to advance mutual power assistance in the renewable energy sector and enhance optimal dispatch. However, a number of factors make solar power generation highly unpredictable, which reduces the accuracy of conventional point forecasting techniques. In this study, the conditional distribution between PV power generation and the influencing factors is expressed using the Vine Copula, and a D-vine copula-based power generation prediction model is proposed. The model employs D-vine Copula for point prediction and probability interval prediction after first comparing the similarity of PV power generation patterns to historical data. The results of daily power generation in Australia show that the D-vine copula model improves the precision of PV generation prediction models and the pattern analysis makes it easier to analyze PV generation patterns that are influenced by multiple factors.

▷ SunA08-30

*Industrial Fault Detection Based on C-Vine Copula Model and Transfer Learning Strategy*

Li, Yan — Shanghai Univ.
Zhou, Yang — Shanghai Univ.
Jia, Li — Shanghai Univ.
Zhao, Yilin — Shanghai Univ.

Fault detection is of great significance to industrial processes, which can ensure the stable operation of the system and the safety of personnel. However, due to factors such as equipment aging and environmental changes, industrial data often has data deviations, which cannot be accurately detected by ordinary models. The copula function can clearly describe the relationship between random variables and has a simple structure, which is suitable to transfer knowledge. Therefore, this paper proposes a transfer learning method based on C-vine copula. The method first determines the structure and parameters of the C-vine copula based on data from the source domain, and then uses a small amount of data from the target domain for fine-tuning. Experimental results show that the model has higher detection accuracy and can express the relationship between variables more clearly than machine learning and deep transfer model.

▷ SunA08-31

*Water Supply Network Optimization Based on Improved Sparrow Search Algorithm*

Huang, Xiaoyi — Beijing Univ. of Chemical Tech.
Wang, Yungan — Beijing Univ. of Chemical Tech.
Chu, Jizheng — Beijing Univ. of Chemical Tech.

The water supply network is an essential infrastructure for urban life, and designing a scientific and reasonable water supply network can not only reduce construction and operation and maintenance costs but also enhance the reliability of the system. However, the design of the system involves complex constraints, as well as optimizing the pipe network is a nonlinear problem that significantly impacts construction investments. Traditional optimization methods have demonstrated poor performance in pipe network optimization due to low convergence accuracy and weak global search capabilities. To address these shortcomings, this paper proposes an Improved Sparrow Search Algorithm (ISSA) that introduces a Levy flight strategy to increase spatial search diversity and eliminate the small search space in the late iteration period and random walk around the optimal solution. The improved algorithm is applied to Hanoi, New York, and ZJ pipe networks, showing that it can efficiently find the best cost design scheme while reducing calculation cost and realizing rapid optimization of the combination optimization problem.

▷ SunA08-32

*A Novel Lazy Learning-based Data Driven Fault Diagnosis Method for Public Transport Vehicles*

Fu, Xiaotian — North China Univ. of Tech.
Wang, Li — North China Univ. of Tech.
Liu, Shida — Beijing Jiaotong Univ.
Ji, Honghai — North China Univ. of Tech.

In this work, a new data driven online local modeling method, which combines relevance vector machine and Lazy Learning (RVM-LL) is proposed for fault diagnosis of public transport vehicles.In proposed RVM-LL, LL builds multiple local models at each query point based on the data query, and determines the best data model in the current query through a selection mechanism. First, the method establishes the similarity function and selects the local nearest neighbor points. Secondly, a local model is built based on RVM algorithm. Third, the optimal local model is selected by leave-one-out cross validation method. The advantages of this method are: LL does not need to establish an accurate bus fault diagnosis model, and it has the characteristics of small sample local online modeling, which does not need to spend a lot of time on training, saves time and is adaptive. In addition, the background of this paper is based on practical applications, and the data used are also from real public transport vehicles, and the accuracy of the method is verified by simulation experiments.

▷ SunA08-33

*Associated Modal Transfer Network of International Crude Oil Futures and Domestic Major Crop Prices' Fluctuation and Its High Order Knots Analysis*

Liu, Jie — Wuhan Textile Univ.

Analysis on the fluctuation correlation between the international oil price and main grain price are carried on via a type of new network analysis method based on sliding window technique, which can map the fragments of WTI international crude oil futures and the three main crop price series into nodes by using the classical visibility graph construction strategy. Four price fluctuation mode transfer networks are constructed and analyzed on details. Main network haracteristics, as well as 16 higher-order knots existed in the associated modal networks, are discussed, too. Our result shows that, the fluctuation modal transfer networks of the WTI international crude oil futures price, the wheat, the corn, and the soybean price all have similar local structures, which means the WTI international futures price has the same time series evolution characteristics with wheat, corn and soybean price series. It indicates that, there exists a potential linkage between the fluctuation of international oil price and the change of domestic grain price in China. We also founded that, the change of corn price is most closely related to the fluctuation of international oil price. This results is helpful for strategies designing under the viewpoint of stable national grain security. Also, the proposed associated modal transfer network constructing method and the high order knots analysis method used here can be easily extended to similar process for other situations.

▷ SunA08-34

*A Constructive Density Function Path Leading to Global Coverage Strategy for A Gaussian Random Field*

Yang, Yuxing — Huazhong Univ. of Sci. & Tech.
Su, Mao — Designing Institude of Hubei Space Tech. Acad.

Fan, Huijin — Huazhong Univ. of Sci. & Tech.
Liu, Lei — Huazhong Univ. of Sci. & Tech.
Wang, Bo — Huazhong Univ. of Sci. & TTech.

The coverage of a given environment is an important issue in detection and rescue problems. This article presents a novel Lloyd algorithm for multi-agent coverage of a Gaussian random field characterized by a density function. The core issue is to construct a density function path (DFP) which ensures the distribution function of agents to converge to the one of targets iteratively. By proposing a triggering condition and a series of Gaussian distributionn functions, local optimum of traditional Lloyd algorithm can be avoided. The proposed algorithm make the coverage function reach a global solution with a small enough iteration interval. Simulation result is provided to illustrate the effectiveness of the proposed approach.

▷ SunA08-35

*Remaining Useful Life Prediction Method for Rolling Bearings Based on CBAM-CNN-BiLSTM*

Zhou, Honggen — Jiangsu Univ. of Sci. & Tech.
Ren, Xiaodie — Jiangsu Univ. of Sci. & Tech.
Sun, Li — Jiangsu Univ. of Sci. & Tech.
Li, Guochao — Jiangsu Univ. of Sci. & Tech.
Liu, Yinfei — Jiangsu Univ. of Sci. & Tech.

Abstract: Rolling bearings, as a rotating component, are of great importance to ensure the normal operation and smooth running of important equipment. Remaining useful life (RUL) prediction is a hot research topic in the engineering field, which is helpful to ensure the operational safety of system equipment and reduce maintenance cost. The topic of how to utilize the important feature information in the time-series data and the reasonable use of attention mechanism are addressed in this study with a CBAM-CNN-BiLSTM-based technique for estimating the remaining service life of rolling bearings. Firstly, multi-domain features of vibration signals are extracted from time domain, frequency domain and time-frequency domain, and the features are normalized to the maximum-minimum value. Then, a convolutional neural network incorporating a hybrid convolutional attention module is used to extract the important features; a bidirectional long- and short-term memory network is employed to obtain the before-and-after dependencies in the features. Next, the self-attention mechanism is introduced into the bidirectional long and short-term network to focus on more important deep features. Finally, the ef-fectiveness of the method is verified by the XJTU-SY dataset. The comparative study shows that the proposed CBAM-CNN-BiLSTM model outperforms other state-of-the-art methods in RUL prediction and system prediction, with higher prediction accuracy and generalization performance.

▷ SunA08-36

*A Robust Variable Projection Algorithm for RBF-AR Model*

She, Yuexin — Fuzhou Univ.
Chen, Guangyong — Fuzhou Univ.
Gan, Min — Fuzhou Univ.

The radial basis function network-based autoregressive (RBF-AR) model is a powerful statistical model which can be expressed as a linear combination of nonlinear functions and frequently appears in a wide range of application fields. Variable projection algorithm is designed for solving smooth separable optimization problems with least squares form and has been used as an efficient tool for the identification of RBF-AR model. However, in real applications, the observations are usually disturbed by non-Gaussian noise or contain outliers. This often leads to nonlinear regression problems. Since there are both linear and nonlinear parameters in such problems, how to optimize such models is still challenging. In this paper, we design a robust variable projection algorithm for the identification of RBF-AR model. The proposed method takes into account the coupling of the linear and nonlinear parameters of RBF-AR model, which eliminates the linear parameters by solving a linear programming and optimizes the reduced function that only contains nonlinear parameters. Numerical results on RBF-AR model to synthetic data and real-world data confirm the effectiveness of the proposed algorithm.

▷ SunA08-37

*Optimized Mutation of Grey-box Fuzzing: A Deep RL-based Approach*

Shao, Jiawei — Southeast Univ.
Zhou, Yan — Southeast Univ.
Liu, Guohua — Southeast Univ.
Zheng, Dezhi — Beijing Inst. of Tech.

As a vulnerability discovery technique, fuzzing has been widely used in the field of software test in the past years. Traditional fuzzing has several drawbacks, including poor efficiency, low code coverage, and a high dependence on expert experience. By introducing the deep reinforcement learning technique, one can train the mutator of the fuzzer to move in a desired direction, such as maximizing code coverage or finding more code paths. This paper proposes a reinforcement learning-based fuzzing method to enhance the code coverage and explore potential code vulnerabilities. First, the concept of the input field is introduced to the seed file, reducing invalid operations by marking whether each byte of the seed file is a valid byte. Then, we optimize mutation by modeling the grey-box fuzzing as a reinforcement learning problem and training mutator’s behavior on test cases. By observing the rewards caused by mutating with a specific set of actions performed on an initial program input, the fuzzing agent learns a policy that can next generate new higher-reward inputs. Finally, experimental results show that the proposed deep reinforcement learning-based fuzzing method outperforms the baseline random fuzzing algorithms.

▷ SunA08-38

*Wind Speed Prediction Based on ARMA and SVR*

Jiao, Xuguo — Qingdao Univ. of Tech.
Zhang, Daoyuan — Qingdao Univ. of Tech.
Yang, Qinmin — Zhejiang Univ.
Zhang, Zhenyong — Guizhou Univ.
Liu, Wenfeng — Qingdao Univ. of Tech.

Wind power generation technology is one of the research hotspots of renewable energy nowadays. In order to ensure the stable and reliable operation of wind power generation equipment, wind speed prediction is very important. This paper provides a new idea for the wind speed prediction based on Autoregressive Moving Average (ARMA) and Support Vector Regression (SVR). First, to reasonably divide the original data into multiple historical data with strong correlation as features to predict the future wind speed, the ARMA model is employed and its partial autocorrelation coefficient is calculated. By this means, the input features can be optimally selected and the training set of the prediction model can be constructed. Further, SVR model is used to build the nonlinear relationship between the input features and future wind speed. Finally, through simulation, it proves that this method saves more time than try and error method in selecting input features, and through comparison with Backpropagation Neural Network (BPNN), it proves that this method can achieves higher wind speed prediction accuracy.

▷ SunA08-39

*A Review of the Current Status and Future Directions of Research on Subspace Clustering Feature Selection*

Song, Xinyu — Beijing Univ. of Tech.
Wang, Xiujuan — Beijing Univ. of Tech.

Feature selection reduces the dimensionality of high-dimensional data by removing redundant or irrelevant features from the original features, thus reducing the negative impact of the ”dimensionality curse.” Subspace clustering feature selection methods focus on the structure and properties within the dataset, so they perform well in unsupervised feature selection work. In this paper, we sort out and classify the research on subspace clustering feature selection and propose several future research trends based on the current status of feature selection in subspace clustering.

▷ SunA08-40

*A Separable Training Algorithm Based on Nonmonotone Trust-region Method for Neural ODE*

Wang, Yaping — Fuzhou Univ.
Chen, Guangyong — Fuzhou Univ.
Gan, Min — Fuzhou Univ.

Neural ordinary differential equations (Neural ODE) interprets deep networks as discretization of dynamical systems, and has shown great promise in the physical science, modeling irregular time series, and mean field games. The Neural ODE comsumes a long time training process, which is arguably one of the main stumbling blocks towards their widespread adoption. To improve the convergence speed of training, in this parper, we formulate the training task as a separable nonlinear optimization problem, and propose a separable training algorithm based on a nonmonotone trust-region method. The proposed algorithm uses the variable projection strategy to reduce the dimension of variables by solving a subproblem and then the trust-region method is used to optimize the reduced function. To accelerate the convergence speed, we introduce the nonmonotone strategy to make the update of trust-region

radius elastic and employ the adaptive technology that uses the gradient information of the objective function to update the radius. Numerical results confirm the effectiveness of the proposed algorithm.

▷ SunA08-41

*Identification Approach of the Hammerstein-Wiener Model Applying Combined Signals*

Zhou, Shibo — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

This paper discusses an identification scheme of the Hammerstein-Wiener model using combined signals. The Hammerstein-Wiener model consists of a linear dynamic block two static nonlinear blocks, in which two nonlinear blocks are modeled through two different neural fuzzy models. The combined signals consisting of two groups of separable signals and a group of random signals are utilized, resulting in the separation identification of the Hammerstein-Wiener model. Firstly, inspired by Bussgang theorem, the correlation analysis method is used to identify the output static nonlinear block based on two groups of separable signals. Then, the least squares method based on correlation analysis is adopted to identify the dynamic linear block. Finally, utilizing the input-output of random signals, the Taylor series expansion method and clustering algorithm are used to identify the input nonlinear block. The simulation results show that the proposed method can effectively identify the Hammerstein-Wiener model, and obtain good identification accuracy.

▷ SunA08-42

*General Decay Synchronization of Delayed Complex-valued Neural Networks with Discontinuous Neuron Activations*

Han, Xiaofang — Xinjiang Univ.
Abdurahman, Abdujelil — Xinjiang Univ.

In this paper, we studied the general decay synchronization control issue for a class of complex-valued neural networks with time-varying delays and discontinuous activation functions. First, the general decay stability lemma for nonlinear systems is introduced. Secondly, based on a new nonlinear feedback controller, some sufficient conditions for the considered system to realize general decay synchronization are established by constructing a suitable Lyapunov-Krasovskii functional. Finally, the feasibility of the obtained results are verified by numerical simulation.

▷ SunA08-43

*Subway Short-term Passenger Flow Prediction Based on Improved LSTM*

Yao, Yajuan — Beijing Jiaotong Univ.
Jin, Shangtai — Beijing Jiaotong Univ.
Qian, Wang — Beijing Jiaotong Univ.

An improved long short-term memory (LSTM) model based on ensemble empirical mode decomposition (EEMD) is designed for short-term passenger flow prediction in view of the complex dynamics, uncertainty and prediction difficulty of subway inbound passenger flow. First, the raw data is decomposed into several stationary components and a residue by EEMD method. Then, a combination of high-correlation components and a combination of low-correlation components obtained by calculating Pearson Correlation Coefficient between each component and the raw data are combined with date feature to form the input set of LSTM neural network. And the predicted passenger flow data is the output set. Finally, compared with the single LSTM model, the trained EEMD-LSTM model is better according to the metrics, and the absolute error of the EEMD-LSTM model is significantly lower during the peak passenger flows. The experimental results of Tiantongyuan Station of Beijing Metro Line 5 show that the improved model can effectively improve the prediction accuracy, which is conducive to the dynamic adjustment of station management plan.

▷ SunA08-44

*Ship Adaptive RBF Neural Network Course Keeping Control Considering System Uncertainty*

Zhang, Sihang — Shandongjiaotong Univ.
Zhang, Qiang — Shandong Jiaotong Univ.
Su, Wenxue — Qingdao Harbour Vocation & Technical College
Li, Haoyang — School of Navigation & Shipping, Shandong Jiaotong Univ.
Gai, Xudong — Shandong Jiaotong Univ.

An adaptive RBF neural network-based nonlinear feedback heading keeping control scheme is proposed for the problem of uncertainty in the dynamic parameters and perturbations of a surface ship's heading keeping model under input saturation. An adaptive neural network technique is used to estimate the model dynamic parameters and external time-varying perturbations, while the minimum learning parameters are used to reduce the computational load, and subsequently, an adaptive neural network nonlinear feedback control scheme is designed using a function with input saturation characteristics embedded in the control law. On the basis of Lyapunov's theorem, it is shown that all signals are consistently bounded in a perturbed uncertain heading-holding system. Finally, the simulation and comparison verify the effectiveness of the designed control scheme.

▷ SunA08-45

*Hierarchical Label Text Classification Method with Deep-Level Label-Assisted Classification*

Cao, Yukun — Shanghai Univ. of Electric Power
Wei, Ziyue — Shanghai Univ. of Electric Power, Shanghai
Tang, Yijia — Shanghai Univ. of Electric Power
Jin, Chengkun — Shanghai Univ. of Electric Power, Shanghai

Hierarchical label text classification is a challenging task in the field of natural language processing, where each document needs to be correctly classified into multiple labels with hierarchical structure. However, in the label set, due to the insufficient semantic information contained in the labels and the small number of documents classified under deep-level labels, the training of deep-level labels is insufficient, leading to a significant imbalance in label training. To address this, a hierarchical label text classification method with deep-level label-assisted classification (DLAC) is proposed. The method proposes a deep-level label-assisted classifier, which effectively utilizes text features and rich features of shallow label nodes corresponding to deep label nodes (i.e., shallow label' s rich features) on the basis of enhanced label semantics to enhance the classification performance of deep labels. The comparison experiment results with eleven algorithms on three datasets show that the model can effectively improve the classification performance of deep-level labels and achieve good results.

▷ SunA08-46

*Identification of MISO Hammerstein Nonlinear Model with Moving Average Noise Based on Hybrid Signal*

Zhao, Caiting — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

The hybrid signal is used to identify the multi-input single-output (MISO) Hammerstein model. The hybrid signal consists of Gaussian signal and random signal, and the identification process is divided into two stages, namely, the stage of dynamic linear part and the stage of static nonlinear part. Firstly, the correlation analysis method is used to identify the linear part parameters. Then, for the parameters of the nonlinear part and the output noise model, an extended stochastic gradient algorithm with forgetting factor (FF-ESG) is adopted to deal with the issue that the convergence of stochastic gradient algorithm is slow. Theoretical analysis and experiments show that the presented method can identify the MISO Hammerstein model with moving average noise and obtain good identification accuracy.

▷ SunA08-47

*Coordinated Voltage Regulation of Microgrid Clusters Based on Deep Reinforcement Learning Approach*

Xue, Xiaozhe — Nanjing Normal Univ.
Ge, Hui — Nanjing Univ. of Posts & Telecommunicaiton

With the rapid development of microgrid cluster operation, the problem of voltage regulation in the coordinated operation of multiple microgrids faces practical challenges. Aiming at the problem of voltage regulation of multi-microgrids, this paper firstly establishes an optimization model of coordinated voltage regulation of multiple microgrids considering the coordination of source, grid, load and storage. Since the difficulty of solving the above optimization problem, it is further reformulated as a Markov game. Then, a novel collaborative voltage regulation algorithm based on multi-agent deep reinforcement learning (MADRL) is proposed. In order to improve the scalability of the algorithm, an attention mechanism is introduced into the multi-agent deep reinforcement learning algorithm. The simulation results show that the proposed algorithm can coordinate with multiple microgrids to regulate the voltage to a safe range.

▷ SunA08-48

*Industrial Time Series Prediction Based on Incremental DBSCAN-KNN with Self-learning Scheme*

Zhong, Xueyan — Dalian Univ. of Tech., Dalian

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| Chen, Long | Dalian Univ. of Tech., Dalian |
| Han, Zhongyang | Dalian Univ. of Tech. |
| Zhao, Jun | Dalian Univ. of Tech. |
| Wang, Wei | Dalian Univ. of Tech. |


Industrial time series data are usually time-varying due to multiple factors such as environmental and human disturbances. As traditional time series predicting methods are often based on offline training ignoring the changes in working conditions, the prediction results may be inaccurate. In this paper, a time series prediction model based on incremental DBSCAN and KNN with self-learning scheme is proposed to address the problem of time-varying working conditions. The proposed model uses the incremental DBSCAN to automatically identify and expand working conditions with adjusting the number of clusters automatically, and then employs the KNN model to make predictions under different working conditions. Compared with the existing methods, the proposed method is more stable and improves the prediction accuracies of the model under different working conditions.

▷ SunA08-49

*Flotation Condition Recognition Based on HGNN and Forth Image Dynamic Feature*


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|---|---|
| Fan, Zunguan | Beijing Univ. of Tech. |
| Wang, Kang | Beijing Univ. of Tech. |
| Li, Xiaoli | Beijing Univ. of Tech. |


The quality of flotation conditions directly affects the flotation efficiency. Aiming at the problems of difficult online detection, strong subjective arbitrariness, and low recognition efficiency of various flotation conditions in actual flotation work, a flotation condition recognition method based on hypergraph neural network (HGNN) and dynamic feature of forth images is proposed in this paper. Firstly, an improved local binary mode (LBP-TOP) algorithm is introduced to extract the dynamic features of forth sequence containing time information, and then features such as kurtosis and skewness are extracted as supplements to integrate the dynamic features of forth with the supplementary features. Based on above features and building a hypergraph, the HGNN model is established, and the high-order complex data correlation coding is realized, so as to realize the precise identification of flotation conditions. Finally, simulation shows the effectiveness of the proposed method.

▷ SunA08-50

*A Multi-objective Optimal Scheduling Method by Considering Energy and Production for Integrated Energy System in Steel Industry*


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| Wang, Jichen | Dalian Univ. of Tech. |
| Jin, Feng | Dalian Univ. of Tech. |
| Zhao, Jun | Dalian Univ. of Tech. |
| Wang, Wei | Dalian Univ. of Tech. |


In the production process of steel enterprise, reasonable scheduling of byproduct energy plays a significant role in reducing operation cost, environmental pollution and improving energy utilization. In this study, a two-stage optimal scheduling method is proposed to solve the problem. The optimal scheduling of coupled gas-steam-electricity system and production scheduling of steelmaking-refining-continuous casting are introduced into this method. The minimum energy purchase cost and carbon emission cost are considered as the objective functions in the optimal scheduling of coupled gas-steam-electricity system. Through the proper adjustment of production plan, the distribution structure of energy is optimized and the space for energy optimization is expanded, which is more profitable to reduce the operation cost of enterprise. The proposed method has been validated with actual operation data of a large domestic steel enterprise, the optimization results show that the total cost of the enterprise can be reduced by 20.75% compared to the actual operating cost of the enterprise and 1.52% compared to the general optimization method, providing support for conducting steel enterprises to save energy and reduce emission, as well as reduce cost and increase efficiency.

▷ SunA08-51

*A Multi-Head Self-Attention-based on GRU Encoder-Decoder Framework for Predicting Molten Iron Silicon Content*


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| Cai, Yu | Zhejiang Univ. |
| Yang, Chunjie | Zhejiang Univ. |
| Lou, Siwei | Zhejiang Univ. |
| Zeng, Zhenyu | Alibaba Cloud |
| Liao, Huanyu | Alibaba Cloud |
| Zhang, Bing | Alibaba Group |


Silicon content is a significant index in the process of blast furnace ironmaking. It is used to measure the quality of molten iron produced. It only meets the requirements if it is too high or too low. In the production process, the silicon content in molten iron needs to be controlled within a stable range. At the same time, due to the time lag, nonlinear and dynamic characteristics of blast furnace itself, it is difficult to predict the silicon content accurately. This paper proposes a multi-head self-attention-based gate recurrent unit encoder-decoder framework that can better extract global dynamic features and local features, improve prediction accuracy and pass the experimental verification.

▷ SunA08-52

*Data Driven Strip Crown Prediction for A Hot Strip Rolling Mill Process*


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|---|---|
| Zhang, Yanyan | Univ. of Sci. & Tech. Beijing |
| Zhang, Kai | Univ. of Sci. & Tech. Beijing |
| Yang, Pengcheng | Univ. of Sci. & Tech. Beijing |
| Peng, Kaixiang | Univ. of Sci. & Tech. Beijing |


Due to the difficulty in strip crown prediction caused by multivariable, nonlinear and strong coupling in the hot strip rolling mill (HSRM) process, this paper proposes a strip crown prediction model based on support vector regression (SVR), and uses sparrow search algorithm (SSA) to optimize the parameter C and $\sigma$ of the model, so as to improve the generalization ability of the prediction model. The overall performance of the model is evaluated by mean square error (MSE), mean absolute error (MAE), mean absolute percentage error (MAPE) and correlation coefficient ($R^2$). It shows that the prediction accuracy and generalization ability of the proposed model are better than the traditional methods. The proposed SSA-SVR model in this paper is successfully applied to the crown prediction of the 2150 production line of Ansteel company. The performance shows that the method can be efficient to predict the steel crown in a real HSRM process.

▷ SunA08-53

*Researching on Signal Transmission Performance of LoRa Technology in Urban Environment*


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| Wu, Zhaobin | Guangxi Univ. of Sci. & Tech. |
| Shen, Qiguang | Guangxi Univ. of Sci. & Tech. |
| Wang, Junhui | Guangxi Univ. of Sci. & Tech. |


The wireless sensor network plays a key role in the Internet of Things (IoT), and the performance characteristic that low-power long-distance transmission has become the focus of academic and industrial research. Long Range (LoRa) technology adopts an unlicensed frequency band, and it can provide a longer communication distance for Low-Power Wide-Area Network (LPWAN) when compared with similar technologies. This paper studies the communication quality of LoRa technology in the complex urban environment with 433MHz band. In this experiment, the LoRa transceivers based on SX1278 were used. Firstly, we studied the communication quality of LoRa transceivers in complex environment. Then, we tested the power consumption of LoRa transceivers and obtained the result that there is a certain linear relationship between the power consumption of node and transmitting power. The higher the transmitting power of the transmitting node is, the higher the power it consumes, and the better the communication quality of the signal and the lower the packet loss rate. The comprehensive experimental results show that the LoRa communication link can be completely established in 433MHz band on the condition that the range between 2 LoRa transceivers in urban environment is within 1200m at least and low-cost rubber rod antennas are used.

▷ SunA08-54

*An Improved Industrial Process Soft Sensor Method Based on LSTM*


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| He, Yan-Lin | Beijing Univ. of Chemical Tech. |
| Wang, Pengfei | Beijing Univ. of Chemical Tech. |
| Xu, Yuan | BEIJING Univ. OF CHEMICAL Tech. |
| Zhu, Qunxiong | Beijing Univ. of Chemical Tech. |


In industrial production processes, online monitoring of critical variables can be achieved by data-driven soft sensor modeling methods. However, due to high dimensionality and high degree of temporal correlation in modern complex industrial data, traditional soft sensor models face challenges in accurately predicting these variables. To address above issues, this paper proposes a novel soft sensor model, AE-LSTM, which combines Autoencoder (AE) with long short-term memory neural networks (LSTM). On the one hand, AE is used to extract features from the input data to reduce the data dimensionality. On the other hand, LSTM is used to build a soft sensor model for the extracted feature variables to capture the dynamic nature of the data.The proposed method is applied to predict the acetic acid content at the top of a normal boiling tower in the industrial production process of purified terephthalic acid (PTA). The

results demonstrate that the prediction accuracy of AE-LSTM surpasses BP, LSTM, and PCA-LSTM by 30%, 18%, and 12%,, indicating higher prediction accuracy compared to traditional methods.

▷ SunA08-55

*A Comparison of LS-based Steel Thickness Prediction Methods for A Hot Rolling Mill Process*


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| Zhang, Xiaowen | Univ. of Sci. & Tech. of Beijing |
| Zhang, Kai | Univ. of Sci. & Tech. Beijing |
| Peng, Kaixiang | Univ. of Sci. & Tech. Beijing |


This paper reviews the prediction methods of multiple linear regression models least squares (LS), Partial least squares (PLS), and higher order partial least squares (HOPLS) and compares the characteristics of these three methods. The methods are applied to the hot rolling mill process. Three kinds of methods are used to predict the exit thickness of finishing rolling steel plates with different thickness specifications. The mean absolute error (MAE), root mean square error (RMSE), and the percentage of the number of samples whose prediction error is within ±3% of the measured value in the total number of predicted samples are used as indices of performance to compare the thickness predicted performance. The experimental results show that HOPLS has better prediction accuracy and generalization performance compared with the other considered methods.

▷ SunA08-56

*Event-Triggered Mechanism-Based Adaptive Cooperative Tracking Control for MHSTs System with Uncertain Dynamics*


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|---|---|
| Zhang, Yusha | Southwest Jiaotong Univ. |
| Ma, Junjie | Southwest Jiaotong Univ. |
| Huang, Deqing | Southwest Jiaotong Univ. |
| Wu, Yue | Southwest Jiaotong Univ. |
| Wang, Jiaxin | Southwest Jiaotong Univ. |


This paper focuses on the adaptive event-triggered cooperative tracking control problem for multiple high-speed trains (MHSTs) system. A new adaptive cooperative tracking control protocol is presented based on the multi-agent system (MAS) concept and the event-triggered control theory. Firstly, to build a refined train dynamical model, the uncertain nonlinear resistances are approximated by a fuzzy logic system. Moreover, a distributed sliding-mode estimator is used to estimate the states of the leader train to obtain the system errors to perform the subsequent backstepping control design. In the event-triggered mechanism, the controller updates are triggered only when the measurement error exceeds a specified threshold, which can reduce the waste of computation resources and the overuse of actuators. It is demonstrated that all signals in the MHSTs system are ultimately bounded. Finally, a simulation example is provided to validate the effectiveness of the proposed event-triggered control methods.

▷ SunA08-57

*Formation Control Based on Active Compensation for Multi-Agent System under Communication Attack*


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| Wang, Jing | North China Univ. of Tech., China |
| Wang, Siyuan | North China Univ. of Tech. |
| Meng, Zhou | North China Univ. of Tech. |


In this paper, the formation control of multi-agent systems under communication attacks is studied. Consider that communication attacks will cause the unknown and time-varying changes in the topology of multi-agent systems, a formation control method of the multi-agent systems based on active compensation is proposed. Firstly, the communication attack is modeled as the time-varying part of the communication weight of the multi-agent system, and then the impact of the communication attack on the closed-loop system is regarded as the disturbance. Then an extended state observer is designed to estimate the state of each agent and the disturbance caused by the communication attack. According to the estimation of the observer, a formation controller based on active compensation is designed to realize the cooperative control of the the multi-agent systems. Finally, simulations are provided to illustrate the effectiveness of the proposed method.

▷ SunA08-58

*Model-free Active Disturbance Rejection Control of Two-dimensional Linear Motor Based on Multi-parameter Genetic Optimization*


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|---|---|
| Chang, Debiao | Beijing Information Sci. & Tech. Univ. |
| Cao, Rongmin | Beijing Information Sci. & Tech. of Univ. |
| Hou, Zhongsheng | Beijing Jiaotong Univ. |
| Jia, Jihui | Beijing Information Sci. Tech. Univ. |
| Li, Yifan | Beijing Information Sci. & Tech. Univ. |


The position tracking accuracy of two-dimensional linear motor is the most important accuracy index in the servo motion process of two-dimensional linear motor, and it is of great significance to the servo motion process of two-dimensional linear motor modeling and control. Aiming at the problem that the complex dynamic characteristics of the two-dimensional linear motor are difficult to carry out conventional mechanism modeling and other disturbances such as friction impedance during its movement a compensation scheme founded on the combination of tight format dynamic linearization model-free adaptive control and active disturbance rejection control technology is proposed, according to the data-driven control idea. The scheme provides an idea for solving the problem of friction disturbance of two-dimensional linear motor. After establishing the mathematical model of two-dimensional linear motor, the scheme uses MATLAB to simulate the algorithm. Then, owing to the influence of many adjustable parameters on the performance of the controller, and the problems of time-consuming and unsatisfactory optimization of many parameters, the controller parameters are optimized based on genetic algorithm to improve the efficiency of parameter tuning.

▷ SunA08-59

*Adaptive Sliding Mode Control of Suppressing Quadrotor Payload Swing with Variable-Length Cable*


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|---|---|
| Wang, Yikun | Beijing Univ. of Chemical Tech. |
| Li, Dazi | Beijing Univ. of Chemical Tech. |
| Huang, Jingwen | Beijing Univ. of Chemical Tech. |


With the development of drone technology, quadrotor transportation has become an important application direction. Most of the control designs for a quadrotor with a cable-suspended payload (QCSP) are aimed at fixed cable lengths, but there are few controller designs for varying cable length QCSP with broad application prospects. In this paper, a controller for varying cable length QCSP is designed using parameter adaptive multi-layer sliding mode structure to control the payload swing, quadrotor position tracking and single-layer sliding mode structure to control the cable length of the suspension system. The nonlinear coupling problem in the QCSP is solved by a simple method, avoiding tedious design reasoning and parameter adjustment. Simulation experiments were conducted and compared with traditional PD controllers, proving the effectiveness of this method in suppressing load swing angles of varying cable length QCSP.

▷ SunA08-60

*GLSUR: POI Recommendations Based on Similar Users and Current Geographic Location*


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| Jia, Zhichun | Bohai Univ. |


With the rise of location-based social networking, predicting users' future POI(point of interest) has also become a key issue. Now there are some methods that can predict the next point of interest based on the user's own history hidden state. Despite this, these approaches take only into account the user's own behavior trajectory, ignoring the impact of similar users. We design a new recommendation model GLSUR to improve the accuracy of the predictions and provide users with a better experience of the actual situation POI recommendations. The three factors of hidden state, similar users and user embedding are considered simultaneously in GLSUR. We invoke RNN networks as the underlying computational model to calculate the user's own hidden state, the similarity formula determines the similar users, and pass the three tensors into the fully connected layer. Finally, a semi-positive vector formula is used to calculate the closest point of interest and recommend it to the user. We conducted extensive experiments using two real data sets in the real world. The results show that GLSUR provides better accuracy compared to other baseline methods.

▷ SunA08-61

*Comparison of Different Domain Randomization Methods for Policy Transfer in Reinforcement Learning*


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|---|---|
| Ma, Mingjun | Chinese Acad. of Sci. |
| Li, Haoran | Univ. of Chinese Acad. of Sci. |
| Hu, Guangzheng | Beijing Inst. of Tech. |
| Liu, Shasha | Univ. of Chinese Acad. of Sci. |
| Zhao, Dong-Bin | Inst. of Automation |


Deep reinforcement learning algorithms have made great progress in the field of control with the help of many high-efficiency simulation environments. However, due to the difference in state distribution and dynamics, these algorithms trained in the simulation cannot be effectively applied to the real world. The ability to reduce the impact of the Sim2Real gap

is critical for transferring policy from the simulation to the real world. Although there are many methods for studying the Sim2Real problem, it is difficult to evaluate the performance of different algorithms due to the different evaluation platforms and methods. In this paper, we construct a uniform robot navigation scenario in the simulation and the real world, and revisit the ability of the popular domain randomization methods to transfer the policies from the simulation to the real world under the dynamics gaps. With the analysis of the performance in the simulation environment and the real world, we provide some recommendations for the domain randomization methods and hope to make these methods more efficient to use.

▷ SunA08-62

*Research of Intelligent Analysis Based on 12328 Transportation Service Supervision Hotline Data*

Chen, Bangju — Beijing Inst. of Tech.
Xue, Guangyue — China Transport Telecommunications & Information Center

Based on large scale of calling record data collected by 12328 Transportation Service Supervision Hotline System, this paper conduct several analysis from the hotline’s complaint issues. For the urban passenger traffic field, studies on the population-based number of complaint issues were conducted to analyze the operational service level of Shanghai, Beijing and other cities with large populations and relatively well-developed public transportation systems. Frequently reported complaint issues and its time distributions in Shanghai were also concluded as a part of research outcomes. Furthermore, this paper established an assessment method towards complaint issues on urban passenger traffic field, the assessment indicators were designed out of consideration on the perspectives of quantity, efficiency and quality.Combining with the recent hot issues of epidemic prevention and anabatic cargo transportation problem, this paper carried out a text clustering method based on LDA topic method, four types of critical cargo transpotation problems throughout the hotline’s receving issues were clustered as the meaningful results of the algorithmic experiment.

▷ SunA08-63

*Stabilization of Port-Controlled Hamiltonian Systems Subject to Exogenous Disturbances via Compensation Control Approach*

Fu, Baozeng — Qingdao Univ.
Wang, Qingzhi — Qingdao Univ.
Liu, Yongchao — Qingdao Univ.

The stabilization of Port-Controlled Hamiltonian (PCH) systems under exogenous disturbances by designing a compensation control approach is studied in the paper. Firstly, a baseline feedback control is proposed utilizing the damping injection method. To estimate disturbances, then a novel exogenous disturbance observer is constructed, based on which a feedforward compensation control is developed. Next, a composite control law is proposed based on the feedforward compensation and the feedback control. For the Hamiltonian system, an asymptotic stability analysis is followed finally. The feasibility of the compensation control strategy is revealed by a numerical simulation example.

▷ SunA08-64

*Graph Context Target Attention Graph Neural Network for Session-based Recommendation*

Xing, Xing — Bohai Univ.

Session-based recommendation is nowadays increasingly popular in e-commerce, aiming at predicting the next action of a user under anonymous sessions. Previous research methods on session recommendation model the temporal information inherent in a session as a sequence or graph, however, they disregard the session’s graph context information, as well as the relationship between the user and the target object, which affects the accuracy of the recommendation. To obtain the rich graph context information in session recommendation and the intrinsic connection between target items and users, we propose a graphcontext target attention graph neural network for session-based recommendation, which uses a self-attentive network and graph neural network to extract the item embedding of graph context information; the target attention then adaptively stimulates various user interests. Experimental results on two real-world datasets demonstrate that our proposed model outperforms other comparison algorithms on the evaluation metrics of Recall@20 and MRR@20 in session-based recommendation.

▷ SunA08-65

*Fault-tolerant Tracking Control for Mobile Robots Based on the Framework of Intermediate Estimator and MPC*

Ying, Liang-Huan — Zhejiang Univ. of Tech.
Zhu, Jun-Wei — Zhejiang Univ. of Tech.

During the actual motion of the wheeled mobile robot(WMR), actuator faults caused by ageing or system components’ misoperation may significantly impact the real-time control performance. Therefore, this paper proposed a fault-tolerant tracking control approach based on MPC and intermediate estimator (IE) that the observer matching condition need not be satisfied. First, a set of reference trajectories is generated from the virtual system, and a nominal tracking error system is obtained based on the relative position of the actual system. Then, an IE is used to estimate the state error and actuator fault of WMR so that an estimation-based predictive model and a fault-compensated composite control law can be obtained to ensure stable control of WMR with an actuator fault. Finally, the simulation that compared to the nominal MPC shown that this fault-tolerant control algorithm has good performance in adapting to actuator faults, which verifies this algorithm’s effectiveness.

**SunB01** 10:10–12:10 2nd Conf. Hall

Regular Session: Data Driven Control

Chair: Wang, Zhu — China Univ. of Petroleum (Beijing)
Co-Chair: Peng, Yunjian — South China Univ. of Tech.

▶ SunB01-1 10:10–10:30

*Real-time Observability of Smooth Continuous Systems and Corresponding Data-based Observability Determination and Observer Design Method*

Liu, Zehua — Beihang Univ.
Wang, Zhuo — Beijing Univ. of Aeronautics & Astronautics
Wang, Ruigang — Beijing Univ. of Aeronautics & Astronautics
Qin, Bodong — Beijing Univ. of Aeronautics & Astronautics
Li, Feng — Beijing Univ. of Aeronautics & Astronautics
Yan, Yifan — Beihang Univ.

Observability determination and observers’ construction have led to ongoing exploration by predecessors due to their importance in the field of control. The definition of observability for linear systems is given by Kalman. The states of the linear time-invariant systems can be determined by the Gramm matrix and constructed by the Luenberger observer based on pole assignment and separability principle. However, the existing definition of observability of linear systems still has room for improvement, due to the lag and approximation of state observation. Therefore, this paper proposes a new definition of real-time observability for both linear and nonlinear systems. The traditional definition of observability utilizes only the input and output information, while the new definition utilizes the derivative or partial derivative information of the input and output. Under the new definition, a state observer must exist if the system is fully observable. The new definition expands the conceptual scope of observability in the field of control theory and reduces the difficulty of observable determination and observer design for nonlinear systems.
The differential geometry method is one of the general methods for observability determination, but it is rarely used in engineering due to its high computational complexity. Most of the determination methods are usually determined for a certain class of systems or under limited conditions . Researchers have been looking for a generic, simple and powerful method to determine observability. Based on the new definition, a rank criterion for state observability is proposed. The criterion is directly derived from the new definition. The greatest advantage of this criterion is that it achieves the consistency of smooth continuous system viewability determination because it is applicable to both linear and nonlinear systems. When the system degenerates from a nonlinear to a linear system, the criterion degenerates to the linear criterion accordingly. Compared with the existing rank condition for linear systems, although they are similar in form, the criterion in this paper is proposed based on the new definition of real-time observation. In addition, the criterion has the property of being easy to apply. The relationship between the observability criterion and the existence of the observer has also been rarely studied in previous research; in this paper, the system satisfies the rank condition of the observability criterion representing the observer must exist. In particular, for linear systems, complete observability is a sufficient condition for the existence of state observers. Currently, two strategies are often used to design observers for nonlinear systems. One is to linearize the actual nonlinear system model to a certain degree and apply the corresponding linear system observer design method. However, this approach loses the nonlinear characteristics and accuracy of the system to some extent. Another method constructs the nonlinear system observer by differential homogeneous transformation, but the construction process of homogeneous transformation is often very complicated. The

applicability of most nonlinear observers is limited to special systems. In this paper, a data-driven real-time observer construction method is given for linear systems. The construction block diagram of the linear real-time observer using the designed method proposed in this paper is shown in Fig.1. If the system states of a nonlinear system after differential homogeneous transformation are completely observable, then the real-time observer can be designed. However, the construction of differential homogeneous homeomorphism transformation is often complicated. This paper does not find the construction method of real-time observer for nonlinear systems. So we propose two construction methods of asymptotic observer. For the real-time observer, the system state observability is a necessary and sufficient condition for the existence of the observer. The fully observable state of the nonlinear system is only a sufficient condition for the existence of the state asymptotic observer, rather than a necessary condition.

The Bloch equation reflects the change of atomic states and is a common class of models used in quantum instrumentation. The Bloch equation for an atomic magnetometer based on the spin-exchange relaxation-free (SERF) effect is a nonlinear model with coupled input and state. In the nonlinear part, this paper uses the Bloch equation of SERF magnetometer as a simulation model to verify that the nonlinear progressive observer designed in this paper can effectively observe the internal state of the system, and the simulation results are shown in 2-3. Fig.2 and 3 represent the system state observation results under rectangular wave signal and chirp signal input, respectively.

In this paper, the observability of the control system is investigated and a new data-based definition is proposed. A system is said to be observable when its state can be determined by the derivatives or partial derivatives of the inputs and outputs. For this definition, the corresponding rank criterion is proposed, and the system is fully state observable when the system satisfies the rank criterion. Then, this paper also proposes the necessary conditions for the existence of state observers, and proposes the construction methods of linear real-time state observers and nonlinear asymptotic observers, and proves the correctness and validity of the theory with examples.

