FINAL PROGRAM and BOOK OF ABSTRACTS

2021 IEEE 10th Data Driven Control and Learning Systems Conference (DDCLS'21)

Suzhou, China

May 14–16, 2021

Organized by

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

Qingdao University

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Welcome Message from General Chairs

Zhongsheng Hou
General Chair of DDCLS'21

Pengming Jiang
General Chair of DDCLS'21

Dear Friends and Colleagues,

On behalf of the Organizing Committee, it is our greatest pleasure to welcome you to the 2021 IEEE 10th Data Driven Control and Learning Systems Conference (DDCLS'21), which is organized by Technical Committee on Data Driven Control, Learning and Optimization (DDCLO), Chinese Association of Automation and Qingdao University, locally organized by Suzhou University of Science and Technology, and sponsored by IEEE Beijing Section. The conference is held at Tongli Lakeview Hotel, Suzhou, Jiangsu Province, China, May 14–16, 2021.

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 nine conferences, DDCLS'21 continues to attract broad interest throughout the world, with the submission of 351 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 Suzhou 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'21 technical program comprises 10 regular sessions, 22 invited sessions, 1 best paper award session and 2 poster sessions. Besides the technical sessions, the highlights of the DDCLS'21 are the keynote addresses given by world-class level scholars, Prof. Zongli Lin from USA, Prof. Thomas Parisini from UK, Prof. Yaonan Wang from China, Prof. Bin Jiang from China, and the distinguished lectures given by active young scholars. They are Prof. Xiao He, Prof. Zhengguang Wu, Prof. Hongyi Li, Prof. Yalin Wang, Prof. Quan Quan, all from China. During the conference, the other academic activities, including Panel Discussion on the coming control science, Industrial Control Practice Forum, Pre-Conference Workshop and Laoshan Academic Forum are also held for various research interests of the conference participants. These activities provide high quality research and professional interactions on the subject of mode-free adaptive 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 Suzhou, Jiangsu Province, China, and enjoy the colorful scenery and magic foods.

Best wishes

Zhongsheng Hou
General Chair of DDCLS'21

Pengming Jiang
General Chair of DDCLS'21

Message from Technical Program Chairs

Mingxuan Sun
Technical Program Chair

Huaguang Zhang
Technical Program Chair

Dear Friends and Colleagues,

On behalf of the Technical Program Committee, it is our great honor to welcome you to the 2021 IEEE 10th Data Driven Control and Learning Systems Conference (DDCLS'21) in Suzhou, 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'21 has received enthusiastic responses with a total of 351 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 305 accepted papers which are divided into 33 oral sessions and 2 poster sessions for presentation.

Ahead of the parallel technical sessions, we will have four 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. Zongli Lin (University of Virginia), Prof. Thomas Parisini (Imperial College London), Prof. Yaonan Wang (Hunan University), and Prof. Bin Jiang (Nanjing University of Aeronautics and Astronautics) as the keynote address speakers. Besides, we are very fortunate to have the distinguished lectures given by the five outstanding young scholars, Prof. Xiao He (Tsinghua University), Prof. Zhengguang Wu (Zhejiang University), Prof. Hongyi Li (Guangdong University of Technology), Prof. Quan Quan (Beihang University), and Prof. Yalin Wang (Central South University). DDCLS'21 is also rich in all kinds of academic activities, including Panel Discussion, Industrial Control Practice Forum, Pre-Conference Workshop and Laoshan Academic Forum. More than eighteen distinguished scholars will present their new research findings, in the field of artificial intelligence, data-driven automatic control and industrial applications, such as Prof. Chenghong Wang, Prof. Long Wang, et al. 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

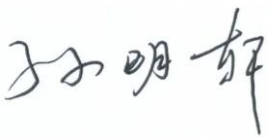
enthusiastic contributions and strong supports to DDCLS’21.

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’21. Based on reviewers' comments and nominations as well as the evaluations of Technical Program Committee members, 21 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, six papers were shortlisted as the finalists for the award. During the conference, the oral presentations of the six finalists will be further assessed by the DDCLS’21 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 93 papers in 2 poster sessions will be assessed by the DDCLS’21 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. Zengqiang Chen, Prof. Darong Huang, Prof. Jing Na, Prof. Fei Qiao, Prof. Senping Tian, Prof. Qinglai Wei, Prof. Zhanshan Wang, Prof. Jinpeng Yu, Prof. Weiwei Che, Prof. Yi Liu, and Dr. Zhengtian Wu, Subject Session Chairs Prof. Zhihuan Song, Prof. Dongbin Zhao, 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’21 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’21 in Suzhou is really stimulating, rewarding, enjoyable, and memorable.



Mingxuan Sun
Technical Program Chair

Huaguang Zhang
Technical Program Chair

Keynote Address

Keynote Address 1

多机器人协作关键技术应用与发展趋势

Applications and Development Trend of Key Technologies for Multi-robots Collaboration

Prof. Yaonan Wang
Hunan University, China

Saturday, May 15, 2021
08:30-09:20
International Hall & Function room ABC / 国际会议厅+ABC 厅

Abstract

多机器人协作是具有协同感知、规划决策、优化控制、执行功能的智能系统技术，它是信息技术和人工智能的深度融合。多机器人协作系统在国防、工业、农业等领域都具有重要的应用价值和广泛的应用前景。1.报告概述了多机器人研究背景及意义，国内外研究现状，对现有人工智能技术提出的巨大挑战，亟需研究多机器人协同感知与控制技术。2.详细介绍了多机器人协作的技术难题及解决方案。3.探讨了协同视觉感知、高效规划、多机协同控制等关键技术，并应于智能制造、国防等领域。4.总结与展望多机器人发展与前景。

Multi-robots collaboration is an intelligent system technology, which has the function of collaborative perception, planning and decision, optimization and control, and execution. It is a deep integration of information technology and artificial intelligence. It has important value and broad prospect for application in the fields of national defense, industry, and agriculture. 1. In this report, the background and significance and state of art of multi-robot research is overviewed. In face of the challenges to the existing artificial intelligence technology, there is an urgent need for studying multi-robots collaborative sensing and control technology. 2. The technical problems and solutions of multi-robot collaboration are introduced in detail. 3. The key technologies such as collaborative visual perception, high-efficiency planning and multi-agent collaborative control are discussed and applied to intelligent manufacturing, national defense and other fields. 4. A summary and outlook on the development and prospects of multi-robots is given.