► SunB01-2 10:30–10:50

*Interval Observer Based Extended Predictive Controller for Heavy Duty Gas Turbine*


Liu, Ke — School of Control Sci. & Engineering
Liu, Yang — School of Control Sci. & Engineering
Zhao, Jun — Dalian Univ. of Tech.
Wang, Wei — Dalian Univ. of Tech.


As the main component of gas-steam combined cycle power plant, heavy-duty gas turbine (HDGT) with the property of safety, reliability and high efficiency, which can greatly improve the performance of deep-peak shaving capability and fast frequency modulation performance of power system. With respect to the variable load control strategy for HDGT, an interval observer based extended model predictive control is proposed in this study by combining the interval observer and model predictive control, which is built upon the stability analysis of linear state feedback control. The salient property of proposed method lies in the reduction of negative effect caused by external in the process of variable load control. The typical study cases are selected for verifying the effect of the proposed methods, which outperforms the others methods in aspect of stable and safe.

► SunB01-3 10:50–11:10

*Q-Learning-based Finite Control Set Model Predictive Control for LCL-Coupled Inverters with Deviated Parameters*


Zhang, Lei — South China Univ. of Tech.
Peng, Yunjian — South China Univ. of Tech.
Sun, Weijie — South China Univ. of Tech.
Li, Jinze — South China Univ. of Tech.


Finite Control Set (FCS) Model Predictive Control (MPC), as an efficient method used for current tracking of LCL-Coupled three-phase inverters, runs into high computational complexity while finding its optimal version with a long predictive interval. For such a difficult problem we take a value function with discounted factors as an indicator to measure the pros and cons of control and propose a novel alternative method based on Q-learning algorithm. In the control scheme, the value function is approximated by reinforcement learning (RL) algorithm and furthermore, the long horizons prediction is transformed into an iterative multi-step matrix calculation. At the same time, the optimal switching position is directly obtained without a modulation link, which greatly reduces the computational complexity. Accordingly, a data-driven Q-learning algorithm is designed with a proof of convergence. Last, the proposed algorithm' s performance in the case of complete deviation from the (unknown) system parameters is verified by simulations.

► SunB01-4 11:10–11:30

*Outlier Detection of Traction Energy Consumption Based on Local Density and Cluster for Time Series Data*


Zhang, Chengxi — Beijing Jiaotong Univ.
Xun, Jing — Beijing Jiaotong Univ.
Ji, Zhihui — Beijing Jiaotong Univ.
Yin, Chenkun — Beijing Jiaotong Univ.
Cao, Jiang — CRRC Qingdao Sifang Rolling Stock Co., Ltd


Traction energy consumption accounts for 40%-50% of the total energy consumption of urban rail transit, which is the largest part. Outlier detection of traction energy consumption data is the key technology of traction energy consumption fluctuation analysis. In order to accurately detect abnormal traction energy consumption, this paper first proposes a calculation method of typical value of traction energy consumption indicator based on the combination of ARIMA model and XGBoost algorithm. Its core idea is to extract residual item information based on the XGBoost algorithm, and then integrate all information for modeling; Then, based on the calculated typical values, this paper uses an incremental local density and cluster-based outlier factor (iLDCBOF) method to detect outliers. The experimental results show that the prediction effect of ARIMA+XGBoost hybrid model is better than that of single model, and the proposed method can effectively detect abnormal energy consumption values in data streams.

► SunB01-5 11:30–11:50

*DDPG-based Path Planning Approach for Autonomous Driving*


Li, Yimin — Sun Yat-sen Univ.
Chen, Yanfang — Sun Yat-sen Univ.
Lao, Jingtao — Sun Yat-sen Univ.
Li, Tianru — Sun Yat-sen Univ.
Li, Xuefang — Sun Yat-sen Univ.


The present work develops a DDPG-based path planning algo-rithm that integrates the artificial potential field method into reinforcement learning to learn and generate an obstacle-free path quickly and autonomously. The vehicle kinematic model is adopted to describe the motion of autonomous vehicles, and the potential field function of obstacles, road boundaries as well as reference waypoints are considered to construct re-wards of reinforcement learning, which enables the vehicle to realize the trade-off between avoiding obstacles, preventing driving off the road and following the reference route. In con-trast to the existent path planning algorithms, the proposed approach is able to learn autonomously in different driving environments, which is more suitable to autonomous vehicles. Moreover, simulations are provided to further demonstrate the effectiveness and adaptability of the proposed algorithm.

► SunB01-6 11:50–12:10

*Set-membership Identification Recursive Algorithm Based on Adaptive Noise Bounding*


Wang, Zhu — China Univ. of Petroleum (Beijing)
Wang, Qian — China Univ. of Petroleum (Beijing)
Wang, Shao Xian — China Univ. of Petroleum (Beijing)


Set-membership identification recursive algorithm (SMIR) is proposed based on adaptive noise bounding in order to achieve complete dynamic modeling for a linear ordinary dynamic process without increment. Here we describe the output set as an ellipsoid under the framework of set-membership. First, we select an CARMA model with a single-input-single-output (SISO) system, and the measurement noise is unknown but bounded. The long pieces of historical data are selected based on the complexity of the dynamic characteristics of the actual object under study. Second, the designed algorithm can significantly determine the optimal noise bound-tuning coefficient on this model, making the noise bound more compatible with the actual noise environment. Next, the stability of the algorithm is proved using the Lyapunov method. Then, simulation experiments are conducted to model and predict both linear input processes and actual process data on a liquid-level control loop of the distillation tower section. Finally, the experimental results on two general examples verify the effectiveness of the proposed algorithm.

**SunB02** 10:10–12:10 3rd Conf. Hall

Invited Session: Recent Advances for Control-theoretic Iterative Methods

Chair: Li, Juntao — Henan Normal Univ.
Co-Chair: Meng, Deyuan — Beihang Univ. (BUAA)

▶ SunB02-1 10:10–10:30

*Robust $H_infty$ Control for Switched Stochastic Nonlinear Systems under Periodic Sampling*

Zhao, Hongpeng — Henan Normal Univ.
Xiong, Jiandong — Henan Normal Univ.
Mu, Xiaoxia — Henan Normal Univ.

The switching control system, as an important hybrid system, is widely used in the actual systems, where the robustness and stochastic disturbances often affect the performance of the systems cite2020Neural,Mao2019Sampled,NiuB2017Adaptive. This suggests replacing the switched system with the switched stochastic system on the robust $H_infty$ control theory citeXiang2012Stability,Ren2020Robust. So an output feedback control problem of the switched stochastic nonlinear system under sampled-data was considered by the back-stepping method in this paper.

To simplify the operation, take a change of coordinates on the switched stochastic nonlinear system by the scaling gain $Lgeq1$ which is a design parameter to avoid the computational explosion of the differential terms. Then, the observer can be constructed, and the error system can also be obtained. And without loss of generality, it can be assumed that at most one switch occurs in each sampling period $T$, which implies $TleqT_d$, where $T_d$ is the duration of the minimum adjacent switch. Therefore, the system will be analyzed in two cases:

Case 1: no switching during sampling interval, then the activated subsystem is synchronous with its matched controller.

Case 2: there is a switch in sampling interval, then before the switch, the activated subsystem is synchronous with its corresponding controller, while after the switch instant, the process is asynchronous until the next sampling instant.

Next, the output feedback controller will be obtained by back-stepping and based only on sampled and observed information in both cases, which solves the problem that the system state cannot be measured in citeMa2015Stochastic. Unlike the relaxed switching rules in citeGuan2021Sampled, the switching signal only needs to satisfy the condition of average dwell time $tau_a$. And the difficulty of not being able to determine whether a switch has occurred is solved by the introduction of a judgment function that establishes a link between the sampling point and the switching signal. Later, a relationship between $tau_a$ and $T$ is derived, where $tau_a$ is an important index that affects the switching frequency of the system and limits the selection of $T$, and the sampling period $T$ is closely related to the system performance. Moreover, the smaller the sampling period $T$, the more accurate the system results obtained.

For given positive constant $gamma$, designed controllers $u_{sigma}(cdot)$, and relationship between $tau_a$ and $T$, the closed-loop system is globally mean-square asymptotically stable with the disturbance input $vartheta(t)equiv0$, and has a weighted $L_2$-gain level which is an evaluation index of system performance and based on the globally mean-square asymptotically stable of the system. And the smaller the weighted $L_2$-gain level, the better the performance of robust $H_infty$ control of systems.

This paper is devoted to the robust $H_infty$ control of switched stochastic nonlinear systems under sampled-data. The following are the main contributions:

1) A relationship between the average dwell time and the sampling period is derived to ensure that the system is mean-square asymptotically stable and has a weighted $L_2$-gain.

2) The output feedback controllers are constructed by the back-stepping method to solve the problem that the system state cannot be measured.

3) The difficulty of not being able to determine whether a switch has occurred is solved by the introduction of a judgment function that establishes a link between the sampling point and the switching signal.

▶ SunB02-2 10:30–10:50

*Chattering-Free Adaptive Iterative Learning for Attitude Tracking Control of Uncertain Spacecraft*

Zhang, Fan — Beihang Univ.
Meng, Deyuan — Beihang Univ. (BUAA)
Li, Xuefang — Sun Yat-sen Univ.

This extended abstract introduces our existing research that focuses on the chattering-free adaptive iterative learning for attitude tracking tasks of spacecraft subject to initial state errors. Thanks to the proposed reduction mechanism in the parametric learning law, iteration-varying initial state errors, as well as the unknown inertia matrix and external disturbances, can be addressed effectively. Moreover, to avoid the chattering phenomenon of the control signals, we introduce an approximation of the sign function. Of note is that this approximation leads to a class of non-negative definite problems. A new analytical method is consequently exploited with a Lyapunov-like theory based on contraction-mapping and composite-energy-function, which rigorously shows the boundedness and convergence of the iterative learning process in the presence of initial state errors and non-negative definite problems.

▶ SunB02-3 10:50–11:10

*Fixed-time Synchronization of Nonlinear Non-affine System*

Liu, Dandan — Qilu Univ. of Tech.
Lv, Hui — Qilu Univ. of Tech. (Shandong Acad. of Sci.)
Zhao, Fuyu — Qilu Univ. of Tech.
Han, Andong — Qilu Univ. of Tech.
Du, Mingjun — Qilu Univ. of Tech. (Shandong Acad. of Sci.)

This paper concerns with the fixed-time control problem of nonlinear non-affine system. First, based on a Taylor series expansion, the nonlinear non-affine system is transformed into an affine system. Second, by using norm-normalized sign functions and providing sufficient Lyapunov conditions, it is shown that the nonlinear non-affine system can be achieved synchronization in a fixed time, regardless of its initial value. In addition, the settling time is calculated by using an enhanced estimation method. Third, compared with the classical calculate method, a switching sliding-mode control technique is adopted to deal with the possible singularity problem.

▶ SunB02-4 11:10–11:30

*Distributed Algorithm for Solving Sylvester Matrix Equation via Iterative Learning Control*

Liang, Cong — Henan Normal Univ.
Huo, Xuanmin — State Grid Henan Electric Power Company Xinxiang Power Supply Company
Xu, Shizhou — Henan Normal Univ.
Wang, Lei — Henan Normal Univ.
Li, Juntao — Henan Normal Univ.

As the most fundamental type of matrix equation, the Sylvester equation has been widely applied in control theory, signal processing, and many other scientific fields in recent years. The traditional method for solving the Sylvester equation is to transform it into a linear algebraic equation (LAE). However, this method will lead to an increase in the dimension of the coefficient matrix, which makes it difficult to solve the LAE. To alleviate the above problem, a distributed algorithm for solving the Sylvester equation is presented in this paper. Firstly, we obtain a LAE equivalent to the Sylvester equation by utilizing vectorization operation and Kronecker product. Then, a group of agents in the multi-agent system is considered to implement the distributed solution for LAE, where each agent only solves its local task by constantly exchanging information with its neighbors. By constructing the iterative learning control system, a discrete linear system about the tracking error of the agent is obtained. Based on the average neighbor information and the feedback control design, an updating rule for each agent iteratively updating its state is obtained. It is shown that all agents converge to the vectorization solution of the Sylvester equation when the communication topology between agents is undirected complete graph. Finally, a simulation example is provided to demonstrate the effectiveness of the proposed distributed algorithm.

▶ SunB02-5 11:30–11:50

*Average Bipartite Consensus Problems over Directed Signed Networks Subject to Saturation Constraints*

Yan, Zhiguo — Qilu Univ. of Tech.
Chen, Baicheng — Qilu Univ. of Tech.
Du, Mingjun — Qilu Univ. of Tech. (Shandong Acad. of Sci.)
Lv, Hui — Qilu Univ. of Tech. (Shandong Acad. of Sci.)

In this paper, the average bipartite consensus problem of single-integrator agents subject to saturation constraints is studied. For the signed networks under weight unbalanced signed digraph, a mirror signed digraph is constructed by using the left eigenvector corresponding to the zero eigenvalue of the Laplace matrix, where the control protocol is designed according to the properties of the mirror signed digraph. For the problem of saturation constraints, signed networks is not subject to saturation constraints by selecting the appropriate gain. From the convergence analysis, when the signed digraph satisfies structural balance, it is obtained that the signed networks can reach average bipartite consensus. When the signed digraph satisfies structural unbalance, the signed networks can reach state stability.

▶ SunB02-6 11:50–12:10

*A Distributed Patrol Algorithm for Multi-robot Systems Based on Discrete-time Consensus Theory*

Zhang, Pengchao Lanzhou Jiaotong Univ.
Li, Zonggang Lanzhou Jiaotong Univ.

In the multi-robot patrol task, it is difficult for a single robot to obtain global information due to the limitation of communication distance and other factors. However, most existing multi-robot distributed patrol algorithms require each robot to obtain global information of its patrol area. Therefore, this paper proposes a multi-robot distributed patrol algorithm based on discrete-time consensus theory. First, whether the robot exists, the number of node visits, and the node intention value are used as the negotiation variables. Local information is used to provide initial values for the negotiation variables. The discrete-time consensus protocol is used to achieve the negotiation behavior among neighbors, so that all robots can reach an agreement on the negotiation variables. Then, the average idle time of the node is estimated and whether a robot plans to visit the node is determined to make a decision. Finally, the simulation verifies that the proposed multi-robot distributed patrol algorithm based on local information enables the robot to judge the global state without global information and complete the patrol task based on the negotiation between neighbors.

**SunB03** 10:10–12:10 4th Conf. Hall
Invited Session: Advanced Motion Control Methods for Modern Mechatronics Systems

Chair: Wang, Junxiao Zhejiang Univ. of Techology
Co-Chair: Chen, Qiang Zhejiang Univ. of Tech.

► SunB03-1 10:10–10:30
*Extended RVR Based Degradation Modeling for RUL Prediction of DC-Link Capacitors in High-Speed Trains*

Wang, Xiuli Zhejiang Univ. of Tech.
Li, Zhongxin Zhejiang Univ. of Tech.
Li, Yang Shanghai Univ.

This paper extends RVR model into a multivariate and high-accuracy degradation model for RUL prediction. Specifically, the classical RVR is expanded into a multivariate one by introducing a matrix Gaussian distribution to model weight. Then the hyperparameters are estimated via an analytical method - Nesterov's accelerated gradient method, to avoid the exhausting re-estimation problem. And the degradation path is forecasted by extending the established Multivariate RVR (MRVR) model into a probability manifold for high prediction accuracy. Finally, the RUL of capacitors is predicted by First Hitting Time (FHT) method.

► SunB03-2 10:30–10:50
*High Precision Position Control of Magnetic Levitation Ball System Based on Generalized Disturbance Estimation*

Lu, Qinkun Zhejiang Univ. of Tech.
Wang, Junxiao Zhejiang Univ. of Techology

In this paper, a position control method based on generalized disturbance estimation is proposed to solve the problem of position accuracy of magnetic levitation ball system under the influence of mismatched multiple disturbances. Firstly, an Luenberger observer is designed to estimate the state variables of the system. Considering the known disturbance information, a generalized disturbance estimator is designed to estimate the disturbance using the internal model principle. Then, the disturbance estimation and its derivative are introduced into the control law design to eliminate the influence of the mismatched multiple disturbances on the position output, and the disturbance compensation gain is designed for the control law. At the same time, the reference input compensation gain is designed to solve the problem of tracking the time-varying reference position under mismatched disturbance. Then, the stability and disturbance rejection performance of the proposed method are analyzed, and it is proved that the proposed method can achieve high precision position control of the magnetic levitation ball system under mismatched multiple disturbances. In order to verify the effectiveness of the proposed method, MATLAB/Simulink is used to simulate and verify the proposed method.

► SunB03-3 10:50–11:10
*A Novel Predefined - Time Control Strategy for Attitude Stabilization of Rigid Spacecraft*

Xie, Shuzong College of Information Engineering, Zhejiang Univ. of Tech.
Yang, Qinmin Zhejiang Univ.
Chen, Qiang Zhejiang Univ. of Tech.

In this paper, a novel predefined-time control strategy is proposed for attitude stabilization of rigid spacecraft. By establishing a novel practical predefined-time convergence theorem, a predefined-time attitude controller is systematically presented to ensure that the spacecraft attitude can converge into a small region around the origin within a predefined time, which can be explicitly determined in advance by tunning one parameter. Simulations are conducted to verify the effectiveness of the proposed strategy.

► SunB03-4 11:10–11:30
*Fuzzy Adaptive Nonsingular Predefined-Time Attitude Tracking Control of Quadrotor UAVs*

Tao, Meiling Anhui Polytechnic Univ.
Chen, Qiang Zhejiang Univ. of Tech.

In this paper, a quadrotor UAV attitude-tracking adaptive neural control problem is presented. In order to ensure the stability of the predetermined time, a non-singular predetermined time attitude tracking control method based on sliding surfaces is proposed. Independent of the initial conditions of the system, the attitude tracking error converges to a neighborhood near the origin. Instead of using any piecewise continuous function in the controller design, the potential singularity problem is solved by establishing auxiliary procedures to achieve the predetermined temporal stability. Experiments on a real Quanser quadrotor platform are used to verify the effectiveness of the proposed system.

► SunB03-5 11:30–11:50
*Position Sensorless Control of Permanent Magnet Synchronous Motor at Standstill and Low Speed*

Hu, Kailin Zhejiang Univ. of Tech.
Wang, Junxiao Zhejiang Univ. of Techology

Permanent magnet synchronous motors have been widely applied in industrial fields for the advantages of high efficiency, high power factor, and good dynamic perf- ormance. The traditional control strategy of permanent magnet synchronous motor ad- opts vector control, which usually requires the installation of position sensor to obtain in the operating position information of the motor. However , in the actual engineering environment, the position sensor is easy to be affected by the adverse environment, such as high temperature and humidity, thus affecting the operating performance of the whole servo motor system. In addition, in some small capacity and low-cost servo motor operating system, the use of position sensor will increase the cost. So the sensorless control technology has become the focus and hotspot in the field of motor control because of its reliability and low-cost . Generally, it could be divided into the signal-injection method and the model-based method, the former is applicable to the motor runs at zero or low speed, and the latter usually applies in the areas of high speed. The high-frequency signal injection method utilizes the motor saliency to estimate the rotor position, which has a good application prospect[6-10]. The traditional high frequency sine wave injection method was first proposed by Lorenz, the advantage of this method is that the high frequency rotating signal is dire- ctly injected into the stationary shafting, so the rotor position information does not need to be pre-estimated , but there are still some shortcomings, it is mainly reflected in the excessive number of filters, which limits the system bandwidth and affects the dynamic performance, especially, the use of SRFF makes the engineering implementation complicated [11-18]. In order to solve the shortcomings of traditional methods, the h- igh frequency pulsating signal injection was proposed by Sul who teaches at Seoul National University in South Korea, the advantage of this method is that injecting high frequency sine signal in the observed d axis, so the current pulsation component in the q axis is small and nearly negligible, this method can avoid the torque pulsation an -d high frequency loss caused by injection, more importantly, the low pass filter in the q-axis current feedback can be omitted, thus improving the current loop bandwidth and dynamic performance of the sensorless control of permanent magnet synchronous mo -tor system[16-19]. However, the injection frequency of these method could be up to 1/6 of the PWM switching frequency. The injection of low frequency limits the dynamic performance of PMSM sensorless control system. Compared with sinusoidal injection, square wave injection has a better application prospect because of its higher injection frequency and better dynamic performance[1-5]. In this paper, using a non-filter rotor initial position detection method and low s- peed closed-loop operation of sensorless control scheme, compared with the traditional method, it can accelerate the dynamic performance and improve accuracy of rotor polarity and position observation, and also could realize the quickly starting of motor at any initial position, improving the dynamic performance of the servo system at low speed operation. The whole scheme is divided into two parts, the first is initial position detection, and the another is low speed position non-sensor control[7-10].

Initial position detection : Firstly, a high-frequency square wave is injected into the estimated d-axis .Then, the high-frequency current response is obtained by HPF in the d-q coordinate system. Next, the position error decoupling step is used to obtain t- he rotor position estimation error information. Finally, through PLL phase-locked loo- p technique to obtain the estimated angle. Low speed position non-sensor control: First of all, inject high frequency square-wave in the stationary coordinate system rather than the traditional estimated d-q axis, in this way can avoiding the ambiguous convergent points of angle error , and it would make the system more stable. Then, a position estimation method without low-pass filters is proposed, and the phase shifts caused by high-pass filters are also reduced,and common drawbacks of the current SRF-based injection methods is effectively reduced. In the end, a method is designed to reduce digital latency

▶ SunB03-6 11:50–12:10

*Spatial Adaptive Iterative Learning Control for Nonparametric Uncertain Systems*


| | |
|---|---|
| Su, Yang | Zhejiang Univ. of Tech. |
| Shi, Huihui | Zhejiang Univ. of Tech. |
| Chen, Qiang | Zhejiang Univ. of Tech. |
| Zhang, Zhihao | Zhejiang Univ. of Tech. |


In this wok, the spatial adaptive iterative learning control (SAILC) method is proposed for uncertain systems with both parametric and nonparametric uncertainties. By designing spatial full saturation adaptive iterative learning update laws, the parametric and nonparametric uncertainties and expected control inputs are estimated, and the estimated values are limited to the specified bounds. Besides, it is not necessary to know the Lipschitz bound function when estimating the upper bound of the nonparametric uncertainties of the system. The above simulation shows that the spatial adaptive iterative learning control law realizes the complete tracking of the system state to the given reference trajectory with initial drift, and fully reflects the effectiveness of the method.

## SunB04 10:10–12:10 5th Conf. Hall

Invited Session: Intelligent Cooperative Control for Multiagent Systems

Chair: Liang, Hongjing — Univ. of Electronic Sci. & Tech. of China
Co-Chair: Pan, Yingnan — Bohai Univ.

▶ SunB04-1 10:10–10:30

*Observer-based Data-driven Sliding Mode Control for A Discrete-time Nonlinear Multiagent Systems*


| | |
|---|---|
| Yin, Caiyun | Guangdong Univ. of Tech. |
| Lin, Guohuai | Guangdong Univ. of Tech. |
| Chen, Guangdeng | Guangdong Univ. of Tech. |
| Ma, Hui | Guangdong Univ. of Tech. |
| Li, Hongyi | Guangdong Univ. of Tech. |


In this work, an observer-based sliding mode control strategy is proposed for a discrete-time nonlinear multiagent systems (MASs) with unknown disturbance. Only some agents are capable of acquiring the reference trajectory, and the dynamic models of the agents are unknown. Unlike the traditional model-based consensus control protocol, this method is data-driven and solely dependent on the input/output (I/O) data of the agents. The stability of the proposed control strategy is ensured by theoretical analysis and the simulation outcomes ultimately validate the viability of the developed approach.

▶ SunB04-2 10:30–10:50

*Event-Triggered Optimal Tracking Control for Multiplayer Non-Zero-Sum Games of Nonlinear Systems via Concurrent Learning*


| | |
|---|---|
| Qin, Yi | Bohai Univ. |
| Wang, Lijie | Qingdao Univ. |


This paper develops an event-triggered optimal tracking control algorithm to handle the problem of the N-player non-zero-sum (NZS) games for nonlinear systems with infinite horizon discount cost. A decay term is introduced to accelerate the convergence rate of the value function containing multiple control inputs. To lighten the correspondence burden, a state-dependent triggering condition is designed to ensure that the lower bound of the minimal triggering time interval is positive. Moreover, the single critic neural network is applied such that the computational complexity is greatly reduced. Unlike existing optimization results that require the continuous excitation condition, the concurrent learning technique is introduced into the update rate of neural network weights, thereby removing the limitation of additional noise excitation. Eventually, all signals of the closed-loop system are guaranteed to be uniformly ultimately bounded via the Lyapunov stability theory. Meanwhile, simulation results are presented to verify the feasibility of the proposed scheme.

▶ SunB04-3 10:50–11:10

*Manufacturing Big Data Modeling Algorithm Based on GM (1,1)-LSTM and Its Application in Sales Forecasting*


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|---|---|
| Long, Yinren | Guangdong Univ. of Tech. |
| Xiao, Yi | Guangdong Univ. of Tech. |
| Ren, Hongru | Guangdong Univ. of Tech. |
| Lu, Renquan | Guangdong Univ. of Tech. |


It is a new period for the development of automobile industry, the economic situation is complex and changing, and the policies of automobile industry are frequently issued, so accurate prediction of automobile sales is extremely important and practical for both government and enterprises. In this paper, the GM(1,1) model and the long short-term memory (LSTM) neural network model are combined and optimized, and the sales of a brand of cars from January 2019 to September 2022 are used as sample data, and the car sales in the next three months are predicted by two single models and linear combination forecasting models, respectively. The experimental results show that the linear combined forecasting model outperforms the other two single models in terms of forecasting results and has better resistance to the interference of external factors.

▶ SunB04-4 11:10–11:30

*A Parameter Optimized Variational Mode Decomposition Method for Harmonic and Inter-harmonic Detection*


| | |
|---|---|
| Xi, Xinze | N/A |
| Sun, Pengqi | Kunming Univ. of Sci. & Tech. |
| Xing, Chao | Electric Power Research Inst. |
| Li, Shengnan | Electric Power Research Inst. |
| Tian, Xincui | Kunming Univ. of Sci. & Tech. |


An variational mode decomposition (VMD) has been applied in the field of harmonic detection, but the error will be large if the decomposition parameters are set artificially. To improve the accuracy of VMD in interharmonics detection, we need to determine the number of wolves, maximum number of iterations, convergence factor and other parameters, and then select component sample entropy function as the fitness function of the Grey Wolf algorithm. The variational mode decomposition can be utilized to extract the harmonic signal and choose a minimum envelope entropy weight as the best component. The Fourier transform is used to obtain the amplitude and frequency information of interharmonic signals. The simulation results show that the proposed method can effectively optimize the parameters and reduce the VMD decomposition error. Compared with empirical mode decomposition (EMD), complementary ensemble empirical mode decomposition (CEEMD) and empirical wavelet transform (EWT), the VMD with optimized parameters can significantly improve the accuracy of interharmonic detection and improve the accurate trace of accident source.

▶ SunB04-5 11:30–11:50

*Backstepping Sliding Mode Control of Dual-motor Servo System Based on Improved Double Power Reaching Law*


| | |
|---|---|
| Xu, Sha Man | Anhui Polytechnic Univ. |
| Tao, Liang | Anhui Polytechnic Univ. |
| Tao, Meiling | Zhejiang Univ. of Tech. |
| Xu, Binzi | Anhui Polytechnic Univ. |
| Deng, Xiongfeng | Anhui Polytechnic Univ. |
| Shi, Linlin | Zhejiang Univ. of Tech. |


An improved double power reaching law is proposed in this paper to solve the nonlinear problem of the backlash in the mechanical transmission link of the dual motor driving servo system. Firstly, the dual-motor servo system with gear is established. Then, the traditional double power reaching law and sliding mode surface are employed to obtain the filtered variables, which can construct a compensation term in original reaching law to reduce the compact of system uncertainties and disturbances. The convergence analysis and boundness of the improved double power reaching law are provided. Besides, the backstepping sliding mode control is investigated to greatly improves the convergence efficiency of the system, and the stability analysis is carried out. Finally, the effectiveness of the proposed methods is verified by simulations.

▶ SunB04-6 11:50–12:10

*Capsule Endoscopes Actuated with Permanent Magnet:A Model-Free Adaptive Control Approach*


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|---|---|
| Li, Yijia | Zhejiang Univ. of Tech. |
| Chen, Jiashu | Zhejiang Univ. |
| Chen, Peng | Zhejiang Univ. of Tech. |
| Ou, Xianhua | Zhejiang Univ. of Tech. |

He, Xiongxiong Zhejiang Univ. of Tech.

A model free adaptive control technique with multiple inputs and multiple outputs was presented to deal with the issue of attitude tracking of the magneto-controlled capsule endoscope during the shooting task in the stomach. The cost function is employed in the development of acceptable parameter estimation and control algorithms. Only input and output data are required for the control technique in this paper; no complicated model information is necessary. It is a means of control based on data. Finally, simulation is used to validate and evaluate the effectiveness of the adaptive parameter estimates and controller design.

**SunB05** 10:10–12:10 6th Conf. Hall
Invited Session: Data-driven Based Complex Network Learning and Security Analysis

Chair: Zhang, Guangchen North Minzu Univ.
Co-Chair: He, Shuping Anhui Univ.

► SunB05-1 10:10–10:30
*A Novel Data-Driven Fault-Tolerant Control Method Based on Convex Optimization*

Wang, Siqing Northwestern Polytechnical Univ.
Fan, Quan-Yong Northwestern Polytechnical Univ.
Li, Jiaxuan Northwestern Polytechnical Univ.
Zhang, Naizong Northwestern Polytechnical Univ.

In this study, for discrete-time linear systems, a data-driven and passive fault-tolerant control design is delivered. This design starts from a novel expression of the classical linear–quadratic regulator (LQR) problem, modifies it into a semi-definite programming (SDP) optimization problem method, expands the constraint conditions by using the properties of convex functions, and obtains the fault-tolerant control method of actuator failure based on data. Finally, a discrete time system is simulated to show the feasibility and effectiveness of this design.

► SunB05-2 10:30–10:50
*Distributed Pneumatic Physiotherapy Robot for Human Acupoints*

Wan, Xiao Wuhan Inst. of Tech.
Huang, Zixin Wuhan Inst. of Tech.
Li, Yun Hubei Provincial Hospital of Traditional Chinese Medicine
Wang, Wei Zhongnan Univ. of Economics & Law
Yang, Zhixuan Wuhan Inst. of Tech.
Wang, Liheng Wuhan Inst. of Tech.

With the growth of age, the body function of the elderly continues to decline, so they often suffer from various diseases, and long-term medication brings many additional diseases. In the context of the development of artificial intelligence, there is a lack of a robot with both portability and therapeutic functions to solve the problems of home care and long-term medication for the elderly. Considering that TCM (Traditional Chinese Medicine) physiotherapy belongs to physical therapy, it has a good treatment and prevention effect on the diseases of the elderly, without the side effects of drug therapy. Based on the principle of TCM physiotherapy, a pneumatic wearable physiotherapy robot is designed in this paper, so that the elderly can complete the physiotherapy process at home. In this paper, the structure composition and function of the robot are designed, and the experiment is carried out. Therefore, the physical therapy robot proposed in this paper has good portability when completing physical therapy operations.

► SunB05-3 10:50–11:10
*Secure Control for the Discrete-time CPSs under DoS Attacks via A Switching Strategy*

Zhang, Ruifeng Shandong Univ.
Li, Guitong Shandong Univ.
Yang, Rongni Shandong Univ.

In this work, the stability analysis and stabilization problem for a class of discrete-time cyber-physical systems (CPSs) under denial of service (DoS) attacks is investigated. Firstly, combined with reasonable formulation of DoS attacks, different scenarios according to presence or absence of DoS attacks are developed. Then the input-to-state stability (ISS) and globally asymptotical stability (GAS) of the considered system can be guaranteed in terms of DoS frequency and duration restrictions, respectively. Finally, one example is given to illustrate the applicability of our proposed theoretical result.

► SunB05-4 11:10–11:30
*Iterative Learning Control for 2-D Discrete Systems in Frequency Domain*

Wan, Kai Huizhou Univ.
Xu, Qing-Yuan Guangdong Polytechnic Normal Univ.

In this paper, the robust convergence problem of iterative learning control (ILC) is investigated for two-dimensional (2-D) discrete systems with iteration-varying boundary states and errors in the frequency domain. A classical P-type ILC law is designed. By using 2-D Z-transformation analysis, a sufficient condition of the ILC law can be obtained. By the rigorous mathematical proof, the ultimate ILC tracking error can converge to a bounded region, which is dependent on the upper bound of boundary states/errors. In particular, when all the boundary states and errors are zero, the practical tracking output can precisely track a 2-D desired trajectory.

► SunB05-5 11:30–11:50
*Speed and Heading Control of An Unmanned Surface Vehicle Using Deep Reinforcement Learning*

Wu, Ting Jiangsu Univ. of Sci. & Tech.
Ye, Hui Jiangsu Univ. of Sci. & Tech.
Xiang, Zhengrong Nanjing Univ. of Sci. & Tech.
Yang, Xiao-Fei Jiangsu Univ. of Sci. & Tech.

In this paper, a deep reinforcement learning-based speed and heading control method is proposed for an unmanned surface vehicle (USV). A deep deterministic policy gradient (DDPG) algorithm which combines with an actor-critic reinforcement learning mechanism, is adopted to provide continuous control variables by interacting with the environment. Moreover, two types of reward functions are created for speed and heading control of the USV. The control policy is trained by trial and error so that the USV can be guided to achieve the desired speed and heading angle steadily and rapidly. Simulation results verify the feasibility and effectiveness of the proposed approach by comparisons with classical PID control and S plane control.

► SunB05-6 11:50–12:10
*Dynamic Route Planning Method Based on Deep Reinforcement Learning and Velocity Obstacle*

Lou, Mengmeng Jiangsu Univ. of Sci. & Tech.
Yang, Xiao-Fei Jiangsu Univ. of Sci. & Tech.
Xiang, Zhengrong Nanjing Univ. of Sci. & Tech.
Wang, Qi Jiangsu Univ. of Sci. & Tech.
Hu, Jiabao Jiangsu Univ. of Sci. & Tech.

Route planning is a key technology for unmanned surface vessel (USV) autonomous navigation. Traditional route planning algorithm usually has the shortcomings of complex calculation, long time and single algorithm function. In this paper, aiming at the shortcomings of traditional algorithm, the route planning strategy of USV based on deep reinforcement learning (DRL) and velocity obstacle (VO) is designed. Using electronic nautical chart to build visual environment model; Based on the kinematics of USV, Markov decision process is established, and combined with the advantages of VO method and DRL, a general reward mechanism is designed, so that USV can achieve fast and safe route planning strategy in the complex marine environment where dynamic obstacles and static obstacles exist at the same time. In order to prove our method, a simulation experiment is introduced, and the results confirm the correctness and effectiveness of the proposed method.

**SunB06** 10:10–12:10 Yuetang Conf. Hall
Regular Session: Active Disturbance Rejection Control and Applications

Chair: Pang, Zhonghua North China Univ. of Tech.
Co-Chair: Ai, Wei South China Univ. of Tech.

► SunB06-1 10:10–10:30
*Cascaded Generalized Extended State Observer-Based Control for Servo Systems with Matched and Mismatched Disturbances*

Jiang, Fuxi Key Laboratory of Image Processing & Intelligent Control, School of Artificial Intelligence & Automation, Huazhong Univ. of Sci. & Tech.
Ye, Jie Huazhong Univ. of Sci. & Tech.
Cheng, Shanmei Key Laboratory of Image Processing & Intelligent Control, School of Artificial Intelligence & Automation, Huazhong Univ. of Sci. & Tech.

This paper proposes a cascaded generalized extended state observer-based control (CGESOBC) implementation scheme for a class of nonlinear servo systems with nonintegral-chain form and multiple matched and mismatched disturbances. In this approach, the total disturbances in each channel are reconstructed by designing a GESO, and a reference model is developed with the estimated disturbances and the reference input, together with a state tracking error model containing the multiple residual disturbances. Another GESO is then devised to estimate the

primary estimation errors, based on which a state feedback control law incorporating a dynamic compensator is formulated for robust stabilization of the state tracking error system. Moreover, the Lyapunov stability theory is applied to prove the bounded stability of the closed-loop system. Finally, the efficacy of the proposed control method is verified by a numerical example.

▶ SunB06-2 10:30–10:50

*Disturbance Rejection Based Adaptive Fast Terminal Sliding Mode Control for Ship Course Control*

Qin, Huayang — Nankai Univ.
Zheng, Chen — Beijing Inst. of Astronautical Sys. Engineering
Tan, Panlong — Nankai Univ.
Sun, Mingwei — Nankai Univ.
Chen, Zengqiang — Nankai Univ.
Sun, Qinglin — Nankai Univ.

As the main means of transportation in global trade, ships have received great attention in industry and academia. Aiming at the automatic control of the ship in the ocean, an adaptive fast terminal sliding mode control (FTSMC) method is proposed and regulates the ship course effectively. In particular, considering the nonlinear dynamics of the ship and unexpected external disturbances, the linear extended state observer (LESO) is employed to estimate and compensate for the total disturbance in ship course control. Specifically, an adaptive control gain is elaborately designed to eliminate the tracking error caused by the estimation error of the total disturbance, which ensures the asymptotic convergence of the closed-loop system. Based on the designed sliding manifold, the proposed method can achieve the control objective without singularity. Furthermore, the closed-loop stability are proved by rigorous Lyapunov-based analysis. In addition, the simulations with comparative results are provided to validate the effectiveness and robustness of the proposed method.

▶ SunB06-3 10:50–11:10

*Changed Extended State Observer Based Position Control for Autonomous Underwater Vehicle*

Song, Wanping — Nankai Univ.
Zheng, Chen — Beijing Inst. of Astronautical Sys. Engineering
Chen, Zengqiang — Nankai Univ.
Sun, Mingwei — Nankai Univ.
Sun, Qinglin — Nankai Univ.

Extended state observer (ESO) has been used to estimate the unknown nonlinear function of the system using input and output data. Recently, a new observer, the compensation function observer (CFO), has a significant improvement over ESO in estimating accuracy. This paper refers to the theory of CFO of fully using the available information and the innovation of the new definition of disturbance, designs a new observer, and verifies the availability of the new observer on the depth control simulation of the autonomous underwater vehicle (AUV). The simulation results demonstrate that the new observer is capable of estimating the unknown nonlinear function more quickly and accurately.

▶ SunB06-4 11:10–11:30

*Fixed-time Nonsingular Terminal Sliding Mode Control for Vehicle Platoon with Disturbance Observer*

Wang, Yan-Bo — Jiangnan Univ.
Li, Yu-Ling — Jiangnan Univ.
Liu, Cheng-Lin — Jiangnan Univ.

This article investigates a fixed-time nonsingular terminal sliding mode control (FNTSMC) method with disturbance observer (DO). Using the vehicle's acceleration information, a fixed-time DO is designed to estimate the external uncertain disturbance of the system. Considering the nonzero initial error, a modified constant time headway strategy is proposed to overcome the influence of the nonzero initial error on the vehicle controller. In addition, a new terminal sliding mode control method is introduced to avoid the nonsingular problem and ensure that the vehicle spacing error converges in a fixed time. Finally, a numerical simulation is presented to show the proposed method's effectiveness.

▶ SunB06-5 11:30–11:50

*ADRC with Built-in RLC Control Scheme for Uncertain Systems with Periodic Reference Input*

Li, Xiangyang — South China Uni. of Tech
Huang, Jian — Kunming Shipborne Equipment Research & Test Center
Tian, Senping — South China Univ. of Tech.
Ai, Wei — South China Univ. of Tech.

Active disturbance rejection control (ADRC) method has shown strong capabilities to handle system uncertainties. As for dealing with the periodic reference input signal, the repetitive learning control (RLC) method is often applied in practice to improve the system performance. In this paper, a distinct framework is proposed for the design and implementation of integrating the advantages of RLC and ADRC for uncertain systems with periodic reference input. An extra control input produced by built-in RLC scheme is added to the state error feedback (SEF) part of ADRC system. The stability of ADRC with built-in RLC scheme is proved. Simulations show that the proposed method is effective and can achieve better performance than the classic ADRC.

▶ SunB06-6 11:50–12:10

*Speed Tracking Control of PMSM Using Adaptive Extended Harmonic State Observer*

Wang, Xianyu — North China Univ. of Tech.
Pang, Zhonghua — North China Univ. of Tech.
Guo, Haibin — Beijing Inst. of Tech.
Gao, Shengnan — Dalian Maritime Univ.

This paper investigates the speed tracking control issue of a permanent magnet synchronous motor (PMSM). A speed tracking controller based on an adaptive extended harmonic state observer and an extended state observer is proposed under the PMSM non-cascaded structure to suppress multiple disturbances and improve the speed tracking performance. Specifically, an adaptive extended harmonic state observer is designed to estimate mismatched periodic and mismatched aperiodic disturbances with uncertain frequencies, and another extended state observer is developed to estimate matched disturbances. Based on the disturbance estimates, a linear feedback controller is designed to solve the PMSM speed tracking problem under matched and mismatched disturbances. Finally, the effectiveness of the proposed control scheme is verified by the simulation study.

**SunB07** 10:10–12:10 Hongqi Conf. Hall

Invited Session: Data-driven Intelligent Control and Public Security of Traffic Network System

Chair: Ji, Honghai — North China Univ. of Tech.
Co-Chair: Liu, Shida — Beijing Jiaotong Univ.

▶ SunB07-1 10:10–10:30

*Adaptive Feedforward Feedback Iterative Learning Control Method and Its Application to Autonomous Bus*

Liu, Shida — Beijing Jiaotong Univ.
Huang, Wei — North China Univ. of Tech.
Ji, Honghai — North China Univ. of Tech.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.

Aiming at the longitudinal speed control of autonomous buses, an improved Adaptive Feedforward Feedback Iterative Learning Control (AFF-ILC) algorithm was proposed. The controller structure of this method adopts the PD-ILC control structure. At the same time, by introducing the time domain integral operator and the iterative domain differential operator, combined with the adaptively adjusted PD parameters, the feedforward and feedback learning ability of the AFF-ILC control algorithm can be preserved simultaneously. In addition, considering the bus overspeed protection and other factors, the controller design process also considers the saturation constraints of control input and controller parameters. The advantage of the proposed method is that it combines the characteristics of repeated bus operation with the characteristics of an iterative learning control algorithm, and the controller design process does not require accurate modeling of the system, only the input and output data can be used for controller design. A series of simulation results verify the effectiveness of the proposed method.

▶ SunB07-2 10:30–10:50

*Parameter Optimization Design of MFAC Based on Reinforcement Learning*

Liu, Shida — Beijing Jiaotong Univ.
Jia, Xiongbo — North China Univ. of Tech.
Ji, Honghai — North China Univ. of Tech.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.

In this paper, a novel data-driven model-free adaptive control method based on Reinforcement Learning (RL-MFAC) is proposed for a class of discrete-time single-input and single-output nonlinear systems. In RL-MFAC, according to the dynamic linearization theorem, the pseudo-partial derivative (PPD) concept is introduced to design the controller results. Finally, the controller parameters are tuned by the Reinforce-

ment Learning (RL) method. Moreover, RL optimizes MFAC parameters using increasing and decreasing fractions as reward and punishment schemes, respectively. Such that the controller not only has good robustness, but also can solve the problem that MFAC needs to reset the optimal parameters on different control objects.The feature of the RL-MFAC is that the self-learning ability of Reinforcement Learning is used to optimize the parameters of MFAC controller, and only the Input/Output (I/O) measurement data of the system is used. Furthermore, in the Python environment, two different nonlinear systems are used as objects for numerical simulation Simulation results show that after parameter optimization by reinforcement learning, the performance of the MFAC controller is significantly improved, which demonstrates the effectiveness of the proposed approach.

▶ SunB07-3 10:50–11:10

*Interpretable Diagnosis of Glaucoma Based on Attention Mechanism and Embedded Class Activation Map*


Liu, Bao — Xi'an Univ. of Sci. & Tech.
Li, Shuqi — College of Electrical & Control Engineering
He, Ruilong — Xi 'an Univ. of Sci. & Tech.
Zhao, Yu-Ge — College of Electrical & Control Engineering


Glaucoma is a group of heterogeneous neurodegenerative diseases, which has become the main cause of irreversible blindness worldwide, so the early screening of glaucoma has become crucial. Although the methods of visualizing the feature maps of convolutional layers increase the transparency of deep learning models to a certain extent, these methods often embed high-level connectivity constraints, which leads to the fact that the interpretable diagnosis of glaucoma can only obtain interpretation results from high-dimensional information. The proposed GAMNet based on attention mechanism and embedded class activation map not only solve the problem that the feature information to be concerned under multi-scale cannot be accurately focused by attention, but also release the constraints of high convolutional layer features on the interpretation results of the model from the perspective of fusion features. Firstly, a dynamic receptive field module is introduced on the basis of the multi-scale feature pyramid structure, and the embedded coordinate attention mechanism is used to effectively capture long-distance dependencies, so as to construct a semantically rich dynamic multi-scale feature pyramid for accurate and efficient diagnosis of glaucoma fundus images. Secondly, the hierarchical gradient function of gradient-weighted class activation map is established, and the class activation map after feature fusion is used to provide a more detailed attention map, which provides a decision-making basis for glaucoma diagnosis. GAMNet provides the evidence activation map, compared with Garbor, Wavelet, GRI and Superpixel in the performance of optic disc segmentation, the results show that GAMNet classification is accurate, and provides the evidence activation map. It not only shows diagnostic results, but also has good interpretation performance without high-level connectivity constraints.

▶ SunB07-4 11:10–11:30

*Global-Local Attention Mechanism Based Small Object Detection*


Liu, Bao — Xi'an Univ. of Sci. & Tech.
Huang, Jinlei — Xi'an Univ. of Sci. & Tech.


A small object detection method based on the combination of global and local attention mechanism is proposed in this paper to detect small objects distributed in images. object detection model based on local attention mechanism has good detection accuracy and speed. However, its performance will be reduced due to the smaller size of the object, especially in the case of missed detection and false detection, and the proposed Global Local Detection Model (GLD) can solve this problem. Specifically, a model solution of the Global and Local Combined Attention Block (GL-CAB) combining deep global features and shallow local features of the network is proposed to solve the problem of small object missed detection. On the one hand, the model focuses on small object s in the local and global ranges, and on the other hand, it supplements the small object information lost during the down-sampling process. Aiming at the situation of pseudo-information generated by small object feature fusion, a multi-branch feature pyramid network (MBFPN) is proposed. Multi-input is used to form multi-scale feature maps for multi-feature fusion on different branches, which reduces the formation of pseudo-information and enhances the extraction of detailed features of small object by the network. Then, the AU-AIR and VOC2007 datasets are selected for experimental training, and the object detection evaluation indicators (AP, AR, F1, mAP, and FPS) are introduced for comparative analysis. Finally, the simulation results show that the proposed method has better performance to solve the problem of missed detection and false detection of small object.

▶ SunB07-5 11:30–11:50

*A Modified Data-driven Distributed Information-Weighted Kalman Consensus Filtering with Switching Topology and Packet Loss*


Ji, Honghai — North China Univ. of Tech.
Wu, Yuxin — North China Univ.of Tech.
Liu, Shida — Beijing Jiaotong Univ.
Wang, Li — North China Univ. of Tech.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.
Xiong, Shuangshuang — Beijing Information Sci. & Tech. Universtiy


This paper is concerned with distributed state estimation problem over sensor networks with uncertainty in communication networks. Because of the instability of communication in real systems, it is meaningful to consider packet loss and topol-ogy change. Thus, based on Kalman consensus filtering algorithm and Data-driven filtering technique, we proposed a modified Data-driven Distributed information-weighted Kalman Consensus Filter to estimate the state. Finally, the effec-tiveness of the designed algorithm is validated by a simulation example.

▶ SunB07-6 11:50–12:10

*Deep Knowledge Tracing Model with An Evolved Transformer Structure*


Li, Zhijun — North China Univ. of Tech.
Xue, Zixiao — North China Univ. of Tech.
Liu, Chen — North China Univ. of Tech.
Feng, Yanzhang — Beijing AIKANG Medical


Deep Learning based Knowledge Tracing (DKT) has become a research hotspot in the intelligent education field. Compared to conventional methods, DKT has better predictive performance, but it also has some problems such as poor interpretability, difficulties in reflecting the causal association between the learning process and test results. In this paper, a new DKT model is proposed based on an evolved Transformer structure (DKT-ETS). The encoder layer is composed of three coding networks with multi-head self-attention mechanism, while inputs are three types of pre-processed data: process characteristic data, test label data, and answer results data. Output as three matrices of V, Q, K. The decoder layer also uses the attention mechanism, which input is the three matrices come from encoder, the output is the predicted result. By improving the structure, the new model introduces certain interpretability into the V, Q and K matrices of attention mechanism. Thus, the causal relationship between learning process and test results can be reflected to a certain extent: the V matrix represents the characteristic information of the testee' s learning process; the Q matrix reflects the knowledge point information examined by the current test item; and the K matrix represents the results of the previous tests. DKT-ETS was validated by using large-scale knowledge tracking data set EdNet, and the results show that its ACC and AUC evaluation indicators have been significantly improved.

## Poster Session SunB08
May 14, 10:10–12:10
6th Conf. Hall

Chair: Wang, Xianghua — Shandong Univ. of Sci. & Tech.
Co-Chair: Hui, Yu — Beihang Univ. (BUAA)

▷ SunB08-01

*Global Self-optimizing Control of A Solid Oxide Fuel Cell*


Fu, Shengdong — Zhejiang Univ.
Ye, Lingjian — Huzhou Univ.


The design of control structure is very important for improving the efficiency of a solid oxide fuel cell (SOFC). In this paper, we propose a self-optimizing control (SOC) system for the direct internal reforming SOFC, aiming for maximizing the power generation profit after deducting carbon tax. Based on the lumped parameter model of the SOFC, we evaluate and identify the optimal controlled variables (CVs), and maintain them at constant setpoints to optimize the efficiency, regardless of changes in interference and uncertain parameters. The results show that the stack temperature is identified as the active constraint which should be controlled to maintain the cell performance. Differs from several previous proposals, the outlet methane fraction is considered not suitable as the CV. We configure the linear combination of outlet hydrogen fraction, carbon dioxide fraction and voltage as CV to achieve acceptable economic loss. The SOC structure is able to maximize the SOFC efficiency and reduce carbon emission without using online optimization techniques. The validity of the novel scheme is verified through both static and dynamic evaluations.

▷ SunB08-02

*Prediction of Aeration Quantity of Biochemical Tank Based on Ensemble*

*Learning Algorithm*


| | |
|---|---|
| Tao, Yuxin | North China Univ. of Tech. |
| Yang, Bin | Beijing KingTrol Data Tech. Co., Ltd |
| Pang, Zhonghua | North China Univ. of Tech. |
| Fan, Lanzhi | North China Univ. of Tech. |


This paper presents an intelligent prediction method for aeration capacity of biochemical tank for sewage treatment. Firstly, the data collected in the field is processed from the actual sewage treatment plant and the data set is obtained through correlation analysis. Secondly, after optimizing the model parameters, RF, GBDT, LGB and LR models are established respectively to obtain the forecasting capabilities of each model. Furthermore, the fusion of the Stacking model is introduced by using RF, GBDT and LGB as the first layer and LR as the second layer. Experimental results show that the optimized model can better predict the aeration required by the biochemical tank according to the real-time incoming and outbound water quality and quantity data, so as to ensure that the urban sewage treatment plant can save energy and reduce consumption to a certain extent and maintain the sustainable development of carbon neutrality.

▷ SunB08-03

*PH Nonlinear Process Control Method Based on Lyapunov Stability Theory*


| | |
|---|---|
| Chen, Juan | Beijing Univ. of Chemical Tech. |
| Ou, Baoming | Beijing Univ. of Chemical Tech. |


The process of pH is widely present in various fields such as chemical engineering, pharmaceuticals, and environmental protection. Different reactions and production processes have varying pH value requirements and precision levels. With the rapid development of technology, the demand for pH process control accuracy and effectiveness is increasing in all fields. This article proposes a control method based on the Lyapunov stability theory design, addressing the nonlinearity and disturbance complexity of the pH process. Starting from the control objective, this method designs the Lyapunov function for the linearized system to obtain the control rate expression. Simulation studies demonstrate that this control method has the advantages of fast response speed, disturbance rejection, and robustness. Moreover, compared to other model-based control methods, this method has a simpler structure and is easier to implement in practical industrial processes.

▷ SunB08-04

*Model Predictive Control of Permanent Magnet Synchronous Motor Based on Recursive Least Square Parameter Identification*


| | |
|---|---|
| Yang, Dandan | North China Univ. of Tech. |
| Yang, Bin | Beijing KingTrol Data Tech. Co., Ltd |
| Pang, Zhonghua | North China Univ. of Tech. |
| Zheng, Changbing | Henan Univ. of Urban Construction |


Model predictive control (MPC) has simple control structure and can achieve dynamic optimization control under constraint conditions. Due to the predictive control based on the system model, MPC has a high requirement for the accuracy of model parameters. This paper proposes a recursive least squares method based on the mathematical model of the motor for online parameter identification of permanent magnet synchronous motor (PMSM), which addresses the issue of sudden parameter changes that affect control effectiveness during operation. Through online identification, it is possible to effectively track changes in motor parameters and obtain real-time and accurate motor models. In addition, the updated motor model can serve as a predictive model for MPC. Thus, MPC can achieve more dynamic accurate prediction. Finally, the simulation is carried out to verify the effectiveness of the method that is proposed in this paper.

▷ SunB08-05

*Group Consensus for Second-order Linear Multi-agent Systems with Intermittent Control*


| | |
|---|---|
| Wu, Zhaoqin | Tianjin Univ. of Tech. & Educatuon |
| Li, Weixun | Tianjin Univ. of Tech. & Education |
| Du, Xiangyang | Tianjin Univ. of Tech. & Education |
| Xiao, Jingyu | Tianjin Uinversity of Tech. & Education |
| Zhang, Limin | Zhongyuan Univ. of Tech. |


This paper focused on the tracking group consensus problem in a second-order multi-agent system, which is based on a multigroup network structure under the constraint of non-periodic intermittent communication. We proposed a new intermittent consensus protocol and performed a convergence analysis using Lyapunov stability theory and algebraic graph theory. The convergence analysis mainly adopts two assumptions on which the protocol relies, which are that the communication interval is time-varying and the inter-group relations. Based on these assumptions, sufficient conditions for achieving group consensus in a second-order multi-agent system with non-periodic intermittent communication are derived. To verify the conclusions drawn from the mathematical analysis, the paper finally used MATLAB to perform numerical simulations to verify the validity and correctness of the results.

▷ SunB08-06

*Research on UAV Formation Obstacle Avoidance Based on Consistency Control*


| | |
|---|---|
| Liu, Ruoyang | Zhongyuan Univ. of Tech. |
| Qu, Boyang | Zhongyuan Univ. of Tech. |
| Wei, Tao | Henan Univ. of Engineering |
| Zhang, Limin | Zhongyuan Univ. of Tech. |
| Yan, Li | Zhongyuan Univ. of Tech. |
| Chai, Xuzhao | Zhongyuan Univ. of Tech. |


Based on the graph theory, multi-UAV form a formation through the leader-follower method. The control command is sent to the leader UAV, and the formation of UAVs is led by the leader to the target location and avoids obstacles through an improved artificial potential field method, and the formation is controlled by a consistency protocol to keep the formation stable during the flight. If the leader UAV is balanced by forces at a certain place when it does not reach the target point, a random disturbance is triggered to make it jump out of the local minimum. Through the formation consistency obstacle avoidance algorithm, the formation of UAVs is kept constant during the obstacle avoidance process to achieve formation position consistency control. Finally, the effectiveness of the algorithm is verified by MATLAB simulation.

▷ SunB08-07

*Non-parametric Model Adaptive Control Based on Gaussian Process Regression*


| | |
|---|---|
| Lin, Chenxu | Yunnan Univ. |
| Li, Mingyao | Yunnan Univ. |
| Zhu, Juanping | Yunnan Univ. |


A non-parametric adaptive control algorithm based on Gaussian process regression is proposed for a class of discrete-time nonlinear systems. The pseudo-partial derivative estimation based on Gaussian process regression is devised, and the subset of data approximation is applied to improve this estimation. The estimation of the pseudo-partial derivative and the control law algorithm are combined to give a novel data-driven adaptive control scheme that does not depend on the mathematical model of the controlled system. The monotonic convergence and the BIBO stability of the proposed control algorithm is proved. Simulations indicate the effectiveness and robustness to the models and environments.

▷ SunB08-08

*Model-free Adaptive Tension Control of New Energy Vehicle Winding Machine*


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|---|---|
| Mu, Chenglin | Qingdao Univ. of Sci. & Tech. |
| Yao, Wen-Long | Qingdao Univ. of Sci. & Tech. |
| Chi, Ronghu | Qingdao Univ. of Sci. & Tech. |
| Yan, Chengyang | Qingdao Univ. of Sci. & Tech. |
| Liu, Wangwang | Qingdao Univ. of Sci. & Tech. |


In this paper, a tension data-driven control method for compressor motor production equipment of new energy vehicles is proposed, which is mainly used to solve the problems of loose winding and uneven distribution of enameled wire caused by difficult modeling and low precision of tension control in the process of tension control of compressor motor production equipment of new energy vehicles.The proposed model-free adaptive control method avoids the difficulty of modeling the traditional winding machine. By comparing with the existing methods, the results show that the dynamic performance and steady-state performance of the winding machine control system are effectively improved, and the tension control accuracy is improved.

▷ SunB08-09

*Collaborative Multi-vehicle Trajectory Tracking Control Based on Model-free Adaptive Iterative Learning under Data Loss*


| | |
|---|---|
| Zhang, Wen Yi | Shandong Univ. of Sci. & Tech. |
| Wang, Xianghua | Shandong Univ. of Sci. & Tech. |


In this paper, the problem of multi-vehicle cooperative trajectory tracking control under communication data loss is taken into consideration. It is assumed that the communication topology among multiple vehicles is fixed and that only partial cars can acquire the desired trajectory information. First, a multi-vehicle cooperative trajectory tracking control

approach based on model-free adaptive iterative learning is presented. Second, the current model-free adaptive iterative learning control method is improved for the case where vehicle communication information is lost, moreover, the convergence of the tracking error is then proved. The simulations are conduced and results demonstrate that the trajectory tracking errors converge with the increase of the number of iterations.

▷ SunB08-10

*Data-driven Temperature Control of Internal Mixers*


| | |
|---|---|
| Zhou, Zhihao | Qingdao Univ. of Sci. & Tech. |
| Chi, Ronghu | Qingdao Univ. of Sci. & Tech. |


Considering the characteristics of large time lag, large inertia, time varying and disturbances in the internal mixer temperature (IMT) system, a model-free adaptive control strategy is proposed. A dynamic linearization method based on state transition is applied to reformulate the internal mixer temperature system into a linear incremental form to facilitate the controller design. A time-varying parameter estimation law for online adjustment is designed and a control law for IMT system is given to achieve setpoint tracking. Input saturation is added to the algorithm to avoid excessive overshoot. An event triggering strategy is applied by designing an event triggering condition. The proposed MFAC method only relies on the I/O data without using any other mechanistic model information. Finally, the effectiveness of the proposed control method is verified through simulation results.

▷ SunB08-11

*Active Disturbance Rejection Control of Diesel Engine Air System Based on Online Optimization of Observation Bandwidth and Control Gain*


| | |
|---|---|
| Liu, Xingyi | Weichai Power |
| Ren, Yuru | Tianjin Univ. |


In this paper, a parameter self-learning multivariable active disturbance rejection control (ADRC) algorithm is proposed for the diesel engine air system equipped with a variable exhaust gas turbocharger (VGT), exhaust gas recirculation (EGR), and intake throttle valve (TVA). Firstly, based on the principle of simplified diesel engine operation, a three-in-three-out linear variable parameter air system prediction model is established, with the model deviation equivalent to the total disturbance. A multivariable extended state observer is employed for active observation to enhance the model's adaptability. Secondly, to address the issues of strong noise and variable signal-to-noise ratio of the air signal, the gain matrix of the extended state observer is dynamically adjusted to achieve a real-time trade-off between observation speed and disturbance fluctuation amplitude. Finally, in order to improve tracking accuracy while compensating for the total disturbance, extremum seeking is utilized to optimize the control input gain online and enhance the algorithm's adaptability to nonlinearities. The algorithm is verified on a diesel engine stand, and compared with a PID controller with global parameter optimization, it achieves the same response speed while reducing the overshoot of intake manifold pressure and EGR rate tracking by 24.9% and 10.3%, respectively. The proposed algorithm's parameters can be automatically adjusted with the change of working conditions, avoiding the need for sectional calibration.

▷ SunB08-12

*Design of Neutral Mixed Delay Multi Stochastic Systems with Event Triggering*


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|---|---|
| Yi, Shuai | Qilu Univ. of Tech. |
| Lu, Hong Qian | Qilu Univ. of Tech. |
| Wang, Renren | Qilu Univ. of Tech.,Jinan |
| Feng, Xin | Qilu Univ. of Tech. |


This article investigates systems with Neutral, Mixed Delay, and Multi Stochastic Systems (NMMSs) with Event Triggering. Using Lyapunov Krasovskill functional (LKF) and generalized Ito? formula and linear matrix inequality to prove a new stability method. We designed an event triggered controller, integrated the zero value equation, and combined it with singular decomposition to solve the controller gain. Our paper further analyzes the latest literature and explores new methods.

▷ SunB08-13

*Indirect Prediction Method for Remaining Useful Life of Lithium-ion Battery Based on Gray Wolf Optimized Extreme Learning Machine*


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| Ding, Miaomiao | Shandong Univ. of Sci. & Tech. |
| Wang, Xianghua | Shandong Univ. of Sci. & Tech. |


In this paper, a novel indirect method for predicting the remaining useful life (RUL) of lithium-ion battery is proposed, not requiring the direct measurement of capacity. Firstly, a variety of indirect health indicators (HI) that can characterize the degradation state of lithium-ion battery are extracted from the charging and discharging process curves of lithium-ion battery. To reduce the redundancy among indirect HIs Principal Component Analysis (PCA) is used to fuse all these HIs into one indirect HI that can represent the degradation characteristics. Then, in order to avoid the interference of noise on the prediction accuracy of the model, we use the Complete Ensemble Empirical Mode Decomposition with Adaptive Noise (CEEMDAN) to decompose and denoise the fused indirect HI. Finally, the Gray Wolf Optimized Extreme Learning Machine (GWO-ELM) model is applied to make the RUL prediction and compare its prediction results with the prediction results of other models. Finally, simulations are conducted and the results show that the proposed indirect prediction method can predict lithium-ion battery RUL more accurately.

▷ SunB08-14

*Insulator Defect Detection Based on Improved YOLOv5 Algorithm*


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|---|---|
| Wang, Yongheng | Hubei Minzu Univ. |
| Li, Qin | Hubei Minzu Univ. |
| Liu, Yachong | Hubei Minzu Univ. |
| Wang, Chao | Hubei Minzu Univ. |


Due to the issues with a high number of parameters and the sluggish detection speed of the present insulator defect identification algorithm, an enhanced YOLOv5 target detection approach is proposed. To begin, replacing the YOLOv5 backbone network with the lightweight network MobileNetV3 minimizes the amount of processing and the number of parameters used during feature extraction, resulting in faster detection. Afterward, clustering with K-means++ is used to produce anchor frames that are better suited for insulators on transmission lines with thin structures. The network model can then be used to discover small targets for insulator flaws by adding a coordinate attention mechanism at the feature fusion stage. Last but not least, the edge regression is optimized for accurate target localization, which raises the recognition rate and improves the loss function. The revised YOLOv5 network model has a file size of just 7.2 MB, which is only 51% smaller than that of the original YOLOv5 network. This results in a reduction in the number of parameters, an increase in detection speed and accuracy, and a 98% average detection accuracy for mAP. The inference time is also reduced by 21 ms.

▷ SunB08-15

*A Remaining Useful Life Prediction Method for Rolling Bearing Based on Multi-channel Fusion Hierarchical Vision Transformer*


| | |
|---|---|
| Li, Zhixuan | Southwest Jiaotong Univ. |
| Zhang, Kai | Southwest Jiaotong Univ. |
| Lai, Xuwei | Southwest Jiaotong Univ. |
| Zheng, Qing | Southwest Jiaotong Univ. |
| Ding, Guofu | Southwest Jiaotong Univ. |


In order to effectively improve the remaining useful life (RUL) prediction accuracy and timely replace the critical components of rotating machinery represented by rolling bearings, this study proposes an RUL prediction method based on a multi-channel fusion hierarchical vision transformer. In this innovative network architecture, a multi-channel of hierarchical vision transformer is used to extract high degradation correlation features efficiently. The introduction of multi-headed attention channel fusion can effectively reduce the redundancy effect of multi-channel depth features and construct a better regression mapping relationship to improve the accuracy of prediction results. Through experimental verification using rolling bearing samples under different operating conditions, the improved method is able to show higher prediction accuracy in more degradation processes. It can improve prediction accuracy by up to 28.48% compared to the classical RUL method. This indicates that the improved method can be better applied to the rolling bearing RUL prediction problem in practical engineering.

▷ SunB08-16

*A Graph Convolutional Shrinkage Network-based Fault Diagnosis Method for Industrial Process*


| | |
|---|---|
| Xu, Yuan | Beijing Univ. of Chemical Tech. |
| Zou, Xun | BUCT |
| Ke, Wei | Macao Polytechnic Inst. |
| Zhu, Qunxiong | Beijing Univ. of Chemical Tech. |
| He, Yan-Lin | Beijing Univ. of Chemical Tech. |
| Zhang, Ming-Qing | Beijing Univ. of Chemical Tech. |
| Zhang, Yang | Beijing Univ. of Chemical Tech. |


With the increasing demand of safety monitoring for industrial process, fault diagnosis is facing greater challenges. In the paper, a graph con-

volutional shrinkage network is proposed for fault diagnosis. First, considering the correlation between process variables, Pearson correlation coefficient is used to convert the time series to graph structure with nodes and edges. Second, a graph convolutional shrinkage layer with anti-noise ability is designed, in which Chebyshev kernel is used as convolution kernel to extract the feature information of graph structure. In addition, a soft thresholding shrinkage layer is added to help adaptively determine the filtering thresholds of graphic feature information. Third, the graph classification for fault diagnosis is carried out by readout layer, fully connected layer and softmax layer. Finally, the effectiveness and robustness of the proposed fault diagnosis method are examined by using TE process data. The results of the experiments demonstrate that the proposed fault diagnostic approach is reliable and capable of correctly identifying the fault states in noisy situations.

▷ SunB08-17

*Intelligent Fault Diagnosis for Unknown Faults of Rotating Machinery Based on the CNN and the DCGAN*


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|---|---|
| Yu, Gongye | Beijing Univ. of Chemical Tech. |
| You, Yapeng | Beijing Univ. of Chemical Tech. |
| Ma, Bo | Beijing Univ. of Chemical Tech., Diagnosis & Self-Recovery Engineering Research Center |
| Han, Yongming | Beijing Univ. of Chemical Tech. |


The fault diagnosis model based on machine learning can only achieve accurate recognition of the fault types included in the training, but in practical applications, it is limited by the classification mechanism of the diagnosis model and cannot achieve the recognition of new faults, which is unknown faults. To address this problem, this paper proposes a fault identification method for rotating machinery based on the Convolutional Neural Networks (CNN) and the Deep Convolutional Generative Adversarial Network (DCGAN) to identify unknown faults of rotating machinery. The method first trained CNN with each known class data to build the initial diagnosis model, and trained DCGAN to obtain the discriminative network of each known class to build the confidence probability calculation model, and then the results of the initial diagnosis were corrected according to the confidence probability, and finally the intelligent diagnosis of the known and unknown class faults was realized. The analysis results of the centrifugal pump fault simulation showed that the proposed method achieved an average diagnostic accuracy of 96.16% and 91.79% for known and unknown faults, respectively.

▷ SunB08-18

*A Variational Bayesian Dictionary Learning for Process Monitoring*


| | |
|---|---|
| Zhang, Qi | Zhejiang Univ. |
| Xie, Lei | Zhejiang Univ. |
| Xu, Weihua | Zhejiang Univ. |
| Su, Hongye | Zhejiang Univ., China |


Industrial process data acquisition is inevitably disturbed by noise, and data contamination makes process data carry too much redundant information, which will greatly limit the interpretation capability of data-driven modeling approaches. Given that sparse representations can effectively handle noise, a process monitoring method for variational Bayesian dictionary learning (VBDL) is developed in this work. Conventional dictionary learning requires a priori knowledge of the assumed noise variance and sparsity levels, which is not available in real industrial processes. The derived VBDL is built on a Bernoulli distribution with the beta distribution as the conjugate prior, the number of dictionary atoms and their relative importance can be inferred nonparametrically with the iterative update of the variational inference. Since the collected data exhibits temporal correlation, the large noise interference makes dynamic analysis infeasible. A low-rank vector autoregression is developed to dynamically analyze the reconstructed samples, thereby improving the robustness of the model to noise. To illustrate the feasibility and efficacy, the proposed algorithm is verified by a numerical simulation and the CSTR simulation.

▷ SunB08-19

*Fault Diagnosis of Bearings Based on An Improved Lightweight Convolution Neural Network*


| | |
|---|---|
| Li, Qiankun | Beijing Univ. of Chemical Tech. |
| Cui, Mingliang | Beijing Univ. of Chemical Tech. |
| Wang, Youqing | Beijing Univ. of Chemical Tech. |


Great progresses have been made in fault diagnosis of bearings based on convolutional neural networks, but these models bring a significant burden on the hardware, increase industrial costs, and inconvenience to the updating and training of models. A good fault diagnosis model should have a low number of parameters and be able to achieve high accuracy. In order to better reduce the number of network parameters while maintaining high accuracy, this study proposes a lightweight network model that can solve both of these problems through experimental comparison.

▷ SunB08-20

*The Internal Mixers Temperature Iterative Learning Control*


| | |
|---|---|
| Zhou, Zhihao | Qingdao Univ. of Sci. & Tech. |
| Chi, Ronghu | Qingdao Univ. of Sci. & Tech. |


A data-driven iterative learning control (DDILC) method is proposed for the internal mixer temperature (IMT) system where the exact model parameters and disturbances are not available. Firstly, the dynamic model of the IMT system is described. Then, a linear data model describing the input and output dynamics of IMT system is established in iterative domain. An iterative updating algorithm is developed to estimate the time-varying parameters in the linear data model. On this basis, the learning control law is derived. An event triggering strategy is applied to further reduce the number of controller executions and save computation cost. The proposed control method only depends on the measured input/output (I/O) data without requiring any modeling information of the IMT system. Finally, the simulations further verify the effectiveness of the proposed DDILC in the IMT system.

▷ SunB08-21

*ILC for Discrete Linear Switched Systems with Varying Trial Lengths*


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|---|---|
| Kong, Ying | Sun Yat-sen Univ. |
| Li, Xiao-Dong | Sun Yat-sen Univ. |


This paper proposes an iterative learning control (ILC) method for discrete linear switched systems with varying trial lengths. By using the contraction mapping method with lambda-norm, the convergence of the proposed iteration-average operator based ILC law is theoretically analyzed. As the terminal time point of the output trajectory fluctuates around the switching time point, the ILC tracking errors of the discrete linear switched system can be driven to zero in mathematical expectation sense. Numerical simulations are presented to verify the effectiveness of the proposed ILC scheme.

▷ SunB08-22

*Error Tracking Learning Control for Nonlinearly Parameterized Systems with Input Deadzone*


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|---|---|
| Fan, Longwei | Zhejiang Univ. of Water Resources & Electric Power |
| Yan, Qiuzhen | Zhejiang Univ. of Water Resources & Electric Power |
| Chen, Qiang | Zhejiang Univ. of Tech. |


The trajectory tracking problem for nonlinearly parameterized uncertain systems with unknown input deadzone is investigated in this work. Lyapunov-based ILC strategy is adopted for controller design. Unlike traditional ILC methods, in this paper, the initial condition for each iteration allows to be any bounded value. By using the parameter separation technique combined with the signal replacement mechanism, a Lyapunov functional is constructed to design the ILC law and learning laws. As the iteration cycle increases, the system error can follow the predetermined desired trajectory over the entire interval, and all the signals in close-loop system are guaranteed to be bounded. Effectiveness of the proposed method is verified by theoretical results and numerical results.

▷ SunB08-23

*Terminal Iterative Learning Control for Nonaffine Nonlinear Systems with Nonrepetitive Uncertainties*


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|---|---|
| Hui, Yu | Beihang Univ. (BUAA) |
| Chi, Ronghu | Qingdao Univ. of Sci. & Tech. |


In this paper, a terminal iterative learning control (TILC) is proposed for discrete-time nonaffine nonlinear systems with nonrepetitive uncertainties in the plant model, external disturbances, initial states, and reference trajectories. An extended terminal dynamic linearization (TIDL) method is utilized to transform the nonlinear system into a linear data model. A data-driven double dynamics analysis method is presented for TILC, by which we can demonstrate that although there exist nonrepetitive plant model uncertainties, the I/O data is bounded and the tracking error is robustly convergent. The developed analysis method is data-driven since no model information is utilized. Simulations verify the developed theoretical results.

▷ SunB08-24

*Optimized Statistical Model for Complex Chemical Processes Monitoring*


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|---|---|
| Zhang, Jian | Datang East China Electric Power Test & Research Inst. |

Qu, Xiaohe Datang East China Electric Power Test & Research Inst.
Lei, Zhiwei Datang East China Electric Power Test & Research Inst.
Zhang, Haifeng Anhui Univ.
Zhong, Kai Anhui Univerisity

The traditional kernel principal components analysis (KPCA) and linear discriminant analysis (LDA) have been verified to be two effective approaches for fault detection and diagnosis in recent years. Nevertheless, the conventional method and corresponding improved ones still exposed their deficiencies in some ways. Facing this dilemma, this paper presents a combination of optimized KPCA and modified LDA (OKPCAMLDA), in which the OKPCA avoids the loss of original features after centralizing data in the eigenspace by adjusting covariance matrix' s eigenvalue and transforming the distribution of variables thus providing representative and abundant principal components for the classifier. In addition, the MLDA maximizes a brand new objective function in feature space which achieves better classification performance than the conventional LDA, then utilizing diagnostic thresholds and similarity coefficients to identify the fault types. Based on the combined model, not only the fault detection and diagnosis can be realized simultaneously but also the accuracy of detection and diagnosis can be guaranteed. Furthermore, the simulation experiments on Tennessee Eastman (TE) benchmark process clearly illustrated the superiority of our proposed strategy.

▷ SunB08-25

*Dual Quantized Iterative Learning Control over Random Fading Channel*

Liu, Taojun Renmin Univ. of China
Shen, Dong Renmin Univ. of China

In the field of stochastic ILC, researchers tend to treat channel fading and data quantization as two separate random disturbances. In this paper, we give an analysis of the convergence of quantized ILC in the presence of channel fading. In addition, we design a dual quantized ILC, which can further reduce the deviation before and after channel fading while ensuring convergence. The first quantization is before the channel fading to relieve the transmission pressure; the second quantization is after the channel fading to reduce the error caused by the channel fading. Here we use the multiplicative fading factor to describe the channel fading. We adjust the quantization interval of the quantizer to ensure that the dual quantized ILC has a greater probability of smaller errors than the quantized ILC. Illustrative simulations are provided to verify the theoretical results.

▷ SunB08-26

*Iterative Learning Control Based on First-order Accelerated Gradient Method*

Qian, Jiaxi Jilin Univ.
Jiang, Hao Renmin Univ. of China
Shen, Dong Renmin Univ. of China

This paper proposes iterative learning control methods based on first-order accelerated optimization for linear discrete-time systems. The iterative learning control problem is transformed into an iterative quadratic function problem. Then, the Momentum gradient, Conjugate gradient, and Nesterov accelerated gradient methods are introduced into the iterative learning control framework. It is shown that the algorithms presented in this paper can guarantee the input tracking error converges to zero with faster convergence rates. Numerical simulations verify the validity and effectiveness of the proposed approach.

▷ SunB08-27

*Improved Mixed Discrete Particle Swarms Based Multi-task Assignment for UAVs*

Jia, Zhenshuai Northwestern Polytechnical Univ.
Xiao, Bing Harbin Inst. of Tech.
Qian, Hanyu Northwestern Polytechnical Univ.

Aiming at the problem of multi-task distribution for Unmanned Aerial Vehicle (UAV) swarm, a new type of multi-task distribution model for UAVs is established in this paper, various constraints are considered, such as bomb load and damage loss. To solve the multi-task allocation problem, an improved mixed discrete particle swarm optimization algorithm (IM-DPSO) is proposed, a two-dimensional particle coding matrix with task priority is designed, the genetic variation rules with particle update strategies are combined, and then the inertia weight and learning factors are optimized to enhance the algorithm's ability of solving the problem. Simulation results show that the improved algorithm can better solve the problem of multi-task allocation for UAVs under the distribution model.

▷ SunB08-28

*Optimal Dispatch of An Integrated Energy System Based on Deep Reinforcement Learning Considering New Energy Uncertainty*

Zhou, Yang Shanghai Univ.
Jia, Li Shanghai Univ.
Zhao, Yilin Shanghai Univ.
Zhan, Zhiyong Shanghai Univ.

As the uncertainties of intermittent energy and load in the integrated energy system gradually increase, traditional dispatch methods are limited to fixed physical models and parameter settings that can hardly respond to the random fluctuations in the dynamic system with source-load. In this paper, a deep reinforcement learning-based dynamic dispatch method for the integrated energy system is proposed to address this problem. First, a data-driven deep reinforcement learning model is constructed for the integrated energy system. Through the continuous interaction between the agent and the integrated energy system, the dispatch strategies are learned adaptively to reduce dependence on the physical models. Secondly, the variations of source-load uncertainties are characterized by adding random disturbances. Pivotal aspects such as state spaces, action spaces, reward mechanisms, and the training process of the deep reinforcement learning model are improved according to the characteristics of uncertainties. Then a proximal policy optimization algorithm is used to solve the problem, and the dynamic dispatch decisions of the integrated energy system are realized. Finally, simulation results verify the feasibility and effectiveness of the proposed method over different time scales and in uncertain environments.

▷ SunB08-29

*A Salp Swarm Algorithm-based Model-free Adaptive Control Method and Its Application in Transformer Constant Temperature System*

Li, Zhen North China Univ. of Tech.
Jin, Lei TBEA Tianjin Transformers CO., Ltd
Ma, Guangjuan TBEA Tianjin Transformers CO., Ltd
Liu, Shida Beijing Jiaotong Univ.

Aiming at the problem of temperature control of transformer, a salp swarm algorithm-based model free adaptive control (SSA-MFAC) algorithm is proposed. In SSA-MFAC, the nonlinear dynamics of the transformer temperature control system is linearized using the dynamic linearization technology and a time-varying parameters named pseudo-partial derivative (PPD). Then, an SSA-MFAC controller is designed, and the salp swarm algorithm (SSA) is introduced to automatically optimize the controller parameters. Based on the salps group behavior in the ocean, the SSA method achieves the goal of controller parameter optimization by simulating the predatory behavior of the salps. The main advantage of SSA-MFAC method is that the controller only makes use of the operation data of the transformer constant temperature oil bath refrigeration unit instead of the specific mathematical model, and the controller parameters are obtained by using the SSA algorithm instead of experience. The algorithm is proved to be effective based on MATLAB/Simulink simulation platform.

▷ SunB08-30

*An AGV Task Scheduling Method Based on Multi-Agent Reinforcement Learning*

Zhao, Yuxin Zhejiang Univ.
Zhu, Ke Zhejiang Univ.
Song, Xueming Zhejiang Univ.
Zhang, Jianming Institution of Cyber-Sys. & Control

In order to improve the transportation efficiency of hospital AGV logistics system, we have studied the task scheduling of AGVs.We mathematically describe the multi-vehicle scheduling problem in hospital AGV logistics system, propose a task scheduling method based on multi-agent reinforcement learning, and demonstrate that this scheduling strategy outperforms the traditional heuristic scheduling strategy in terms of both solution results and computational efficiency.

▷ SunB08-31

*Prediction of HVAC Energy Consumption Using PSO Optimized Deep Neural Network*

Du, Linhui Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.
Wang, Kang Beijing Univ. of Tech.
Li, Yang Communication Univ. of China

Heating, Ventilation and Air Conditioning (HVAC) system is a highly nonlinear system with a large amount of complex coupled inputs. This paper presents a novel prediction method for HVAC energy consumption based

on deep neural network (DNN). In order to solve the problem that traditional neural networks tend to fall into local optima, batch normalization and Adam optimization algorithm are significantly adopted in the DNN. In addition, particle swarm optimization (PSO) is utilized to search for the optimal number of hidden layer nodes and increase the accuracy of prediction model. The cooling tower data of HVAC is used to validate the network. The results show the mean absolute error and the mean square error of PSO-DNN model, from which it can be seen obviously that our proposed prediction model performs better than traditional ones. Accordingly, DNN optimized by PSO algorithm is of great validity and superiorities for energy consumption prediction of HVAC system.

▷ SunB08-32

*Contrastive Representation Learning for Time Series via Compound Consistency and Hierarchical Contrasting*


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|---|---|
| Zheng, Teng | DongHua Univ. |
| Cao, Guanghao | Donghua Univ. |
| Chen, Lei | The Engineering Research Center of Digitized Textile & Apparel Tech., Ministry of Education |
| Hao, Kuangrong | Donghua Univ. |


In this paper, a novel contrastive representation learning framework for time series data is proposed. The framework is designed to learn general representations of time series at various semantic levels and is capable of transferring across different datasets. The framework incorporates two key components. Firstly, a hierarchical contrasting method is used to consider both the temporal and instance dimensions of the time series and captures information at different levels through maximum pooling at corresponding timestamps, enabling the model to learn fine-grained and multi-scale time-stamped representations for time series prediction tasks. Secondly, a compound consistency constraint is leveraged, which combines transformation consistency and temporal-frequency consistency, to effectively learn a universal representation of the time series, thereby ensuring its transferability across different datasets. Additionally, the framework considers both the temporal and frequency information of the time series, and uses an adaptive wavelet transform to obtain the frequency domain representation while maintaining temporal alignment, facilitating the contrast of temporal-frequency consistency. Finally, the proposed framework is evaluated through extensive experiments on time series prediction tasks and compared with existing models on four public datasets. The results show that the linear regressor trained with the representations learned by the proposed model outperforms existing time series prediction models in terms of prediction accuracy and transferability.

▷ SunB08-33

*Feature Extraction Method of Sludge Bulking Using Multi-KPCA*


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| Yang, Hongyan | Beijing Inst. of Tech. |
| Ding, Yingfan | Beijing Univ. of Tech. |
| Han, Honggui | Beijing Univ. of Tech. |


Sludge bulking is a common abnormal condition in municipal wastewater treatment process (WWTP). It is difficult for WWTP to effectively achieve high-precision feature extraction since it has complex reactions, many influencing factors, and strong coupling of factors. In this paper, a multi-kernel combined principal component analysis (MKPCA) method for extracting characteristic variables of sludge bulking based on multi-innovation random gradient is proposed. Firstly, based on the nonlinear characteristics of kernel functions and the advantages of adaptability of different kernel functions, a multi-kernel combination mechanism is designed. Then, a principal component analysis method based on multi-kernel combination is proposed. Secondly, a multi-innovation random gradient identification method is designed, which introduces a sliding window mechanism to update the structure and parameters of kernel functions with multiple time data. In addition to ensuring the identification accuracy, the variable feature extraction effect of sludge bulking process can be improved. Finally, the method is tested with actual data from wastewater treatment plant. The results show that the proposed method has a better feature extraction effect.

▷ SunB08-34

*Long Short-term Memory Modeling Method with Monotonicity Analysis as Constraints Base on Spearman Coefficient*


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| Zhan, Zhiyong | Shanghai Univ. |
| Zhou, Yang | Shanghai Univ. |
| Jia, Li | Shanghai Univ. |
| Zhao, Yilin | Shanghai Univ. |


This paper proposes a new method of monotonicity, which is used to solve the overfitting problem of the Long-Short-Term Memory (LSTM) model. The main contribution of this paper is applying the monotonicity as priori knowledge to the modeling process. This study uses scatter plots to describe bivariate variables and the Spearman coefficient to extract the monotonicity of data. To exclude most noise point, the scatter diagram is filtered by a binary 0-1 liner program. Base on the monotonicity of data have known, an optimization problem with constraint is proposed to obtain the LSTM neural network model. An experiment of ethylene cracking show that the proposed method can achieve a good predicting performance and less overfitting effects.

▷ SunB08-35

*Establishment and Analysis of Carbon Sequestration Model by Using Grey Correlation Analysis Method*


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| Yu, Xiyu | Qingdao Univ. of Sci. & Tech. |
| Li, Junhao | Qingdao Univ. of Sci. & Tech. |
| Li, Xin | Qingdao Univ. of Sci. & Tech. |
| Zhang, Ruikun | Qingdao Univ. of Sci. & Tech. |


Since the twentieth century, the greenhouse effect caused by greenhouse gases, mainly carbon dioxide, and consequently global warming has become a hot topic for the international community. Suppose some of the forests manage effectively, and the appropriate cutting of trees increases the amount of carbon dioxide stored outside the atmosphere. In that case, we can eventually achieve the goal of environmental protection. In this paper, we established a carbon sequestration model using grey correlation analysis and other methods to determine the relationship between the forest and its products over time, and the amount of carbon dioxide sequestered. Besides, we established a forest management plan model after assessing the equilibrium and obtaining the forest area benefit function OS.