Biography

王耀南，中国工程院院士，机器人技术与智能控制专家。湖南大学教授、博士生导师、机器人视觉感知与控制技术国家工程实验室主任。2001-2020年湖南大学电气与信息工程学院院长，2016-2020年湖南大学机器人学院院长。德国洪堡学者、欧盟第五框架国际合作重大项目首席科学家，入选国家"百千万人才工程"、中国自动化学会会士、中国计算机学会会士、中国人工智能学会会士、国家863计划智能机器人领域主题专家。兼任中国自动化学会常务理事、中国人工智能学会监事、教育部科技委能源与交通学部委员、湖南省自动化学会理事长等。成果获国家技术发明二等奖1项、国家科技进步二等奖4项、国际IEEE机器人与自动化领域"工业应用最高奖"。培养博士60余名（含IEEE Fellow、长江学者、国家杰青等），发表SCI论文170余篇，出版著作9部，获国家发明专利80余项。获得全国高等学校优秀教师、全国五一劳动奖章、全国先进工作者、全国创新争先奖等荣誉称号。

Yaonan Wang, Academician of Chinese Academy of Engineering, the expert of robotics and intelligent control. He is Professor, doctoral supervisor, and director of the National Engineering Laboratory for Robot Visual Perception and Control at Hunan University. He was the dean of the School of Electrical and

Information Engineering at Hunan University from 2001 to 2020, and the dean of the School of Robotics at Hunan University from 2016 to 2020. He was a Humboldt Fellow in Germany, the chief scientist of an international cooperation major project under EU's Fifth Framework. He is a national candidate for the “New Century Talents Project”. Prof. Wang is a fellow of Chinese Association of Automation, a fellow of the China Computer Federation, a fellow of the Chinese Association for Artificial Intelligence, and a principal expert of the National 863 Program in the field of intelligent robots. He is also an Executive Director of Chinese Association of Automation, a Supervisor of Chinese Association for Artificial Intelligence, a member of Energy and Transportation Department in Science and Technology Commission of Ministry of Education, and the Chairman of Hunan Association of Automation.

Keynote Address 2

Control of Linear Systems Subject to Actuator Saturation: From Model-Based Design to Reinforcement Learning Control

Prof. Zongli Lin
University of Virginia, USA

Saturday, May 15, 2021
09:40-10:30
International Hall & Function room ABC / 国际会议厅+ABC 厅

Abstract

This talk will discuss the problem of controlling a linear system subject to actuator saturation through reinforcement learning. In particular, it is illustrated how the model-based control design techniques motivate the design of iterative Q-learning algorithms for global asymptotic stabilization of discrete-time linear systems that are asymptotically null controllable with bounded control. It is hoped that the discussion will stimulate interest in constrained control problems among the data driven control and learning systems research community.

Biography

Zongli Lin is the Ferman W. Perry Professor in the School of Engineering and Applied Science and a Professor of Electrical and Computer Engineering at the University of Virginia. He received his B.S. degree in Mathematics and Computer Science from Xiamen University, Xiamen, China, in 1983, his Master of Engineering degree in automatic control from Chinese Academy of Space Technology, Beijing, China, in 1989, and his Ph.D. degree in electrical and computer engineering from Washington State University, Pullman, Washington, in 1994. His current research interests include nonlinear control, robust control, and control applications.

Professor Lin has served on the editorial boards of several journals, including those of IEEE Transactions on Automatic Control, IEEE/ASME Transactions on Mechatronics, IEEE Control Systems Magazine, and IEEE/CAA Journal Automatica Sinica. He was elected a member of the Board of Governors of the IEEE Control Systems Society (2008-2010 and 2019-2021) and chaired the IEEE Control Systems Society Technical Committee on Nonlinear Systems and Control (2013-2015). He has also served on the operating committees of several conferences and was the program chair of the 2018 American Control Conference and a general chair of the 13th and 16th International Symposia on Magnetic Bearings, held in 2012 and 2018, respectively. He currently serves on the editorial boards of several journals and book series, including Automatica, Systems & Control Letters, Science China Information Sciences, and Springer/Birkhauser book series Control Engineering. He is a Fellow of IEEE, IFAC, AAAS and CAA.

Keynote Address 3

高速列车牵引传动系统故障诊断、预测与容错控制技术

Fault Diagnosis, Prediction and Fault-Tolerant Control Technology for Traction Drive System of High-Speed Train

Prof. Bin Jiang
Nanjing University of Aeronautics and Astronautics, China

Saturday, May 15, 2021
10:30-11:20
International Hall & Function room, ABC / 国际会议厅+ABC 厅

Abstract

作为高效便捷运输工具之一高速列车，随着其全世界的普及，其安全性和可靠性也越来越受到重视。牵引传动系统为高速列车提供动力，其包含整流器，逆变器，牵引电机，中间电容等电气设备，一旦发生故障会导致列车损失动力，造成减速、停车甚至事故。因此，开展基于模型和数据驱动的牵引系统故障诊断、剩余寿命预测与容错控制研究具有重要的意义。针对高速列车牵引系统和设备级故障进行建模和传播机理分析，考虑到列车运行中的干扰和噪声，研究干扰下故障诊断、预测与容错控制方法，基于半物理仿真实验平台和车载实验开展了牵引传动系统的故障诊断应用研究。

As one of the efficient and convenient means of transportation, with its popularity all over the world, safety and reliability of high-speed train have been paid more and more attention. Traction drive system, which includes rectifier, inverter, traction motor, intermediate capacitor and other electrical equipment, provides power for high-speed train. In case of failure, the train will lose power, resulting in deceleration, parking and even accidents. Therefore, it is of great significance to carry out the research on fault diagnosis, prediction of residual life and fault-tolerant control of traction system based on model and data-driven. In this paper, the modeling and propagation mechanism analysis of high-speed train traction system and equipment-level faults are carried out. Considering the interference and noise in train operation, the fault diagnosis, prediction and fault-tolerant control method under interference are studied. Based on semi physical simulation experimental platform and on-board experiment, research on application of fault diagnosis on traction drive system is carried out.

Biography

姜斌，南京航空航天大学教授、博导、副校长，IEEE Fellow，教育部“长江学者”特聘教授， 中国自动化学会会士。曾经先后在新加坡、法国、美国、加拿大做博士后、研究员、邀请教授和访问教授。目前担任国际期刊 IEEE Trans. on Cybernetics，Neurocomputing，J. of Franklin Institute， 和国内期刊《宇航学报》、《控制与决策》、《系统工程与电子技术》等多个学术期刊的编委、Int. J. Control, Automation and Systems 领域主编，《控制工程》副主编，IEEE南京分部控制系统分会主席，中国航空学会导航、制导与控制分会副主任，中国自动化学会技术过程故障诊断与安全性专业委员会副主任， 中国自动化学会数据驱动控制与学习系统专委会委员，江苏省自动化学会副理事长。从事故障诊断和容错控制及其在飞控系统和高铁牵引系统中的应用研究，主持获得国家自然科学二等奖、教育部自然科学一等奖、江苏省科技一等奖等科研奖励；获得授权发明专利28项，出版学术专著8部，在IEEE Transactions, Automatica, AIAA JGCD, 中国科学，自动化学报等国内外学术期刊发表论文80余篇。

Jiang Bin is, professor, doctoral supervisor and vice president of Nanjing University of Aeronautics and Astronautics, IEEE fellow, distinguished professor of Cheung Kong Scholar Program in the Ministry of

Education, and member of Chinese Association of Automation. He has been postdoctoral, researcher, invited professor and visiting professor in Singapore, France, the United States and Canada.

At present, he is member of editorial board of several academic journals. There are international academic journals such as IEEE Trans. on Cybernetics, Neurocomputing, J. of Franklin Institute, and domestic academic journals such as Journal of Astronautics, Control and Decision, System Engineering and Electronic Technology. He has been chief editor of Int. J. Control, Automation and Systems, deputy editor of Control Engineering, chairman of control system branch of Nanjing branch of IEEE, deputy director of Guidance, Navigation and Control branch of CSAA, deputy director of Technical Process Fault Diagnosis and Safety Professional Committee of CAA, member of Data Driven Control and Learning System Special Committee of CAA, vice president of Jiangsu Association of Automation.