▷ SunB08-36

*Novel Virtual Sample Generation Using Gibbs Sampling Integrated with GRNN for Handling Small Data in Soft Sensing*


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| Zhu, Qunxiong | Beijing Univ. of Chemical Tech. |
| Zhao, Qiqian | Beijing Univ. of Chemical Tech. |
| Xu, Yuan | Beijing Univ. of Chemical Tech. |
| He, Yan-Lin | Beijing Univ. of Chemical Tech. |


In order to optimize complex industrial processes, an accurate model is essential. The mainstream approach for complex industrial modeling is data-driven soft sensors. However, the accuracy of the established models is often low due to an insufficient amount of effective data, so the method of generating virtual samples has been proposed to achieve data augmentation, but the previous virtual sample generation methods have ignored the correlation between samples. To solve this problem, an effective virtual sample generation method based on Gibbs Sampling algorithm (GS-VSG) is proposed in this paper. In the proposed method, virtual input samples are first generated using the prior knowledge of the original data through the Gibbs Sampling method. Next, a generalized regression neural network (GRNN) model is constructed from the raw data, which is used to predict the output values of the virtual samples. Finally, the input and output parts of the virtual samples are combined to create a virtual sample set, which completes the extension of the original data set. To demonstrate the feasibility of the proposed GS-VSG method, numerical example and real industrial process dataset are used for simulation experiments. The results show that GS-VSG generated samples can improve the model accuracy and is a good technique for virtual sample generation.

▷ SunB08-37

*Cultivation of Students' Language Production Ability by Blend Learning*


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| Wu, Liping | Shenyang Aerospace Univ. |
| Wang, Yan | Shenyang Aerospace Univ. |


Most of Chinese students are lack of effective language production ability even after learning English for many years. In order to solve the problem, scientific and interesting English course design is urgently needed. Combining the online Corpus of Contemporary American English and other selected online resource into the traditional classroom teaching will motivate the students' interest in English learning and encourage their participation in the classroom activities. The design of the blend learning can be based on production-oriented approach (POA). It is conducive to the cultivation of students' language production ability through motivating, enabling and assessing.

▷ SunB08-38

*An RGB-D Semantic Map Building and Global Localization Method*


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| Fu, Tianqi | Southwest Jiaotong Univ. |

Tian, Facun Southwest Jiaotong Univ.
Ma, Lei Southwest Jiaotong Univ.
Sun, Yongkui Southwest Jiaotong Univ.

Aiming at the shortcomings of indoor visual SLAM system such as lack of environment awareness, sparse map construction, low global positioning accuracy and poor robustness, this paper proposes a semantic map building and global positioning method based on visual semantic descriptors and dense point cloud map. Abstract semantic descriptors are extracted and keyframe dense point cloud map is built by real-time object detection of color images. Global positioning adopts the off-line positioning method combining coarse and fine tuning. By quickly comparing the similarity between descriptors in the map set, the most similar reference keyframe is selected from the keyframe map, and the pose is obtained as the rough estimation result. The iterative calculation is continued in the dense point cloud map to complete the off-line positioning. In this paper, an available semantic mapping and positioning system is constructed and tested on the public RGB-D sequence dataset. The result shows that the proposed method can generate high-quality indoor point cloud maps and also finish global localization with higher accuracy and better robustness than the classical algorithm.

▷ SunB08-39

*A Data-Driven Residual Life Prediction Method for Rolling Bearings*

Li, Shangrui Univ. of Electronic Sci. & Tech. of China
Li, Meng Univ. of Electronic Sci. & Tech. of China
Liu, Zhilong Nuclear Power Inst. of China

Rolling bearing is a key component of rotating machinery, which affects the reliability of the equipment. In order to make the equipment intelligent, facilitate the maintenance of the equipment, and improve the operation efficiency of the equipment, a data-driven residual life prediction method of rolling bearing is proposed, which is used to intelligently predict the remaining service life of the equipment, providing great convenience for the maintenance of the equipment. First, wavelet packet de-noising method is used to remove the noise in the original signal, and then extract the time-domain and frequency-domain features of the de-noised signal, after that PCA is used to reduce the dimension of the feature information and fuse it into the comprehensive life characteristics of the bearing.Last, with the input of the subsequent life prediction features, the residual life prediction model based on PCA-SVR is finally constructed. The experimental results show that the residual life prediction model based on PCA-SVR has low error rate and high accuracy which can accurately predict the residual life of rolling bearings.

▷ SunB08-40

*Analysis and Prediction of Glass Product Composition by Using Control Variable Method*

Li, Xin Qingdao Univ. of Sci. & Tech.
Li, Junhao Qingdao Univ. of Sci. & Tech.
Yu, Xiyu Qingdao Univ. of Sci. & Tech.
Zhang, Ruikun Qingdao Univ. of Sci. & Tech.

This paper investigates the composition and identification of ancient glass artefacts. First, the collected data were pre-processed to determine the chemical composition content of the glass artefacts before weathering. Then, based on the variable control method, the effects of decoration and colour of two types of glass, high potassium glass and lead-barium glass, on the weathering of artefacts were determined. The statistical law of the presence or absence of weathering chemical composition on the surface of artefact samples was summarized by establishing a weathering change rate solution model. Meanwhile, based on the weathering change rate, the solution model for the content of chemical substances before weathering is summarized, and the content of different chemical components in ancient glass artefacts before weathering is predicted. Next, the second problem is carried out, which is to classify the glass and select the appropriate chemical composition for subclassification. Ancient glass artefacts were classified into the high-potassium glass and lead-barium glass based on their chemical composition and content, and the classification rules were analyzed. On this basis, the top eight indicators of chemical composition differences between the two types of artefacts were determined by comparison and subclassified by the K-means algorithm. Finally, model experiment results verified the correctness and validity of the models proposed in this paper.

▷ SunB08-41

*YOLO-Log: A Light-weight Object Detector for Logistics Safe Driving*

Ye, Linhua Chinese Acad. of Sci.
Chen, Songhang Chinese Acad. of Sci.
Lai, Zhiqing Chinese Acad. of Sci.

Object detection algorithms are attracting more and more attention in the application of intelligent logistics, but current object detection algorithms have problems such as high computational cost, low detection accuracy, and difficulty in deploying edge devices with limited computing resources in complicated logistics scenarios. This paper proposes a logistics object detection network (YOLO-Log) with a light-weight residual structure GhostNet. YOLO-Log is based on YOLOv5, which incorporates a light-weighted residual structure in Backbone and substantially reduces the model parameters of Backbone. Then, a simple and effective weighted bi-directional feature pyramid network is invoked to enhance the network to extract feature information of the target from the complicated logistics background. Finally, in light of the current lack of publicly available logistics object detection datasets, we collected and produced the logistics object detection dataset Logistics-3k. YOLO-Log achieves 91.4% mAP on the Logistics-3k dataset, which reduces the model parameters by 14.2% compared to YOLOv5s, and the detection time is only 10.2ms, addressing the industrial requirements of logistics scenarios.

▷ SunB08-42

*Substation Helmet Detection Based on Improved YOLOX-S Algorithm*

Tong, Xiaodong Sichuan Univ. of Sci. & Engineering
Li, Zhaofei Sichuan Univ. of Sci. & Engineering

The improved YOLOX-S algorithm is proposed for the detection of small helmet targets based on an improved YOLOX-S algorithm for the detection of helmets worn by relevant personnel in hazardous scenarios in substations. First, the ECA attention mechanism is introduced into the C-SPLayer structure in YOLOX-S to direct the model to pay more attention to channel features of small target information and enhance the model's ability to utilize useful features. Secondly, the addition of the ConvNext Block module after the three feature layers of the backbone feature extraction network to enhance the model's ability to exploit useful features. Finally, the weighted feature fusion mechanism of BiFPN is introduced in the enhanced feature extraction network by changing the original concat to BiFPN_concat, adding learnable weights to each input feature to learn the importance of different input features, distinguishing the importance of different features in the feature fusion process, and better focusing on the target information to be detected. The experimental results show that the mAP of the improved algorithm is 92.65%, which is an average accuracy improvement of 2.55% over the original YOLOX-S algorithm and meets the practical requirements.

▷ SunB08-43

*Chiller Load Prediction Based on CEEMDAN-BiLSTM-Attention Model for Sufficient Data and Small Sample Data Cases*

Zhang, Xu Wuhan Univ. of Tech.
Li, Xiangshun Huazhong Univ. of Sci. & Tech.

Maintaining indoor thermal comfort with heating, ventilation, and air conditioning (HVAC) systems requires a significant amount of energy, with chillers accounting for over 50% of the total. Therefore, a technical path based on chiller load prediction is essential to achieve low energy operation of air conditioning systems in buildings. Many machine learning methods have been widely used for load prediction, but for new buildings, there is still a lack of data to support model training for HVAC chiller load prediction. To address the above load prediction problems, this paper proposes the CEEMDAN-BiLSTM-Attention method for improving chiller load prediction accuracy. The final experimental findings are contrasted with the traditional prediction models like CNN, LSTM and hybrid models (CNN-LSTM, CNN-BiLSTM) and so on. Meanwhile, as for the case of small data samples, this paper builds two migration models CNN-LSTM-TL and CNN-BiLSTM-TL for the comparison. The results demonstrate that the CEEMDAN-BiLSTM-Attention model outperforms the other models in predicting chiller load for both buildings with sufficient data and buildings with small sample data.

▷ SunB08-44

*An Optimization Algorithm with Hausdorff-like Derivative in GRU for SOC Estimation of Lithium-ion Battery*

Jia, Kai Liaoning Univ.
Gao, Zhe Liaoning Univ.
Li, Mingdi Liaoning Univ.
Chai, Haoyu Liaoning Univ.

This paper proposes an optimization algorithm in the gate recurrent unit (GRU) for state of charge (SOC) estimation. To introduce the error into the optimization algorithm, the Hausdorff-like derivative with the cost function is first defined. The Hausdorff-like derivative as one type of frac-

tal derivatives is applied to the back propagation in the GRU, and the Adam algorithm with Hausdorff-like derivative are proposed to optimize GRU networks. An adaptive method of the order is proposed to tune the parameters of GRU networks. The SOC estimation experiments are carried out with different working conditions, and the experimental results are given to verify the effectiveness of proposed algorithm.

▷ SunB08-45

*Event-based Object Detection Using Graph Neural Networks*

Sun, Daobo — Univ. of Sci. & Tech. of China
Ji, Haibo — Univ. of Sci. & Tech. of China

Event-based object detection is a challenging but promising task, as the nature of sparsity and asynchrony of events is incompatible with state-of-the-art object detection approaches. Conventional deep neural networks do not take advantage of the event camera's high event sampling rate, low power consumption and robustness of brightness changes. Recent works addresses the problem of redundant computations by using a graph representation to model the feature of event streams that the graph representation and graph neural networks for event streams can efficiently extract the meaningful information and reduce the computational complexity. Nevertheless, there is still room for improvement in terms of accuracy and computation efficiency. In this work, we propose a graph-based architecture and a new mechanism for updating the graph, which significantly increases the capacity of graph neural networks while maintaining highly efficient per-event processing. In object detection task, our model achieves higher accuracy and lower FLOPS per event compared to various synchronous/asynchronous methods. To our belief, the framework we proposed is effective and robust, as well as being a significant reduction in the amount of redundant computation.

▷ SunB08-46

*Fuzzy Adaptive Sliding Mode Attitude Control of Quaternion Model for Aircraft Based on Back-stepping Method*

Zhuang, Huixuan — Nankai Univ.
Zhang, Xuefeng — Northeastern Univ.
Sun, Qinglin — Nankai Univ.
Chen, Zengqiang — Nankai Univ.

This paper investigates the adaptive sliding mode attitude control of quaternion aircraft model based on fuzzy approximation principle. Firstly, a sliding mode controller is designed based on the back-stepping method for the nonlinear aircraft model. Secondly, a fuzzy approximation algorithm is designed to compensate for the unknown and uncertain parts of the aircraft system. Thirdly, we construct a sliding mode controller, which ensures the stability and convergence of the entire closed-loop system through the adjustment of fuzzy adaptive law. Finally, the anti-interference performance of the controller is verified by simulations, which show that the proposed method has good control performance.

▷ SunB08-47

*Research on Dissolved Oxygen Fuzzy Controller in Sewage Treatment Process*

Lv, Zhiguo — Shaoyang Univ.

Aiming at the problem of precise aeration in AAO processes, a new dual-fuzzy controller is presented in this paper. For the oxygen rising and falling process with different time scale characteristics, two fuzzy controllers are respectively designed comprehensively considering dissolved oxygen and influent loads. Simulation results based on BSM1 experimental data verify the feasibility of the method, and the system has been tested on some sewage plant. Compared with some published relevant methods, the experimental results show that the presented method can still achieve good precision of dissolved oxygen when influent loads change.

▷ SunB08-48

*A LSTM Model with Attention Mechanism for Soft Sensor of SO2 Conversion Rate in Flue Gas Acid Production Process*

Zhang, Yongzheng — Beijing Univ. of Tech.
Li, Xiaoli — Beijing Univ. of Tech.
Wang, Kang — Beijing Univ. of Tech.
Li, Yang — Communication Univ. of China

The sulfur dioxide (SO2) concentration of flue gas in metal smelting industry is high and difficult to recycle. The commonly used SO2 desulfurization treatment is acid production from flue gas, but it is difficult to directly measure the conversion rate of SO2. In order to solve these problems, we present a soft sensor method based on Long Short-Term Memory (LSTM) which integrates the attention mechanism for predicting SO2 conversion rate in this paper. Since the change of SO2 conversion rate is affected by many external factors, the attention mechanism is used to quickly and accurately predict the change results by considering the system data of several past moments. The proposed attention mechanism uses LSTM units to encode the hidden state of the look back time data, obtains different attention weights, and then decodes and predicts SO2 conversion rate according to the hidden state. The experimental results indicate that LSTM model with attention mechanism has lower training cost compared with LSTM model. The training accuracy and soft sensor accuracy are also improved owing to the attention mechanism. It is instructive for SO2 conversion rate soft sensor in acid production from flue gas.

▷ SunB08-49

*Optimized SAC Deep Reinforcement Learning Control for Electro-hydraulic Servo Systems*

Yu, Zhen — Xiamen Univ.
Hu, Huiteng — Xiamen Univ.
Jiang, Mengman — Xiamen Univ.
Tang, Yifan — Xiamen Univ.
Qian, Rongrong — AECC Commercial Aircraft Engine Company LTD
Liu, Lijun — Xiamen Univ.

In this paper, a reinforcement learning environment based on a polynomial nonlinear model of an electro-hydraulic servo system is established, and an optimized state space sparse reward function is designed to improve the exploration ability of the SAC algorithm under sparse rewards using random network distillation (RND). The control performance of the designed optimized SAC deep reinforcement learning controller is verified through the semi-physical simulation experiment platform, and the time-varying signal is designed according to different tasks to test the dynamic control performance of the controller under complex tasks. The experimental results prove that the optimized SAC deep reinforcement learning controller proposed in this paper has good control performance and strong robustness.

▷ SunB08-50

*Reinforcement Q-Learning and Non-Zero-Sum Games Optimal Tracking Control for Discrete-Time Linear Multi-Input Systems*

Zhao, Jin-Gang — Weifang Univ.

This paper studies the optimal tracking control problem of discrete-time linear multi-input systems from the perspective of Non-Zero-Sum Games (NZSG) using reinforcement Q-learning technique. Firstly, an augmented multi-input systems is constructed by combining the original multi-input systems and the reference trajectory dynamics. Then, the original optimal tracking control problem can be transformed into the NZSG optimal control problem of the constructed augmented multi-input systems. In order to obtain the Nash equilibrium solution of the NZSG optimal control problem, a Q-function is introduced and an reinforcement Q-learning algorithm is designed to learn the Nash equilibrium solution. The convergence of the reinforcement Q-learning algorithm is also given. Finally, a simulation example is given to verify the effectiveness of the proposed reinforcement Q-learning algorithm.

▷ SunB08-51

*Transfer Reinforcement Learning of Robotic Grasping Training Using Neural Networks with Lateral Connections*

Wang, Wenxiao — Xidian Univ.
Wang, Xiaojuan — Xidian Univ.
Li, Renqiang — Xidian Univ.
Jiang, Haosheng — Xidian Univ.
Liu, Ding — Xidian Univ.
Ping, Xubin — Xidian Univ.

Reinforcement learning, as an effective framework for solving continuous decision tasks in machine learning, has been widely used in manipulator decision control. However, for manipulator grasping tasks in complex environments, it is difficult for intelligence to improve performance by exploring to obtain high-quality interaction samples. In addition, the training models of reinforcement learning usually lack task generalization and need to be relearned to adapt to task changes. To address these issues, researchers have proposed transfer learning that uses external prior knowledge to help the target task to improve the reinforcement learning process. In this paper, the transfer of the manipulator grasping source task to the grasping target task based on the deep Q-network algorithm is achieved by constructing lateral connections between fully convolutional neural networks using Densenet. Experimental results in the CoppeliaSim simulation environment show that the methods successfully achieve inter-task transfer by constructing lateral connections

between fully convolutional neural networks. The validated transfer reinforcement learning approach improves the effectiveness of task training while reducing the complexity of the network due to lateral connections.

▷ SunB08-52

*Composite Multi-Vector Model Predictive Control for Permanent Magnet Synchronous Motor*

Gao, Lin AnHui Univ.
Pan, Tian-Hong Anhui Univ.

Model Predictive Control (MPC) has been widely used in the permanent magnet synchronous motor. However, in the finite control set MPC, only one voltage vector is applied, which leads to high current harmonics and torque fluctuations. Meanwhile, three-vector MPC inevitably increases the switching frequency of inverter. In this article, a multi-vector switching control approach is established. Based on the location information of the created reference voltage vector, the relevant control technique is implemented. The proposed control method with single-vector, two-vector and three-vector composite modes of action is designed to achieve low switching frequency with excellent steady-state performance. The proposed method's effectiveness is confirmed by the experimental results.

▷ SunB08-53

*Non-cooperative Target Localization and Grasp Based on Visual Closed Loop*

Tian, Miaomiao China Acad. of Space Tech.
Yu, Jiyang China Acad. of Space Tech.

Non-cooperative target grasp is one of the most fundamental tasks in robotic grasping. However, it remains challenging to achieve high grasp accuracy, especially in a low-cost and high-error hardware environment. In this paper, to address this issue, we propose a self-adaptive error correction framework, which consists of three well-designed components. First, the Pixel-level Target Localization Module locates the three-dimensional spatial coordinates of the target and robotic arm. Second, the Incremental Pose Correction Module bridges the gap, caused by the error of the robotic arm execution unit, between the target and mechanical arm. Third, the Three-stage Communication Protocol, which aims to synchronize the motion phases of both sides, establishes detailed communication rules. The three stages include absolute coordinate positioning, difference coordinate approach, and center point alignment. In detail, we use deep learning-based detection network, HSV filtering, end-point attitude adjustment, and pixel-level alignment to push the mechanical arms closer to the maximum extent of accepted target grasping in these stages. By interacting the visual supervision information with the execution results of the robotic arm execution unit multiple times, the visual pixel-level alignment of the non-cooperative target and the grasping point at the end of the robotic arm is achieved. Finally, the experimental manipulator verifies the feasibility of the system scheme, which demonstrates that the scheme can be implemented with high accuracy and efficiency.

▷ SunB08-54

*Multi-objective Optimization Control of Flotation Process Based on Policy Iteration*

Xu, Hang Beijing Univ. of Tech., Beijing 100124, China
Wang, Kang Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.

This paper proposes a data-driven, multi-objective optimization control method based on policy iteration for flotation process, addressing the limitations of existing control methods that rely on the system model and cannot satisfy multiple performance indices simultaneously. Firstly, The ordinary linear quadratic regulator algorithm is improved with process data, enabling the algorithm to obtain optimal feedback gain without relying on the internal dynamics model of the system. Then, This method is further extended to the situation where multiple objectives exist, minimizing the deviation of the final additive amount while meeting control requirements for both concentrate and tailings grade. Finally, the convergence and effectiveness of the proposed method are verified by simulation experiments.

▷ SunB08-55

*Generalized Predictive Control of Converter Inlet Temperature in the Process of Acid Production with Flue Gas*

Liu, Minghua Beijing Univ. of Tech.
Li, Xiaoli Beijing Univ. of Tech.
Wang, Kang Beijing Univ. of Tech.

The effective control of converter inlet temperature in the process of acid production with flue gas is an effective means to improve the conversion rate of sulfur dioxide and reduce environmental pollution. According to the characteristics of the process of acid production with flue gas, the control process of converter inlet temperature is studied in this paper. Firstly, the CARIMA model of converter inlet temperature is established. Then, a generalized predictive controller based on CARIMA model is designed. Finally, the proposed method is verified by experiment and compared with PID controller. Experimental results show that the proposed method has a better tracking effect and smaller error. The effectiveness of the proposed method is verified.

▷ SunB08-56

*Soft Sensor Based on JITL-SVR for Ultrasonic Chinese Medicine Extraction*

Chen, Juan Beijing Univ. of Chemical Tech.
Xue, Zepeng Beijing Univ. of Chemical Tech.

Ultrasonic extraction method is an important modern extraction technology for traditional Chinese medicine, however, the existing detection techniques cannot meet the online detection requirement of the extraction rate during the extraction process. As a batch process, there exists process nonlinearity in ultrasonic extraction of Chinese medicine and requires a model with adaptive capability to cope with the process variation from batch to batch. In this work, a non-linear adaptive soft sensor for online prediction of extraction rate in the process of ultrasonic extraction of Chinese medicine is proposed. This method is based on a Just-In-Time Learning (JITL) modeling framework with Support Vector Regression (SVR) as the local model to update the soft sensor model online. In this paper, experiments on ultrasonic extraction of puerarin were conducted separately under different initial temperature conditions, and experimental data from different batches of the extraction process were collected and labeled. The proposed method was validated using the collected data, and the results showed that the support vector regression-based JITL model (JITL-SVR) has higher prediction accuracy than the SVR soft sensor model.

▷ SunB08-57

*Model Free Adaptive Control for Air-Conditioning System in Office Buildings Based on Improved NSGA-II Algorithm*

Chen, Pan Univ. of Sci. & Tech. Beijing
Gao, Jingjing Univ. of Sci. & Tech. Beijing
Yang, Xu Univ. of Sci. & Tech. Beijing
Zhang, Tao Univ. of Sci. & Tech. Beijing

Driven by the increasing demand for thermal comfort in office building environment and energy saving in building operation process, a model free adaptive control (MFAC) method for air conditioning system based on optimal environmental parameter settings is proposed in this paper. To this end, on the basis of the energy consumption model of common office buildings, the cooling load brought by the fresh air system is considered. The model is combined with the predicted mean vote (PMV) thermal comfort model to constitute an optimization problem. The improved non-dominated sorting genetic algorithm is used to solve the optimization problem to obtain the optimal environmental parameter settings at first. Then, an improved model-free adaptive control method is used for regulation. An adjustment item is added to the estimation algorithm to make the pseudo partial derivative reach the ideal value faster, to reach the optimal environmental parameter setting value faster. Finally, the experimental verification is carried out on the building environment monitoring system of an office building demonstration room, which shows the proposed method can achieve the optimal environment parameter settings, and at the same time can reduce the number of regulation of the air conditioning system and extend the service life of the equipment.

▷ SunB08-58

*Safe Sliding Mode Control Design with Its Application to Mobile Robot Path Tracking*

Zhao, Gan Beijing Jiaotong Univ.
Liu, Xiangbin Beijing Jiaotong Univ.
Lu, Shan Shenzhen Polytechnic
Lou, Zhijiang Shenzhen Polytechnic

In this paper, we propose a safe sliding mode control (SSMC) algorithm that combines sliding mode control (SMC) with control barrier function (CBF) through quadratic program (QP) criterion to simultaneously guarantee safety and tracking performance of nonlinear uncertain system. The SMC part in controller is used to handle disturbance and realize satisfying tracking performance while CBF part controller is used to guarantee system safety. The two controllers are manipulated by QP criterion. The proposed controller is applied on path tracking of mobile robots. As

the leader robot moves along a given trajectory, and the follower can track the leader and maintain a certain safety range.

▷ SunB08-59

*Two-stage Anaerobic Digestion Process Optimal Control Study Based on Extremum-seeking Control and Self-optimizing Control*

Li, Hongxuan — Nanjing Univ. of Sci. & Tech.
Wang, Haoping — Nanjing Univ. of Sci. & Tech.
Tian, Yang — Nanjing Univ. of Sci. & Tech.

In this paper, a new dynamic nonlinear gradient observer-based extremum-seeking control algorithm (DNGO-based ESC) and a dynamic Jacobian matrices estimator-based self-optimizing control algorithm (DJE-based SOC) are designed for the control of two-stage anaerobic digestion (TSAD). None of two algorithms requires priori knowledge about the system model. The proposed algorithms are compared with the classical extremum-seeking control algorithm and the Kalman Filter based Newton extremum-seeking control algorithm. The simulation results show that in the presence of disturbance both of proposed control algorithms can maintain the system at the optimal operating point and drive the hydrogen and methane yields to the extreme point. Future work is to validate the designed control algorithm in an actual two-stage anaerobic digestion process.

▷ SunB08-60

*Multi-attribute Decision Web Service Selection Based on Optimal Ant Colony Algorithm*

Jia, Zhichun — Bohai Univ.

This paper focuses on issues related to the selection of Web services in multi-attribute states. With the rapid development of the Internet, how to choose a quality service for users under the constraints of multi-attribute factors is a question worth thinking about. To select the optimum combination of services for the user among a large number of multi-attribute services is our goal. User requirements can be viewed as a workflow, and a complete requirements workflow contains multiple tasks. Each task consists of different services, and different tasks are used to satisfy different user requirements. How to select the optimal services from each task and combine them to form a complete service portfolio is the work we need to accomplish. In this work, we optimize the candidate service attributes and calculate the attribute weights using a weighted arithmetic mean operator, and then select the optimal service combination using an optimal ant colony algorithm. Compared with the original method in the service selection process, MDM based on OACO Algorithm can solve the multi-attribute service selection problem, while the service data after the weight calculation avoids the constraints of multiple attributes on the service selection results. The complexity of the algorithm traversal is greatly decreases by using the Cartesian product idea to group the services based on the same attribute values and then using the ant colony algorithm. For the experimental results, the multi-attribute optimization based on the optimized ant colony algorithm has significant benefits over the original algorithm in terms of time performance

▷ SunB08-61

*Research on Virtual Widening of Power Information Acquisition Channel Based on LoRa and Data Compression*

Jiang, Jing — Shandong Foreign Trade Vocational College
Wang, Mingjia — Qingdao Univ. of Sci. & Tech.

Limited by the channel bandwidth and information rate of the communication network of the electric energy information acquisition system, the energy data of the power system terminal lacks a suitable access method response to the above problems, this article combines the wide coverage characteristics and data compression technology achieved by LoRa (Long Range Radio，LoRa) spread spectrum communication, and proposes a new method of access communication based on LoRa spread spectrum and improved data compression coding for embedded applications. This technology can not only take into account the advantages of low design cost, strong coverage, anti-interference, etc. But also increases the virtual bandwidth of the channel, optimizes the comlink, and lay a solid foundation for high-frequency data collection and large-scale data transmission.

▷ SunB08-62

*Modeling and Estimation of Train Traction Characteristics under Emergency Traction Considering On-board Energy Storage Devices*

Wang, Jiaxin — Southwest Jiaotong Univ.
Hu, Yuanjiang — Southwest Jiaotong Univ.
Huang, Deqing — Southwest Jiaotong Univ.
Zhang, Yusha — Southwest Jiaotong Univ.
Fang, Jiaxin — Southwest Jiaotong Univ.

When the electric multiple units (EMUs) encounter a power supply failure, it is urgent to formulate a reasonable emergency traction strategy, and rely on the on-board energy storage device to pull to the nearby station as soon as possible. During emergency propelling, the train's maximum traction force is affected by the maximum power of the on-board energy storage device. Therefore, in this paper, we propose a novel model for describing the traction characteristics of the train based on on-board energy storage devices in the case of emergency traction. First, to depict the power relationship between the train traction motor and the on-board energy storage device, an train emergency traction power model is developed. Then, while online updating of battery equivalent model parameters is realized by fitting experimental data, a binary search algorithm is adopted to the long-time state of power (SOP) estimation of on-board lithium batteries (¿120s) under the state of charge (SOC), battery design and voltage constraints. Finally, the train simulation experiments show that the proposed method achieves excellent SOC estimation and the accurate description of the emergency traction characteristics of the train.

▷ SunB08-63

*Reinforcement Learning Based Data-driven Optimal Control Strategy for Systems with Disturbance*

Fan, Zhong-Xin — Southeast Univ.
Li, Shihua — Southeast Univ., China
Liu, Rongjie — Florida State Univ.

This paper proposes a partially model-free optimal control strategy for a class of continuous-time systems in a data-driven way. Although a series of optimal control have achieving superior performance, the following challenges still exist. (i) The controller designed based on the nominal system is difficult to cope with sudden disturbances. (ii) Feedback control is highly dependent on system dynamics and generally requires full state information. Noticing that the output feedback and input-output model are wildly used in industrial systems, we combine output feedback reinforcement learning and input-output disturbance observer to formulate a composite controller. Firstly, an output feedback policy iteration (PI) algorithm is given to acquire the feedback gain iteratively. Simultaneously, the observer continuously provides estimates of the disturbance. System dynamic information and states information are not needed to be known in advance in our approach. Finally, an example is given to show the effectiveness of the proposed controller.

▷ SunB08-64

*Fault Estimation for Nonlinear Systems with Time Delay Based on Iterative Learning Scheme*

Xu, Shuiqing — Chongqing Univ.
Dai, Haosong — Hefei Univ. of Tech.
Huang, Darong — Anhui Univ.
Tao, Songbing — Chongqing Univ.
Hu, Chong — Chongqing Micro Standard Tech. Co. Ltd

In this paper, the problem of fault estimation for a class of nonlinear systems with time delay is studied. First, an iterative learning observer and exponential function based fault estimation law are designed to improve the accuracy of fault estimation results. Then, by using the $\lambda$-norm method, the convergence conditions of the designed fault estimator are obtained and the relevant convergence proof is completed. Finally, the simulation results show that the proposed fault estimation method can effectively reconstruct the fault signal.

▷ SunB08-65

*Dynamical Linearization Based PLS Modeling and Model-free Adaptive Control*

Lin, Mingming — Qingdao Universtiy of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.
Lin, Na — Qingdao Univ. of Sci. & Tech.
Liu, Zhiqing — Qingdao Univ. of Sci. & Tech.

In this paper, a new model free adaptive control (MFAC) strategy based on partial least squares (PLS) framework is proposed to achieve trajectory tracking for multivariable nonlinear processes. The nonlinear dynamic characteristics of the multivariable systems are addressed by a dynamic linearization method and a linear PLS inner data model is obtained consequently including an unknown pseudo-partial derivative (PPD) parameter. Under the PLS framework, the multivariable system can be decomposed into multiple single-loop systems to facilitate the controller design. The controller design only depends on the measured input and output data. Simulation results demonstrate the effectiveness of the pro-

posed method.

▷ SunB08-66

*Trajectory Tracking by An Adaptive Controller for High-Speed Train Based on Neural Network and Sliding Mode Control*


| | |
|---|---|
| Zhou, Cen | Southwest Jiaotong Univ. |
| Li, Zhi | Southwest Jiaotong Univ. |
| Wang, Qingyuan | Southwest Jiaotong Univ. |
| Sun, Pengfei | Southwest Jiaotong Univ. |
| Guo, Youxing | Southwest Jiaotong Univ. |


Abstract: This paper proposes an adaptive sliding mode controller (ASMC) for trajectory tracking of high-speed trains (HST) with uncertainties. The ASMC incorporates a radial basis function neural network (RBFNN) to approximate the model uncertainties and uses a sigmoid function to reduce chattering. The Lyapunov function is employed to prove the stability of the controller. Numerical simulations using the data of China Railway High-Speed (CRH) 380 train demonstrate the effectiveness of the controller in ensuring the train follows the tracking target under different prior knowledge conditions.

## SunC01 13:30–15:30 2nd Conf. Hall

Invited Session: In-depth Exploration and Learning of Industrial Data I

Chair: Liu, Yi — Zhejiang Univ. of Tech.
Co-Chair: Yao, Yuan — National Tsing Hua Univ.

▶ SunC01-1 13:30–13:50

*Dynamic Graph Learning Soft Sensor in Process Industry*


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|---|---|
| Jia, Mingwei | Zhejiang Univ. of Tech. |
| Xu, Danya | Northeastern Univ. |
| Yang, Tao | Northeastern Univ. |
| Yao, Yuan | National Tsing Hua Univ. |
| Liu, Yi | Zhejiang Univ. of Tech. |


The development of an accurate soft sensor modeling method in the process industry remains a great challenge because the coupling relationship between variables is always intricate and difficult to model. In this work, a dynamic graph learning (DGL) soft sensor is proposed to alleviate this problem. The proposed model realizes the ability of the soft sensor to perceive the coupling relationship in real time by automatically learning the dynamic graph. Then, a causal convolutional mechanism and a multi-hop graph attention mechanism are used to systematically construct the dependencies of variables in the spatial-temporal dimension and model their variation patterns effectively. Finally, the proposed method is tested on the penicillin fermentation process and shown to be feasible and effective. The results showed that the change of the dynamic graph in the spatial-temporal dimension was in line with the process mechanism.

▶ SunC01-2 13:50–14:10

*Short-term Load Forecasting of CCHP System Based on PSO-LSTM*


| | |
|---|---|
| Zhu, Yu-Rong | Shanghai Univ. |
| Wang, Jian-Guo | Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ. |
| Sun, Yuqian | Shanghai Univ. |
| Wu, Jia Jun | Shanghai Univ. |
| Zhao, Guoqiang | Shanghai Univ. |
| Yao, Yuan | National Tsing Hua Univ. |
| Liu, Jianlong | Shanghai Minghua Power Tech. Co., Ltd |
| Chen, He-Lin | Baoshan Iron & Steel Co. Ltd |


With the inherent need to accelerate the high-quality development of China's economy, it is necessary to build a clean, low-carbon, safe and efficient modern energy system. The traditional energy system is centralized and large-scale, and the transmission and distribution system are complex, with low adaptability and reliability. The Combined cooling, heating and power system has been widely promoted and concerned for its advantages of improving energy efficiency, saving energy and reducing emissions. This paper takes the Combined cooling, heating and power system of Shanghai Qiantan Energy Station as the research object and establishes a load prediction model on the user side. This paper first introduces the Combined cooling, heating and power system of Shanghai Qiantan Energy Station, then explores the influencing factors of load data, builds the PSO-LSTM model and analyzes the prediction results, and finally draws a conclusion.

▶ SunC01-3 14:10–14:30

*Operation Optimization of CCHP System Based on Improved PSO Algorithm*


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|---|---|
| Yu, Guo-Yuan | Shanghai Univ. |
| Wang, Jian-Guo | Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ. |
| Deng, Dai-Shihao | Shanghai Univ. |
| Wu, Jia Jun | Shanghai Univ. |
| Zhao, Guoqiang | Shanghai Univ. |
| Yao, Yuan | National Tsing Hua Univ. |
| Liu, Jianlong | Shanghai Minghua Power Tech. Co., Ltd |
| Chen, He-Lin | Baoshan Iron & Steel Co. Ltd |


With the rapid development of the world economy, all countries are faced with energy shortage and environmental pollution. The traditional energy system is centralized and large-scale, the transmission and distribution system is complex, and the adaptability and reliability are not high. Combined Cooling Heating and Power (CCHP) system has been widely promoted and paid attention to because of its advantages of improving energy utilization, energy saving and emission reduction. In this paper, a single-objective optimal scheduling model for the CCHP system of an energy station is established, and the shortcomings of the simple particle swarm optimization (PSO) are improved. Using simple particle swarm optimization and improved particle swarm optimization to optimize and solve the joint supply system, the daily operating cost of the joint supply system after optimization is greatly reduced compared with that before the optimization, and the daily operating cost of the improved particle swarm optimization algorithm is the lowest. The advantages of the CCHP generation system in energy saving and emission reduction are verified.

▶ SunC01-4 14:30–14:50

*Features Masked Auto-Encoder-Based Anomaly Detection in Process Industry*


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|---|---|
| Hu, Junhao | Zhejiang Univ. of Tech. |
| Jia, Mingwei | Zhejiang Univ. of Tech. |
| Yang, Qinmin | Zhejiang Univ. |
| Liu, Yi | Zhejiang Univ. of Tech. |


With the development of the modern process industry, accurate anomaly detection methods are increasingly needed. However, identifying anomalies from high-dimensional data continues to be a challenge for the process industry. In this work, a feature masked autoencoder (FMAE) method is proposed to meet this challenge. As a masked-reconstruction task, a high mask rate is first adopted to mask the feature of data. Then, the intrinsic information of unmasked features is extracted through the encoder and masked features are recovered through the decoder. This task forces the intrinsic information learned by the model to increase while alleviating the high-dimensional problem. Additionally, anomaly tends to be reconstructed to a normal by FMAE because only normal data is used for training. Thus, anomalies are detected and localized by computing input-output residuals. Finally, the effectiveness of the model is verified on the Lublin Sugar Factory dataset.

▶ SunC01-5 14:50–15:10

*Orthogonal Feature Separation Autoencoder for Process Monitoring*


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|---|---|
| Yang, Chao | Northeastern Univ. |
| Zhang, Congcong | Northeastern Univ. |
| Liu, Qiang | Northeastern Univiersity |


With excellent feature representation capabilities, deep autoencoder networks have attracted attention in process monitoring. However, it cannot simultaneously consider process information separation and quality indicators to identify whether the faults are quality-relevant. To address this issue, an orthogonal feature separation autoencoder (OFSAE) method is developed for quality-relevant fault monitoring, which mainly consists of the quality-relevant encoder network, quality-irrelevant encoder network, decoder network, and regression network. Through parallel learning and orthogonal projection for process variables, the quality-relevant and quality-irrelevant information can be separated while maintaining good prediction performance. Finally, in comparison with conventional monitoring methods, the superiority of OFSAE is validated by the Tennessee Eastman (TE) process.

▶ SunC01-6 15:10–15:30

*Gated Recurrent Unit Neural Networks for Wind Power Forecasting Based on Surrogate-Assisted Evolutionary Neural Architecture Search*


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|---|---|
| Zhang, Kehao | Faculty of Information Engineering & Automation, Kunming Univ. of Sci. & Tech. |
| Jin, Huaiping | Kunming Univ. of Sci. & Tech. |
| Jin, Huaikang | Huaneng Renewables Co.,Ltd.Yunnan Branch |
| Wang, Bin | Kunming Univ. of Sci. & Tech. |

Yu, Wangyang Wuhan Maritime Communication Research Inst.

Wind energy has become an important part of national power systems due to its wide distribution, low cost, and non-polluting characteristics. However, the intermittence, randomness, and fluctuating of wind energy make it extremely difficult to connect wind power to the grid, which in turn affects the normal dispatch of power resources. Therefore, accurate wind power forecasting is crucial for power systems. Deep neural networks (DNNs) can efficiently capture high-dimensional nonlinear spatiotemporal features and are employed. The architectures of state-of-the-art DNNs are usually hand-designed by users with extensive expertise. In this paper, gated recurrent unit neural networks for wind power forecasting approach based on surrogate-assisted evolutionary neural architecture search (SA-ENAS) is proposed. Firstly, SA-ENAS uses gated recurrent unit neural networks (GRU) to capture high-dimensional nonlinear spatiotemporal features, while incorporating delay variables into ENAS. Secondly, the GRU architecture is jointly encoded with delay variables. Then, the architecture search and delay variable selection are achieved using a surrogate model based ENAS approach. Finally, the effectiveness and superiority of the proposed method are verified through the case study of an actual wind farm dataset.

## SunC02 13:30–15:30 3rd Conf. Hall

Invited Session: Modeling, Optimization and Control of Data-driven Energy Internet Systems I

Chair: Gao, Zhe Liaoning Univ.
Co-Chair: Li, Shengquan Yangzhou Univ.

### ▶ SunC02-1 13:30–13:50

*Detecting False Data Injection Attacks Using Spatial-temporal Graph Neural Network*

Wei, Xingshen NARI
Liu, Wei State Grid Electric Power Research Inst.
Zhou, Jian State Grid Electric Power Research Inst.
Zhou, Xiaoming State Grid Liaoning Electric Power Supply Co
Zhang, Wenjie State Grid Liaoning Electric Power Supply Co
Cao, Yongjian Nanjing Nari Information Communication Tech.

There are a large number of cyber-attacks in the power system, especially the false data injection attack (FDIA). This attack can bypass the traditional bad data detection mechanism (BDDM), and affect the operation of the power system. In this paper, for the purpose of guaranteeing the reliable operation of the cyber-physical power system (CPPS), a novel FDIA detection model is proposed based on spatial-temporal graph neural network (STGNN). The STGNN can extract the temporal features and spatial features of measurement data simultaneously in the CPPS. Specially, the spatial features and the temporal features are extracted by graph neural network (GNN) and recurrent neural network (RNN), respectively. Simulation results based on IEEE 14-bus system verify the performance of the proposed method.

### ▶ SunC02-2 13:50–14:10

*Active Disturbance Rejection Vibration Control Based on Delay Compensator for An All-clamped Plate with Inertial Actuator*

Zhang, Lujin Yangzhou Univ.
Li, Juan Southeast Univ.
Qiu, Ruikang Yangzhou Univ.
Li, Shengquan Yangzhou Univ.
Cao, Wei Yangzhou Univ.

Considering the problems of system delay and uncertainties in an all-clamped plate structural vibration control system with inertial actuator, an active disturbance rejection control strategy based on system-delay compensation is proposed in this paper. First, the electromechanical coupling model of the vibration system is established according to the motion equation of the all-clamped plate and the electromagnetic equation of the inertial actuator Second, a smith predictor is employed to eliminate the influence of time delay on the vibration control system. In addition, the internal and external disturbances, i.e. modeling error, high harmonics and external excitation of vibration system are estimated and compensated via a feedforward part. Finally, based on the real-time simulation environment of MATLAB/SIMULINK and the NI PCIe data acquisition card, the semi-physical simulation platform of the all-clamped plate with the inertial actuator is built to verify the effectiveness and superiority of the proposed active vibration control method. Compared with the linear active disturbance rejection control strategy, the results show that the proposed control strategy has better anti-disturbance ability and vibration suppression performances.

### ▶ SunC02-3 14:10–14:30

*Hidden Markov model based finite-time H∞ guaranteed cost control for singular discrete-time Markov jump delay systems*

Chen, Zhiwen Jiangsu Univ. of Tech.
Li, Bo Jiangsu Univ. of Tech.
Zhao, Junjie Jiangsu Univ. of Tech.
Li, Feng Jiangsu Univ. of Tech.
Du, Youwu China Univ. of GeoSci.

Considering partially known transition rates and saturating actuators, the finite-time H∞control problem for a class of singular discrete-time Markovian jump delayed systems is studied in this article. First, by employing local sector conditions and an appropriate Lyapunov function, a hidden Markov model based state feedback controller is designed to guarantee that the resulted closed-loop constrained system is mean-square locally finite-time stabilizable, and the closed-loop cost function value is not more than a specified upper bound. Furthermore, some sufficient conditions for the solution to this problem are derived in terms of linear matrix inequalities. Finally, a numerical example is provided to demonstrate the effectiveness of proposed method.

### ▶ SunC02-4 14:30–14:50

*Two-dimensional Iterative Learning Model Predictive Control Based on Just-in-Time Learning Method for Batch Processes*

Zheng, Chuangkai Yangzhou Univ.
Zhou, Liuming Yangzhou Univ.
Li, Feng Jiangsu Univ. of Tech.

In this paper, the predictive control problem of two-dimensional iterative learning model based on just-in-time learning (JITL) model is studied for batch processes. A new error compensation strategy is proposed based on two-dimensional JITL model by using MPC-ILC integrated control method. Batch axis and time axis are integrated into a comprehensive objective function, and the JITL model is used to solve the problem of large computation of comprehensive objective function. The proposed control algorithm is applied to a typical batch reactor, and the results show that the proposed control strategy has good control performance.

### ▶ SunC02-5 14:50–15:10

*Optimal Control of Stochastic Power System Based on Braking Resistance*

Lin, Xue Jiangsu Univ. of Tech.
Wang, Qi Jiangsu Univ.
Luo, Yinsheng Jiangsu Teachers Univ. of Tech.
Cai, Changchun Hohai Univ.

How to suppress the adverse effects of the uncertainty of renewable energy on power systems has always been a major technical requirement for power system operation, which has not be considered in the design of the traditional power system controller. Therefore, it is necessary to consider the stability control of the power system under stochastic disturbances. In this paper, a controlled single-machine infinite-bus system model is established based on the stochastic averaging method of quasi-Hamiltonian systems, and a one-dimensional diffusion equation based on energy function with control item is obtained. According to the stochastic optimal control theory, the optimal control law of the system is obtained from the diffusion equation with the maximum reliability of the bounded fluctuation of the system as the control target. The effectiveness of the control method is verified by simulation.

### ▶ SunC02-6 15:10–15:30

*Tuning Method for Parameters in Fractional-Order PID Controllers Based on Neural Networks with Improved Borges Derivative*

Li, Mingdi Liaoning Univ.
Gao, Zhe Liaoning Univ.
Jia, Kai Liaoning Univ.
Xiao, Shasha Liaoning Univ.

This paper investigates the turning method of fractional-order PID (FOPID) controllers based on neural networks with Borges derivative. The Borges derivative is applied to the controller structure and the turning of parameters in FOPID controllers. To ensure the Borges derivative can be applied for the negative real number as the independent variable, the improved Borges derivative is defined in this paper. Borges derivative is also used to update the coefficients and the orders of a novel type of FOPID controllers with the Borges difference and the Borges sum. In this paper, the selections of the orders in Borges derivative are discussed, and FOPID controllers based on neural networks are improved to gain the higher optimization speed and accuracy than that via the integer-order PID controllers. Finally, we give an example to verify the effeteness of turning method.

**SunC03** 13:30–15:30 4th Conf. Hall
Invited Session: Intelligent Control of Nonlinear Networked Systems

Chair: Li, Yuan Xin Liaoning Univ. of Tech.
Co-Chair: Che, Wei-Wei Qingdao Univ.

▶ SunC03-1 13:30–13:50
*A Fault Diagnosis Method Based on Wavelet Denoising and 2DCNN under Background Noise*

Liu, Kexin Hunan Univ.
Li, Zhe Hunan Univ.
He, Wenbin Hunan Univ.
Peng, Jia State Grid Hunan Electric Power Company Limited
Wang, Xudong Hunan Univ.
Wang, Yaonan Hunan Univ.

This paper develops a novel method named wavelet denoising convolutional neural network (WDECNN) for fault diagnosis with background noise. The continuous wavelet transform (CWT) is first applied to transform the measured raw vibration data into time-frequency images which serve as the inputs of WDECNN. Then, a light-weight two-dimensional CNN (2DCNN) model is incorporated in WDECNN to simplify the network architecture, while a wavelet denoising module is also applied in it to achieve high accuracy of fault identification in the noisy environment. Particularly, the wavelet denoising module which consists of wavelet decomposition and denoising is parallel to the 2DCNN model, and the denoising results are integrated into pooling layers in the 2DCNN model. Thus, the denoised information is added to the 2DCNN model to improve its feature learning ability. Finally, the effectiveness of the developed method is validated on Paderborn bearing dataset, which illustrates its fault diagnosis capability under background noise.

▶ SunC03-2 13:50–14:10
*Tracking Control of High-Speed Trains Based on An Improved Disturbance Observer*

Zhang, Jian-Ping East China Jiaotong Univ.
Deng, Lin-Bao East China Jiao Tong Univ.
Xie, Chun-Hua East China Jiaotong Univ.

Accurate tracking of position and velocity is a critical problem to be solved for the automatic train operation (ATO) system. However, achieving automatic operation for high-speed trains (HSTs) is difficult due to unknown disturbances and actuator faults. This paper uses an improved disturbance observer-based control (IDOBC) strategy to solve this issue. Each carriage is considered a particle and connected by a flexible coupler to establish the multiple point-mass model for HSTs by considering unknown lumped disturbances and actuator faults. For the lumped disturbances caused by the external environment, an improved disturbance observer is designed to compensate for the impact caused by this component on HSTs. Based on the given linear matrix inequality, the HSTs system satisfies the Hinfty performance under the IDOBC strategy. Compared with traditional DOBC, the proposed IDOBC has higher tracking accuracy.

▶ SunC03-3 14:10–14:30
*Model-Free Adaptive Control for SISO Nonlinear Systems under Sparse Sensor Attacks*

Chen, Yifan Shenyang Aerospace Univ.
Liu, Dong Shenyang Aerospace Univ.

This paper discusses the model-free adaptive control for nonlinear systems under sparse sensor attacks. Firstly, it is proposed that there are multiple transmission channels in the sensor-to-controller transmission network. Secondly, system sensors are affected by DoS attacks and FDI attacks. Then, a channel switching mechanism is used to adjust the channel to compensate for adverse effects of attacks. Finally, it is proved that the tracking error of the system converges to a tiny constant and a numerical simulation example demonstrates the validity of the proposed method.

▶ SunC03-4 14:30–14:50
*Finite-Time Adaptive Fuzzy Control for MIMO Nonlinear Multi-Agent Systems*

Sui, Shuai Liaoning Univ. of Tech.

This paper considers the finite time containment control problem of a class of multi-input and multi-output (MIMO) nonlinear multi-agent systems (MAS). Fuzzy logic systems (FLSs) and a smooth function are first employed to model unknown agent's subsystems, respectively. Then, under the framework of the finite-time stability criterion and adaptive backstepping control design technique, a finite-time adaptive fuzzy control design method is proposed and the semiglobal finite-time stability of the controlled system is rigorously proved. Finally, the simulation results are given to confirm the effectiveness of the proposed control scheme.

▶ SunC03-5 14:50–15:10
*Dynamic Observer-based Controllers for Fractional-order Linear Systems with Positive Real Uncertainty*

He, Li Shenyang Aerospace Univ.
Liu, Shuo Shenyang Aerospace Univ.

This paper investigates the problem of robust dynamic observer-based controller design for fractional-order systems (0¡ α ¡1) with positive real uncertainty. By constructing a linearising change of variables, the conditions for designing the observer and controller gains are obtained in terms of solutions to a set of linear matrix inequalities (LMIs) even in the presence of uncertainties in system and input matrices simultaneously. Compared with the Luenberger observer, the dynamic observer-based controller is an alternative method that does not need to use equality constraint in the LMI conditions. Numerical examples are given to illustrate the validity of the presented method.

▶ SunC03-6 15:10–15:30
*Active Iterative Learning Control Based on Big Data*

Lin, Mingming Qingdao Universtiy of Sci. & Tech.
Chi, Ronghu Qingdao Univ. of Sci. & Tech.
Lin, Na Qingdao Univ. of Sci. & Tech.
Liu, Zhiqing Qingdao Univ. of Sci. & Tech.

In this paper, we introduce the concept of data similarity for a class of nonlinear time-varying discrete time systems. By combining the large data processing method with the iterative learning control algorithm, an active iterative learning control algorithm is proposed. Different from the updating method in traditional iterative learning control algorithm, in this paper, the control input of the current iteration is given by using K-means algorithm and support vector machine (SVM) algorithm to pick out the closest state control input from the historical database. The control algorithm is verified by ethanol fermentation process. The simulation result shows that the active iterative learning control scheme based on data similarity can greatly improve the convergence speed of the system compared with the traditional one. It is worth noting that the historical data is used in the update process, so it will not affect the convergence and stability of the system, and it has good popularization value.

**SunC04** 13:30–15:30 5th Conf. Hall
Regular Session: Data-driven Modeling, Optimization and Scheduling

Chair: Zhang, Jianming Institution of Cyber-Sys. & Control
Co-Chair: Han, Weixin Northwestern Polytechnical Univ.

▶ SunC04-1 13:30–13:50
*Heterogeneous AGVs Scheduling in Hospital Using ALNS-based Meta-heuristic Algorithm*

Song, Xueming Zhejiang Univ.
Zhu, Ke Zhejiang Univ.
Zhao, Yuxin Zhejiang Univ.
Zhang, Jianming Institution of Cyber-Sys. & Control

Automated Guided vehicles (AGVs) provide a better solution to hospital logistics. In this paper, a mathematical model for point-to-point pickup and delivery tasks in a hospital with time windows and capacity constraints based on heterogeneous AGVs fleet is established, and a meta-heuristic algorithm based on ALNS is designed to solve the static scheduling problem of AGVs in the hospital environment. The effectiveness of the proposed algorithm is verified by numerical experiments and comparison with the basic algorithm. Finally, we summarized the direction of the further work.

▶ SunC04-2 13:50–14:10
*Optimal Scheduling of Distribution Network Maintenance Personnel Based on the Northern Cthulhu Algorithm*

Liu, Chengwei Hunan Univ. of Sci. & Tech.
Chen, Chao-Yang Hunan Univ. of Sci. & Tech.
Chen, Zuguo Hunan Univ. of Sci. & Tech.
Li, Pei Hunan Univ. of Sci. & Tech.

Extreme events have caused large-scale power disruptions across the planet in recent years. Extreme events can cause multiple faults in the distribution network, and since the distribution network cannot be completely repaired by islanding and reconfiguration, maintenance personnel must be sent out to fix the faulty lines. However, the number of faulty lines typically exceeds the amount of the maintenance workforce, and there are also variations in the maintenance times of individual maintenance personnel. The issue this study seeks to address is how to rationally schedule maintenance staff in order to minimize total econom-

ic cost. First, in order to model load uncertainty, various scenarios are simulated using the Monte Carlo approach. Second, the modified Northern Hawk optimization technique is used to solve the best scheduling scheme. Finally, the effectiveness of the proposed method is verified by concrete examples.

▶ SunC04-3 14:10–14:30

*On Consistent Filter Design for Angle of Attack Estimation with Airspeed Rate Measurement*


| | |
|---|---|
| Huang, Shuyan | AMSS, CAS |
| Xiang, Feiyu | Univ. of Chinese Acad. of Sci. |
| Xue, Wenchao | Chinese Acad. of Sci. |
| Fang, Hai-Tao | Chinese Acad. of Sci. |


This paper is concerned with the problem of estimating the angle of attack (AOA) of the aircraft. The aerodynamics model of airspeed under constant wind disturbances and the airspeed rate measurement model with the nonlinearity of quadratic form is considered. Firstly, the observability-established nonlinear system model for the AOA estimation is rigorously analyzed. Secondly, the consistent extended Kalman filter algorithm is designed to estimate the airspeed vector by introducing a compensation parameter matrix to linearization error in the measurement model. Finally, the numerical simulation based on two typical cases of aircraft maneuvers is carried out. It is shown that the proposed method can achieve the desired accuracy of the AOA estimation.

▶ SunC04-4 14:30–14:50

*A Data-driven Physical Mechanism Modeling Method for the Spin-Exchange Relaxation-Free Comagnetometer*


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|---|---|
| Li, Feng | Beijing Univ. of Aeronautics & Astronautics |
| Wang, Zhuo | Beijing Univ. of Aeronautics & Astronautics |
| Zhang, Min | Beijing Univ. of Aeronautics & Astronautics |
| Wang, Ruigang | Beijing Univ. of Aeronautics & Astronautics |
| Qin, Bodong | Beijing Univ. of Aeronautics & Astronautics |
| Chai, Yanchao | Beijing Univ. of Aeronautics & Astronautics |


The Spin-Exchange Relaxation-Free Comagnetometer (SERFCM) is a new quantum instrument with ultra-high accuracy. Normally, the atomic ensembles of SERFCM operate in an open-loop state, which is not conducive to long-term high-precision measurements. In order to realize closed-loop control of its atomic polarization state, it is necessary to model and analyze the dynamic characteristics of the SERFCM system. In this paper, a Data-driven physical mechanism (DDPM) modeling method is proposed to realize the modeling of the SERFCM, a multi-input multi-output system. First, the state space equations of the SERFCM are established based on the Bloch equation, which are transformed into a discrete transfer function matrix. Then, based on the criterion of least variance in estimation, we realize the modeling of the discrete transfer function matrix using the excitation input data, the measured output data, and the estimated output data. Finally, the simulation results of modeling under different longitudinal magnetic fields confirm the validity of the proposed method. This work enables the online modeling of SERFCM system and facilitates the analysis of the effects of various parameters on the dynamic characteristics.

▶ SunC04-5 14:50–15:10

*Chiller System Modeling Using PSO Optimization Based NARX Approach*


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| Song, Zilong | Beijing Univ. of Tech. |
| Li, Xiaoli | Beijing Univ. of Tech. |
| Wang, Kang | Beijing Univ. of Tech. |
| Li, Yang | Communication Univ. of China |


The HVAC system is a system responsible for heating, ventilation, and air conditioning in buildings. Accurate modeling of the HVAC refrigeration room system is crucial for building temperature control and optimization of energy consumption. Levenberg-Marquardt (LM) algorithm is used to establish a nonlinear autoregressive model (NARX) with exogenous variables to model the catalytic water chiller system. NARX is a dynamic neural network. Its delay term and output feedback structure are suitable for modeling complex systems. In addition, particle swarm optimization (PSO) is used to improve the accuracy of the prediction model. The experimental results show that the NARX model can effectively describe the actual dynamic characteristics of the chiller system and has better prediction and generalization capabilities than the traditional artificial neural network model.

▶ SunC04-6 15:10–15:30

*Safety Predefined-Time Tracking Control of Second-Order Nonlinear Systems*


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|---|---|
| Xu, Yang | Soochow Univ. |
| Sun, Yuan | Soochow Univ. |
| Chen, Yiyang | Soochow Univ. |
| Tao, Hong-Feng | Jiangnan Univ. |


This paper examines a category of second-order nonlinear systems' predefined-time tracking control issue restricted by the state and input from the control. The safety predefined-time control framework proposed by this work aims at tracking a desired trajectory in a predefined time while maintaining safe system outputs and control inputs. The safety predefined-time controller is specifically created by a safety filter utilizing the control barrier function approach and a predefined-time controller on the basis of the backstepping technique. The predefined-time controller establishes an explicit relation between the controller parameters and the convergence time constraint. Moreover, the safety filter enforces the state and control input constraints by constructing a quadratic programming problem. In an effort to demonstrate the feasibility of the safety predefined-time controller, a second-order practical system is simulated.

**SunC05** 13:30–15:30 6th Conf. Hall

Invited Session: Adaptive Control for Nonlinear Mechanical System

Chair: Huang, Yingbo Kunming Univ. of Sci. & Tech.

Co-Chair: Zhang, Menghua Shandong Univ.

▶ SunC05-1 13:30–13:50

*Periodic SMC Method for 4-DOF Tower Crane Systems under Unknown Control Direction*


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| Zhang, Menghua | Shandong Univ. |


A new periodic SMC method is constructed for 4-DOF tower crane systems under unknown control direction constraints. It should be pointed out that, compared with other existing control direction-related control methods, the designed control coefficient is allowed to cross 0 in a continuous way. Lyapunov techniques is carried out to demonstrate the stability of the controlled tower crane system. Several simulation results are provided to prove the satisfactory control performance of the proposed periodic SMC method.

▶ SunC05-2 13:50–14:10

*Prediction of Matte Grade in the Oxygen-rich Top Blown Smelting Based on WD-SSA-SVM Algorithm*


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| Li, Xincai | Kunming Univ. of Sci. & Tech. |
| Yang, Chunxi | Kunming Univ. of Sci. & Tech. |
| Zhang, Xiufeng | Yunnan International Joint Laboratory of Intelligent Control & Application of Advanced Equipment |
| Li, Gengen | Kunming Univ. of Sci. & Tech. |


In view of the defects of noise in the industrial data of the oxygen-rich top blown smelting and time lag in off-line detection of matte grade, it is difficult to accurately establish the prediction model of process parameters. A process parameter prediction model based on wavelet denoising sparrow search algorithm optimized support vector machine (WD-SSA-SVM) was proposed. Firstly, wavelet denoising is used to improve the quality of the data. Secondly, the sparrow search algorithm was used to optimize the support vector machine to establish the nonlinear relationship model between the melting process and the process index, and the model parameters were identified by the sample data after denoising, so as to effectively predict the process index of frosted sand grade in the process of the oxygen-rich top blown smelting. The experimental results on the actual production data of a smelter show that the WD-SSA-SVM model proposed in this paper has high accuracy, meets the accuracy requirements in the actual industrial production, and can effectively guide the optimization and adjustment of the operating parameters of the oxygen-rich top blown smelting process.

▶ SunC05-3 14:10–14:30

*GSC-YOLOv5: An Algorithm Based on Improved Attention Mechanism for Road Creak Detection*


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| Wang, Jianhao | Shandong Univ. of Sci. & Tech. |
| Gao, Xuehui | Shandong Univ. of Sci. & Tech. |
| Liu, Zhen | Shandong Univ. of Sci. & Tech. |
| Wan, Yu | Shandong Univ. of Sci. & Tech. |


Pavement damage detection is of great significance for traffic safety and pavement maintenance. Traditional detection methods require a lot of time and cost, and there are many problems in image detection. Therefore, an improved YOLOv5 pavement damage detection algorithm, GSC-YOLOv5, is proposed. First of all, to solve the problem that small cracks are similar to pavement and difficult to detect, we introduced the self-designed Spatial Pyramid Pooling module into the backbone network of the original YOLOv5 model: GM-SPPF to enhance the feature extraction

of the network and improve the detection ability of fine cracks. Secondly, to solve the problem that it is difficult to locate defects under special lighting conditions, ShuffleAttention, an improved lightweight attention module, is introduced to help the model accurately locate features and improve the accuracy of object detection. Finally, the upsampling mode of the original model is changed to the lightweight CARAFE upsampling, so as to reduce the number of parameters in the model. The experiment was carried out on RDD2022 data set. The results showed that the improved YOLOv5 model reached 54.6%, which was 3.3% higher than the Baseline, and the F1 score reached 57.5%. Our algorithm can detect and locate the defects on the outlet surface, saving a lot of manpower and material resources, which is of great significance for the evaluation of highway damage and its maintenance.

▶ SunC05-4 14:30–14:50

*Cogging Torque Compensation in PMSM with Spatial Repetitive Learning Control*

Li, Mingyu — Zhejiang Univ. of Tech.
Shi, Huihui — Zhejiang Univ. of Tech.
Chen, Qiang — Zhejiang Univ. of Tech.
Ji, Qianzhen — Zheiiang Univ. of Tech.

In this extended abstract, a spatial repetitive learning controller is proposed for the PMSM. Firstly, in order to take advantage of the spatial periodicity of the cogging torque, the PMSM system in the temporal domain is transformed into the spatial domain through state transformation. Then, using the backstepping method, the spatial repetitive learning controller and update law are designed to compensate the position-periodic disturbance and the accurate position tracking of the PMSM in the spatial domain is achieved. Finally, the simulation results show that the proposed method is efficient for the disturbance compensation in the spatial domain and achieves the high-precision position tracking performance.

▶ SunC05-5 14:50–15:10

*PD Control with Gravity Compensation for 3-RPS Parallel Manipulator*

Lv, Zhiyuan — Ocean Univ. of China
Ning, Donghong — Ocean Univ. of China
Liu, Pengfei — Ocean Univ. of China
Liao, Peng — Ocean Univ. of China

This paper proposes a new controller based on the kinematic model of a 3-degrees of freedom (DOFs) parallel manipulator with strongly coupled, nonlinear characteristics. The 3RPS (revolute–prismatic–spherical) parallel manipulator can be seen as a multi-body system composed of multiple links. Therefore, to achieve motion control of the robot, it is necessary to perform kinematic and dynamic modelling to understand the motion of the robot's end effector and the various forces acting on it. The controller applies a dynamic gravity compensation (GC) term into the traditional proportional derivative (PD) controller to improve the trajectory tracking performance of the system, which can reduce shaking in control and further eliminate the system' s steady-state error. Specifically, the gravity term in the dynamic model can be separated, converted to joint space, and added to the PD controller to obtain a PD controller with gravity compensation. As a result, the improved controller will provide smoother motion and better control. The simulation results show that the PD controller with gravity compensation term has a better control effect than the traditional one. The root mean square (RMS) values of tracking errors in three degrees of freedom under sinusoidal excitation were reduced by 49.18%, 70.25% and 88.28%, respectively.

▶ SunC05-6 15:10–15:30

*USDE-based Synchronization Control for Bilateral Teleoperation System Subject to Time-Varying Delay*

Bai, Zhiqiang — Kunming Univ. of Sci. & Tech.
Wang, Xian — Kunming Univ. of Sci. & Tech.
Hao, Duan — Kunming Univ. of Sci. & Tech.
Huang, Yingbo — Kunming Univ. of Sci. & Tech.

Time-varying delay, as one of the most prominent issues existing in teleoperation system, throws a critical threat on the teleoperation system stability. To address this issue, this paper proposes a novel synchronization control for nonlinear uncertain bilateral teleoperation systems in the presence of time-varying delay. Firstly, a filter error variable is designed to avoid using both local and remote acceleration signals. Then, a set of first-order low-pass filter operations are employed to construct an unknown system dynamics estimator (USDE) to handle the system uncertain dynamics, which revolves the Coriolis/gravity dynamics, external disturbances and remote velocity. With the suggested filtered error and USDE, a feedback controller is developed, which can not only improve the system synchronization but also has the capability of accommodating the influence of time-varying delay. Rigorously theoretical analysis is conducted by choosing the Lyapunov-Razumikhin candidate function to prove the stability of the closed-loop system. Finally, simulation results are provided to illustrate the effectiveness of the proposed method.

**SunC06** 13:30–15:30 Yuetang Conf. Hall

Invited Session: Networked Control System Simulation and Engineering

Chair: Guo, Shenghui — Suzhou Univ. of Sci. & Tech.
Co-Chair: Meng, Zhou — North China Univ. of Tech.

▶ SunC06-1 13:30–13:50

*Signal Reconstruction of Output Attacks on Autonomous Vehicles*

Chen, Li — Suzhou Univ. of Sci. & Tech.
Guo, Shenghui — Suzhou Univ. of Sci. & Tech.

This paper mainly studies the problem of vehicle attack signal estimation when autonomous vehicles contain network attacks and multiple autonomous vehicles communicate with each other. This paper first selects the appropriate vehicle dynamics model and vehicle lane-keeping model to model the vehicle. Then, considering the network attack of the vehicle and the mutual influence of multiple autonomous vehicles, the subsystem model is established, and the subsystem is converted into the form of the whole system. Then, the intermediate variable observer is designed for the whole system, and the output attack signal is reconstructed using the system state estimated by the observer. Finally, an example of two autonomous vehicles communicating with each other is used for simulation analysis to verify the feasibility of the proposed method.

▶ SunC06-2 13:50–14:10

*Minimal Detectable and Isolable Faults of Active Fault Diagnosis*

Xu, Feng — Tsinghua Univ.

This paper aims to compute guaranteed minimal detectable and isolable faults of set-based active fault diagnosis methods for discrete linear time-invariant systems. First, guaranteed detectable and isolable faults of set-based active fault diagnosis methods are defined in this paper. Second, an augmented vector is defined to integrate the effect of both inputs and faults such that the couplings of inputs and faults can be handled effectively. Third, guaranteed minimal detectable and isolable faults are computed by solving a mixed integer quadratic fractional programming problem under a proposed theoretic framework. At the end of this paper, an example is used to illustrate the effectiveness of the proposed solution.

▶ SunC06-3 14:10–14:30

*In-distribution Stability Analysis for Neural Markovian Jump Systems: A Delay-feedback Control Method*

Li, Xiaohang — Shanghai Univ. of Engineering Sci.

In this paper, a new idea of in-distribution stability is analyzed for a class of neural Markovian jump systems with non-differential time-delays and $Ithato$ type disturbance. To achieve such a goal, an asynchronous state-feedback controller is proposed to facilitate the design. Consider the fact that there always exist delays during practical signal transmissions, and therefore a new asynchronous delay-feedback control is reconstructed to render the closed-loop system to satisfy two preconditions (Theorems 2 and 3). Whereupon, the closed-loop system is proved to be in-distribution stable through three steps. Note that the boundary of the designed controller does not need to be known in advance, which shows superiority over the existing delay-involved controllers.

▶ SunC06-4 14:30–14:50

*Sludge Bulking Prediction Method for Sewage Treatment Plant Based on GWO-CPSO Algorithm*

Xue, Tong Lai — North China Univ. of Tech.
Gao, Yutao — North China Univ. of Tech.
Meng, Zhou — North China Univ. of Tech.
Han, Fei — Hebei Univ. of Sci. & Tech.
Liu, Chun — Hebei Univ. of Sci. & Tech.

The process of sludge bulking is influenced by a variety of biological and abiotic factors, showing a high degree of nonlinearity, and a variety of inducing factors interact with each other and strong coupling. In theory, artificial neural network can approximate any nonlinear system with any precision, so it is determined to use neural network algorithm for prediction. Middle BP algorithm is the most common and effective method. This paper proposes a prediction method based on the BP neural network optimized by grey wolf optimization algorithm and chaotic particle swarm optimization algorithm to predict the trend of sludge bulking, in which the grey wolf algorithm and chaotic particle swarm optimization method are used to optimize the neural network algorithm. This algo-

rithm can solve the problems of BP neural network in the early stage, such as too convergence, easy to fall into the local minimum value, too dependent on the early weight, and effectively improve the calculation speed and prediction accuracy of the neural network.

▶ SunC06-5 14:50–15:10

*Research on Target Grab of Leg-arm Cooperative Robot Based on Vision*

Xia, Haichuang NUAA
Zhang, Xiaoping North China Univ. of Tech.

Leg-arm cooperative robot can not only expand the motion space of traditional manipulator, but also make up the operation ability of traditional mobile robot. This paper studies the target grab of leg-arm cooperative robot based on vision. First of all, independently develop the leg-arm cooperative robot. Secondly, for the operation of the manipulator, a height-angle uncoupling PID algorithm is innovatively designed in the cylindrical coordinate system. The target position information obtained by the YOLOv3 algorithm is used as feedback to realize the accurate control of the manipulator, which can avoid the complex process of trajectory planning. Furthermore, combined with three-element trajectory planning method and motion control scheme under triangular gait, a target grab control strategy for the leg-arm cooperative robot is designed, including the height allocation decision maker and the target tracking controller. Finally, the proposed algorithm and schemes are verified with the entity robot.

▶ SunC06-6 15:10–15:30

*A Review of Sound Source Localization Research in Three-Dimensional Space*

Yang, Fan Beijing Univ. of Sci. & Tech.
Song, Ruizhuo Univ. of Sci. & Tech. Beijing

Sound source localization in three-dimensional space refers to using acoustic sensors to collect sound source information and combine it with localization algorithms to identify the distance and direction of the sound source. Sound source localization technology is widely used in industrial and intelligent robotics fields, which greatly facilitates people's daily life. This paper summarizes the key technologies of sound source localization in the past five years, including time difference of arrival, direction of arrival, and neural network-based localization algorithms. The advantages and disadvantages of these methods, and the factors affecting the localization accuracy are also analyzed. Finally, it introduces a series of challenges of sound source localization in 3-D space and the problems that need to be solved for future development.

## SunC07 13:30–15:30 Hongqi Conf. Hall

Invited Session: Distributed Learning, Optimization and Control

Chair: Liu, Yang Beihang Univ. (BUAA)
Co-Chair: Mo, Lipo Beijing Tech. & Business Univ.

▶ SunC07-1 13:30–13:50

*Distributed Online Convex Optimization with Adaptive Event-triggered Scheme*

Suo, Wei Beihang Univ.
Li, Wenling Beihang Univ.

This paper is concerned with the distributed online convex optimization problem in which a series of agents try to track the minimizer of a global convex function. A consensus then adaptive with gradient exchange (CTAGE) algorithm is proposed where the gradient information exchanged among agents is adopted to facilitate reaching consensus. To alleviate the communication overhead among agents, an adaptive event-triggered scheme (AETS) is adopted, which can dynamically adjust the threshold. Specifically, the threshold would hold when there are consecutive triggers, and it would decrease while the triggering condition is not satisfied for several steps. Then, theoretical results indicate that dynamic regret of CTAGE can reach sublinear upper bound. Finally, a target tracking example is utilized to demonstrate the usefulness of the proposed algorithm.

▶ SunC07-2 13:50–14:10

*Differential Dynamic Programming for Finite-Horizon Multi-Player Non-Zero-Sum Differential Games of Nonlinear Systems*

Zhang, Yuqi Beijing Univ. of Posts & Telecommunications
Zhang, Bin Beijing Univ. of Posts & Telecommunications (BUPT)

In this paper, an iterative algorithm based on differential dynamic programming (DDP) is developed to solve the finite-horizon multi-player non-zero-sum (NZS) games. By using the DDP, the coupled Hamilton-Jacobi (HJ) equations are expanded from partial differential forms to higher-order differential forms. By approximating the value functions and optimal control policies through several finite sets of basis functions, the DDP expansions are transformed into algebraic matrix equations in integral forms. Then a policy iteration (PI) algorithm is provided to solve the feedback Nash equilibrium of above NZS games. Finally, two simulation examples are given to demonstrate the feasibility of the developed algorithm.

▶ SunC07-3 14:10–14:30

*Event-Triggered Adaptive Gain-Varying Finite-Time Consensus Tracking Control for Multi-Manipulator Systems*

Zhao, Lin Qingdao Univ.

In recent years, with the increasing application demand of robot manipulators (RMs) in manufacturing industry, the research on the consensus tracking control of multiple RMs has attracted extensive attention, especially for the robots in complex working environment. Note that a large number of controller design algorithms have been proposed for RMs, which involve the adaptive control, $H_infty$ control, sliding mode control and so on. Besides, backstepping technique based on Lyapunov stability theory is also an easy-to-use controller design tool, which can skillfully combine many other advantageous algorithms. For example, the backstepping is utilized to solve the tracking issue of uncertain RMs with the help of adaptive control technique, and is also applied to the consensus tracking of multiple uncertain RMs. But the direct differentials of virtual controllers in backstepping process may cause the computational complexity problem. The dynamic surface control (DSC) utilizes the first-order filter to avoid the direct differentiation, but the filtering errors have hardly been removed in DSC-based backstepping strategies for RMs or multi-RM systems, which may affect the tracking precision to some extent. Furthermore, the finite-time control can improve the convergence speed and robustness through employing the fractional power signals, and the finite-time DSC strategy has been investigated. Taking the filtering process into account, the command filtered backstepping (CFB) with compensation strategy can eliminate the adverse affect of filtering process on the control precision while cutting down the computational complexity. The CFB method with finite-time convergence has been proposed, and the finite-time CFB (FTCFB) has been employed to control single systems or multi-agent systems and been also applied to the uncertain RMs or multi-RM systems respectively. It can be noted that all the above backstepping schemes are based on static gains.

As for the finally formed Lyapunov conditions $dotVleq - c_1V + c_2$ and $dotVleq - c_1V^a + c_2$, where $c_1$ and $c_2$ jointly determine the boundary of error convergence region. It can be found that $c_1$ depends on the self-selected gains, and $c_2$ depends on the disturbance amplitude and dynamics approximation error, so $c_2$ is hard to be reduced. Undoubtedly, the larger $c_1$, the faster the convergence rate and the smaller the convergence region. However, when the size of static gain exceeds a certain limit, the large $c_1$ will cause the large overshoot and violent controller chattering in the RM, that is, the stability of manipulator system will be seriously affected. If the value of $c_1$ can vary flexibly with the state of RM, the above contradiction can be alleviated to some extent. Fortunately, the time-varying gains can flexibly meet the control requirements and a number of time-varying gain-based strategies have been proposed for nonlinear systems. But for the RM or multi-RM systems, the time-varying gains based control methods are hardly considered. Furthermore, the dynamic gain-algorithm is not limited to the design based on time-dependent gains, and especially for the uncertain systems with irregular strong disturbances, the time-dependent dynamic gains may not be flexibly changed to maintain the system performance.

On the other hand, as for the waste of communication resources in many control schemes, the event-triggered mechanism can greatly reduce it and maintain fine control precision compared with the time-triggered mechanism. A number of event-triggered protocols save the communication cost between neighbor robots in the multi-RM systems. Moreover, there is another great waste of communication resources caused by frequent controller updating, and some available event-triggered control protocols have been given for the practical mechanical systems to reduce such waste effectively. However, most of the existing event-triggered backstepping control approaches are constructed based on static gains without considering the significance and design of dynamic control gains. Thus, the dynamic gains-based event-triggered CFB control, which focuses on reducing the updating frequency of controller for each RM, should be further considered for complex multi-RM systems. Especially, how to design the virtual control signals and error compensation under the dynamic gains and event-triggered mechanism remains a

challenging issue.
Based on the above discussion, the consensus tracking problem of uncertain multi-manipulator systems with disturbances is investigated in this article, a distributed adaptive gain-varying event-triggered finite-time control scheme is introduced. To connect the local error information and control gains, the suitable error-based gain-varying functions are added to static gains, so the anti-disturbance capability of the multi-manipulator system is enhanced when the strong disturbances appear. The command filters avoid the direct differentials of virtual controllers and the effect of filtering process is reduced by the compensation strategy. The event-triggered communication mechanism is further employed to reduce the waste of communication resources.

▶ SunC07-4 14:30–14:50
*Distributed Containment Control for Nonlinear HOFA-MASs*
Liu, Yang Beihang Univ. (BUAA)
Zhang, Jiaming Beihang Univ.

This work provides the distributed containment control protocols for nonlinear high-order fully actuated multi-agent systems (HOFA-MASs) under a directed communication topology graph. Based on the nonlinear HOFA model of the system, the closed-loop system can be always converted to a constant linear one with a desired eigenstructure by simplydesigning a controller. A reference generator is constructed for each follower by using the state information between its neighbors, then constructing the coordinate transformation so that each follower’ s output can track the corresponding virtual reference signal which is confined to the convex hull generated by the leaders. By using the radial basis function (RBF) neural networks (NNs) technique and the Lyapunov theorem of stability, the distributed controllers are designed for nonlinear HOFA-MASs with known nonlinear functions, nonlinear functions with unknown parameterizations and completely unknown nonlinear functions, which can guarantee that the outputs of followers can enter into the convex hull. Finally, the simulation results on robotic system demonstrate the availability of the designed protocols.

▶ SunC07-5 14:50–15:10
*LMS Algorithms Based on Fractional Order Gradient and Difference*
Mo, Lipo Beijing Tech. & Business Univ.
Zhang, Haozhe Beijing Tech. & Business Univ.

With the development of engineering technology, adaptive filtering algorithms have received increasing attention because of their powerful capabilities in signal processing and system control. As the main part of adaptive filtering theory, the least mean square (LMS) algorithm was proposed by Widrow and Hoff in 1959 based on the gradient descent method. Thanks to its simple structure, low computational complexity and stable performance, it has been widely used in some cutting-edge fields such as system engineering, aerospace, digital communication. Fractional calculus is a powerful mathematical tool for describing memory properties and intermediate processes, numerous studies have shown that fitting fractional calculus to LMS algorithm can effectively improve its convergence speed and accuracy while bringing a wider design freedom. This paper first devote to the study of fractional order gradient LMS algorithm (FOGLMS), which extends the first order gradient of LMS algorithm to fractional order. Since the LMS algorithm generally does not converge to the true extreme value point of the objective function when fractional order gradient is used. To ensure convergence, the strategy of truncating second order term of the fractional order gradient expansion of the objective function is adopted. The step size condition for convergence is given and the performance of the algorithm with different fractional orders is analyzed. It is shown that under certain conditions, a larger fractional order will lead a faster convergence speed. Next, in order to get better performance, based on FOGLMS, the fractional order difference is introduced to construct a double fractional order LMS algorithm (DFOLMS), in which a variable initial value strategy is adopted to ensure the convergence accuracy. Through a model approximation, the DFOLMS is transformed into two fractional order difference models to analyze its convergence and steady state properties indirectly. The results indicate that the DFOLMS has different convergence characteristics in different difference intervals; meanwhile, a larger difference order and gradient order will lead to a faster convergence speed but a larger steady state noise.

▶ SunC07-6 15:10–15:30
*Almost Sure Stability Analysis of Dual Switching Continuous-time Nonlinear System*
Mu, Qianqian Guizhou Univ.
Long, Fei Guizhou Univ.
Mo, Lipo Beijing Tech. & Business Univ.

In this paper, the almost surely globally asymptotical stability and the almost surely exponential stability for dual switching continuous-time nonlinear system are investigated by using the probability analysis method and stochastic Multi-Lyapunov functions, respectively. Different from the previous research results, it is the first time that dual switching continuous-time nonlinear system is used as a study object to investigate its switching stability. Then, the probability analysis method is used to overcome the deficiency that the ergodicity no longer holds due to the variable transition rate of Markov process. Some sufficient conditions for the globally asymptomatic stability almost surely and the almost surely exponential stability of dual switching continuous-time nonlinear system are given under the pre-designed deterministic switching strategy. Finally, two numerical examples are provided to verify the effectiveness of the proposed approach.

**SunD01** 15:40–17:40 2nd Conf. Hall
Invited Session: In-depth Exploration and Learning of Industrial Data II
Chair: Liu, Yi Zhejiang Univ. of Tech.
Co-Chair: Yao, Yuan National Tsing Hua Univ.

▶ SunD01-1 15:40–16:00
*An Adaptive Soft Sensor Method Based on Online Deep Evolving Fuzzy System for Industrial Process Data Streams*
Gao, Yu Kunming Univ. of Sci. & Tech.
Jin, Huaiping Kunming Univ. of Sci. & Tech.
Wang, Bin Kunming Univ. of Sci. & Tech.
Yang, Biao Kunming Univ. of Sciecnce & T
Yu, Wangyang Wuhan Maritime Communication Research Inst.

In recent years, deep learning techniques have been widely applied in soft sensor modeling. Stacked autoencoder (SAE) networks are particularly effective at discovering complex data patterns due to their hierarchical structures. However, process data are typically generated as data streams, which poses a great challenge to capture the time-varying characteristics of the process for traditional soft sensor models based on SAE. Furthermore, the insufficiency of offline pre-training data further limits the feature representation capability of SAE. To address these problems, an online deep evolving fuzzy system (ODEFS) based adaptive soft sensor method for process data streams is proposed. In the offline modeling phase, quality-related stacked autoencoder (QSAE) is pre-trained as representation layer to mine quality-related feature representations, while an evolving fuzzy system with self-organization capability is built as the prediction layer. In the online implementation phase, the topology-preserving loss is added to the learning process of QSAE feature network to enable continuous learning of feature representations and alleviate the catastrophic forgetting problem. Meanwhile, the shallow EFS network handles concept drift in data patterns by self-adjusting the structure and parameters. The proposed ODEFS method can improve the feature representation capability of SAE in a data streaming environment and the ability to handle time-varying characteristics, thus ensuring better prediction accuracy. The effectiveness and superiority of the proposed method are verified on TE process.

▶ SunD01-2 16:00–16:20
*A Soft Sensor Method Based on Unsupervised Multi-layer Domain Adaptation for Batch Processes*
Xiong, Qin Kunming Univ. of Sci. & Tech.
Jin, Huaiping Kunming Univ. of Sci. & Tech.
Wang, Bin Kunming Univ. of Sci. & Tech.
Liu, Haipeng Kunming Univ. of Sci. & Tech.
Yu, Wangyang Wuhan Maritime Communication Research Inst.

In batch processes, soft sensors frequently face the problem of irregular distributions between current and past data owing to variations in operating circumstances, as well as and poor model performing resulting from the absence with labels in the current data. This paper proposes a soft sensor method that is founded on dynamic multi-layer domain adaptation (DMDA). The method being proposed first training a convolutional neural network model with a substantial quantity of labeled data in the source domain, and subsequently use the obtained parameters as the beginning stage for the target model. Then, by utilizing multi-kernel maximum mean discrepancy (MK-MMD) and conditional embedding operator discrepancy (CEOD), the multi-layer convolutional neural network can effectively measure the difference in the overall (marginal) and specific (conditional) distributions between the source and target domains. Furthermore, the incorporation of an adaptive factor facilitates the dy-

namic adjustment of distribution weight, enabling precise fine-tuning of the target model. Finally, a regression model is established using the distribution-adapted historical data to achieve unsupervised soft sensor modeling. The substrate concentration in different fermentation tanks of the chlortetracycline fermentation process can be predicted through the utilization of the proposed approach. The experimental findings indicate that this method can accomplish tank-to-tank knowledge transfer, and significantly outperform traditional transfer learning-based soft sensor methods.

▶ SunD01-3 16:20–16:40

*Multi-objective Optimization for CCHP System Operation Based on NSGA-II Algorithm*

Zhu, Kai-Kai — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Wang, Yixin — Shanghai Univ.
Zhao, Guoqiang — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Jianlong — Shanghai Minghua Power Tech. Co., Ltd
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

In recent years, the Combined Cooling Heating and Power (CCHP) system has received extensive attention and applications. Nowadays, the pursuit of green and sustainable development of energy development needs to ensure the system economy while ensuring the energy saving and environmental of the system, so the multi-objective optimization research of CCHP system has been paid attention and this paper will comprehensively consider economic goals and environmental objectives, and carry out multi-objective optimization of the energy station CCHP system. Aiming at the problem that multiple objectives cannot achieve the optimal at the same time, it is proposed to use Pareto theory to solve the problem, and the Non-dominated Sorting Genetic Algorithms-II (NSGA-II) based on Pareto theory are used to optimize and solve it. Finally, experiments verify that the total daily operation cost and carbon dioxide treatment cost of the system are reduced after optimization.

▶ SunD01-4 16:40–17:00

*Choquet Integral-based Multimodal Fusion Strategy in the Application of Atherosclerosis Risk Prediction*

Xue, Yihang — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Chen, Rui — Shang Hai Univ.
Chang, Daoduo — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

Atherosclerosis (AS) is the main root cause of cardiovascular disease. In order to make full use of the information contained in different modals data for auxiliary diagnosis, this paper proposes a risk prediction method for AS based on multimodal fusion of three types of modal data (Risk factors, Chief complaints and Electrocardiogram), which are low-cost, non-invasive and easy to obtain. The three types of modal data are respectively input into the classical classifiers, Bi-LSTM and 1D-ResNet, and the corresponding preliminary prediction results can be obtained. Then, based on the Choquet integral, a decision-making mechanism is proposed to effectively fuse the information contained in the three types of modal data and obtain the final prediction results. The experimental results show that, compared with the existing multimodal fusion methods, the proposed method can significantly improve the index of recall and accuracy (Recall: 0.85, Accuracy: 0.88).