He works for research on application of fault diagnosis and fault-tolerant control in flight control system and high-speed railway traction system. He has won the second prize of National Natural Science Award, the first prize of Natural Science Award of Ministry of Education, the first prize of Science and Technology of Jiangsu Province and other scientific research awards. He has obtained 28 authorized invention patents and published 8 academic monographs. More than 80 papers have been published in IEEE Transactions, Automatica, AIAA JGCD, Science China, Acta Automatica Sinical and other academic journals.

Keynote Address 4

Digital Twins for Distributed Fault Detection in the Process Industry

Prof. Thomas Parisini
Imperial College London, UK

Saturday, May 15, 2021
13:30-14:20
Function room ABC / ABC 厅

Abstract

In an increasingly "smarter" planet, it is expected that interconnected process systems will be safe, reliable, available 24/7, and of low-cost maintenance – the Industry 4.0 vision. Therefore, health monitoring, fault diagnosis and fault-tolerant control are of customary importance to ensure high levels of safety, performance, reliability, dependability, and availability. In the lecture, the process industry I considered as a paradigmatic context in which, faults and malfunctions can result in off-specification production, increased operating costs, production line shutdown, danger conditions for humans, detrimental environmental impact, and so on. Faults, malfunctions and cyber-attacks need to be detected promptly and their source and severity should be diagnosed so that corrective actions can be taken as soon as possible. Once a fault is detected, the faulty subsystem can be unplugged to avoid the propagation of the fault in the interconnected large-scale system. Analogously, once the issue has been solved, the disconnected subsystem can be re-plugged-in.

High-fidelity digital twins represent a game-changing key enabling technology to design effective and accurate distributed fault diagnosis systems in the absence of reliable process data under faulty scenarios. A real industrial use-case is addressed in the lecture.

Biography

Thomas Parisini received the Ph.D. degree in electronic engineering and computer science from the University of Genoa, Genoa, Italy, in 1993. He was with Politecnico di Milano and since 2010, he has been

holding the Chair of Industrial Control and is the Director of Research with Imperial College London, London, U.K. He is a Deputy Director of the KIOS Research and Innovation Centre of Excellence, University of Cyprus, Nicosia, Cyprus. Since 2001, he has also been the Danieli Endowed Chair of Automation Engineering with University of Trieste, Trieste, Italy. In 2009–2012, he was the Deputy Rector of University of Trieste. In 2018, he received an Honorary Doctorate from University of Aalborg, Aalborg, Denmark. He authored or coauthored more than 320 research papers in archival journals, book chapters, and international conference proceedings. His research interests include neural-network approximations for optimal control problems, distributed methods for cyber-attack detection and cyber-secure control of large-scale systems, fault diagnosis for nonlinear and distributed systems, nonlinear model predictive control systems, and nonlinear estimation.

Dr. Parisini was the Co-recipient of the IFAC Best Application Paper Prize of the Journal of Process Control, Elsevier, for the three-year period 2011–2013 and of the 2004 Outstanding Paper Award of the IEEE Transactions on Neural Networks. He was also the Recipient of the 2007 IEEE Distinguished Member Award. In 2016, he was awarded as Principal Investigator at Imperial of the H2020 European Union flagship Teaming Project KIOS Research and Innovation Centre of Excellence led by University of Cyprus with an overall budget of over 40 Million Euro. In 2012, he was awarded an ABB Research Grant dealing with energy-autonomous sensor networks for self-monitoring industrial environments.

He is currently the 2020 President-Elect of the IEEE Control Systems Society and will serve as thre 2021-2022 President. He has served as Vice-President for Publications Activities and during 2009–2016, he was the Editor-in-Chief for the IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY. Since 2017, he has been the Editor for Control Applications of Automatica and since 2018 he has been the Editor-in-Chief for the European Journal of Control. He served as Chair of the IFAC Technical Committee on Fault Detection, Supervision and Safety of Technical Processes–SAFEPROCESS. He was the Chair of the IEEE Control Systems Society Conference Editorial Board and a Distinguished Lecturer of the IEEE Control Systems Society. He was an elected member of the Board of Governors of the IEEE Control Systems Society and of the European Control Association and a Member of the board of evaluators of the 7th Framework ICT Research Program of the European Union and member the ERC Advanced and Consolidator Grant board of Reviewers.He is currently an Associate Editor for the International Journal of Control and was an Associate Editor for the IEEE TRANSACTIONS ON AUTOMATIC CONTROL, IEEE TRANSACTIONS ON NEURAL NETWORKS, Automatica, and International Journal of Robust and Nonlinear Control.

Among other activities, he was the Program Chair of the 2008 IEEE Conference on Decision and Control and General Co-Chair of the 2013 IEEE Conference on Decision and Control. He is a Fellow of the IEEE and the IFAC.

Distinguished Lecture

Distinguished Lecture 1

Fault Diagnosis Technology for Brake Control System of High-Speed Trains

Prof. Xiao He
Tsinghua University, China

Saturday, May 15, 2021
14:20-15:00
Function room B / B 厅

Abstract

In order to improve the safety of the brake control system of high-speed railway in China, some key problems of state estimation and fault diagnosis are studied. Aiming at the challenges of non-ideal channels such as bandwidth constraint and data link failure to distributed state estimation, we proposed a series of new distributed filtering methods based on innovation measurement and performance upper bound optimization. These techniques reduce the excessive consumption of bandwidth and energy in existing distributed estimation, and provide a new way for the transmission and utilization of high frequency sampling data. Aiming at the open problem of closed-loop fault diagnosis, we discussed the failure reason of open loop fault diagnosis method in closed-loop system, and an effective improvement method based on historical observation data is proposed and shown. Aiming at the diagnosis bottleneck caused by small amplitude and short duration of intermittent fault, we gave a diagnosability criterion of intermittent fault, and systematic research framework of intermittent fault diagnosis for stochastic dynamic systems is established. Relevant results have been applied to the fault diagnosis of high-speed train brake control system.

Biography

He Xiao, with the Department of automation, Tsinghua University, is a tenured associate professor, doctoral advisor and deputy head of the Department. The research direction is networked system, fault diagnosis and fault tolerant control. More than 180 papers have been published in domestic and foreign journals and conferences, of which more than 80 have been retrieved by SCI, with more than 1300 times citation in web of science data base. He presided over one key project and two general projects of NSFC, participated in two major projects of NSFC and one major international cooperation project of NSFC, and was funded by excellent youth fund of NSFC in 2015. He is now a senior member of China Association of Automation (CAA), IEEE senior member, sigma Xi full member, and the editorial board member of Control Engineering Practice and other international journals. At present, he is a member of Technical Committee on fault detection, supervision and safety (tc6.4) of IFAC, and Secretary General of Professional Committee on fault diagnosis and safety of CAA. He has won the GIAR award of Sigma Xi - the Scientific Research Society in 2010, Frank best theoretical paper nomination award of SAFEPROCESS International Conference in 2012, the first prize of science and technology progress award of Jilin Province in 2018, and the first prize of Natural Science Award of CAA in 2015 and 2020.