▶ SunD01-5 17:00–17:20

*Granger-Based Root Cause Diagnosis with Improved Backward-in-Time Selection*

Xue, Yihang — Shanghai Univ.
Chen, Rui — Shang Hai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Liu, Wei — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Jianlong — Shanghai Minghua Power Tech. Co., Ltd
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

With the emergence of data science and large number of sensor data, data-based disturbance root diagnosis methods have attracted widespread attention. Among these methods, the Granger causality test is one of the most common methods which can infer causal associations between signals based on temporal precedence. However, the causal effect between process variables often has some lag characteristics, but the response variable does not depend on all lag of the cause variable. The Granger causality analysis method based on VAR model does not consider the different lag dependency structures in the multivariate time series, which may lead to inaccurate causality test. In view of the above problems, this paper constructs the regression model through Improved Backward-in-Time Selection algorithm, realizes the supervised stepwise selection guided by the order of variable lag, obtains the optimal lag structure of the regression model through stepwise evaluation, and tests the Granger causality on this basis. The effectiveness of the proposed method is further proved by the fault source diagnosis experiment of Tennessee Eastman process.

▶ SunD01-6 17:20–17:40

*A Granger Causality Analysis Method Based on GRBF Network*

Chen, Huang — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Ding, Pang-Bin — Shanghai Univ.
Ye, Xiangyun — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Chen, He-Lin — Baoshan Iron & Steel Co. Ltd

Accurate and efficient fault root cause diagnosis is an effective means to prevent major accidents in industrial systems. Due to the difficulty of modeling complex systems, Granger causal analysis is widely used. Root cause diagnosis in the shortest possible time after a fault occurs can improve the accuracy of diagnostic results. Due to the strong nonlinear relationship in the short observation data, this paper introduces Generalized Radial Basis Function(GRBF) neural network of the nonlinear dimensionality reduction method into the Granger causal model to realize the root cause diagnosis of Granger faults based on the nonlinear short observation data. The effectiveness of the proposed method is verified by numerical simulation and fault diagnosis experimental study of Tennessee Eastman,(TE) chemical process. The results show that the proposed method improves the processing ability of Granger causal analysis for nonlinear causality, and can use a small amount of the fault data to complete accurate fault root cause diagnosis.

**SunD02** 15:40–17:40 3rd Conf. Hall

Invited Session: Modeling, Optimization and Control of Data-Driven Energy Internet Systems II

Chair: Li, Shengquan — Yangzhou Univ.
Co-Chair: Li, Feng — Jiangsu Univ. of Tech.

▶ SunD02-1 15:40–16:00

*Optimization Scheduling Strategy of Integrated Energy System Based on Improved Particle Swarm Optimization Algorithm*

Liu, Shiheng — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

In this paper, the integrated energy system with the goal of system economy is studied and analyzed and the optimal scheduling strategy of the integrated energy system is proposed under the condition of minimum operation cost. Firstly, considering the characteristics of electric cooling and heat system when different energy sources are co-supplying energy, the system optimization model of gas internal combustion engine, gas turbine and other units is established. Secondly, the improved particle swarm optimization algorithm is used to solve the system. Finally, the scheduling strategy to minimize the operation cost of the integrated energy system is given. The simulation results show that the proposed scheduling strategy and optimization method can effectively reduce the system operation cost and provide an early basis for the future planning of power supply system.

▶ SunD02-2 16:00–16:20

*Multi-objective Optimization of Electric-gas-thermal Integrated Energy System Based on Non-dominant Sorting Genetic Algorithm*

Liu, Lei — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.
Cao, Qingfeng — Yangzhou Univ.

With the development of the times, human society has put forward higher requirements on how to dispatch energy. In order to consider economic factor and environment factor, this paper proposed a dispatching plan with multi-objections promotion based on integrated energy system (IES). This system is composed of three parts, energy input part, energy

transform part and energy output part. Based on the system above, economic objective function and environmental objective function are constructed. And then, we use non-dominant sorting genetic algorithm (NSGA-Ⅱ) with elite strategy to calculate the pareto front of objection functions. As a result, economic factors and environmental factors are considered at the same time, energy utilization efficiency is the highest. And the rationality of the model is verified by case.

▶ SunD02-3 16:20–16:40

*Intermittent Semi-global Containment Control of Descriptor Multi-agent Systems with Input Saturation*

Li, Xiaofang — Lanzhou Univ. of Tech.
Wang, Zhiwen — Lanzhou Univ. of Tech.
Lu, Yanrong — Lanzhou Univ. of Tech.
Sun, Hongtao — Qufu Normal Univ.
Wang, Yuying — Lanzhou Univ. of Tech.

This paper studies intermittent semi-global containment control for continuous descriptor multi-agent systems (MASs) with input saturation under undirected communication topology. The premise of most of the existing work is based on continuous communication between agents, however, when the communication network between agents are disturbed or attacked, the agents can only communicate intermittently with their neighbors. In view of this, firstly, using the low gain method of parametric generalized algebraic Riccati equation (GARE), we propose a distributed aperiodic intermittent containment control strategy based on state feedback. Secondly, Using the generalized Lyapunov stability theorem, exponential stability theory and mathematical induction, the sufficient conditions for realizing intermittent semi-global containment control are obtained when the control rate of the descriptor MASs is larger than a fixed value. Lastly, numerical simulation is used to verify that the control strategy is correct .

▶ SunD02-4 16:40–17:00

*Bettering Iterative Solution Methods for Nonlinear Equations: A Control-Theoretic Perspective*

Ding, Shufen — Beihang Univ.
Meng, Deyuan — Beihang Univ. (BUAA)

This extended abstract aims to improve the trapezoidal Newton method for iteratively solving nonlinear equations from a control-theoretic point of view. The sufficient convergence conditions in terms of linear matrix inequalities are presented by interpreting the iterative solution process into a control framework of the Lure' s type nonlinear systems. In particular, the convergence conditions can be ensured for the initial conditions arbitrarily specified from the solving domain of interest, which relaxes the requirement on the initial evaluation of the conventional trapezoidal Newton method.

▶ SunD02-5 17:00–17:20

*Dynamic Event-triggered Fixed-time Average Consensus for Multi-agent Systems under Switching Topologies*

Ning, Xiaogang — Lanzhou Jiaotong Univ.
Li, Zonggang — Lanzhou Jiaotong Univ.

Aiming at the practical fixed-time average consensus problem of general continuous linear multi-agent systems under switching topologies, a distributed fixed-time consensus control protocol based on dynamic event-triggered mechanism is designed by using the local information exchange between individual agents. The protocol introduces internal dynamic variable, and the triggering condition changes in real time based on the dynamic variable obtained online, which can significantly reduce the number of triggering times, effectively reduce the energy dissipation of the system and the update frequency of the controller. Then, under the designed control protocol, the sufficient conditions for the multi-agent system to solve the practical fixed-time average consensus problem are given, and it is proved that there is no Zeno behavior in the system. Finally, the simulation results verify the effectiveness of the conclusions.

▶ SunD02-6 17:20–17:40

*Estimation of Wiener Model Based on Neural Fuzzy Network*

Qian, Shengyi — Jiangsu Univ. of Tech.
Ding, Zhenyu — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.

This paper proposes a two-stage parameter estimation approach of Wiener model based on correlation analysis method and Taylor series expansion theory. The developed Wiener model is characterized through the dynamic block modeled by a rational transfer function, followed by a nonlinear block based on neural fuzzy network. The input test signal consisting of Gaussian signal and random signal is applied to the parameter separation and estimation of Wiener model. Firstly, based on the input-output data of Gaussian signal measured, correlation analysis is used to obtain the parameters of the linear block. Then, using Taylor series expansion theory and clustering algorithm, the nonlinear block parameters are estimated based on random signals. Through theoretical derivation and experimental results, it can be seen that this method can usefully estimate the Wiener model with output noise and obtain favorable estimation accuracy.

**SunD03** 15:40–17:40 4th Conf. Hall

Regular Session: Data-driven Fault Diagnosis and Health Maintenance II

Chair: Zhang, Xinmin — Zhejiang Univ.
Co-Chair: He, Yan-Lin — Beijing Univ. of Chemical Tech.

▶ SunD03-1 15:40–16:00

*Quality Control and Feature Restoration of High-Speed Magnetic Flux Leakage Signals Based on Signal Compensation Method*

Xiao, Qi — Northeastern Univ.
Feng, Jian — Northeastern Univ.
Wang, Lei — Northeastern Univ.
Li, Qiangxin — Northeastern Univ.
Xu, Hang — Northeastern Univ.

Quality control of the magnetic flux leakage (MFL) signal plays a vital role in the integrity assessment of pipelines. However, most MFL detection suffers from low magnetization levels and large signal distortion due to the velocity effect. Current methods typically require the MFL tool to operate at relatively low inspection speeds, which will reduce detection efficiency. In this paper, a signal compensation method is proposed to address the issue. First, the formation mechanism of signal distortion in high-speed MFL detection is analyzed. Compared with previous studies, we find that the signal distortion is formed in two steps: longitudinal compression and oblique stretching. Second, the magnetic circuit between the MFL tool and the pipe is optimized to improve the pipe magnetization level. Finally, a signal compensation method is proposed to reduce the MFL signal distortion. Results validate the superiority of the proposed method in signal feature restoration. In general, our compensation method has the potential to improve detection efficiency and signal features.

▶ SunD03-2 16:00–16:20

*Rolling Bearing Fault Diagnosis Based on Time-frequency Transform-assisted CNN: A Comparison Study*

Song, Baoye — Shandong Univ. of Sci. & Tech.
Liu, Yiyan — Shandong Univ. of Sci. & Tech.
Lu, Peng — Shangdong Univ. of Sci. & Tech.
Bai, Xingzhen — Shandong Univ. of Sci. & Tech.

This paper is concerned with a comparison study on three time-frequency transform methods for CNN-based rolling bearing fault diagnosis, including short-time Fourier transform (STFT), continuous wavelet transform (CWT), and S-transform. The time-frequency transforms are exploited to transform the bearing fault data from 1D vibration signals to 2D time-frequency images, which are then fed into a dedicatedly designed 2D-CNN for fair performance comparison. To evaluate the performance of the time-frequency transform-assisted CNNs, several experiments are implemented based on the designed CNN and the bearing fault data. The superiority of S-transform assisted CNN is confirmed through the evaluation indicators calculated by the fault diagnostic results.

▶ SunD03-3 16:20–16:40

*A Remaining Useful Life Prediction Method with Degradation Model Calibration*

Ren, Chao — Xi'an Inst. of Hi-Tech
Li, Huiqin — Xi'an Inst. of Hi-Tech
Zhang, Zhengxin — Xi'an Inst. of High-Tech
Si, Xiaosheng — Xi'an Inst. of Hi-Tech

In the existing studies on statistical data-driven remaining useful life (RUL) prediction, degradation modeling is generally performed in the form of a fixed degradation model function. In this case, it is difficult to accurately predict the RUL of equipment by only updating the model parameters when the model function form is not selected properly. This paper proposes a method for predicting the RUL of equipment based on the degradation model calibration. First, a widely used linear Wiener proces based degradation model is initially constructed and the model parameters are updated based on the degradation monitoring data to predict the future degradation trend of equipment. Then, a data-driven

parametric error model is established to compensate for the initial degradation model using the prediction error data to calibrate the degradation model function. Concurrently, the parameters of the calibrated degradation model are estimated and updated by using the Bayesian method. As such, the functional form of the degradation model and the associated parameters can be calibrated at the same time. Finally, the superiority of the proposed method is verified by lithium battery data.

▶ SunD03-4 16:40–17:00

*Novel Autoencoder Based on Variable Correlation Analysis for Industrial Soft Sensing*


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|---|---|
| He, Yan-Lin | Beijing Univ. of Chemical Tech. |
| Guo, Shuaifeng | Beijing Univ. of Chemical Tech. |
| Xu, Yuan | BEIJING Univ. OF CHEMICAL Tech. |
| Zhu, Qunxiong | Beijing Univ. of Chemical Tech. |


In today's industrial processes, data-driven soft sensors are a frequently used tool for predicting quality variables. Autoencoder (AE) is an unsupervised algorithm which can extract latent features from initial data. However, during the feature extraction process, the traditional autoencoder does not consider the correlation between modeling input variables and quality variables to be predicted. To solve this issue, a novel autoencoder based on variable correlation analysis (VCA-AE) is proposed. In VCA-AE, the correlation of modeling input variables and quality variables to be predicted is performed by correlation analysis, and input variables are divided into two parts, which are input to the sub-autoencoder to extract latent features, respectively. In each sub-autoencoder, input variables and quality variables have the same correlation. Next, a feedforward neural network Extreme Learning Machine (ELM) is used to develop soft sensor model based on the extracted latent feature variables and quality variables. Finally, the effectiveness of the proposed soft sensor model combining VCA-AE and ELM is illustrated by an experiment of the industrial PTA process.

▶ SunD03-5 17:00–17:20

*Fault Diagnosis for Rolling Bearings Based on Novel Visibility Graph and GCN Scheme*


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|---|---|
| Gao, Shoupeng | Univ. of Jinan |
| Li, Yueyang | Univ. of Jinan |
| Zhao, Dong | Beihang Univ. |


Recently, the field of intelligent fault diagnosis has made great breakthroughs and achievements since feature extraction has a powerful ability to learn data. However, in non-Euclidean spaces, the types of bearing fault relationships are complex and the number of relationships is inconsistent, resulting in traditional deep learning methods that cannot accurately mine the potential relationships between fault information. To solve this problem, we propose a fault diagnosis method for rolling bearings based on a novel visibility graph (VG) and a new graph convolution neural (GCN) network. Specifically, a novel weighted visibility graph (WVG) method which can convert time series data into graph data is proposed. It can superiorly reflect the complex relationship between each factor in bearing fault diagnosis. In order to achieve fault diagnosis in the way of graph classification, we propose a new method SGIN+. It combines GraphSAGE and an improved graph isomorphic network (GIN), so that it can accurately learn the graph structure in large-scale classification tasks. The effectiveness of both WVG and SGIN+ is verified by a real bearing dataset.

▶ SunD03-6 17:20–17:40

*Inference Attack and Privacy Security of Data-driven Industrial Process Monitoring Systems*


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|---|---|
| Zhang, Xinmin | Zhejiang Univ. |
| Zhang, Xuerui | Zhejiang Univ. |
| Song, Zhihuan | Zhejiang Univ. |
| Ren, Qinyuan | Zhejiang Univ. |
| Wei, Chihang | Hangzhou Normal Univ. |


In modern industry, data-driven process monitoring systems (PMS), as the initial defense line of industrial control system security, have been widely used in all walks of life. However, the privacy security of the data-driven PMS itself has rarely or never received serious attention. Once the data-driven PMS suffers from intrusion and malicious attacks, it will not only interfere with the normal operation of the industrial control system, but also lead to the disclosure of industrial confidential and privacy information and major economic losses. To handle this issue, this work proposes a novel pioneering study on the inference attack and privacy security problem in the data-driven PMS. Firstly, the potential attack and privacy violation risks of data-driven PMS are investigated. Second, a novel industrial inference attack and privacy security benchmark on data-driven PMS is presented, in which a series of membership inference attack and defense experiments are designed and conducted. Third, we provided a detailed discussion about which member reasoning attacks are the most potential threats to the data-driven PMS and which defense technologies are most suitable for mitigating the attack. The experimental results will provide researchers and practitioners with a new perspective when designing a novel data-driven PMS with more robust and privacy protection performance.

**SunD04** 15:40–17:40 5th Conf. Hall

Regular Session: Statistical Learning and Machine Learning in Automation Field

Chair: Zhang, Hongwei — Zhejiang Univ.

Co-Chair: Han, Yongming — Beijing Univ. of Chemical Tech.

▶ SunD04-1 15:40–16:00

*Network Intrusion Detection Method Based on Conditional Generative Adversarial Network Integrating Multi-scale CNN*


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|---|---|
| Geng, Zhiqiang | Beijing Univ. of Chemical Tech. |
| Xi, Xiang | Beijing Univ. of Chemical Tech. |
| Hu, Xuan | Beijing Univ. of Chemical Tech. |
| Han, Yongming | Beijing Univ. of Chemical Tech. |


Data imbalance is a key problem existing in most network traffic datasets that restricts the performance of intrusion detec-tion. In addition, traditional intrusion detection methods are insufficient to extract features of network traffic effectively, which result in low detection accuracy. Therefore, a novel intrusion detection method based on the conditional Generative Adversarial Network (CGAN) integrating the improved Multi-scale Convolution Neural Network (MSCNN) is proposed to deal with the problem of data imbalance and improve the classification performance. In the level of data, the CGAN is applied to generate minority network traffic samples to decrease the false alarm rate of intrusion detection. In the level of the neural network, the MSCNN of novel structure adapt to the network traffic is applied to promote the detection per-formance by using multiple convolution kernels for feature extraction. According to the experimental result on UNSW-NB15 and CIC-IDS2017 datasets, the proposed method can detect the network traffic of minority classes effec-tively, and acquires higher detection accuracy and F1-score compared with other existing methods, which proves the pro-posed method is advanced in network intrusion detection.

▶ SunD04-2 16:00–16:20

*A Variable Projection-based Parameter Estimation Algorithm for the Nonsmooth Separable Nonlinear Problems*


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|---|---|
| Cheng, Siqing | Fuzhou Univ. |
| She, Yuexin | Fuzhou Univ. |
| Wang, Yaping | Fuzhou Univ. |


In this paper, we consider the identification of RBF-type models with nonsmooth constraint, where the parameters can be partitioned into a linear part and a nonlinear part. Taking advantage of this special structure, we design a variable projection-based parameter estimation algorithm for the optimization of the RBF-type models with nonsmooth constraint. The proposed algorithm decomposes the original optimization problem into an inner subproblem and an outer subproblem. The linear parameters are eliminated by solving the easier solved inner problem, resulting in a reduced function that only contains nonlinear parameters. Then we separately utilize the proximal gradient method to optimize the linear parameters and trust region method to optimize the remaining nonlinear parameters. Simulation results on synthetic data and real-world data confirm the efficiency and effectiveness of the proposed algorithm.

▶ SunD04-3 16:20–16:40

*Time Series Generator Adversarial Network with Stochastic Process for the Degradation Generation and Prediction*


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|---|---|
| Shangguan, Anqi | Xi'an Univ. of Tech. |
| Feng, Nan | Xi'an Univ. of Tech. |
| Mu, Lingxia | Xi'an Univ. of Tech. |
| Fei, Rong | Xi'an Univ. of Tech. |
| Hei, Xinhong | Xi'an Univ. of Tech. |
| Xie, Guo | Xi'an Univ. of Tech. |


Since the cumbersome collection process and high cost, the collected degradation of the product is basically small samples, which will affect the accuracy of reliability evaluation. It is necessary to expand the degradation to improve the accuracy of later reliability assessment. Therefore, a degradation generation and prediction method is proposed combining the time series generator adversarial network (TimeGAN) and stochastic

process. Firstly, the input degradation is expanded by the sliding window to improve the later training accuracy; Then, the construction of the generator in TimeGAN is linked with the stochastic process to make the generation data more realistic. Finally, the results of degradation prediction by the Gated Recurrent Unit (GRU) can be obtained. Two datasets and different generation methods are adopted to evaluate the effectiveness of the proposed method. The results shows that the Kullback-Leibler(KL) divergence is the smallest, and the prediction error is the smallest compared with the other methods. So, the proposed method is proved that it isvalid in the degradation generation and prediction, and can be used for the further reliability assessment of the product in the industrial system.

► SunD04-4 16:40–17:00

*Comparative Study on Segmentation Methods of Fundus Images*

Cao, Juan Chongqing Jiaotong Univ.
Liu, Jinjia Chongqing Jiaotong Univ.

As a traditional image segmentation method, image segmentation methods based on threshold, edge detection, and region have some differences in the effect of fundus image segmentation. In this paper, the watershed algorithm, Ostu, and Canny operator edge detection algorithms are selected for comparative study. By comparing the segmentation effects of 28 medical fundus images, the experimental results show that the Ostu has the highest segmentation accuracy and the best segmentation effect.

► SunD04-5 17:00–17:20

*Dual Attention Embedded Reconstruction Distillation for Unsupervised Yarn-dyed Fabric Defect Detection*

Zhang, Hongwei Zhejiang Univ.
Liu, Shuaibo Xi 'an Polytechnic Univ.
Meng, Liping Xi'an Polytechnic Univ.
Lu, Shuai Beijing Univ. of Chemical Tech.
Li, Pengfei Xi'an Polytechnic Univ.

Detecting defects of yarn-dyed fabrics automatically in industrial scenarios can improve economic efficiency, but the scarcity of defect samples makes the task more challenging in the customized and small-batch production scenario. At present, most reconstruction-based methods have high requirements on the effect of reconstructing the defect area into the normal area, and the reconstruction performance often determines the final defect detection result. To solve this problem, this paper proposes an unsupervised learning framework of dual attention embedded reconstruction distillation (DAERD). Firstly, different from the encoder-encoder structure of traditional distillation, the teacher-student network in this paper adopts the encoder-decoder structure. The purpose of the student network is to restore the normal feature representation of the pre-trained teacher network. Secondly, this paper proposes a dual attention residual module (DARM), which can effectively remove redundant information and defective feature information from the teacher network through the double feature weight allocation mechanism. This helps the student network to recover the normal feature information output by the teacher network. Finally, the multi-level training deployment at the feature level in this paper aims to make the model obtain accurate defect detection results. The proposed method has been experimentally verified on the YDFID-1 dataset. The results show that this method has good performance in detecting and locating fabric defects.

► SunD04-6 17:20–17:40

*Adaptive Quasi-Newton Algorithm for Remote Sensing*

Wang, Jun Soochow Univ.
Yu, Wenbo Soochow Univ.
Huang, He Soochow Univ.

Recurrent neural networks (RNNs) have been widely applied to model time series and temporal data due to inherent memory storing past information. However, the optimization algorithms for RNNs either only exploit the first-order information with low computational complexity or gain the second-order information with heavy per-iteration cost. In this paper, an adaptive quasi-Newton algorithm (ADA-L-BFGS) is proposed on the basis of limited-memory BFGS algorithm whose memory size can be determined adaptively during the process of iteration and used to train deep neural networks for extracting deep features of hyperspectral data. Our algorithm can retain low per-iteration cost and ensure fast convergence. It is emphasized that ADA-L-BFGS has two appealing features. One is that multiple memory sizes are selected to construct hybrid search direction for strengthening the usage of recent curvature information. Another is that a promising calculation criterion for step size is introduced to achieve efficient training of deep neural networks for hyperspectral images classification. Experimental results clearly illustrate that the proposed ADA-L-BFGS can achieve faster convergence and better performance than previous methods.

**SunD05** 15:40–17:40 6th Conf. Hall

Invited Session: Model-free Control, Optimization and Their Applications

Chair: Xu, Dezhi Jiangnan Univ.
Co-Chair: Mao, Zehui Nanjing Univ. of Aeronautics & Astronautics

► SunD05-1 15:40–16:00

*Frequent Real-time Optimization Using Dynamical Disturbance Observers*

Ye, Lingjian Huzhou Univ.
Shen, Feifan Ningbo Inst. of Tech., Zhejiang Univ.
Zhou, Zhe Huzhou Univ.
Yang, Zeyu Huzhou Univ.

The presence of disturbances and uncertainties calls for real-time optimization (RTO) of chemical processes, such that the operational optimality is restored. The classical formulation of the two-step RTO relies on steady state measurements for model updates and re-optimization, which is often slow in the optimizing performance. To accelerate the RTO speed, this paper proposes a new frequent RTO scheme that can be performed in the transient phase. In the control community, the dynamic disturbance observers have been widely adopted for setpoint tracking. In this study, the disturbance observers are employed to identify and compensate the plant-model mismatches for the RTO purpose. Efficient dynamic disturbance estimation makes it possible to extract information that is required for performing the static optimizations, without the need of reaching steady states. A CSTR example is studied to illustrate the proposed approach.

► SunD05-2 16:00–16:20

*Fractional Order Terminal Sliding Mode Observer for State of Charge Estimation of Lithium-Ion Battery*

Ma, Yunchen Jiangnan Univ.
Xu, Dezhi Jiangnan Univ.
Yang, Weilin Jiangnan Univ.
Pan, Tinglong Jiangnan Univ.
Ding, Yueheng Univ. of Kent

Lithium-ion battery is widely used for its high energy density, long cycle life, non-pollution and other advantages. They are expected to be mainstream power source for future applications on electrochemical energy storage. However, it has been a long-standing problem to obtain an accurate real-time state estimation for lithium-ion battery with high nonlinearity and inevitable inconsistency. In this paper, the design of a new estimation method for state of charge (SOC) of lithium-ion battery is introduced. Based on the equivalent Thevenin model, a fractional order sliding mode observer is proposed to estimate terminal voltage, SOC and polarization voltage and the stability proof is given. Compared to the frequently-used Kalman filter method and the current integration method, this method shows higher accuracy and robustness. As a result, the feasibility of the proposed method is verified.

► SunD05-3 16:20–16:40

*Multi-agent Adaptive Virtual Inertia Cooperative Control of AC/DC Microgrid Based on Virtual Synchronous Generators*

Dou, Zhenlan State Net Overseas Integrated Energy Service Co., Ltd
Tang, Lianqing Jiangnan Univ.
Zhang, Chunyan State Grid Shanghai Municipal Electric Power Company
Yang, Haitao STATE GRID SHANGHAI SHIBEI ELECTRIC POWER SUPPLY COMPANY
Han, Dong State Grid Shanghai Municipal Electric Power Company
Jiang, Jingjing STATE GRID SHANGHAI SHIBEI ELECTRIC POWER SUPPLY COMPANY
Xu, Dezhi Jiangnan Univ.

Driven by new energy technology, the scale of AC/DC micro-grid connected to the power grid is growing. In order to make distributed power source have similar inertia support and damping characteristics as synchronous generator (SG), virtual synchronous generator (VSG) technology is introduced into inverter control. To solve the problems of frequency consistency and oscillation in the parallel operation of multiple VSGs, a multi-agent adaptive virtual inertia cooperative control strategy based on VSGs is proposed. Firstly, an advanced control method based on phase-

locked loop is introduced to suppress the impact of frequency and power caused by grid connection. Then, a multi-agent adaptive virtual inertia cooperative control strategy is proposed to shorten the adjustment time required for the system to reach stability and improve the transient performance of the system. Finally, the simulation experiment verifies that the proposed control strategy can make the frequency of the parallel VSGs reach the same quickly, weaken the oscillation phenomenon in the frequency regulation process, and improve the transient performance of the system.

▶ SunD05-4 16:40–17:00

*Data-driven Fault-tolerant Controller Design for Hypersonic Vehicles with Sensor Fault*


| | |
|---|---|
| Han, Jingtian | Huazhong Univ. of Sci. & Tech. |
| Fan, Huijin | Huazhong Univ. of Sci. & Tech. |
| Liu, Lei | Huazhong Univ. of Sci. & Tech. |
| Wang, Bo | Huazhong Univ. of Sci. & TTech. |


A data-driven fault diagnosis and fault-tolerant control method are proposed for the problem of sensor faults in the attitude system during hypersonic vehicle flight. Firstly, a sliding window-based fault detection method is proposed by analyzing the residuals of the real-time data. Then, based on the support vector machine (SVM), a fault identification model is designed to classify the faults using the time domain feature parameters in the fault process. The fault dynamic response process is analyzed and the fault estimation method is proposed. Finally, the controller is designed based on the improved full-form dynamic linearization model-free sliding mode control (FFDL-MFSMC) method. And the effectiveness of the proposed fault tolerance strategy is illustrated by simulation.

▶ SunD05-5 17:00–17:20

*Observer Based Model-Free Adaptive Iterative Learning Constrained Control for Nonlinear Systems*


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|---|---|
| Hua, Fei | Jiangnan Univ. |
| Zhang, Weiming | Jiangnan Univ. |
| Lu, Wenzhou | Jiangnan Univ. |
| Xu, Dezhi | Jiangnan Univ. |


In this paper, the large class of nonlinear control systems with repeating tasks are addressed by the proposal of a new model-free adaptive iterative learning (MFAILC) constrained control strategy. With the aid of the compact form dynamic linearization (CFDL) technique, a new observer-based pseudo partial derivative (PPD) iterative estimation algorithm is created. Then, an anti-windup compensator would be suggested to modify reference trajectory in to avoid parameter expansion and system instability, with the goal of solving the input constraint problem driven on by actuator saturation. Furthermore, an iterative constrained controller is proposed and the stability of the controller is proved. Finally, it is demonstrated by numerical simulation that the suggested control algorithm has excellent tracking capability and reliability.

▶ SunD05-6 17:20–17:40

*Formation Control Method Based on Guidance and LADRC for Underactuated USVs*


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| Ma, Yuhe | Tianjin Univ. |
| Hu, Chaofang | Tianjin Univ. |
| Xiang, Yiyi | Tianjin Univ. |


In this work, to deal with the formation problem of underactuated Unmanned Surface Vehicles (USVs) with obstacle avoidance, the synthesized formation control strategy based on Line-of-Sight (LOS) guidance law and the Linear Active Disturbance Rejection Control (LADRC) method is proposed. Firstly, the mathematical model of the USV is established. Secondly, the formation controller is designed according to the LOS guidance law. Then the Artificial Potential Field (APF) method is introduced to solve the obstacle avoidance problem. Moreover, the LADRC method is used to realize the motion control. The simulation results show that the formation control method works well.

**SunD06** 15:40–17:40 Yuetang Conf. Hall

Invited Session: Model Predictive Control of Cyber-physical Systems

Chair: He, Ning Xi'an Univ. of Architecture & Tech.

Co-Chair: Wang, Xin Heilongjiang Univ.

▶ SunD06-1 15:40–16:00

*Distributed Model-Free Adaptive Command-Filter-Backstepping Sliding Mode Control for High-Order Multi-Agent Systems Consensus Tracking*


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| Chen, Mingchao | Shenyang Aerospace Univ. |
| Liu, Dong | Shenyang Aerospace Univ. |


This paper investigates the distributed sliding mode control for high-order multi-agent systems. First, a sliding mode control algorithm with backstepping method is proposed to consensus tracking of high-order multi-agent systems. Furthermore, due to the complexity explosion caused by backstepping method, the discrete-time command filters is introduced to eliminate the influences of complexity explosion. Next, the observer which only using I/O data is designed to estimate the pseudo-partial derivative. Finally, the effectiveness of the proposed method is verified by simulation result.

▶ SunD06-2 16:00–16:20

*Nonlinear Large Maneuver Control of Thrust Vector UAV for Flying-Wing Layout*


| | |
|---|---|
| Chen, Zhuoying | Northwestern Polytechnical Univ. |
| Li, Huiping | Northwestern Polytechnical Univ. |
| Chen, Huaimin | Northwestern Polytechnical Univ., |
| Zhou, Shaobo | Northwestern Polytechnical Univ. |


The flying-wing layout UAV (Unmanned Aerial Vehicle) adopts the aerodynamic layout of wing-body fusion. Compared with conventional aircraft, the cancellation of vertical tail and other protruding components reduces the cross-sectional area of radar reflection, but also brings about directional static instability, transverse & longitudinal aerodynamic coupling and other defects, which bring challenges to the design of control law. Therefore, an improved dynamic inverse algorithm is proposed in this paper, which constructs a pseudo-linear system to eliminate nonlinear factors of the original system. Moreover, the effectiveness of the method is verified by route-tracking simulation. Since the relative shorter steering force arm and rapid decrease of control surface efficiency, flying-wing UAV is difficult to realize maneuver flight only by relying on the aerodynamic moment. Therefore, this paper designs a control allocation method based on serial-chain. The additional control moment generated by the vector thrust is used to compensate for the shortage of aerodynamic moment. The maneuverability of the aircraft is effectively enhanced and the simulation of Immelman large maneuver is completed

▶ SunD06-3 16:20–16:40

*Fault-Tolerant Intermediate Estimator-Based Output Feedback Control for A Class of Interconnected Systems with Nonlinear Coupling Interconnections*


| | |
|---|---|
| Ma, Zhijuan | Heilongjiang Univ. |
| Yu, Tingting | Heilongjiang Univ. |
| Wang, Xin | Heilongjiang Univ. |


The problem of decentralized output feedback fault-tolerant control (FTC) of networked interconnected systems with actuator faults and unreliable interconnections is addressed in this paper. An intermediate estimator based fault reconstruction method and a decentralized FTC scheme are designed. In comparison to previous results, the proposed decentralized FTC approach deals with interconnected dynamical systems that have unknown nonlinear interconnections and unreliable connections. In addition, by combing intermediate estimate algorithm and decentralized FTC scheme, it is proved that the estimation errors and interconnected systems are uniformly ultimately bounded (UUB), which is analyzed by applying the Lyapunov method and algebraic graph theory. Finally, the simulations on networked chemical reactor recycles servo systems are given to validate the effectiveness of the proposed FTC scheme.

▶ SunD06-4 16:40–17:00

*A Cyber-security Framework for ST-MPC of State and Input Constrained CPS under False Data Injection Attacks*


| | |
|---|---|
| He, Ning | Xi'an Univ. of Architecture & Tech. |
| Li, Yuxiang | Xi'an Univ. of Architecture & Tech. |
| Ma, Kai | Xi'an Univ. of Architecture & Tech. |


Self-triggered model predictive control (ST-MPC) is widely applied in various aspects currently, however, the STMPC mechanisms that have seldom been developed consider the possible malicious false data injection (FDI) attacks in the cyber-physical system (CPS). Therefore, in this paper, a novel resilient ST-MPC strategy based on input reconstruction (IR) against FDI attacks is proposed for a nonlinear input-affine discrete-time system with state and input constraints, which combines both cyber security and resource consumption. More specifically, when faced with FDI attacks in controller-to-actuator (C-A) channels at the triggering instants, on the actuator side, two key control data are selected to reconstruct input control signals for application into the system, otherwise, the optimal input control signals will be applied into the controlled system. Furthermore, a resilient ST-MPC algorithm with a dual-mode control strategy is proposed, and its closed-loop stability is also analyzed, in which the state constraint is elaborated. Finally, a simulation and its resultant com-

parisons illustrate the effectiveness of the proposed method.

▶ SunD06-5 17:00–17:20

*An Improved Method for Calculating the Meshing Clearance of Cycloidal Pin Wheel*


| | |
|---|---|
| Zhou, Shidong | Jiangsu Univ. of Tech. |
| Han, Zhenhua | Jiangsu Univ. of Tech. |
| Li, Rirong | Jiangsu Univ. of Tech. |
| Du, Youwu | China Univ. of GeoSci. |
| Wang, Hao | Jiangsu Univ. of Tech. |


At present, the traditional method for calculating the meshing clearance of cycloidal pinwheel in RV reducer only considers a special position, which leads to some differences between the theoretical result and actual value. Therefore, an improved method for calculating circumferential clearance of cycloidal pinwheel is proposed. The method considers the motion form of cycloidal wheel, and takes the minimum arc length in the rotation direction of the cycloidal gears as the circumferential clearance. Based on the transformation mechanism method and the coordinate transformation principle, a geometric analysis model for the circumferential clearance is established. Analyzing the circumferential clearance under different input angle, the results show that the circumferential clearance presents a periodic change, and its period is the angle between adjacent pin teeth.

▶ SunD06-6 17:20–17:40

*Dynamic Modeling and Transmission Error Analysis of Cycloid Drive Based on Variable Clearance*


| | |
|---|---|
| Zhou, Yunchen | Jiangsu Univ. of Tech. |
| Han, Zhenhua | Jiangsu Univ. of Tech. |
| Wang, Hao | Jiangsu Univ. of Tech. |
| Du, Youwu | China Univ. of GeoSci. |
| Li, Rirong | Jiangsu Univ. of Tech. |


In order to precisely construct the nonlinear dynamic analysis model of the N-cycloidal pin reducer in the transmission process, the paper employs the Load tooth contact analysis (LTCA) to determine the time-varying meshing clearance and the time-varying torsional stiffness, and it takes into account the influence of the revolution displacement and meshing damping of the cycloid gear pair. Based on the lumped parameter method build a six degree of freedom (DOF) nonlinear dynamic analysis model. The dynamic differential equation is deduced using the general Lagrange function. Then, using the fourth-order Runge Kutta method to calculates the dynamic response. The transmission errors (TE) under various examples of profile modification are calculated and analyzed through the result of dynamic response. The results show that the transmission error value and the fluctuation increase with the meshing clearance, leading to a decrease in reducer stability.

**SunD07** 15:40–17:40 Hongqi Conf. Hall

Invited Session: Data-driven Motion and Vibration Control for Micro/Nano Scale Positioning Systems

Chair: Liu, Yang Harbin Inst. of Tech.

Co-Chair: Song, Fazhi Harbin Inst. of Tech.

▶ SunD07-1 15:40–16:00

*Position Control of X-Y Precision Planar Motion Stage Based on Iterative Learning and Cross-coupling*


| | |
|---|---|
| Fang, Jingzhe | Shenyang Univ. of Tech. |
| Zhang, Tao | Shenyang Inst. of Automation Chinese Acad. of Sci. |
| Chen, Xi-You | Dalian Univ. of Tech. |
| Qi, Chen | Dalian Univ. of Tech. |
| Zhang, Guopeng | Shenyang Univ. of Tech. |
| Zhang, Hualiang | Chinese Acad. of Sci. |
| Yan, Hongyu | Shenyang Univ. of Tech. |


In some precision machining applications, not only should we pay attention to the tracking accuracy of the X-Y precision plane motion table, but the more important criterion is the contour accuracy. This paper proposes an adaptive iterative learning control that adjusts in real time with the system's working state for the X-Y precision plane motion stage control system. Then on the basis of adaptive iterative learning control, the relationship between the two axes is established by cross-coupling control, the contour error of the system is calculated in real time, and the stability of the system is improved. The final experimental results show that the improved algorithm has smaller contour error and better robustness.

▶ SunD07-2 16:00–16:20

*Data-driven Feedforward Tuning Algorithm Based on Self-adaptive Hybrid Self-learning TLBO*


| | |
|---|---|
| Chen, Siwen | Harbin Inst. of Tech. |
| Liu, Yang | Harbin Inst. of Tech. |
| Song, Fazhi | Harbin Inst. of Tech. |


Data-driven feedforward tuning algorithm, extensively used in ultra-precision motion stage, can significantly compensate tracking errors and optimize task adaptability.However, the rational basis based feedforward optimization usually faces non-convex optimization, numerical stability and initial value problems. The purpose of this paper is to propose a feedforward tuning algorithm based on the heuristic method self-adaptive hybrid self-learning TLBO . The algorithm can converge to the ideal feedforward parameter, so that the system can achieve high tracking accuracy, and has good numerical properties and low initial value requirements. The effectiveness and superiority of the proposed method are verified by simulation.

▶ SunD07-3 16:20–16:40

*Adaptive Learning Control with Extended Bandwidth for Synchronization Motion Stages*


| | |
|---|---|
| Sun, Pengyu | Harbin Inst. of Tech. |
| Song, Fazhi | Harbin Inst. of Tech. |
| Chen, Shuaiqi | Harbin Inst. of Tech. |
| Liu, Yang | Harbin Inst. of Tech. |


This paper proposes a novel method to improve synchronization precision and reduce the influence of stochastic noises in lithography motion stages. Specifically, the multiple-channel adaption-learning-function synchronization iterative learning control (MASILC) method we give uses a multiple-channel approach based on A-type of ILC, with adaptive parameters to address the divergence situation caused by stochastic noises in different channels. We verify the superiority of the MASILC method and analyze its stability and convergence performance in theory. Furthermore, we introduce an effective adaptive method inspired by the stochastic acceleration optimization method. Simulation comparisons with analogous approaches demonstrate the effectiveness and superiority of the proposed method in various circumstances.

▶ SunD07-4 16:40–17:00

*Iterative Control Decoupling Tuning by Feedforward Compensation for Precision Motion Stage*


| | |
|---|---|
| Zhao, Hongyang | Harbin Inst. of Tech. |
| Li, Li | Harbin Inst. of Tech. |
| Liu, Yang | Harbin Inst. of Tech. |


Abstract: In multi-input multi-output (MIMO) ultra-precision motion control system, high-performance decoupling method is the key to reduce the interactions between different degree of freedoms (DOFs). However, the manufacturing and assembling errors will greatly affect the decoupling performance. Some non-negligible factors, such as the center of gravity (Cog) and actuator positions, cannot be accurately determined, which will deteriorate the control accuracy. To tackle this problem, an iterative control decoupling tuning method by feedforward compensation is proposed in this paper. The proposed strategy using feedback signal to tune the parameters of feedforward compensator iteratively and further compensate for the closed-loop dynamics. The simulation results show that the proposed method is more effective, including the convergence accuracy, convergence speed and the improvement of the tracking error caused by the coupling.

▶ SunD07-5 17:00–17:20

*Event-triggered Extended Kalman Filter for UAV Monitoring System*


| | |
|---|---|
| Zang, Yunge | Beijing Aerospace Automatic Control Inst. |
| Li, Yan | Beijing Aerospace Automatic Control Inst. |
| Duan, Yuting | Beijing Aerospace Automatic Control Inst. |
| Li, Xiangyu | Beijing Aerospace Automatic Control Inst. |
| Chang, Xi | Beijing Aerospace Inst. for Metrology & Measurement Tech. |
| Li, Zhen | Beijing Inst. of Tech. |


To facilitate ground station monitoring and command uploading, unmanned aerial vehicles (UAVs) need to frequently exchange individual state data between units. However, this results in a significant usage of communication bandwidth. To address this issue, on the basis of an event-triggered strategy, this paper proposes an Extended Kalman Filter (EKF). aimed at reducing the communication burden of UAVs while maintaining high accuracy. Specifically, a state measurement triggered by an event is selected for filtering only if it contains innovation, thereby reducing the amount of data that needs to be communicated. Since UAV systems are nonlinear, EKF is adopted to fully utilize the information obtained from event-triggered strategies, thereby enhancing the estimation

performance. In this paper, a physical UAV was used to verify the proposed algorithm, and it proved to have robust dynamic performance and to effectively reduce the communication rate.

▶ SunD07-6 17:20–17:40

*Load Tooth Contact Analysis of Composite Cycloidal Planetary Transmission with Small Tooth Difference*


| | |
|---|---|
| Zhou, Shuhan | Jiangsu Univ. of Tech. |
| Han, Zhenhua | Jiangsu Univ. of Tech. |
| Zhou, Yunchen | Jiangsu Univ. of Tech. |
| Zhao, Yunda | Jiangsu Univ. of Tech. |
| Wang, Hao | Jiangsu Univ. of Tech. |
| Du, Youwu | China Univ. of GeoSci. |


Based on the profile equation of composite cycloidal tooth, the coordinate system of the contact analysis model of composite cycloidal gear teeth is established. Depending on the conjugate contact conditions of gears, the vector equation of tooth contact analysis (TCA) is created. The backlash and transmission error of the composite cycloidal planetary gear pair with small tooth difference (Abbreviated as compound cycloidal gear pair) after modification are calculated by solving the equation. The load tooth contact analysis (LTCA) model of the composite cycloid is built using Hertzian contact theory, a moment balancing equation, and deformation compatibility condition. The composite cycloidal transmission error and contact force in the load tooth contact analysis mode are solved. The distribution of contact force under different crank shaft angles and the sensitivity of bearing transmission error and contact force to tooth profile adjustment coefficient are analyzed with examples. The results show that the transmission accuracy of composite cycloid gears under load conditions is within 1 arcmin, which meets the requirements for precision transmission performance.

# Author Index

(C=Chair, CC=Co-Chair)


**A**

Abdurahman, Abdujelil ... SunA08-42 71
Ai, Wei ... SunB06 CC
... SunB06-5 80

**B**

Bai, Weiwei ... SunA03 CC
... SunA03-3 61
Bai, Xingzhen ... SunD03-2 99
Bai, Zhiqiang ... SunC05-6 95
Bian, Yongming ... SunA08-01 64
Bo, Guihua ... SatB02-2 53
... SunA02-6 60
Bu, Xuhui ... SunA08-22 68

**C**

Cai, Changchun ... SunC02-5 92
Cai, Yu ... SunA08-51 72
Cao, Bo ... SatA03-6 47
Cao, Guanghao ... SunB08-32 86
Cao, Jiang ... SunB01-4 75
Cao, Juan ... SunD04-4 101
Cao, Liang ... SunA05-2 62
Cao, Qingfeng ... SunD02-2 99
Cao, Rongmin ... SunA08 CC
... SunA08-06 65
... SunA08-07 65
... SunA08-58 73
Cao, Wei ... SunC02-2 92
Cao, Yan ... SunA04-3 61
Cao, Yongjian ... SunC02-1 92
Cao, Yukun ... SunA08-45 71
Chai, Haoyu ... SunB08-44 88
Chai, Xuzhao ... SunB08-06 82
Chai, Yanchao ... SunC04-4 94
Chang, Daoduo ... SunD01-4 98
Chang, Debiao ... SunA08-06 65
... SunA08-07 65
... SunA08-58 73
Chang, Xi ... SunD07-5 103
Che, Wei-Wei ... SunC03 CC
Chen, Baicheng ... SunB02-5 76
Chen, Bangju ... SunA08-62 74
Chen, Chao-Yang ... SunC04-2 93
Chen, Guangdeng ... SunB04-1 78
Chen, Guangyong ... SunA08-36 70
... SunA08-40 70
Chen, Hao ... SunA06-1 63
Chen, He-Lin ... SunC01-2 91
... SunC01-3 91
... SunD01-3 98
... SunD01-4 98
... SunD01-5 98
... SunD01-6 98
Chen, Hongtian ... SatB04 C
... SatB04-5 55
Chen, Huaimin ... SunD06-2 102
Chen, Huang ... SunD01-6 98
Chen, Jiani ... SatA05-1 48
Chen, Jiashu ... SunB04-6 79
Chen, Juan ... SunB08-03 82
... SunB08-56 89
Chen, Lei ... SunB08-32 86
Chen, Li ... SunC06-1 95
Chen, Lian ... SatA04-6 48
Chen, Long ... SunA08-48 72
Chen, Mingchao ... SunD06-1 102
Chen, Pan ... SunB08-57 89
Chen, Peng ... SunB04-6 79
Chen, Qiang ... SatB06 C
... SatB06-4 56
... SatB06-5 57
... SatB06-6 57
... SunA05-6 63
... SunB03 CC
... SunB03-3 77
... SunB03-4 77
... SunB03-6 78
... SunB08-22 84
... SunC05-4 95
Chen, Rui ... SunD01-4 98
... SunD01-5 98
Chen, Sen ... SatB03 C
... SatB03-1 53
... SatB03-2 54
Chen, Shuaiqi ... SunD07-3 103
Chen, Siwen ... SunD07-2 103
Chen, Songhang ... SunB08-41 87
Chen, Wenze ... SunA01-1 59
Chen, Xi-You ... SunD07-1 103
Chen, Xiangyong ... SunA05-3 62
Chen, Yanfang ... SunB01-5 75
Chen, Yifan ... SunC03-3 93
Chen, Yiyang ... SatB04-5 55
... SunA08-24 68
... SunC04-6 94
Chen, Yong Zhi ... SunA08-05 65
Chen, Yuan ... SatB01-2 52
Chen, Yujing ... SunA01-6 59
Chen, Zengqiang ... SatA05-3 49
... SatB02-3 53
... SunA08-09 66
... SunB06-2 80
... SunB06-3 80
... SunB08-46 88
Chen, Zhichao ... SatA07-2 50
Chen, Zhiwen ... SunC02-3 92
Chen, Zhiwen ... SatB00-4 51
Chen, Zhuoying ... SunD06-2 102
Chen, Zuguo ... SunC04-2 93
Cheng, Chen ... SatB06-3 56
Cheng, Junqiang ... SatB00-3 51
Cheng, Long ... SunA05-3 62
Cheng, Shanmei ... SunB06-1 79
Cheng, Siqing ... SunD04-2 100
Cheng, Zhang ... SatA03-5 47
Chi, Ronghu ... SunA02-5 60
... SunA08-01 65
... SunB08-08 82
... SunB08-10 83
... SunB08-20 84
... SunB08-23 84
... SunB08-65 90
... SunC03-6 93
Chu, Jizheng ... SunA08-31 69
Cong, Shuang ... SatB01-3 52
Cui, Jiarui ... SatA03-2 47

. . . . . SatB01-6 52
Cui, Mingliang . . . . . SunB08-19 84
Cui, Mingzhe . . . . . SunA01-5 59
Cui, Ronghua . . . . . SatB03-5 54

**D**

Dai, Haosong . . . . . SunB08-64 90
Dai, Jun . . . . . SunA01-4 59
Dai, Xisheng . . . . . SatA07-1 50
Dang, Jiali . . . . . SatB05-2 55
Deng, Dai-Shihao . . . . . SunC01-3 91
Deng, Gaofeng . . . . . SatB01-4 52
Deng, Lin-Bao . . . . . SunC03-2 93
Deng, Xiongfeng . . . . . SunB04-5 78
Deng, Zhaoyang . . . . . SatB04-3 55
Ding, Guofu . . . . . SatA02-6 46
. . . . . SunB08-15 83
Ding, Jiacheng . . . . . SatB05-2 55
Ding, Miaomiao . . . . . SunB08-13 83
Ding, Pang-Bin . . . . . SunD01-6 98
Ding, Shufen . . . . . SunD02-4 99
Ding, Yingfan . . . . . SunB08-33 86
Ding, Yueheng . . . . . SunD05-2 101
Ding, Zhenyu . . . . . SunA08-41 71
. . . . . SunA08-46 71
. . . . . SunD02-1 98
. . . . . SunD02-6 99
Dong, Na . . . . . SatA05 CC
. . . . . SatA05-4 49
Dong, Xiangyu . . . . . SatB06-3 56
Dong, Xueming . . . . . SatB03-6 54
Dong, Yuxuan . . . . . SatA07-3 50
Dou, Zhenlan . . . . . SunD05-3 101
Du, Linhui . . . . . SunB08-31 86
Du, Mingjun . . . . . SunB02-3 76
. . . . . SunB02-5 76
Du, Songtao . . . . . SunA08-15 67
Du, Xiangyang . . . . . SunB08-05 82
Du, Youwu . . . . . SunA07-2 64
. . . . . SunC02-3 92
. . . . . SunD06-5 103
. . . . . SunD06-6 103
. . . . . SunD07-6 104
Du, Zhenbin . . . . . SunA05-5 63
Duan, Yuting . . . . . SunD07-5 103
Duan, Zhaoxia . . . . . SunA01-4 59

**F**

Fan, Huijin . . . . . SunA08-34 70
. . . . . SunD05-4 102
Fan, Lanzhi . . . . . SunB08-02 82
Fan, Lingling . . . . . SatA06-1 49
. . . . . SunA02-2 60
. . . . . SunB07-1 80
. . . . . SunB07-2 80
. . . . . SunB07-5 81
Fan, Longwei . . . . . SunB08-22 84
Fan, Quan-Yong . . . . . SunB05-1 79
Fan, Xinyu . . . . . SatB00-4 51
Fan, Zhihao . . . . . SatA01-6 45
Fan, Zhong-Xin . . . . . SunB08-63 90
Fan, Zunguan . . . . . SunA08-49 72
Fang, Hai-Tao . . . . . SunC04-3 94
Fang, Jiaxin . . . . . SunB08-62 90
Fang, Jingzhe . . . . . SunD07-1 103
Fang, Mingxing . . . . . SunA07-2 64
Fang, Xing . . . . . SunA04-5 62
Fang, Xing . . . . . SatA05-6 49
Fei, Rong . . . . . SunD04-3 101
Fei, Shijie . . . . . SatB04-5 55
Fei, Xiangyin . . . . . SunA07-5 64
Feng, Jian . . . . . SunD03-1 99
Feng, Nan . . . . . SunD04-3 101
Feng, Xin . . . . . SunB08-12 83
Feng, Yanzhang . . . . . SunB07-6 81
Fu, Baozeng . . . . . SunA08-63 74
Fu, Shengdong . . . . . SunB08-01 81
Fu, Tianqi . . . . . SunB08-38 87
Fu, Xiaotian . . . . . SunA08-32 69
Fu, Xingjian . . . . . SatB04-6 55

**G**

Gai, Xudong . . . . . SunA08-44 71
Gan, Min . . . . . SunA08-36 70
. . . . . SunA08-40 70
Gao, Guanbin . . . . . SatB05-1 55
Gao, Hejia . . . . . SatB05-4 56
Gao, Jingjing . . . . . SunB08-57 89
Gao, Lin . . . . . SunB08-52 89
Gao, Qianhui . . . . . SunA08-25 68
Gao, Shengnan . . . . . SunB06-6 80
Gao, Shoupeng . . . . . SunD03-5 100
Gao, Shuai . . . . . SunA08-18 67
Gao, Weinan . . . . . SatB00-2 51
Gao, Xuehui . . . . . SunC05-3 94
Gao, Yu . . . . . SunD01-1 97
Gao, Yutao . . . . . SunC06-4 95
Gao, Zhe . . . . . SunB08-44 88
. . . . . SunC02 C
. . . . . SunC02-6 92
Ge, Hui . . . . . SunA08-47 71
Geng, Jiahao . . . . . SunA08-10 66
. . . . . SunA08-17 67
Geng, Yan . . . . . SatA01-3 45
Geng, Zhiqiang . . . . . SatA02-2 46
. . . . . SunD04-1 100
Gong, Weitai . . . . . SatA07-1 50
Gong, Yizhou . . . . . SatA04-2 48
Gu, Panpan . . . . . SatA01-5 45
Guo, Bin . . . . . SatB07-5 57
Guo, Haibin . . . . . SunB06-6 80
Guo, Jia . . . . . SunA01-2 59
Guo, Jiajia . . . . . SatA05-5 49
Guo, Jiazhe . . . . . SatB00-1 51
Guo, Jinli . . . . . SunA08-22 68
Guo, Li . . . . . SunA08-10 66
. . . . . SunA08-17 67
Guo, Shenghui . . . . . SunC06 C
. . . . . SunC06-1 95
Guo, Shikai . . . . . SatA06-4 50
Guo, Shuaifeng . . . . . SunD03-4 100
Guo, Shuang . . . . . SunA02-1 60
Guo, Yan . . . . . SunA08-02 65
Guo, Youxing . . . . . SunB08-66 91
Guo, Zhendong . . . . . SatA05-4 49
Gutierrez, Hector . . . . . SatB00-2 51

H

Han, Andong ..... SunB02-3 76
Han, Dong ..... SunD05-3 101
Han, Fei ..... SunC06-4 95
Han, Honggui ..... SunB08-33 86
Han, Jingtian ..... SunD05-4 102
Han, Ning ..... SunA04-6 62
Han, Weixin ..... SunC04 CC
Han, Xiaofang ..... SunA08-42 71
Han, Yongming ..... SatA02-2 46
..... SunB08-17 84
..... SunD04 CC
..... SunD04-1 100
Han, Zhenhua ..... SunA07-2 64
..... SunD06-5 103
..... SunD06-6 103
..... SunD07-6 104
Han, Zhongyang ..... SunA08-48 72
Hao, Duan ..... SunC05-6 95
Hao, Kuangrong ..... SunB08-32 86
Hao, Li-Ying ..... SatA06 C
..... SatA06-3 49
..... SatA06-6 50
He, Li ..... SunC03-5 93
He, Ning ..... SunD06 C
..... SunD06-4 102
He, Ruilong ..... SunB07-3 81
He, Shuping ..... SunB05 CC
He, Wenbin ..... SunC03-1 93
He, Xingshi ..... SatA01-3 45
He, Xiongxiong ..... SatA03-6 47
..... SatA05-1 48
..... SatB06-3 56
..... SunB04-6 79
He, Xun ..... SunA08-19 67
He, Yan-Lin ..... SunA08-16 67
..... SunA08-54 72
..... SunB08-16 84
..... SunB08-36 86
..... SunD03 CC
..... SunD03-4 100
He, Zhao ..... SatA02-5 46
Hei, Xinhong ..... SunD04-3 101
Hong, Wenjing ..... SatA01-1 45
Hou, Jin ..... SunA08-14 67
Hou, Zhongsheng ..... SatA01-6 45
..... SunA02-2 60
..... SunA02-3 60
Hou, Zhongsheng ..... SunA08-06 65
..... SunA08-07 65
..... SunA08-58 73
Hu, Chaofang ..... SunD05-6 102
Hu, Chong ..... SunB08-64 90
Hu, Guangzheng ..... SunA08-61 73
Hu, Huiteng ..... SunB08-49 88
Hu, Jiabao ..... SunB05-6 79
Hu, Junhao ..... SunC01-4 91
Hu, Juqi ..... SatB05-4 56
Hu, Kailin ..... SunB03-5 77
Hu, Xuan ..... SunD04-1 100
Hu, Yuanjiang ..... SatB02-6 53
..... SunB08-62 90
Hua, Fei ..... SatB00-5 52
..... SunD05-5 102
Huang, Darong ..... SatA03-4 47
..... SatB04-1 54
..... SatB04-3 55
..... SatB04-4 55
..... SunB08-64 90
Huang, Darong ..... SatB04-2 54
Huang, Deqing ..... SatB00-3 51
..... SatB01-2 52
..... SatB02-6 53
..... SunA08-56 73
..... SunB08-62 90
Huang, Hanxin ..... SunA08-11 66
Huang, He ..... SunD04-6 101
Huang, Jian ..... SatA03-2 47
Huang, Jian ..... SunB06-5 80
Huang, Jiangyang ..... SatA03-3 47
Huang, Jingwen ..... SunA08-59 73
Huang, Jinlei ..... SunB07-4 81
Huang, Meiqun ..... SatB03-2 54
Huang, Ming Yu ..... SatB02-4 53
Huang, Shuyan ..... SunC04-3 94
Huang, Wei ..... SunB07-1 80
Huang, Xiaoyi ..... SunA08-31 69
Huang, Yande ..... SunA08-24 68
Huang, Yingbo ..... SatB06-4 56
..... SunC05 C
..... SunC05-6 95
Huang, Zhenghong ..... SunA08-14 67
Huang, Zixin ..... SunB05-2 79
Hui, Yu ..... SunB08 CC
..... SunB08-23 84
Huo, Xin ..... SunA06 CC
..... SunA06-6 63
Huo, Xuanmin ..... SunB02-4 76

I

Iwasaki, Makoto ..... SunA07-6 64

J

Ji, Haibo ..... SunB08-45 88
Ji, Honghai ..... SatA06-2 49
..... SunA08-32 69
..... SunB07 C
..... SunB07-1 80
..... SunB07-2 80
Ji, Honghai ..... SatA06-1 49
..... SunB07-5 81
Ji, Qianzhen ..... SunC05-4 95
Ji, Shuangjie ..... SatB06-5 56
Ji, Wenchengyu ..... SatA02-4 46
Ji, Wenkai ..... SunA03-6 61
Ji, Xiaoqiang ..... SunA08-27 68
Ji, Zhihui ..... SunB01-4 75
Jia, Fengyi ..... SatA04-4 48
Jia, Jihui ..... SunA08-06 65
..... SunA08-07 65
..... SunA08-58 73
Jia, Kai ..... SunB08-44 88
..... SunC02-6 92
Jia, Li ..... SunA08-29 69
..... SunA08-30 69
..... SunB08-28 85
..... SunB08-34 86
Jia, Mingwei ..... SunC01-1 91
..... SunC01-4 91
Jia, Pengpeng ..... SunA08-11 66
Jia, Xiongbo ..... SunB07-2 80
Jia, Zhenshuai ..... SunB08-27 85
Jia, Zhenzhen ..... SatA07-5 51
Jia, Zhichun ..... SunA08-60 73
..... SunB08-60 90
Jiang, Fuxi ..... SunB06-1 79
Jiang, Hao ..... SatA01-2 45
..... SunA08-19 67
..... SunB08-26 85
Jiang, Haosheng ..... SunB08-51 88
Jiang, Jing ..... SunB08-61 90
Jiang, Jingjing ..... SunD05-3 102
Jiang, Lichen ..... SatB05-1 55
Jiang, Mengman ..... SunB08-49 88
Jiang, Minghao ..... SatB05-6 56
Jiang, Xiaoyu ..... SatA07-4 50

. . . . . SatA07-6 51
Jiang, Xue . . . . . SunA08-16 67
Jiang, Yuchen . . . . . SatB04 CC
Jiao, Xuguo . . . . . SunA08-38 70
Jin, Chengkun . . . . . SunA08-45 71
Jin, Chengwu . . . . . SatB01-1 52
Jin, Feng . . . . . SunA08-50 72
Jin, Huaikang . . . . . SunC01-6 92
Jin, Huaiping . . . . . SunC01-6 92
. . . . . SunD01-1 97
. . . . . SunD01-2 97
Jin, Lei . . . . . SunB08-29 85
Jin, Shangtai . . . . . SunA08-43 71

**K**

Kang, Qitong . . . . . SatA05-3 49
Ke, Haobin . . . . . SatB00-4 51
Ke, Wei . . . . . SunB08-16 84
Kong, Ying . . . . . SunB08-21 84
Kong, Ying . . . . . SatB06 CC
. . . . . SatB06-1 56
Kuang, Hangdong . . . . . SatB04-3 55

**L**

Lai, Xuwei . . . . . SatA02-6 46
. . . . . SunB08-15 83
Lai, Zhiqing . . . . . SunB08-41 87
Lang, Yilin . . . . . SatB00-1 51
Lao, Jingtao . . . . . SunB01-5 75
Lei, Zhiwei . . . . . SunB08-24 85
Li, Bo . . . . . SunA07-2 64
. . . . . SunC02-3 92
Li, Chao . . . . . SunA08-04 65
Li, Chengyang . . . . . SunA06-4 63
Li, Dazi . . . . . SatB02 C
. . . . . SatB02-5 53
. . . . . SunA08-59 73
Li, Feng . . . . . SunA07 C
. . . . . SunA08-41 71
. . . . . SunA08-46 71
. . . . . SunC02-3 92
. . . . . SunC02-4 92
. . . . . SunD02 CC
. . . . . SunD02-1 98
. . . . . SunD02-2 99
. . . . . SunD02-6 99
Li, Feng . . . . . SunB01-1 74
. . . . . SunC04-4 94
Li, Gengen . . . . . SunC05-2 94
Li, Guitong . . . . . SunB05-3 79
Li, Guochao . . . . . SunA08-35 70
Li, Haoran . . . . . SunA08-61 73
Li, Haoyang . . . . . SunA08-44 71
Li, Hongxuan . . . . . SunB08-59 90
Li, Hongyi . . . . . SunB04-1 78
Li, Hui . . . . . SatA06-4 49
Li, Huiping . . . . . SunD06-2 102
Li, Huiqin . . . . . SatA02-1 45
. . . . . SunD03-3 99
Li, Jiaxuan . . . . . SunB05-1 79
Li, Jinna . . . . . SatB02 CC
. . . . . SatB02-1 53
. . . . . SunA03-2 60
Li, Jinsha . . . . . SunA08-25 68
Li, Jinze . . . . . SatA01-5 45
. . . . . SunB01-3 75
Li, Juan . . . . . SatB03-5 54
. . . . . SunC02-2 92
Li, Junhao . . . . . SunB08-35 86
. . . . . SunB08-40 87
Li, Juntao . . . . . SunB02 C
. . . . . SunB02-4 76
Li, Lei . . . . . SatA03-6 47
Li, Li . . . . . SunD07-4 103
Li, Liang . . . . . SunA01-5 59
Li, Linwei . . . . . SatB07 CC
. . . . . SatB07-1 57
Li, Liya . . . . . SatA04-5 48
Li, Meiliu . . . . . SunA07 CC
. . . . . SunA07-4 64
. . . . . SunA07-5 64
Li, Meng . . . . . SunB08-39 87
Li, Mingdi . . . . . SunB08-44 88
. . . . . SunC02-6 92
Li, Mingyao . . . . . SunB08-07 82
Li, Mingyu . . . . . SunC05-4 95
Li, Panshuo . . . . . SunA03-1 60
Li, Pei . . . . . SunC04-2 94
Li, Peiyuan . . . . . SunA03-1 60
Li, Pengfei . . . . . SunD04-5 101
Li, Qiangxin . . . . . SunD03-1 99
Li, Qiankun . . . . . SunB08-19 84
Li, Qin . . . . . SunB08-14 83
Li, Qing . . . . . SatB01-6 52
Li, Qingkui . . . . . SunA08-13 66
Li, Renqiang . . . . . SunB08-51 88
Li, Rirong . . . . . SunD06-5 103
. . . . . SunD06-6 103
Li, Rui . . . . . SunA08-13 66
Li, Shangrui . . . . . SunB08-39 87
Li, Sheng . . . . . SatA03-6 47
. . . . . SatA05-1 48
Li, Shengnan . . . . . SunB04-4 78
Li, Shengquan . . . . . SatB03-5 54
. . . . . SunC02 CC
. . . . . SunC02-2 92
. . . . . SunD02 C
Li, Shihua . . . . . SunB08-63 90
Li, Shiyan . . . . . SatA01-4 45
Li, Shuo . . . . . SunA01-5 59
Li, Shuqi . . . . . SunB07-3 81
Li, Tianmei . . . . . SatA02-1 45
Li, Tianru . . . . . SunB01-5 75
Li, Tieshan . . . . . SunA08-20 67
Li, Weixun . . . . . SunB08-05 82
Li, Wenling . . . . . SunC07-1 96
Li, Xia . . . . . SatA04-1 47
Li, Xiangshun . . . . . SunB08-43 87
Li, Xiangyang . . . . . SunB06-5 80
Li, Xiangyu . . . . . SunD07-5 103
Li, Xiankun . . . . . SunA01-4 59
Li, Xiao-Dong . . . . . SunB08-21 84
Li, Xiaofang . . . . . SunD02-3 99
Li, Xiaohang . . . . . SunC06-3 95
Li, Xiaoli . . . . . SunA08-03 65
. . . . . SunA08-49 72
. . . . . SunB08-31 86
. . . . . SunB08-48 88
. . . . . SunB08-54 89
. . . . . SunB08-55 89
. . . . . SunC04-5 94
Li, Xin . . . . . SunB08-35 86
. . . . . SunB08-40 87
Li, Xincai . . . . . SunC05-2 94
Li, Xinye . . . . . SunA08-12 66
Li, Xuefang . . . . . SunB02-2 76
Li, Xuefang . . . . . SatA01-4 45
. . . . . SunB01-5 75
Li, Yan . . . . . SunA08-29 69
. . . . . SunA08-30 69
Li, Yan . . . . . SunD07-5 103
Li, Yang . . . . . SunB03-1 77
Li, Yang . . . . . SunA08-03 65
. . . . . SunB08-31 86
. . . . . SunB08-48 88

. . . . . SunC04-5 94
Li, Yaqian . . . . . SunA05-6 63
Li, Yifan . . . . . SunA08-06 65
. . . . . SunA08-07 65
. . . . . SunA08-58 73
Li, Yijia . . . . . SunB04-6 79
Li, Yimin . . . . . SunB01-5 75
Li, Yiming . . . . . SatB07-6 58
Li, Yu-Ling . . . . . SunB06-4 80
Li, Yuan Xin . . . . . SunC03 C
Li, Yueyang . . . . . SatA02 C
. . . . . SatA02-3 46
. . . . . SunD03-5 100
Li, Yuhan . . . . . SunA08-22 68
Li, Yun . . . . . SunB05-2 79
Li, Yuxiang . . . . . SunD06-4 102
Li, Zhaofei . . . . . SunA08-14 67
. . . . . SunB08-42 87
Li, Zhaoyang . . . . . SatB00-1 51
Li, Zhe . . . . . SunC03-1 93
Li, Zhen . . . . . SunB08-29 85
Li, Zhen . . . . . SunD07-5 104
Li, Zhenxuan . . . . . SunA02-1 60
Li, Zhenyan . . . . . SatB07-6 57
Li, Zhi . . . . . SunB08-66 91
Li, Zhijun . . . . . SunB07-6 81
Li, Zhixuan . . . . . SatA02-6 46
. . . . . SunB08-15 83
Li, Zhongxin . . . . . SunB03-1 77
Li, Zonggang . . . . . SunB02-6 77
. . . . . SunD02-5 99
Liang, Cong . . . . . SunB02-4 76
Liang, Hongjing . . . . . SunB04 C
Liang, Xiao . . . . . SunA07-1 64
Liao, Huanyu . . . . . SunA08-51 72
Liao, Peng . . . . . SunC05-5 95
Liao, Yu . . . . . SunA08-10 66
. . . . . SunA08-17 67
Lin, Chenxu . . . . . SunB08-07 82
Lin, Guohuai . . . . . SunB04-1 78
Lin, Jinquan . . . . . SunA03-5 61
Lin, Mingjun . . . . . SatB06-5 57
. . . . . SatB06-6 57
Lin, Mingming . . . . . SunB08-65 90
. . . . . SunC03-6 93
Lin, Na . . . . . SunB08-65 90
. . . . . SunC03-6 93
Lin, Xue . . . . . SunC02-5 92
Liu, Bao . . . . . SunB07-3 81
. . . . . SunB07-4 81
Liu, Bo Wei . . . . . SunA04-3 61
Liu, Chen . . . . . SunB07-6 81
Liu, Cheng-Lin . . . . . SunB06-4 80
Liu, Chengwei . . . . . SunC04-2 93
Liu, Chiqiang . . . . . SatB02-5 53
Liu, Chun . . . . . SunC06-4 96
Liu, Dandan . . . . . SunB02-3 76
Liu, Dawei . . . . . SunA04-3 61
Liu, Derong . . . . . SunA03-5 61
Liu, Dexin . . . . . SunA04-2 61
Liu, Ding . . . . . SunB08-51 88
Liu, Dong . . . . . SunC03-3 93
. . . . . SunD06-1 102
Liu, Dongliang . . . . . SatB05-4 56
Liu, Genfeng . . . . . SunA02-3 60
Liu, Guilong . . . . . SunA04-4 62
Liu, Guohua . . . . . SunA08-37 70
Liu, Haipeng . . . . . SunD01-2 97
Liu, Hong . . . . . SatB06-2 56
Liu, Huiying . . . . . SatA06-3 49
Liu, Jianan . . . . . SatA01-1 45
Liu, Jianlong . . . . . SunC01-2 91
. . . . . SunC01-3 91
. . . . . SunD01-3 98
. . . . . SunD01-5 98
Liu, Jianxing . . . . . SatB00-5 52
Liu, Jie . . . . . SunA08-33 69
Liu, Jingbo . . . . . SunA06-6 63
Liu, Jinhai . . . . . SatA02-5 46
Liu, Jinjia . . . . . SunD04-4 101
Liu, Kaiyue . . . . . SunA06-3 63
Liu, Ke . . . . . SunB01-2 75
Liu, Keping . . . . . SunA03-6 61
Liu, Kexin . . . . . SunC03-1 93
Liu, Lei . . . . . SunA08-34 70
. . . . . SunD05-4 102
Liu, Lei . . . . . SunD02-2 99
Liu, Lei . . . . . SunA05 CC
Liu, Lijun . . . . . SunB08-49 88
Liu, Lingyi . . . . . SatB01-6 52
Liu, Minghua . . . . . SunB08-55 89
Liu, Pengfei . . . . . SunC05-5 95
Liu, Qiang . . . . . SunC01-5 91
Liu, Qingquan . . . . . SunA06-6 63
Liu, Qingyun . . . . . SatB05-5 56
Liu, Rongjie . . . . . SunB08-63 90
Liu, Ruoyang . . . . . SunB08-06 82
Liu, Shan . . . . . SatB01 C
. . . . . SatB01-4 52
. . . . . SatB01-5 52
Liu, Shasha . . . . . SunA08-61 73
Liu, Shida . . . . . SunA08-32 69
. . . . . SunB07 CC
. . . . . SunB07-1 80
. . . . . SunB07-2 80
. . . . . SunB07-5 81
. . . . . SunB08-29 85
Liu, Shiheng . . . . . SunD02-1 98
Liu, Shuaibo . . . . . SunD04-5 101
Liu, Shuguang . . . . . SunA08-05 65
Liu, Shuo . . . . . SunC03-5 93
Liu, Suijun . . . . . SatA07-3 50
Liu, Taojun . . . . . SunB08-25 85
Liu, Tingzhen . . . . . SunA08-28 69
Liu, Wangwang . . . . . SunA02-5 60
. . . . . SunB08-08 82
Liu, Wei . . . . . SunD01-5 98
Liu, Wei . . . . . SunC02-1 92
Liu, Wenfeng . . . . . SunA08-38 70
Liu, Xia . . . . . SatB01-1 52
Liu, Xiangbin . . . . . SunB08-58 89
Liu, Xiaomin . . . . . SunA01-3 59
Liu, Xingyi . . . . . SunB08-11 83
Liu, Xu Dong . . . . . SunA08-05 65
Liu, Yachong . . . . . SunB08-14 83
Liu, Yang . . . . . SunB01-2 75
Liu, Yang . . . . . SunA05 C
. . . . . SunA05-3 62
Liu, Yang . . . . . SunD07 C
. . . . . SunD07-2 103
. . . . . SunD07-3 103
. . . . . SunD07-4 103
Liu, Yang . . . . . SunC07 C
. . . . . SunC07-4 97
Liu, Yanli . . . . . SatA06-6 50
Liu, Yi . . . . . SunC01 C
. . . . . SunC01-1 91
. . . . . SunC01-4 91
. . . . . SunD01 C
Liu, Yinfei . . . . . SunA08-35 70
Liu, Ying . . . . . SatA07-3 50
Liu, Yiyan . . . . . SunD03-2 99
Liu, Yongchao . . . . . SunA08-63 74
Liu, Zehua . . . . . SunB01-1 74
Liu, Zhen . . . . . SunC05-3 95
Liu, Zhilong . . . . . SunA08-21 68
. . . . . SunB08-39 87
Liu, Zhiqing . . . . . SunB08-65 91

. . . . . SunC03-6 93
Liu, Zhongxin . . . . . SatA05-3 49
Liu, Zhuofu . . . . . SatA06-5 50
Long, Fei . . . . . SunC07-6 97
Long, Teng . . . . . SunA04-3 61
Long, Yinren . . . . . SunB04-3 78
Long, Yue . . . . . SunA08-20 67
Lou, Mengmeng . . . . . SunB05-6 79
Lou, Siwei . . . . . SunA08-51 72
Lou, Zhijiang . . . . . SunB08-58 90
Lu, Cheng . . . . . SatA07-3 50
Lu, Hong Qian . . . . . SunB08-12 83
Lu, Peng . . . . . SunD03-2 99
Lu, Qinkun . . . . . SunB03-2 77
Lu, Renquan . . . . . SunA05-4 62
. . . . . SunB04-3 78
Lu, Senxiang . . . . . SatA02-5 46
Lu, Shan . . . . . SunB08-58 90
Lu, Shuai . . . . . SunD04-5 101
Lu, Wenzhou . . . . . SunD05-5 102
Lu, Yanrong . . . . . SunD02-3 99
Luo, Hao . . . . . SatA03 C
Luo, Shihua . . . . . SatA07-3 50
Luo, Yinsheng . . . . . SunC02-5 92
Lv, Hui . . . . . SunB02-3 76
. . . . . SunB02-5 76
Lv, Jin . . . . . SunA04-1 61
Lv, Yongfeng . . . . . SatB07 C
. . . . . SatB07-3 57
Lv, Zhiguo . . . . . SunB08-47 88
Lv, Zhiyuan . . . . . SunC05-5 95

**M**

Ma, Bo . . . . . SatA02-2 46
. . . . . SunB08-17 84
Ma, Guangjuan . . . . . SunB08-29 85
Ma, Haoyu . . . . . SatB04-1 54
Ma, Hui . . . . . SunB04-1 78
Ma, Junjie . . . . . SunA08-56 73
Ma, Kai . . . . . SunD06-4 102
Ma, Lei . . . . . SunB08-38 87
Ma, Mingjun . . . . . SunA08-61 73
Ma, Xianchao . . . . . SunA08-10 66
. . . . . SunA08-17 67
Ma, Yue . . . . . SatA03-6 47
. . . . . SatA05-1 48
Ma, Yuhe . . . . . SunD05-6 102
Ma, Yunchen . . . . . SunD05-2 101
Ma, Zhijuan . . . . . SunD06-3 102
Mai, Xiaoming . . . . . SatA05-4 49
Mao, Weiqi . . . . . SatB04-1 54
Mao, Yongyi . . . . . SatB04-2 54
Mao, Zehui . . . . . SunD05 CC
Meng, Deyuan . . . . . SunB02 CC
. . . . . SunB02-2 76
. . . . . SunD02-4 99
Meng, Liping . . . . . SunD04-5 101
Meng, Zhou . . . . . SunA08-57 73
. . . . . SunC06 CC
. . . . . SunC06-4 95
Mi, Bo . . . . . SatA03-4 47
. . . . . SatB04-1 54
. . . . . SatB04-2 54
. . . . . SatB04-3 55
. . . . . SatB04-4 55
Mo, Congcong . . . . . SatB06-6 57
Mo, Lipo . . . . . SunC07-6 97
Mo, Lipo . . . . . SunC07 CC
. . . . . SunC07-5 97
Mu, Chenglin . . . . . SunA02-5 60
. . . . . SunB08-08 82
Mu, Lingxia . . . . . SunD04-3 101
Mu, Qianqian . . . . . SunC07-6 97
Mu, Xiaoxia . . . . . SunB02-1 76

**N**

Na, Jing . . . . . SatB05-1 55
. . . . . SatB05-3 55
. . . . . SatB06-4 56
Nie, Hao . . . . . SunA03-2 60
Nie, Liduo . . . . . SunA02-4 60
Ning, Donghong . . . . . SunC05-5 95
Ning, Xiaogang . . . . . SunD02-5 99

**O**

Ou, Baoming . . . . . SunB08-03 82
Ou, Xianhua . . . . . SatB06-3 56
. . . . . SunB04-6 79

**P**

Pan, Changzhong . . . . . SunA07-5 64
Pan, Guangyuan . . . . . SunA07-1 64
Pan, Tian-Hong . . . . . SunB08-52 89
Pan, Tinglong . . . . . SunD05-2 101
Pan, Yingnan . . . . . SunA05-1 62
. . . . . SunB04 CC
Pang, Zhonghua . . . . . SunA08-04 65
. . . . . SunB06 C
. . . . . SunB06-6 80
. . . . . SunB08-02 82
. . . . . SunB08-04 82
Peng, Bo . . . . . SunA02-6 60
Peng, Jia . . . . . SunC03-1 93
Peng, Kaixiang . . . . . SunA08-52 72
. . . . . SunA08-55 73
Peng, Li . . . . . SunA08-08 66
Peng, Liu . . . . . SatB01-6 52
Peng, Tao . . . . . SatB00-4 51
Peng, Yunjian . . . . . SatA01-5 45
. . . . . SunB01 CC
. . . . . SunB01-3 75
Peng, Yuyang . . . . . SatA05-1 48
Ping, Xubin . . . . . SunB08-51 88

**Q**

Qasem, Omar . . . . . SatB00-2 51
Qi, Chen . . . . . SunD07-1 103
Qi, Guoyuan . . . . . SatA04 C
. . . . . SatA04-1 47
Qi, Xuexin . . . . . SatA06-4 49
Qian, Hanyu . . . . . SunB08-27 85
Qian, Jiaxi . . . . . SunB08-26 85
Qian, Rongrong . . . . . SunB08-49 88
Qian, Shengyi . . . . . SunD02-6 99
Qian, Wang . . . . . SunA08-43 71
Qian, Yihui . . . . . SunA06-6 63
Qin, Bodong . . . . . SunB01-1 74
. . . . . SunC04-4 94
Qin, Huayang . . . . . SunB06-2 80
Qin, Na . . . . . SatB01-2 52
Qin, Yi . . . . . SunB04-2 78
Qiu, Jianlong . . . . . SunA05-3 62
Qiu, Ruikang . . . . . SatB03-5 54
. . . . . SunC02-2 92
Qu, Boyang . . . . . SunB08-06 82
Qu, Qilin . . . . . SunA01-6 59
Qu, Xiaohe . . . . . SunB08-24 85
Quan, Quan . . . . . SatA04 CC
. . . . . SatA04-6 48
. . . . . SunA06-2 63

**R**

Ren, Chao . . . . . SunD03-3 99
Ren, Hongru . . . . . SunA05-4 62
. . . . . SunB04-3 78
Ren, Jin-Rui . . . . . SatA04-3 48
Ren, Junsheng . . . . . SunA03-3 61
. . . . . SunA03-4 61
Ren, Qinyuan . . . . . SatB00-1 51

. . . . . SunD03-6 100
Ren, Xiaodie . . . . . SunA08-35 70
Ren, Xuemei . . . . . SatB03-6 54
. . . . . SatB05-3 55
. . . . . SunA04-6 62
Ren, Ye . . . . . SatA06-2 49
Ren, Yuru . . . . . SunB08-11 83

**S**

Sato, Daiki . . . . . SunA07-3 64
Shangguan, Anqi . . . . . SunD04-3 101
Shao, Jiawei . . . . . SunA08-37 70
She, Jinhua . . . . . SunA07-3 64
. . . . . SunA07-6 64
She, Yuexin . . . . . SunA08-36 70
. . . . . SunD04-2 100
Shen, Bingbing . . . . . SatA07-2 50
. . . . . SatA07-4 50
. . . . . SatA07-6 51
Shen, Dong . . . . . SatA01-2 45
. . . . . SunA08-19 67
. . . . . SunA08-23 68
. . . . . SunB08-25 85
. . . . . SunB08-26 85
Shen, Feifan . . . . . SunD05-1 101
Shen, Qiguang . . . . . SunA08-53 72
Shen, Xiangkai . . . . . SatA02-5 46
Shi, Huihui . . . . . SunA05-6 63
. . . . . SunB03-6 78
. . . . . SunC05-4 95
Shi, Huiyuan . . . . . SatB02-2 53
. . . . . SunA02-6 60
Shi, Jia . . . . . SatA01 C
. . . . . SatA01-1 45
Shi, Linlin . . . . . SunB04-5 78
Shi, Xiaoyu . . . . . SatB01-1 52
Si, Xiaosheng . . . . . SatA02-1 45
. . . . . SunD03-3 100
Song, Baoye . . . . . SunD03-2 99
Song, Fazhi . . . . . SunD07 CC
. . . . . SunD07-2 103
. . . . . SunD07-3 103
Song, Jiangchao . . . . . SatB05-3 55
Song, Ruizhuo . . . . . SunA01 CC
. . . . . SunA01-1 59
. . . . . SunC06-6 96
Song, Wanping . . . . . SunB06-3 80
Song, Xinyu . . . . . SunA08-39 70
Song, Xueming . . . . . SunB08-30 85
. . . . . SunC04-1 93
Song, Yang . . . . . SunA08-02 65
Song, Zhihuan . . . . . SatA07-6 51
. . . . . SunD03-6 100
Song, Zilong . . . . . SunC04-5 94
Su, Chengli . . . . . SatB02-2 53
. . . . . SunA02-6 60
Su, Hongye . . . . . SunB08-18 84
Su, Mao . . . . . SunA08-34 70
Su, Peng Peng . . . . . SatA04-5 48
Su, Wenxue . . . . . SunA08-44 71
Su, Yang . . . . . SunB03-6 78
Sui, Shuai . . . . . SunC03-4 93
Sun, Daobo . . . . . SunB08-45 88
Sun, Dehui . . . . . SunA08-04 65
Sun, Guofa . . . . . SatB02-4 53
Sun, Hongtao . . . . . SunD02-3 99
Sun, Jianqiang . . . . . SunA05-3 62
Sun, Jingbo . . . . . SunA04-5 62
Sun, Jingliang . . . . . SunA04-3 61
Sun, Li . . . . . SunA08-35 70
Sun, Mingming . . . . . SunA04-2 61
Sun, Mingwei . . . . . SatB02-3 53
. . . . . SunA08 C
. . . . . SunA08-09 66
. . . . . SunB06-2 80
. . . . . SunB06-3 80
SUN, Mingxuan . . . . . SatB00 C
Sun, Pengfei . . . . . SunB08-66 91
Sun, Pengqi . . . . . SunB04-4 78
Sun, Pengyu . . . . . SunD07-3 103
Sun, Qinglin . . . . . SunA08-09 66
. . . . . SunB06-2 80
. . . . . SunB06-3 80
. . . . . SunB08-46 88
Sun, Weijie . . . . . SunB01-3 75
Sun, Yihua . . . . . SatA06-6 50
Sun, Yongbo . . . . . SatA04-4 48
. . . . . SunA06-4 63
Sun, Yongkui . . . . . SunB08-38 87
Sun, Yuan . . . . . SunC04-6 94
Sun, Yuqian . . . . . SunC01-2 91
Sun, Zhongbo . . . . . SunA03-6 61
Suo, Wei . . . . . SunC07-1 96

**T**

Tan, Panlong . . . . . SunB06-2 80
Tan, Xiaowei . . . . . SunA03-4 61
Tang, Guoqing . . . . . SatB05-5 56
Tang, Lianqing . . . . . SunD05-3 101
Tang, Xiaoheng . . . . . SatA05-1 48
Tang, Yifan . . . . . SunB08-49 88
Tang, Yijia . . . . . SunA08-45 71
Tao, Hong-Feng . . . . . SatB04-5 55
. . . . . SunA08-24 68
. . . . . SunC04-6 94
Tao, Liang . . . . . SunB04-5 78
Tao, Meiling . . . . . SunB04-5 78
Tao, Meiling . . . . . SunB03-4 77
Tao, Songbing . . . . . SunB08-64 90
Tao, Yujuan . . . . . SunA08-24 68
Tao, Yuxin . . . . . SunB08-02 82
Teng, Fei . . . . . SunA04-1 61
Tian, Facun . . . . . SunB08-38 87
Tian, Fengchen . . . . . SatA01-6 45
Tian, Miaomiao . . . . . SunB08-53 89
Tian, Senping . . . . . SatA01-5 45
. . . . . SunB06-5 80
Tian, Xincui . . . . . SunB04-4 78
Tian, Yang . . . . . SunB08-59 90
Tian, Yu-Ping . . . . . SunA01-5 59
Tong, Xiaodong . . . . . SunB08-42 87
Tu, Rang . . . . . SatA03-3 47