Distinguished Lecture 2

Stabilization of Boolean Control Networks

Prof. Zhengguang Wu
Zhejiang University, China

Saturday, May 15, 2021
14:20-15:00
Function room A / A 厅

Abstract

The purpose of this report is to use some new techniques to discuss the stabilization of Boolean control networks. First, stabilization and finite time stabilization of probabilistic Boolean control networks is investigated. A complete family of reachable sets is defined, based on which, state feedback control stabilization conditions are obtained. Secondly, pinning control is studied to be applied to the Boolean networks to achieve the stabilization control objective. A necessary and sufficient condition is given for the stability of BNs with stochastic disturbances. Thirdly, sampled-data state feedback control with stochastic sampling periods is considered to stabilize Boolean control networks. At last, sampled-data state feedback control with Lebesgue sampling is considered to stabilize Boolean control networks. A necessary and sufficient condition for stabilization is obtained for the considered Boolean control networks.

Biography

Zheng-Guang Wu was born in 1982. He received the B.S. and M.S. degrees in mathematics from Zhejiang Normal University, Jinhua, China, in 2004 and 2007, respectively, and the Ph.D. degree in control science and engineering from Zhejiang University, Hangzhou, China, in 2011. He is currently a Professor of Institute of Cyber-Systems and Control, Zhejiang University. His research interests include networked systems, intelligent control, Markov jump systems, smart grid, cyber-physical systems, and reinforcement learning. He has published 100+ papers in IEEE Transactions. He was a recipient of the Highly Cited Researcher Award by Clarivate Analytics. He is an Invited Reviewer of Mathematical Review of the American Mathematical Society. He serves (or has served) as the Associate Editor/Editorial Board Member for some international journals, such as the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS; SCIENCE CHINA Information Sciences; Journal of Systems Science and Complexity; Journal of the Franklin Institute; Neurocomputing; International Journal of Control, Automation, and Systems; IEEE ACCESS; International Journal of Sensors, Wireless Communications and Control; Cyber-Physical Systems; Sensors; Symmetry; and IEEE Control Systems Society Conference Editorial Board.

Distinguished Lecture 3

Cooperative Control and Its Applications of Unmanned Autonomous Systems

Prof. Hongyi Li
Guangdong University of Technology, China

Saturday, May 15, 2021
14:20-15:00
Function room C / C 厅

Abstract

Unmanned autonomous systems are quite important applications in the artificial intelligence yield. The research of cooperative control has received considerable attention due to extensive applications of unmanned autonomous systems. In this talk, firstly, the background and current research status of cooperative control for unmanned autonomous systems are reported. Then, the main cooperative control problems are addressed for a class of unmanned autonomous systems. Furthermore, the above theories are applied to unmanned autonomous systems. Finally, some future challenges in this area are introduced.

Biography

Hongyi Li (SM'17) received the Ph.D. degree in intelligent control from the University of Portsmouth, Portsmouth, U.K., in 2012. He was a Research Associate with the Department of Mechanical Engineering, University of Hong Kong, Hong Kong and Hong Kong Polytechnic University, Hong Kong. He was a Visiting Principal Fellow with the Faculty of Engineering and Information Sciences, University of Wollongong, Wollongong, Australia. He is currently a professor with the Guangdong University of Technology, Guangdong, China. His research interests include intelligent control, cooperative control, sliding mode control and their applications. He was a recipient of the 2016 and 2019 Andrew P. Sage Best Transactions Paper Awards from IEEE System, Man, Cybernetics Society, the Best Paper Award in Theory from ICCSS 2017 and the Zadeh Best Student Paper from IEEE ICCSS 2019, respectively. He has been in the editorial board of several international journals, including IEEE Transactions on Neural Networks and Learning Systems, IEEE Transactions on Fuzzy Systems, IEEE Transactions on Systems, Man and Cybernetics: Systems, IEEE Transactions on Cognitive and Developmental Systems, SCIENCE CHINA Information Sciences, IEEE/CAA Journal of Automatica Sinica, Neural Networks, Asian Journal of Control, Circuits, Systems and Signal Processing, and International Journal of Control, Automation and Systems. He has been Guest Editors of IEEE Transactions on Cybernetics and IET Control Theory and Applications. He is a member of the IFAC Technical Committee on Computational Intelligence in Control.

Distinguished Lecture 4

Filtered Repetitive Control with Nonlinear Systems

Prof. Quan Quan
Beihang University, China

Saturday, May 15, 2021
15:00-15:40
Function room B / B 厅

Abstract

In practice, many control tasks are also often of a periodic nature. For these periodic control tasks, repetitive control (RC, or repetitive controller, also designated RC) can achieve high precision control performance. RC often suffers the robustness problem, including stability robustness against uncertain parameters of systems and performance robustness against uncertain or time-varying period-time of external signals. Filters and frequency domain analysis are the primary tools to solve such a problem, resulting in filtered RCs. But, they can be applied only with difficulty, if at all, to nonlinear systems. This talk aims at providing five methods to explore the potential of RC. Commonly-used methods like the feedback linearization method and adaptive-control-like method will be introduced first. However, feedback linearization or error dynamics derived is often difficult for other various types of problems. To this end, three new methods parallel to the two ways mentioned above will also be shared, which are the additive-state-decomposition based method, the actuator-focused design method, and the contraction mapping method.

Biography

Quan Quan received the B.S. and Ph.D. degrees from Beihang University, Beijing, China, in 2004 and 2010, respectively. He was a research fellow in National University of Singapore from June 2011 to October 2011. Since 2013, he has been an Associate Professor with Beihang University, currently with the School of Automation Science and Electrical Engineering. He was also a visiting professor of the University of Toronto in 2017, hosted by Professor W.M. Wonham. His research interests include repetitive control, reliable flight control, and swarm control. He completed the first book about repetitive control for nonlinear systems entitled “Filtered Repetitive Control with Nonlinear Systems.” Also, he published two other books on multicopter systems. He led his group to develop a performance evaluation website flyeval.com for multicopters and a simulation platform RflySim (rflysim.com).

Distinguished Lecture 5

Online Operating Performance Assessment of Hydrocracking Process Under Uncertain Information

Prof. Yalin Wang
Central South University, China

Saturday, May 15, 2021
15:00-15:40
Function room A / A厅

Abstract

In order to timely adjust its production operations and ensure long-term optimized running, it is of great significance for the hydrocracking process to accurately assess whether its current production deviates from the optimal operating performance and determine the deviation degree. However, due to the harsh detection environment and limited detection technology, it is difficult to detect the key operating performance assessment indicators online. The complexity of the process and data also increases the difficulty of online prediction of these key assessment indicators. Moreover, suffer from three uncertainties of operating acknowledge, data measurement and the information interaction of hierarchical operating structure, the accurate online assessment of operating performance is still difficult. Therefore, driven by big data, we have carried in-depth research on the online operating performance assessment method of hydrocracking process under uncertain information. This report summarizes our relevant research results, and introduces them from the aspects of assessment indicator system construction and modeling preprocessing, online prediction of key assessment indicators, and online assessment of operating performance.

Biography

Yalin Wang is a second-level professor, doctoral supervisor and associate dean at the School of Automation, Central South University, and she is an outstanding talent in the new century of the Ministry of Education. Her current research activity addresses complex industrial process modeling and optimization, industrial big data analysis, intelligent scheduling and optimization decision making. Wang is a member of the IFAC Industry Committee, the Process Control Committee of the Chinese Society of Automation, the Technical Process Fault Diagnosis and Safety Committee of the Chinese Society of Automation, and a vice chairman of the Hunan Society of Automation. She presided over 4 major projects or subjects of the National Science and Technology Plan, 18 other research projects, and participated in more than 20 projects of the National Science and Technology Plan. Won 1 second prize of National Technology Invention Award, 1 second prize of National Science and Technology Progress Award, 6 first prizes and 4 second prizes of provincial and ministerial science and technology awards (including Innovation Team Award, Nature Award, Technology Invention Award, and Science and Technology Progress Award). In the past 5 years, she has published 45 SCI papers as the first or corresponding author, including 3 hot papers and 6 highly cited papers; applied for 42 national invention patents and holds 31.

Industrial Control Practice Forum

Industrial Control Practice Forum

Sunday, May 16, 2021
8:00-10:00
Function room B / B 厅

Forum speaker

Speaker 1：Dr. Yuanming Zhu (East China University of Science and Technology)
Title：Data-Driven Control Technology in Cement Industry
Biography：Yuanming Zhu received his B.S. and Ph. D. degree in BJTU and work as a vice professor in ECUST. The candidate of "Sailing Plan Project" in Shanghai. He has undertaken more than 10 national scientific research projects. His research interest includes data-driven control, robust control and intelligent control for industry process. Recent years, his research direction is aimed at the national major strategic demands, committed to the research of key theories and technologies for cement green manufacturing. He has published more than 20 academic papers, including in TNNLS, TII, IJRNC, IECR, etc.; applied for more than 10 national invention patents and obtained 6 software copyrights in the field of optimization and control for cement manufacturing.

Speaker 2：Dr. Minglei Yang (East China University of Science and Technology)
Title：Value Chain Evaluation and Optimization for Petrochemical Process
Biography：Minglei Yang was born in 1985. He received his B.S. and Ph. D. degree in Chemical Engineering from East China University of Science and Technology. He is now the vice director of automation research institute. For the past 10 years, he has been devoted to the steady / dynamic state of complex petrochemical processes, multi-scale mechanism modeling, process optimization and decision making. As the project leader, he undertook 2 National Natural Science Foundation Projects and 1 basic scientific research project of Central University project. As the technical director, he undertook over 10 projects from industry and MIIT, such as the development of large-scale petrochemical process mechanism modeling, plan optimization, profit maximization for reforming process, etc. The developed technics have been successfully applied in Sinopec Jiujiang Branch, Zhenhai Branch, Shanghai Branch and Yangzi Branch. He has published over 30 papers in Chemical Engineering journals, and authorized over 20 Chinese patents. In 2019, he won the First prize of Shanghai Science and Technology Progress Award and Technological Invention.

Speaker 3：Dr. Hao Chen (Haixi Institute, Chinese Academy of Sciences)
Title：Exploration on the Application of Industrial Big Data in Manufacturing Industry
Biography: Hao Chen, a researcher of Haixi Institute, Chinese Academy of Sciences & PI. He received his Bachelor degree in the major of automation from National University of Defense Technology in 2006, Master degree in the major of control system from The University of Sheffield, UK in 2009, Doctor's degree in the major of Cybernetic from University of Reading, UK in 2013. From January 2014 to July 2015, he engaged in industrial data analysis and soft-sensor research in the University of Alberta, Canada / Syncrude oil company. Now he is the director of Fujian Provincial key laboratory for Intelligent Identification and Control of Complex Dynamic System, the committee member of data driven control, learning and optimization Committee of Chinese Association of Automation, the vice director of

Fujian Provincial Industrial Internet Intelligent Sensing and Decision Engineering Research Center. He presided over nearly 30 national / Chinese Academy of Sciences / local scientific research projects, applied for / authorized 36 national invention patents, and published nearly 50 academic papers. He has won the Youth Promotion Association of Chinese Academy of Sciences, Fujian Natural Science Foundation for Distinguished Young Scholars and Fujian May 4th Youth medal. He committed to the research road of combining theory with application. The production optimization series technology and industrial software that developed by the team have been successfully applied in nearly ten leading enterprises in the industry, such as Sunner Group, Seven Group, Shuhua Sports, etc.

Pre-Conference Workshop

Pre-Conference Workshop

Model Free Adaptive Control: Progress and Applications (MFAC 进展及应用)

Friday, May 14, 2021
14:00-17:00
Function room B / B 厅

Workshop Abstract

无模型自适应控制（Model-free adaptive control，MFAC）最早由侯忠生教授在其博士论文中提出（1994），经过近 30 年的持续努力，MFAC 已经得到系统化的发展，并已在实际控制系统中得到广泛应用。MFAC 控制理论体系由间接/直接型 MFAC 方法与间接/直接型无模型自适应迭代学习控制（MFAILC）方法共同组成。理论上可严谨说明，传统 PID、线性时不变系统的自适应控制、以及传统迭代学习控制是其特例。MFAC 的理论基础是描述非线性系统动态行为的伪偏导数/伪梯度等新概念、非线性系统的动态线性化数据模型、以及基于压缩映射原理的稳定性分析方法。MFAC 的内容框架由不同（SISO/MIMO/复杂连接）受控对象、不同等价动态线性化（紧格式/偏格式/全格式）数据模型、不同伪偏导数/伪梯度等的在线估计算法（投影类/最小二乘类等）、不同控制器（最优控制/预测控制/学习控制等）设计方法四维结构组成。MFAC 具有如下优点：(1) 控制系统设计与分析仅利用被控对象 I/O 数据，是纯粹的数据驱动控制方法；(2) MFAC 理论具有广泛的适应性、可实际应用性和理论严谨性；(3) 基于模型控制理论的诸多理论挑战问题，如未建模动力学、持续激励条件以及传统鲁棒性等在 MFAC 控制理论框架下不存在；(4) MFAC 理论具有完整的系统设计和分析理论框架。到目前为止，MFAC 已经被 11 部专著(包括 2 部 Springer 出版专著)2 部教材作为整章或者节内容加以引用，53 篇博士论文（包括海外大学 7 篇）和 250 余篇硕士论文包括 MFAC 理论与应用的整章或节，已在 200 余个不同实际系统中得到实际应用。

本次研讨会的目的是报告 MFAC 的系统体系框架、理论基础以及其最新进展。内容包括基本思想、数学表述、新概念、动态线性化数据模型以及 MFAC 的系统设计方法。此外还包括 MFAC 框架下新的控制理论分支和实际应用举例。

Workshop Speakers

Speaker 1：侯忠生教授（青岛大学）

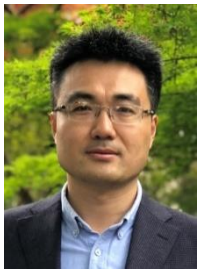
Title：On MFAC Theory and Progress (MFAC 理论体系及发展历程)