**W**

Wan, Kai . . . . . SunB05-4 79
Wan, Xiao . . . . . SunB05-2 79
Wan, Yiming . . . . . SunA08-15 67
Wan, Yu . . . . . SunC05-3 95
Wang, Bin . . . . . SunC01-6 92
. . . . . SunD01-1 97
. . . . . SunD01-2 97
Wang, Bo . . . . . SunA08-34 70
. . . . . SunD05-4 102
Wang, Chao . . . . . SunB08-14 83
Wang, Dongdong . . . . . SunA08-05 65
Wang, Feng . . . . . SunA07-6 64
Wang, Fengxian . . . . . SatB07-1 57
Wang, Fuyong . . . . . SatA05-3 49
Wang, Fuzhi . . . . . SunA04-1 61
Wang, Gang . . . . . SunA08-10 66
. . . . . SunA08-17 67
Wang, Hao . . . . . SunD06-5 103
. . . . . SunD06-6 103
. . . . . SunD07-6 104
Wang, Haoping . . . . . SunB08-59 90
Wang, Jian-Guo . . . . . SunC01-2 91
. . . . . SunC01-3 91
. . . . . SunD01-3 98
. . . . . SunD01-4 98
. . . . . SunD01-5 98

. . . . . SunD01-6 98
Wang, Jianhao . . . . . SunC05-3 94
Wang, Jiaxin . . . . . SunA08-56 73
. . . . . SunB08-62 90
Wang, Jichen . . . . . SunA08-50 72
Wang, Jing . . . . . SunA08-57 73
Wang, Jinling . . . . . SunA01-5 59
Wang, Juan . . . . . SatA05-2 48
. . . . . SatA05-5 49
Wang, Jun . . . . . SunD04-6 101
Wang, Junhui . . . . . SunA08-53 72
Wang, Junxiao . . . . . SunB03 C
. . . . . SunB03-2 77
. . . . . SunB03-5 77
Wang, Kai . . . . . SatA07-5 51
Wang, Kang . . . . . SunA08-03 65
. . . . . SunA08-49 72
. . . . . SunB08-31 86
. . . . . SunB08-48 88
. . . . . SunB08-54 89
. . . . . SunB08-55 89
. . . . . SunC04-5 94
Wang, Lei . . . . . SunD03-1 99
Wang, Lei . . . . . SunB02-4 76
Wang, Li . . . . . SatA06-2 49
Wang, Li . . . . . SunA08-32 69
. . . . . SunB07-5 81
Wang, Liangbin . . . . . SunA04-1 61
Wang, Liheng . . . . . SunB05-2 79
Wang, Lijie . . . . . SunB04-2 78
Wang, Mingjia . . . . . SunB08-61 90
Wang, Minlin . . . . . SatB03-6 54
Wang, Pengfei . . . . . SunA08-54 72
Wang, Qi . . . . . SunB05-6 79
Wang, Qi . . . . . SunC02-5 92
Wang, Qian . . . . . SunB01-6 75
Wang, Qiannan . . . . . SatA02-5 46
Wang, Qingyuan . . . . . SunB08-66 91
Wang, Qingzhi . . . . . SunA08-63 74
Wang, Renren . . . . . SunB08-12 83
Wang, Ruigang . . . . . SunB01-1 74
. . . . . SunC04-4 94
Wang, Shao Xian . . . . . SunB01-6 75
Wang, Shaoping . . . . . SunA01-4 59
Wang, Shenquan . . . . . SatA02 CC
. . . . . SatA02-4 46
Wang, Shitong . . . . . SunA08-04 65
Wang, Shouqin . . . . . SatA01-3 45
Wang, Shubo . . . . . SatB05 C
. . . . . SatB05-2 55
Wang, Siqing . . . . . SunB05-1 79
Wang, Siyuan . . . . . SunA08-57 73
Wang, Wei . . . . . SunB05-2 79
Wang, Wei . . . . . SunA08-48 72
. . . . . SunA08-50 72
. . . . . SunB01-2 75
Wang, Wenxiao . . . . . SunB08-51 88
Wang, Xian . . . . . SunC05-6 95
Wang, Xianghua . . . . . SunB08 C
. . . . . SunB08-09 83
. . . . . SunB08-13 83
Wang, Xianyu . . . . . SunB06-6 80
Wang, Xiaojuan . . . . . SunB08-51 88
Wang, Xiaojuan . . . . . SatA04-4 48
Wang, Xin . . . . . SunA02 C
. . . . . SunA02-4 60
Wang, Xin . . . . . SunD06 CC
. . . . . SunD06-3 102
Wang, Xinru . . . . . SatB02-1 53
Wang, Xiujuan . . . . . SunA08-39 70
Wang, Xiuli . . . . . SunB03-1 77
Wang, Xudong . . . . . SunC03-1 93
Wang, Yalin . . . . . SatA07-5 51
Wang, Yan . . . . . SunB08-37 86
Wang, Yan-Bo . . . . . SunB06-4 80
Wang, Yang . . . . . SatA04-2 48
Wang, Yanwei . . . . . SunA01-6 59
. . . . . SunA08-12 66
Wang, Yaonan . . . . . SunC03-1 93
Wang, Yaping . . . . . SunA08-40 70
. . . . . SunD04-2 100
Wang, Yikun . . . . . SunA08-59 73
Wang, Yixin . . . . . SunD01-3 98
Wang, Yongheng . . . . . SunB08-14 83
Wang, Yongshuai . . . . . SatB02-3 53
. . . . . SunA08-09 66
Wang, Youqing . . . . . SunB08-19 84
Wang, Yuan . . . . . SunA05-5 63
Wang, Yungan . . . . . SunA08-31 69
Wang, Yuying . . . . . SunD02-3 99
Wang, Zenan . . . . . SunA08-14 67
Wang, Zewen . . . . . SunA07-3 64
Wang, Zhenhua . . . . . SatA03 CC
. . . . . SatA03-1 46
Wang, Zhenning . . . . . SatB01-3 52
Wang, Zhiwen . . . . . SunD02-3 99
Wang, Zhu . . . . . SunB01 C
. . . . . SunB01-6 75
Wang, Zhujun . . . . . SunA07-1 64
Wang, Zhuo . . . . . SunB01-1 74
. . . . . SunC04-4 94
Wang, Zhuxin . . . . . SatA05-2 48
Wang, Zihao . . . . . SunA08-03 65
Wei, Chihang . . . . . SunD03-6 100
Wei, Chun . . . . . SatA03-5 47
Wei, Tao . . . . . SunB08-06 82
Wei, Xingshen . . . . . SunC02-1 92
Wei, Ziyue . . . . . SunA08-45 71
Wen, Yanqi . . . . . SunA08-11 66
Wen, Zhitao . . . . . SatA02-5 46
Weng, Yongpeng . . . . . SatA06 CC
. . . . . SatA06-5 50
Weng, Yuan . . . . . SatB04-2 54
Wu, Bin . . . . . SunA05-4 62
Wu, Hao . . . . . SatA03-2 47
Wu, Jia Jun . . . . . SunC01-2 91
. . . . . SunC01-3 91
Wu, Jialian . . . . . SatA02-3 46
Wu, Liping . . . . . SunB08-37 86
Wu, Ting . . . . . SunB05-5 79
Wu, Yanming . . . . . SunA05-5 63
Wu, Yinan . . . . . SunA01-2 59
Wu, Yue . . . . . SunA08-56 73
Wu, Yuxin . . . . . SunB07-5 81
Wu, Zhaobin . . . . . SunA08-53 72
Wu, Zhaoqin . . . . . SunB08-05 82


**X**


Xi, Xiang . . . . . SunD04-1 100
Xi, Xinze . . . . . SunB04-4 78
Xia, Chengyi . . . . . SatA05 C
. . . . . SatA05-2 48
. . . . . SatA05-5 49
Xia, Haichuang . . . . . SunC06-5 96
Xiang, Feiyu . . . . . SunC04-3 94
Xiang, Yiyi . . . . . SunD05-6 102
Xiang, Zhengrong . . . . . SunA01 C
. . . . . SunA01-4 59
. . . . . SunB05-5 79

. . . . . SunB05-6 79
Xiao, Bing . . . . . SunB08-27 85
Xiao, Jingyu . . . . . SunB08-05 82
Xiao, Mohan . . . . . SatB02-2 53
Xiao, Qi . . . . . SunD03-1 99
Xiao, Shasha . . . . . SunC02-6 92
Xiao, Wenbin . . . . . SunA06-4 63
. . . . . SunA07-4 64
Xiao, Yi . . . . . SunA05-4 62
. . . . . SunB04-3 78
Xie, Chun-Hua . . . . . SunC03-2 93
Xie, Guo . . . . . SunD04-3 101
Xie, Lei . . . . . SunB08-18 84
Xie, Linbo . . . . . SunA08-08 66
Xie, Shuzong . . . . . SunB03-3 77
Xing, Chao . . . . . SunB04-4 78
Xing, Xing . . . . . SunA08-18 67
. . . . . SunA08-64 74
Xing, Yashan . . . . . SatB05-1 55
Xiong, Jiandong . . . . . SunB02-1 76
Xiong, Peiyin . . . . . SunA07-5 64
Xiong, Qianqian . . . . . SunA08-28 69
Xiong, Qin . . . . . SunD01-2 97
Xiong, Shuangshuang . . . . . SatA06-1 49
. . . . . SunB07-5 81
Xiong, Shuangshuang . . . . . SunA02 CC
. . . . . SunA02-2 60
Xu, Binzi . . . . . SunB04-5 78
Xu, Chi . . . . . SatA03-1 46
Xu, Danya . . . . . SunC01-1 91
Xu, Dezhi . . . . . SatB00-5 51
. . . . . SunD05 C
. . . . . SunD05-2 101
. . . . . SunD05-3 102
. . . . . SunD05-5 102
Xu, Feng . . . . . SunC06-2 95
Xu, Hang . . . . . SunD03-1 99
Xu, Hang . . . . . SunB08-54 89
Xu, Haorui . . . . . SunA05-2 62
Xu, Jiamin . . . . . SatB00-4 51
Xu, Qing-Yuan . . . . . SunB05-4 79
Xu, Sha Man . . . . . SunB04-5 78
Xu, Shizhou . . . . . SunB02-4 76
Xu, Shu Wei . . . . . SunA08-04 65
Xu, Shuiqing . . . . . SunB08-64 90
Xu, Weihua . . . . . SunB08-18 84
Xu, Yang . . . . . SunC04-6 94
Xu, Ye . . . . . SunA08-08 66
Xu, Yiming . . . . . SunA08-26 68
Xu, Yuan . . . . . SunA08-16 67
. . . . . SunB08-16 83
. . . . . SunB08-36 86
Xu, Yuan . . . . . SunA08-54 72
. . . . . SunD03-4 100
Xue, Guangyue . . . . . SunA08-62 74
Xue, Tong Lai . . . . . SunC06-4 95
Xue, Wenchao . . . . . SatB03 CC
. . . . . SunC04-3 94
Xue, Xiaozhe . . . . . SunA08-47 71
Xue, Yihang . . . . . SunD01-4 98
. . . . . SunD01-5 98
Xue, Zepeng . . . . . SunB08-56 89
Xue, Zixiao . . . . . SunB07-6 81
Xun, Jing . . . . . SunB01-4 75


**Y**


Yan, Chengyang . . . . . SunB08-08 82
Yan, Hang . . . . . SatB04-6 55
Yan, Hongyu . . . . . SunD07-1 103
Yan, Li . . . . . SunB08-06 82
Yan, Qiuzhen . . . . . SatB06-5 57
. . . . . SatB06-6 57
. . . . . SunB08-22 84
Yan, Qun . . . . . SatB01-6 52
Yan, Yifan . . . . . SunB01-1 74
Yan, Yuying . . . . . SunA05-3 62
Yan, Zhiguo . . . . . SunB02-5 76
Yang, Biao . . . . . SunD01-1 97
Yang, Bin . . . . . SunB08-02 82
. . . . . SunB08-04 82
Yang, Chao . . . . . SatB00-4 51
Yang, Chao . . . . . SunC01-5 91
Yang, Chen . . . . . SunA02-6 60
Yang, Chunjie . . . . . SunA08-51 72
Yang, Chunxi . . . . . SatB07-6 57
. . . . . SunC05-2 94
Yang, Chunyu . . . . . SunA01-3 59
Yang, Dandan . . . . . SunB08-04 82
Yang, Fan . . . . . SunC06-6 96
Yang, Haitao . . . . . SunD05-3 101
Yang, Hang . . . . . SatB06-4 56
Yang, Hongyan . . . . . SunB08-33 86
Yang, Jianquan . . . . . SatB07-6 58
Yang, Jielong . . . . . SunA08-08 66
Yang, Jinwei . . . . . SatB03-3 54
. . . . . SatB03-4 54
Yang, Lan . . . . . SunA05-4 62
Yang, Mingxing . . . . . SatB05-5 56
Yang, Pengcheng . . . . . SunA08-52 72
Yang, Qin . . . . . SunA06-4 63
Yang, Qinmin . . . . . SunA08-38 70
. . . . . SunB03-3 77
. . . . . SunC01-4 91
Yang, Rongni . . . . . SunB05-3 79
Yang, Shuai . . . . . SatB05-5 56
Yang, Tao . . . . . SunA07-2 64
Yang, Tao . . . . . SunC01-1 91
Yang, Weilin . . . . . SatB00-5 52
. . . . . SunD05-2 101
Yang, Xiao-Fei . . . . . SunB05-5 79
. . . . . SunB05-6 79
Yang, Xiaoyu . . . . . SunA08-12 66
Yang, Xu . . . . . SatA03-2 47
. . . . . SatA03-3 47
. . . . . SunB08-57 89
Yang, Yong . . . . . SatB01 CC
. . . . . SatB01-1 52
Yang, Yongliang . . . . . SunA04 CC
. . . . . SunA04-4 62
Yang, Yulin . . . . . SatB01-5 52
Yang, Yusong . . . . . SatA06-1 49
Yang, Yuxing . . . . . SunA08-34 69
Yang, Zeyu . . . . . SatA07-4 50
. . . . . SatA07-6 51
. . . . . SunD05-1 101
Yang, Zhixuan . . . . . SunB05-2 79
Yao, Le . . . . . SatA07-2 50
. . . . . SatA07-4 50
. . . . . SatA07-6 51
Yao, Wen-Long . . . . . SunA02-5 60
. . . . . SunB08-08 82
Yao, Yajuan . . . . . SunA08-43 71
Yao, Yuan . . . . . SunC01 CC
. . . . . SunC01-1 91
. . . . . SunC01-2 91
. . . . . SunC01-3 91
. . . . . SunD01 CC
. . . . . SunD01-3 98
. . . . . SunD01-4 98
. . . . . SunD01-5 98
. . . . . SunD01-6 98
Ye, Hui . . . . . SunB05-5 79
Ye, Jie . . . . . SunB06-1 79
Ye, Lingjian . . . . . SatA07-5 51
. . . . . SunB08-01 81

SunD05-1 101
Ye, Linhua SunB08-41 87
Ye, Shufang SatA03-6 47
Ye, Xiangyun SunD01-6 98
Yi, Shuai SunB08-12 83
Yin, Caiyun SunB04-1 78
Yin, Chenkun SunA02-1 60
SunB01-4 75
Yin, Zhenyu SunA01-2 59
Yin, Zijie SatB01-2 52
SatB02-6 53
Ying, Liang-Huan SunA08-65 74
You, Yapeng SunB08-17 84
You, Yiting SatB01-2 52
Yu, Di SunA08-13 66
Yu, Gongye SunB08-17 84
Yu, Guo-Yuan SunC01-3 91
Yu, Jiyang SunB08-53 89
Yu, Mengjun SunA01-3 59
Yu, Qiongxia SatA01 CC
SatA01-6 45
Yu, Renhai SunA04-1 61
Yu, Tingting SunD06-3 102
Yu, Wangyang SunC01-6 92
SunD01-1 97
SunD01-2 97
Yu, Wei SatB00-3 51
Yu, Wenbo SunD04-6 101
Yu, Xian SunA08-27 68
Yu, Xiyu SunB08-35 86
SunB08-40 87
Yu, Yue SunA03-6 61
Yu, Zhen SunB08-49 88
Yuan, Kui SatA02-2 46
Yuan, Ruonan SatB03-1 53
Yuan, Xiaofeng SatA07 CC
SatA07-5 51
Yuan, Yidan SatB02-2 53
Yue, Wancheng SunA03-3 61


## Z


Zang, Yunge SunD07-5 103
Zeng, Jiusun SatA07 C
SatA07-2 50
SatA07-3 50
SatA07-4 50
Zeng, Kun SatA01-2 45
SunA08-23 68
Zeng, Ran SatB04-4 55
Zeng, Siyuan SatA03-4 47
Zeng, Zhenyu SunA08-51 72
Zhan, Zhiyong SunB08-28 85
SunB08-34 86
Zhang, Ancai SunA07-1 64
Zhang, Bin SunC07-2 96
Zhang, Bing SunA08-51 72
Zhang, Bo SunA04-1 61
Zhang, Chao SunA04-6 62
Zhang, Chengxi SunB01-4 75
Zhang, Chengxu SatA05-6 49
Zhang, Chiye SatA07-2 50
Zhang, Chunyan SunD05-3 101
Zhang, Cong SunA08-15 67
Zhang, Congcong SunC01-5 91
Zhang, Daoyuan SunA08-38 70
Zhang, Dongxu SatA06-2 49
Zhang, Fan SunB02-2 76
Zhang, Guangbin SunA03-4 61
Zhang, Guangchen SunB05 C
Zhang, Guoju SatB02-4 53
Zhang, Guopeng SunD07-1 103
Zhang, Haifeng SunB08-24 85
Zhang, Haozhe SunC07-5 97
Zhang, Hong SunA01-6 59
SunA08-12 66
Zhang, Hongwei SunA06-1 63
Zhang, Hongwei SunD04 C
SunD04-5 101
Zhang, Hualiang SunD07-1 103
Zhang, Jiaming SunC07-4 97
Zhang, Jian SunB08-24 85
Zhang, Jian-Ping SunC03-2 93
Zhang, Jianming SunB08-30 85
SunC04 C
SunC04-1 93
Zhang, Jianxiang SatA07-1 50
Zhang, Kai SatA02-6 46
SunB08-15 83
Zhang, Kai SunA08-52 72
SunA08-55 73
Zhang, Kehao SunC01-6 92
Zhang, Kun SatB02-6 53
Zhang, Lei SunB01-3 75
Zhang, Limin SunB08-05 82
SunB08-06 82
Zhang, Lujin SatB03-5 54
SunC02-2 92
Zhang, Menghua SunC05 CC
SunC05-1 94
Zhang, Min SunC04-4 94
Zhang, Ming-Qing SunA08-16 67
SunB08-16 84
Zhang, Naizong SunB05-1 79
Zhang, Nan SatB05-2 55
Zhang, Pengchao SunB02-6 77
Zhang, Pengchao SunA05-1 62
Zhang, Qi SunB08-18 84
Zhang, Qi SatA02-4 46
Zhang, Qiang SunA08-44 71
Zhang, Qichao SunA04 C
SunA04-5 62
Zhang, Qiuxia SatA06-5 50
Zhang, Ruifeng SunB05-3 79
Zhang, Ruikun SunB08-35 86
SunB08-40 87
Zhang, Shengxi SunA08-28 69
Zhang, Shitong SatB03-2 54
Zhang, Sihang SunA08-15 67
Zhang, Sihang SunA08-44 71
Zhang, Tao SunB08-57 89
Zhang, Tao SunD07-1 103
Zhang, Tingyu SatB02-3 53
Zhang, Weiming SatB00-5 51
SunD05-5 102
Zhang, Wen Yi SunB08-09 83
Zhang, Wenjie SunC02-1 92
Zhang, Xiaoping SunC06-5 96
Zhang, Xiaowen SunA08-55 73
Zhang, Xingfan SatA03-5 47
Zhang, Xinmin SunD03 C
SunD03-6 100
Zhang, Xiufeng SatB07-6 58
SunC05-2 94
Zhang, Xu SunB08-43 87
Zhang, Xuefeng SunB08-46 88
Zhang, Xuerui SunD03-6 100
Zhang, Xulong SatA04-5 48
Zhang, Yang SunA08-16 67
SunB08-16 84
Zhang, Yanyan SunA08-52 72
Zhang, Yongzheng SunB08-48 88
Zhang, Yuqi SunC07-2 96
Zhang, Yusha SunA08-56 73
SunB08-62 90
Zhang, Zeyi SatA01-2 45
SunA08-23 68
Zhang, Zhengxin SatA02-1 45

. . . . . SunD03-3 99
Zhang, Zhengxuan . . . . . SatA03-3 47
Zhang, Zhenyong . . . . . SunA08-38 70
Zhang, Zhihao . . . . . SunB03-6 78
Zhang, Zhixin . . . . . SunA08-05 65
Zhang, Zhiyang . . . . . SunA02-1 60
Zhao, Bo . . . . . SunA03 C
. . . . . SunA03-5 61
Zhao, Caiting . . . . . SunA08-46 71
Zhao, Dong . . . . . SatA02-3 46
. . . . . SunD03-5 100
Zhao, Dong-Bin . . . . . SunA08-61 73
Zhao, Erquan . . . . . SatB02-4 53
Zhao, Fuyu . . . . . SunB02-3 76
Zhao, Gan . . . . . SunB08-58 89
Zhao, Guoqiang . . . . . SunC01-2 91
. . . . . SunC01-3 91
. . . . . SunD01-3 98
Zhao, Hongpeng . . . . . SunB02-1 76
Zhao, Hongyang . . . . . SunD07-4 103
Zhao, Huarong . . . . . SunA08-08 66
Zhao, Hui . . . . . SunA06-6 64
Zhao, Jin-Gang . . . . . SunB08-50 88
Zhao, Jun . . . . . SatB07-2 57
Zhao, Jun . . . . . SunA08-48 72
. . . . . SunA08-50 72
. . . . . SunB01-2 75
Zhao, Junjie . . . . . SunC02-3 92
Zhao, Liming . . . . . SunA03-6 61
Zhao, Lin . . . . . SunC07-3 96
Zhao, Lingxiao . . . . . SatA06-4 49
Zhao, Qiangsong . . . . . SunA06-1 63
. . . . . SunA06-3 63
Zhao, Qiqian . . . . . SunB08-36 86
Zhao, Wanqing . . . . . SunA08-02 65
Zhao, Yilin . . . . . SunA08-29 69
. . . . . SunA08-30 69
. . . . . SunB08-28 85
. . . . . SunB08-34 86
Zhao, Yinghao . . . . . SatA03-2 47
Zhao, Yu-Ge . . . . . SunB07-3 81
Zhao, Yuezhou . . . . . SunA08-20 67
Zhao, Yunda . . . . . SunD07-6 104
Zhao, Yuxin . . . . . SunB08-30 85
. . . . . SunC04-1 93
Zhao, Zhiliang . . . . . SatB03-1 53
. . . . . SatB03-2 54
Zhao, Ziliang . . . . . SatB07-4 57
Zheng, Changbing . . . . . SunA08-04 65
. . . . . SunB08-04 82
Zheng, Chen . . . . . SatB02-3 53
. . . . . SunA08-09 66
. . . . . SunB06-2 80
. . . . . SunB06-3 80
Zheng, Chuangkai . . . . . SunC02-4 92
Zheng, Dezhi . . . . . SunA08-37 70
Zheng, Dongdong . . . . . SatB05 CC
. . . . . SatB05-6 56
. . . . . SunA04-6 62
Zheng, Qing . . . . . SatA02-6 46
. . . . . SunB08-15 83
Zheng, Teng . . . . . SunB08-32 86
Zheng, Ying . . . . . SunA01-6 59
. . . . . SunA08-12 66
Zhi, Weimei . . . . . SunA08-26 68
Zhong, Kai . . . . . SunB08-24 85
Zhong, Mingshan . . . . . SunA08-14 67
Zhong, Xueyan . . . . . SunA08-48 72
Zhou, Cen . . . . . SunB08-66 91
Zhou, Funa . . . . . SunA08-11 66
Zhou, Honggen . . . . . SunA08-35 70
Zhou, Huixing . . . . . SunA08-06 65
. . . . . SunA08-07 65
Zhou, Jian . . . . . SunC02-1 92
Zhou, Junwen . . . . . SatB06-1 56
Zhou, Keliang . . . . . SunA06-5 63
Zhou, Lan . . . . . SatA04-4 48
. . . . . SunA06 C
. . . . . SunA06-4 63
. . . . . SunA07-4 64
Zhou, Lan . . . . . SunA07-5 64
Zhou, Linna . . . . . SunA01-3 59
Zhou, Liuming . . . . . SunC02-4 92
Zhou, Shaobo . . . . . SunD06-2 102
Zhou, Shibo . . . . . SunA08-41 71
Zhou, Shidong . . . . . SunD06-5 103
Zhou, Shuhan . . . . . SunD07-6 104
Zhou, Xiaoming . . . . . SunC02-1 92
Zhou, Xinhao . . . . . SunA07-1 64
Zhou, Yan . . . . . SunA08-37 70
Zhou, Yang . . . . . SunA08-29 69
. . . . . SunA08-30 69
. . . . . SunB08-28 85
. . . . . SunB08-34 86
Zhou, Yujian . . . . . SunA07-6 64
Zhou, Yunchen . . . . . SunD06-6 103
. . . . . SunD07-6 104
Zhou, Zhe . . . . . SunD05-1 101
Zhou, Zhihao . . . . . SunB08-10 83
. . . . . SunB08-20 84
Zhu, Erlin . . . . . SunA07-2 64
Zhu, Juanping . . . . . SunB08-07 82
Zhu, Jun-Wei . . . . . SunA08-65 74
Zhu, Kai-Kai . . . . . SunD01-3 98
Zhu, Ke . . . . . SunB08-30 85
. . . . . SunC04-1 93
Zhu, Qunxiong . . . . . SunA08-54 72
. . . . . SunD03-4 100
Zhu, Qunxiong . . . . . SunA08-16 67
. . . . . SunB08-16 84
. . . . . SunB08-36 86
Zhu, Sheng . . . . . SatB06-2 56
Zhu, Wenxin . . . . . SatB00-1 51
Zhu, Yu-Rong . . . . . SunC01-2 91
Zhu, Yun . . . . . SunA01-2 59
Zhuang, Huixuan . . . . . SunB08-46 88
Zou, Peng . . . . . SatB06-3 56
Zou, Xun . . . . . SunB08-16 84
Zou, Yongxing . . . . . SatB04-2 54

# Chair/Co-Chair Index

(C=Chair, CC=Co-Chair)


**A**

Ai, Wei ..... SunB06 CC

**B**

Bai, Weiwei ..... SunA03 CC

**C**

Cao, Rongmin ..... SunA08 CC
Che, Wei-Wei ..... SunC03 CC
Chen, Hongtian ..... SatB04 C
Chen, Qiang ..... SatB06 C
..... SunB03 CC
Chen, Sen ..... SatB03 C

**D**

Dong, Na ..... SatA05 CC

**G**

Gao, Zhe ..... SunC02 C
Guo, Shenghui ..... SunC06 C

**H**

Han, Weixin ..... SunC04 CC
Han, Yongming ..... SunD04 CC
Hao, Li-Ying ..... SatA06 C
He, Ning ..... SunD06 C
He, Shuping ..... SunB05 CC
He, Yan-Lin ..... SunD03 CC
Huang, Yingbo ..... SunC05 C
Hui, Yu ..... SunB08 CC
Huo, Xin ..... SunA06 CC

**J**

Ji, Honghai ..... SunB07 C
Jiang, Yuchen ..... SatB04 CC

**K**

Kong, Ying ..... SatB06 CC

**L**

Li, Dazi ..... SatB02 C
Li, Feng ..... SunA07 C
..... SunD02 CC
Li, Jinna ..... SatB02 CC
Li, Juntao ..... SunB02 C
Li, Linwei ..... SatB07 CC
Li, Meiliu ..... SunA07 CC
Li, Shengquan ..... SunC02 CC
..... SunD02 C
Li, Yuan Xin ..... SunC03 C
Li, Yueyang ..... SatA02 C
Liang, Hongjing ..... SunB04 C
Liu, Lei ..... SunA05 CC
Liu, Shan ..... SatB01 C
Liu, Shida ..... SunB07 CC
Liu, Yang ..... SunA05 C
Liu, Yang ..... SunD07 C
Liu, Yang ..... SunC07 C
Liu, Yi ..... SunC01 C
..... SunD01 C
Luo, Hao ..... SatA03 C
Lv, Yongfeng ..... SatB07 C

**M**

Mao, Zehui ..... SunD05 CC
Meng, Deyuan ..... SunB02 CC
Meng, Zhou ..... SunC06 CC
Mo, Lipo ..... SunC07 CC

**P**

Pan, Yingnan ..... SunB04 CC
Pang, Zhonghua ..... SunB06 C
Peng, Yunjian ..... SunB01 CC

**Q**

Qi, Guoyuan ..... SatA04 C
Quan, Quan ..... SatA04 CC

**S**

Shi, Jia ..... SatA01 C
Song, Fazhi ..... SunD07 CC
Song, Ruizhuo ..... SunA01 CC
Sun, Mingwei ..... SunA08 C
SUN, Mingxuan ..... SatB00 C

**W**

Wang, Junxiao ..... SunB03 C
Wang, Shenquan ..... SatA02 CC
Wang, Shubo ..... SatB05 C
Wang, Xianghua ..... SunB08 C
Wang, Xin ..... SunA02 C
Wang, Xin ..... SunD06 CC
Wang, Zhenhua ..... SatA03 CC
Wang, Zhu ..... SunB01 C
Weng, Yongpeng ..... SatA06 CC

**X**

Xia, Chengyi ..... SatA05 C
Xiang, Zhengrong ..... SunA01 C
Xiong, Shuangshuang ..... SunA02 CC
Xu, Dezhi ..... SunD05 C
Xue, Wenchao ..... SatB03 CC

**Y**

Yang, Yong ..... SatB01 CC
Yang, Yongliang ..... SunA04 CC
Yao, Yuan ..... SunC01 CC
..... SunD01 CC
Yu, Qiongxia ..... SatA01 CC
Yuan, Xiaofeng ..... SatA07 CC

**Z**

Zeng, Jiusun ..... SatA07 C
Zhang, Guangchen ..... SunB05 C
Zhang, Hongwei ..... SunD04 C
Zhang, Jianming ..... SunC04 C
Zhang, Menghua ..... SunC05 CC
Zhang, Qichao ..... SunA04 C
Zhang, Xinmin ..... SunD03 C
Zhao, Bo ..... SunA03 C
Zheng, Dongdong ..... SatB05 CC
Zhou, Lan ..... SunA06 C

| Friday, May 12, 2023, Paragon Hotel, Xiangtan (湘潭 盘龙山庄大酒店) | | | |
|---|---|---|---|
| 14:00 | Lobby of the Great Hall | 3rd Conf. Hall | |
| 14:00-18:00 | Register | 14:00-16:00 | Pre-Conference Tutorial I – Model Free Adaptive Control |
| | | 16:00-18:00 | Pre-Conference Tutorial II – Iteration Learning Control |
| 18:00-20:00 | Dinner, *Golden Hall* (金色大厅) | | |

| Saturday, May 13, 2023, Paragon Hotel, Xiangtan (湘潭 盘龙山庄大酒店) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8:00-8:30 | Opening ceremony, Venue: *1st Conf. Hall*, Chair: Prof. Jing Wang | | | | | | | |
| 8:30-9:20 | Keynote Address 1: Fully Actuated System Approach and Data Driven Control, Prof. *Guangren Duan*, Chair: Prof. Chenghong Wang | | | | | | | |
| 9:20-10:00 | Tea Break and Photo | | | | | | | |
| 10:00-10:50 | Keynote Address 2: The Relevance of Control Science and Engineering for Industry: Perspective, Messages, and Opportunities, Prof. *Tariq Samad*, Chair: Prof. Jing Na | | | | | | | |
| 10:50-11:40 | Keynote Address 3: 预设时间控制理论的最新进展, Prof. *Yongduan Song*, Chair: Prof. Mingxuan Sun | | | | | | | |
| 12:00-13:30 | Lunch, *Banquet Hall* (宴会厅) | | | | | | | |
| Time/Room | 8th Conf. Hall | 2nd Conf. Hall | 3rd Conf. Hall | 5th Conf. Hall | 7th Conf. Hall | 9th Conf. Hall | Yuetang Hall | Hongqi Hall |
| 13:30-15:30 | Distinguished Lecture | SatA01 | SatA02 | SatA03 | SatA04 | SatA05 | SatA06 | SatA07 |
| 13:30-14:10 | Lecture 1: Planning and Control for a Class of Rotor-Driven Hybrid Aerial and Terrestrial Vehicles, Prof. *Lixian Zhang*, Chair: Prof. Youqing Wang | Iterative Learning Control | Data-driven Fault Diagnosis and Health Maintenance I | Process Monitoring and Control for Complex Industrial Systems | Data-driven Control and Learning with Additive Decomposition | Data Driven Information Processing and Intelligent Control | Data Driven Control, Learning and Optimization | Deep Learning Based Soft Sensing and Iterative Learning Control |
| 14:10-14:50 | Lecture 2: Industrial Data Intelligence Driven Technology for Operation of Off-Shore Wind Turbine Swarm, Prof. *Qinmin Yang*, Chair: Prof. Xiongxiong He | | | | | | | |
| 14:50-15:30 | Lecture 3: Efficient Learning and Intelligent Critic Control for Complex Nonlinear Systems, Prof. Ding Wang, Chair: Prof. Zhuo Wang | | | | | | | |
| 15:30-15:40 | Tea Break | | | | | | | |

| Time/Room | 8th Conf. Hall | 2nd Conf. Hall | 3rd Conf. Hall | 5th Conf. Hall | 7th Conf. Hall | 9th Conf. Hall | Yuetang Hall | Hongqi Hall |
|---|---|---|---|---|---|---|---|---|
| 15:40-17:40 | SatB00 | SatB01 | SatB02 | SatB03 | SatB04 | SatB05 | SatB06 | SatB07 |
| 15:40-17:40 | Best Paper Chair: Prof. Mingxuan Sun | Neural Networks, Fuzzy Systems Control in Data Driven Manner | Deep Neural Network and Reinforcement Learning Control | Disturbance Compensation Based Control | Data-driven Fault Diagnosis and Fault-tolerant Control | Adaptive Control for Nonlinear Servo System & Applications | Data-driven Modeling and Adaptive Iterative Learning Control | Identification & Learning Optimal Control for Nonlinear Systems |
| 18:00-20:00 | Dinner, *Banquet Hall* (宴会厅) | | | | | | | |

| Sunday, May 14, 2023, Paragon Hotel, Xiangtan (湘潭 盘龙山庄大酒店) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Time/Room | 8th Conf. Hall | 2nd Conf. Hall | 3rd Conf. Hall | 5th Conf. Hall | 7th Conf. Hall | 9th Conf. Hall | Yuetang Hall | Hongqi Hall | 6th Conf. Hall |
| 8:00-10:00 | Distinguished Lecture | SunA01 | SunA02 | SunA03 | SunA04 | SunA05 | SunA06 | SunA07 | SunA08 |
| 8:00-8:40 | Lecture 4: Data-Driven Calibration for Radio Frequency Communication Systems, Prof. *Zhi Quan*, Chair: Prof. Wenchao Xue | Reinforcement Learning Theory and Its Applications | Model-free Adaptive Control | RL and ADP-based Adaptive Control | Reinforcement Learning and Its Applications in Decision-making and Control Systems | Intelligent and Adaptive Learning Control for Nonlinear Systems | Repetitive Control for Uncertain Nonlinear Systems | Equivalent-Input-Disturbance Approach for Disturbance Estimation and Rejection | Poster Session (I) |
| 8:40-9:20 | Lecture 5: Intelligent Adaptive Control of Nonlinear Servo Systems, Prof. *Qiang Chen*, Chair: Prof. Deyuan Meng | | | | | | | | |
| 9:20-10:00 | Lecture 6: Adaptive Iterative Learning Control for Nonlinear Systems, Prof. *Xuefang Li*, Chair: Prof. Deqing Huang | | | | | | | | |
| 10:00-10:10 | Tea Break | | | | | | | | |

| Time/Room | 8th Conf. Hall | 2nd Conf. Hall | 3rd Conf. Hall | 5th Conf. Hall | 7th Conf. Hall | 9th Conf. Hall | Yuetang Hall | Hongqi Hall | 6th Conf. Hall |
|---|---|---|---|---|---|---|---|---|---|
| 10:10-12:10 | Forum | SunB01 | SunB02 | SunB03 | SunB04 | SunB05 | SunB06 | SunB07 | SunB08 |
| 10:10-12:10 | Industrial Control Practice Forum Chair: Prof. Bo Sun | Data Driven Control | Recent Advances for Control-theoretic Iterative Method | Advanced Motion Control Methods for Modern Mechat. Syst. | Intelligent Cooperative Control for Multiagent Systems | Data-driven Complex Network Learning and Security Analysis | Active Disturbance Rejection Control and Applications | Data-driven Intelligent Control & Public Security of Traffic Syst. | Poster session (II) |
| 12:10-13:30 | Lunch, *Banquet Hall* (宴会厅) | | | | | | | | |

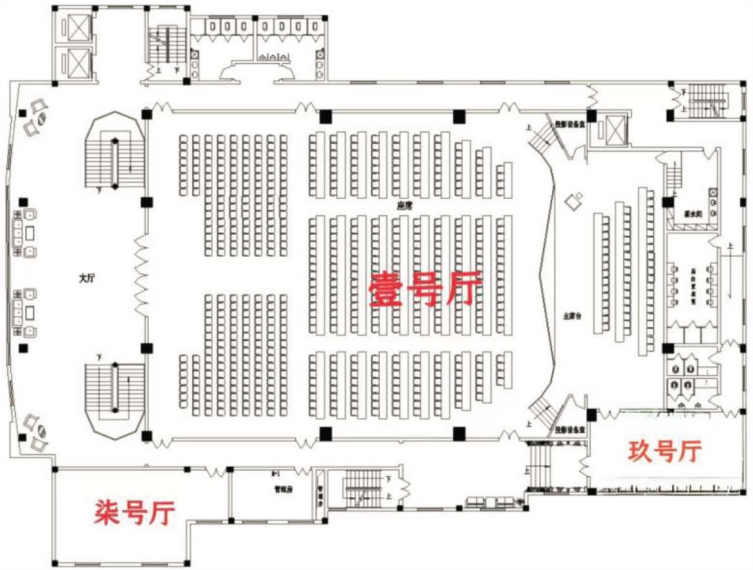
| Time/Room | 2nd Conf. Hall | 3rd Conf. Hall | 5th Conf. Hall | 7th Conf. Hall | 9th Conf. Hall | Yuetang Hall | Hongqi Hall |
|---|---|---|---|---|---|---|---|
| 13:30-15:30 | SunC01 | SunC02 | SunC03 | SunC04 | SunC05 | SunC06 | SunC07 |
| 13:30-15:30 | In-depth Exploration and Learning of Industrial Data I | Modeling, Optimization and Control of Data-Driven Energy Internet Systems I | Intelligent Control of Nonlinear Networked Systems | Data-driven Modeling, Optimization and Scheduling | Adaptive Control for Nonlinear Mechanical System | Networked Control System Simulation and Engineering | Distributed Learning, Optimization and Control |
| 15:30-15:40 | Tea Break | | | | | | |

| Time/Room | 2nd Conf. Hall | 3rd Conf. Hall | 5th Conf. Hall | 7th Conf. Hall | 9th Conf. Hall | Yuetang Hall | Hongqi Hall |
|---|---|---|---|---|---|---|---|
| 15:40-17:40 | SunD01 | SunD02 | SunD03 | SunD04 | SunD05 | SunD06 | SunD07 |
| 15:40-17:40 | In-depth Exploration and Learning of Industrial Data II | Modeling, Optimization and Control of Data-Driven Energy Internet Systems II | Data-driven Fault Diagnosis and Health Maintenance II | Statistical Learning and Machine Learning in Automation Field | Model-free Control, Optimization and Their Applications | Model Predictive Control of Cyber-physical Systems | Data-driven Motion and Vibration Control for Micro /Nano Scale Position Syst. |
| 18:00-20:00 | Closing Ceremony and Banquet, *1st Conf. Hall* (1 号厅), Chair: Prof. Dong Shen | | | | | | |

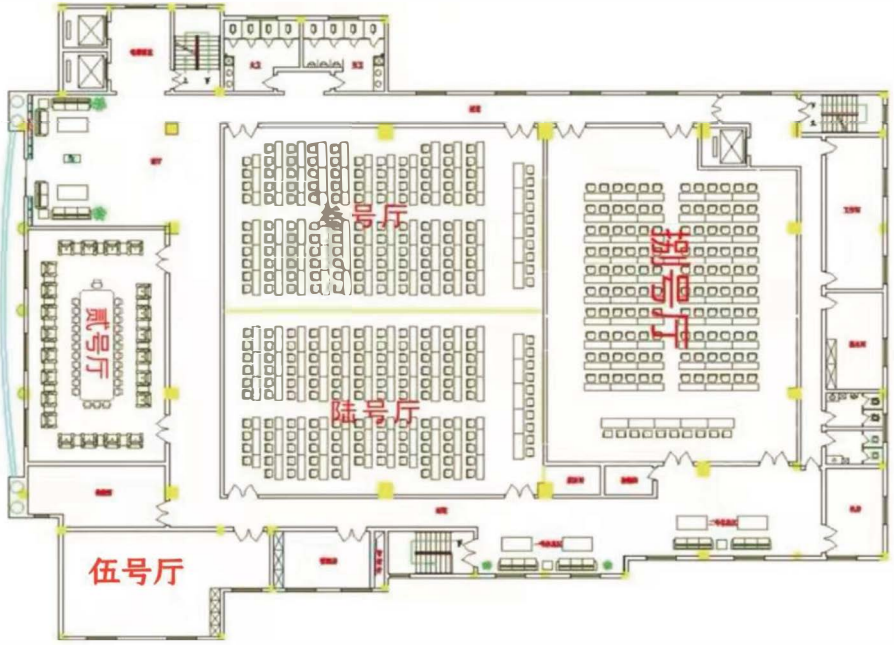
| Room | Room in English | Location | Location in English | Room | Room in English | Location | Location in English |
|---|---|---|---|---|---|---|---|
| 1 号厅 | The 1st Conference Hall | 大会堂二楼 | The 2nd floor of the Great Hall | 8 号厅 | The 8th Conference Hall | 大会堂三楼 | The 3rd floor of the Great Hall |
| 2 号厅 | The 2nd Conference Hall | 大会堂三楼 | The 3rd floor of the Great Hall | 9 号厅 | The 9th Conference Hall | 大会堂二楼 | The 2nd floor of the Great Hall |
| 3 号厅 | The 3rd Conference Hall | 大会堂三楼 | The 3rd floor of the Great Hall | 岳塘厅 | Yuetang Conference Hall | 国际会议中心 | The International Conference Center |
| 5 号厅 | The 5th Conference Hall | 大会堂三楼 | The 3rd floor of the Great Hall | 宏祺厅 | Hongqi Conference Hall | 国际会议中心 | The International Conference Center |
| 6 号厅 | The 6th Conference Hall | 大会堂三楼 | The 3rd floor of the Great Hall | 宴会厅 | Banquet Hall | 大会堂一楼 | The 1st floor of the Great Hall |
| 7 号厅 | The 7th Conference Hall | 大会堂二楼 | The 2nd floor of the Great Hall | 金色大厅 | Golden Hall | 晶宫一楼 | The 1st floor of the Crystal Palace |


一楼：宴会厅（餐）
二楼：壹号楼（主会场）
柒号厅、玖号厅
三楼：贰号厅、叁号厅
伍号厅、捌号厅
陆号厅

岳塘厅、宏祺厅




大会堂二楼平面图




大会堂三楼平面图