Biography：侯忠生，青岛大学教授、卓越百人计划"领军人才"、IEEE Fellow、CAA Fellow、IFAC 技术委员会委员、中国自动化学会"数据驱动控制、学习与优化"专业委员会创始主任、自动化学报、控制理论与应用、控制与决策、系统科学与数学编委；曾是 IEEE 神经元网络与学习系统会刊"基于数据的控制、决策、调度与故障诊断"专刊客座编委、IEEE 工业电子学会刊专刊"数据驱动控制与学习系统"责任客座编委。主持代表性科研项目包括国家自然科学基金重点项目 3 项，国家自然科学基金重大国际合作项目 1 项。在控制理论研究领域提出了"无模型自适应控制"、"数据驱动控制"、"动态线性化技术"、"伪偏导数"、"伪梯度"、"伪 Jacobian 矩阵"，等新概念，并被广泛认可。创立并完善了"无模型自适应控制（MFAC）理论"。出版包括 CRC Press 出版社的《Model Free Adaptive Control: Theory and Applications, 2013》的专著 3 部，发表刊物论文 220 余篇。H 因子 47。同时也提出了系列的交通系统数据驱动学习预报与控制方法，是数据驱动控制、迭代学习控制理论研究领域具有国际影响的活跃学者。

Speaker 2：金尚泰副教授（北京交通大学）
Title：MFAC for Nonlinear Systems（非线性系统无模型自适应控制）
Biography：金尚泰，北京交通大学电子信息工程学院，副教授。从事无模型自适应控制、数据驱动控制、智能交通系统等方向的研究工作。主持国家自然科学金 2 项，作为骨干参与国家自然科学基金重点项目 3 项。相关成果出版专著 2 部，在国内外知名学术期刊和国内外会议上发表论文 80 余篇。

Speaker 3：卜旭辉教授（河南理工大学）
Title：Robust MFAC for Network-Based Systems（网络系统的鲁棒无模型自适应控制）
Biography：卜旭辉，教授，博士生导师。河南省高校科技创新团队负责人，入选中原千人-中原青年拔尖人才、河南省高校科技创新人才、河南理工大学太行学者等计划，兼任中国自动化学会数据驱动控制学习与优化专委会委员、河南省教育厅学术带头人、2017-2020 年中国控制会议（CCC）程序委员会委员等。近年来从事数据驱动控制、工业过程控制、网络系统控制等方向的研究工作。获河南省科技进步二等奖 3 项、主持国家自然基金 3 项、发表 SCI 期刊论文 60 余篇。

Speaker 4：池荣虎教授（青岛科技大学）
Title：Extensions of Dynamic Linearization and Controller Design（动态线性化的外延与控制器设计）
Biography：池荣虎，青岛科技大学自动化与电子工程学院（机器人学院）院长、教授、博导。2016 年入选山东省泰山学者青年专家人才工程。2007 年毕业于北京交通大学获博士学位，2011–2012 年赴新加坡南洋理工大学做访问学者；2014–2015 年赴加拿大阿尔伯塔大学做访问教授；兼任中国自动化学会数据驱动控制、学习与优化委员会副秘书长、中国自动化学会过程控制专业委员会委员、山东省自动化学会理事、International Journal of Automation and Computing 客座编辑、多个国际会议程序委员会委员、Invited Session 主席、Automatica 等多本国际期刊的审稿人。主要研究兴趣包括：数据驱动控制、学习控制、多智能体系统、智能交通等。



Speaker 5：庞中华教授（北方工业大学）
Title：数据驱动网络化预测控制方法研究及实现
Biography：庞中华，北方工业大学教授、博士生导师，入选北京市委组织部青年拔尖人才计划。2011 年在中国科学院自动化研究所获得博士学位，同年进入清华大学从事博士后研究，2016 年-2017 年在英国南威尔士大学访问交流，2019 年、2020 年赴澳大利亚斯威本科技大学访问交流。主要从事网络化控制系统及其安全性方面的理论研究与工业先进控制领域的应用技术研究，兼任 IEEE 高级会员、JSEGC 期刊青年编委、中国自动化学会、中国仪器仪表学会、中国指挥与控制学会等多个专业委员会委员，主持国家自然科学基金、北京市自然科学基金等国家和省部级项目 6 项，出版英文专著 1 部、中文著作 3 部，发表学术论文 80 余篇（IEEE Transactions 论文 12 篇），授权发明专利 5 项和软件著作权 2 项，获中国仪器仪表学会科技进步二等奖等 2 项。

Speaker 6：翁永鹏副教授（大连海事大学）

Title：Data-Driven Sliding-Mode Control and Its Applications（数据驱动滑模控制及其应用研究）

Biography：翁永鹏，大连海事大学船舶电气工程学院，副教授，硕士研究生导师。2017 年毕业于东北大学获博士学位。兼任 International Journal of Fuzzy Systems 客座编辑、IEEE Transactions on Industrial Electronics、IEEE Transactions on Neural Networks and Learning Systems 等多本国际期刊的审稿人。主要研究兴趣包括：数据驱动滑模控制、无人机、无人船及自主控制、复杂工业过程建模、控制与优化等。主持国家自然科学基金 1 项、中国博士后科学基金 1 项、在国内外知名学术期刊和国内外会议上发表论文 20 余篇。

Laoshan Academic Forum

Laoshan Academic Forum(崂山学术论坛)

Artificial Intelligence and Automation Frontiers
(人工智能与自动化前沿)

Sunday, May 16, 2021
10:10-12:10
Function room B / B 厅

Forum speaker

Speaker 1：王成红研究员（国家自然科学基金委员会）
Title：数据、信息和知识自动化
Biography: Chenghong WANG is a researcher at the National Natural Science Foundation of China. He received the PhD degree from the Institute of Automation, Chinese Academy of Sciences in 1997. From August 1997 to November 1999, he served as a postdoctoral fellow and associate researcher at the Academy of Mathematics and System Sciences, Chinese Academy of Sciences. From December 1999 to August 2015, he worked at the Information Science Department, National Natural Science Foundation of China. He is currently a Fellow of the Chinese Association of Automation and a part-time professor at Zhejiang University. His research interests include control theory, system reliability theory and graph theory.

Speaker 2：王龙教授（北京大学）
Title：控制论、博弈论与人工智能的交叉融合
Biography：王龙教授，1992 年于北京大学获得博士学位。1993 年在加拿大多伦多大学作博士后，1995-1997 年获德国洪堡基金资助在德国宇航中心进行合作研究。现为北京大学教授、博士生导师、长江学者，是“新世纪百千万人才工程”国家级人选、国家杰出青年科学基金获得者。近年来，王龙教授主要从事复杂系统智能控制、网络化控制系统的分析与综合、集群行为与集群智能、演化博弈与群体决策等方面的研究工作，取得了一系列具有国际水平的重要成就。其研究成果被国内外广泛引用，并获得国家自然科学奖、教育部自然科学奖（一等奖）等多项奖励。

Speaker 3：张霖教授（北京航空航天大学）
Title：建模仿真的过去、现在和未来
Biography：Lin Zhang, is a professor of Beihang University. He received the B.S. degree in 1986 from the Department of Computer and System Science at Nankai University, China. He received the M.S. degree and the Ph.D. degree in 1989 and 1992 from the Department of Automation at Tsinghua University, China. From 2002 to 2005 he worked at the US Naval Postgraduate School as a senior research associate of the US National Research Council. He served as the President of the Society for Modeling and Simulation International (SCS), the executive vice president of China Simulation Federation (CSF). He is currently the president of Federation of Asian Simulation Societies (ASIASIM), the president of China

Simulation Technology Industry Alliance, a Fellow of SCS, ASIASIM and CSF, a chief scientist of the National 863 Program and National Key R&D Program of China. He serves as the Director of Engineering Research Center of Complex Product Advanced Manufacturing Systems, Ministry of Education of China, Editor-in-Chief and associate editors of 6 peer-reviewed international journals. He authored and co-authored more than 300 papers, 18 books and chapters, among Clarivate Highly Cited Researchers in cross-field. He received the National Award for Excellent Science and Technology Books, the Outstanding Individual Award of National High-Tech R&D Program, the National Excellent Scientific and Technological Workers Awards. His research interests include service-oriented modeling and simulation, cloud manufacturing and simulation, model engineering, model based system engineering, cyber-physical systems, M&S for manufacturing systems, etc.

Speaker 4：张卫东教授（上海交通大学）
Title：海上无人系统自主控制与协同技术
Biography：张卫东，浙江大学学士，硕士和博士学位。国家杰青、教育部长江学者、德国洪堡学者、上海市优秀学科带头人，现任上海高校船舶自动化工程研究中心主任。研究领域包括智能控制理论和人工智能理论，及其在海上无人系统中的应用。出版 1 本英文专著；发表 SCI 论文 200 多篇；申请国家发明专利 52 项。

Speaker 5：贾永楠 副教授（北京科技大学）
Title：集群漫谈——从生物、物理到控制
Biography：贾永楠，北京大学博士。博士毕业后进入航天科工三院三部无人机总体设计室从事无人机系统总体工作，后离职赴匈牙利与 Tamas Vicsek 院士在无人机层级化控制方面开展合作研究，目前为北京科技大学自动化学院副教授，中国仿真学会智能物联系统建模与仿真专委会副秘书长。研究领域包括无人机集群，集群行为优化，水下机器人设计与群体控制。

Speaker 6：陈小杰教授（电子科技大学）
Title：网络群体智能与演化博弈
Biography：Xiaojie Chen is currently a professor at School of Mathematical Sciences in University of Electronic Science and Technology of China, China. He received the Bachelor degree in 2005 from National University of Defense & Technology, China, and the PhD degree in 2011 from Peking University, China. From September 2008 to September 2009, he was a visiting scholar in University of British Columbia, Canada. From February 2011 to January 2013, he was an IIASA postdoctoral research scholar at the International Institute for Applied Systems Analysis (IIASA), Austria. From February 2013 to January 2014, he was a research scholar at IIASA, Austria. He was selected by the Thousand-Talent Program of Sichuan Province in 2015. He severs as the editorial board member for several international journals including Scientific Reports, PLOS ONE, and Frontiers in Physics. His main research interests include evolutionary game dynamics, decision-making in game interactions, game-theoretical control, and collective intelligence. He has published about 100 SCI papers.

Speaker 7：肖峰教授（华北电力大学）
Title：异步采样系统的分析与控制
Biography：Feng Xiao received the PhD degree in Systems and Control from Peking University, Beijing, China, in 2008. In 2008, he became a faculty member with the School of Automation, Beijing Institute of Technology, Beijing, China. From June 2010 to May 2013, he worked as a Post-Doctoral Fellow at the Department of Electrical and Computer Engineering, University of Alberta, Edmonton, Canada. He was also a Professor at the Harbin Institute of Technology, Harbin, China, and is currently a Professor with the School of Control and Computer Engineering, North China Electric Power University, Beijing, China. His current research interests include group intelligence, coordination control, and networked systems. Dr. Xiao was a recipient of the Izaak Walton Killam Post-Doctoral Fellowship and the Dorothy J. Killam Memorial Post-Doctoral Fellow Prize at the University of Alberta in 2010, and was a recipient of the Program for New Century Excellent Talents in University, China and the Excellent Young Scientists Fund by NSFC, China.

Speaker 8：郁文生教授（北京邮电大学）
Title：人工智能与自动推理
Biography：郁文生，1998 年毕业于北京大学，获理学博士学位。现为北京邮电大学，教授，博士生导师，天地互联与融合北京市重点实验室副主任，中国仿真学会理事，中国仿真学会智能物联系统建模与仿真专业委员会副主任委员、中国自动化学会控制理论专业委员会委员等。曾任中国科学院自动化所研究员、博士生导师，华东师范大学教授，博士生导师，新疆维吾尔自治区天山学者等。 2013 年获杨嘉墀科技奖。2017 获吴文俊人工智能自然科学奖。获“华罗庚-吴文俊”出版基金资助，科学出版社出版专著两部。现主持国家自然科学基金重点项目一项。在系统鲁棒控制 理论、时滞系统稳定性分析、线性系统同时镇定及数学定理机器证明等方面做出一系列创新性成果，论文发表于《中国科学》、《科学通报》、《IEEE Trans.》系列等国内外重要学术刊物。曾应邀赴澳大利亚墨尔本大学作高级访问学者。曾多次赴美国、英国、澳大利亚、 西班牙、日本及中国香港等国家和地区参加国际性学术会议。目前研究兴趣为数学定理机器证明与人工智能。

2021 IEEE 10th Data Driven Control and Learning Systems Conference (DDCLS'21)

Technical Program
and
Book of Abstracts

Saturday, May 15, 2021

SatA01 16:00–18:00 Function Room B
Award Session: Best Paper Award

Chair: Chen, Zengqiang Nankai Univ.
Co-Chair: Sun, Mingxuan Zhejiang Univ. of Tech.

▶ SatA01-1 16:00–16:20
Event-based Integral Reinforcement Learning Algorithm for Non-zero-sum Games of Partially Unknown Nonlinear Systems

Su, Hanguang Northeastern Univ.
Zhang, Huaguang Northeastern Univ., China
Luo, Yanhong Northeastern Univ.
Sun, Qiuye Northeastern Univ.

In this work, a novel event-based integral reinforcement learning (IRL) adaptive control method is developed to solve the multiplayer non-zero-sum (NZS) games of the nonlinear systems with unknown drift dynamics. By virtue of the IRL algorithm, the system drift dynamics is no more needed in the controller design. Moreover, different from the existing iteration computation methods, this method is online implemented, on which condition the event-triggered control framework can be combined with the IRL algorithm in solving the NZS game problems. In this method, a state-dependent triggering condition is proposed, thus the computation and communication loads are reduced in the control process. Moreover, the uniform ultimate boundedness (UUB) stability of the controlled system and the convergence of the critic weights have also been proved. Finally, a numerical example is provided to demonstrate the effectiveness of our method.

▶ SatA01-2 16:20–16:40
Time-delay Estimation Based Model-free Control with Adaptive Iterative Learning Compensator for Parallel Back-support Exoskeleton

Wang, Kai Nanjing Univ. of Sci. & Tech.
Wang, Haoping Nanjing Univ. of Sci. & Tech.
Tian, Yang Nanjing Univ. of Sci. & Tech.

To perform the trajectory tracking control of a 4-SPS/SC parallel structure based back-support exoskeleton for the repetitive rehabilitation, a time-delay estimation based model-free control with adaptive Iterative learning compensator and initial state learning (AILTDE-MFC) is proposed in this paper. Firstly, to assist with many types of waist movements and not limit the natural motion, a 4-SPS/SC parallel structure based back-support exoskeleton is designed in SolidWorks and the virtual prototype is built in MATLAB/Simscape Multibody. To obtain the reference trajectory of each linear actuator in the joint space from the task space, the kinematics model of the exoskeleton is studied. Secondly, for the AILTDE-MFC design, an ultra-local model is utilized to reconstruct the system dynamics model and the lumped unknown information in the model is obtained by time-delay estimation(TDE), which can realize model-free trajectory tracking control in time domain. The designed iterative adaptive law is to compensate the estimation error of TDE and the initial state learning is to guarantee the convergence of initial states. The stability of AILTDE-MFC is verified by using the composite energy function (CEF). Finally, to validate the proposed method, a visualized co-simulation is implemented by a virtual prototype. Compared with the results of PD and TDE-iPD controllers, the proposed algorithm demonstrates the high tracking performance in time domain and the error convergence along iteration axis.

▶ SatA01-3 16:40–17:00
Optimal Iterative Learning Control for Discrete Linear Time-Varying Systems with Varying Trial Lengths

Liu, Chen Xian Jiaotong Univ.
Ruan, Xiaoe Xi'an Jiaotong Univ.
An, Shuzhen Xian Jiaotong Univ.

In this paper, an optimal iterative learning control scheme is designed for discrete linear time-varying systems with varying trial lengths. Since the trial lengths are different from iteration to iteration, the theoretical information is used to compensate the absent section at the current iteration. In order to obtain the fast convergence speed, an iteration performance index is to maximize the declining quantity of tracking error at two adjacent iterations, and the argument is the iteration-time-varying learning gain vector. The bigger the difference value, the faster the convergence speed. Furthermore, the optimal iterative learning control scheme is adaptive to the tracking error, which can guarantee the convergence of tracking error. Numerical simulations are shown to verify the effectiveness of the proposed scheme.

▶ SatA01-4 17:00–17:20
Design of Nonlinear Iterative Learning Control Based on Deep Reinforcement Learning Algorithm

Shi, Jia Xiamen Univ.
Wen, Kechao Xiamen Univ.
Xu, Xinghai Department of Chemical & Biochemical Engineering, School of Chemistry & Chemical Engineering, Xiamen Univ.
Hu, Xiongzhe XiaMen Univ.

Iterative learning control (ILC) is an advanced control method which has been studied and widely used in periodical, repetitive or batch processes. However, there is still a lack of an effective method for the design of nonlinear iterative learning control (NILC). In view of the excellent performance of deep reinforcement learning (DRL) in dealing with the decision-making problems for the complex dynamical processes, in this paper, we propose an intelligent design method for NILC system by using deep deterministic policy gradient (DDPG), a typical DRL algorithm. By properly designing the state information and the instant reward, the design algorithm can gradually realize the optimal NILC law through the interaction without any requirement of prior knowledge of the processes. The numerical simulation based on a nonlinear model illustrates the effectiveness and applicability of the proposed design method.

▶ SatA01-5 17:20–17:40
Dynamic Multivariate Alarm Threshold Optimization for Nonstationary Processes Subject to Varying Conditions

Zhao, Yi Zhejiang Univ.
Zhao, Chunhui Zhejiang Univ.
Sun, Youxian Zhejiang Univ.

For the alarm system of nonstationary processes, the conventional alarm thresholds configured for one single operational zone often result in false and missed alarms. Besides, these univariate thresholds isolate interactions among process variables. To address these issues, this paper proposes a novel dynamic multivariate alarm threshold optimization algorithm. Firstly, the process correlation variations can be identified by Toeplitz inverse covariance-based clustering method, pointing to the changes of operating conditions. Each condition is structural interpreted by a covariance inverse matrix of the multivariate Gaussian distribution, revealing similar within-time and cross-time variable interactions. Therefore, it provides a promising foundation to capture the conditional Gaussian distribution and design the corresponding thresholds of each variable, which finely covers the current normal operational zone. Then, offline threshold optimization and online strategy are developed and discussed in details, which can timely adapt to varying conditions, promoting accurate and sensitive alarming performance. Finally, the validity of the proposed thresholds are demonstrated on a real thermal power plant with typical nonstationary characteristics. Results show that the propose threshold can ease operators from nuisance alarms and ensure the reliability of alarm system as well.

▶ SatA01-6 17:40–18:00
Improving the Generalization Performance of Data-Driven Predictive Model for Dynamic Process Systems

Shao, Weiming China Univ. of Petrolieum
Li, Yougao China Univ. of Petroleum (east China)
Zhao, Dongya China Univ. of Petroleum
Ge, Zhiqiang Zhejiang Univ.

Data-driven dynamic predictive models have been extensively applied in dynamic process systems for online predicting difficult-to-measure key variables. However, due to the limitations in quantity, quality and representativity of industrial data, the generalization performance of the developed dynamic models are not reliable. In other words, based on certain unique historical dataset, high-accuracy of the predictive model for online unseen data cannot be guaranteed. To deal with this issue, this paper proposes a switching model-based dynamic modeling framework for improving the generalization accuracy and reliability of data-driven predictive models, which is composed of two stages, i.e., the offline model library construction and online model switch. The performance of the proposed scheme is assessed by a real-life industrial dynamic process using switching dynamic partial least squares models, and its application potentials are verified through comparisons among the state-of-the-art methods.

SatA02 16:00–18:00 Function Room A
Invited Session: Distributed Learning and Control for MAS
Chair: Meng, Deyuan — Beihang Univ. (BUAA)
Co-Chair: Zhang, Jingyao — Beihang Univ.

▶ SatA02-1 16:00–16:20
Distributed Control Algorithm for Leader-Follower Formation Tracking of Multiple Quadrotors
Wang, Zixuan — Univ. of Sci. & Tech. Beijing (USTB)
Zou, Yao — Univ. of Sci. & Tech. Beijing
He, Wei — Univ. of Sci. & Tech. Beijing

A distributed control algorithm for the leader-follower formation tracking of multiple quadrotors is proposed. In particular, multiple quadrotors track a reference trajectory in a desired formation shape. However, the reference trajectory is only available to a subset of quadrotors, and each quadrotor merely interacts with its neighbors. First, with the help of a distributed observer, a distributed command force using saturation strategy is synthesized in the outer position loop for the position tracking in the desired formation shape. Next, a bounded applied force and a non-singular command attitude are extracted from the synthesized command force. Finally, an applied torque is synthesized in the inner loop for the attitude tracking to the command one. The accomplishment of the concerned leader-follower formation tracking control objective of multiple quadrotors is also shown.

▶ SatA02-2 16:20–16:40
Iterative Learning Formation Control of Multi-agent Systems with Randomly Varying Trial Lengths
Liu, Yang — Beihang Univ. (BUAA)

The iterative learning control is studied for continuous-time multi-agent systems, where the trial lengths could be randomly varying at each iteration. ILC-based protocols are proposed for multiple nonlinear agents with switching topologies, and a modified formation tracking error is defined considering the iteration-varying trial lengths. In particular, an iteratively moving average operator is adopted in the protocol design, so that the control information from several previous trials can be used to compensate for the adverse effects of nonuniform trial lengths on the convergence speed. Then convergence conditions are derived for both the fixed and varying initial shift cases, which ensure that the formation performance will still be maintained during the whole motion process when the actual iteration length is greater or less than the desired one. In the end, simulation results illustrate the effectiveness of the proposed protocols.

▶ SatA02-3 16:40–17:00
Command Filter Based Adaptive Fuzzy Bipartite Consensus Tracking of Nonlinear Coopetition Multi-Agent Systems
Zhao, Lin — Qingdao Univ.

Cooperative control of multi-agent systems has gained much attention for its potential applications in multi-spacecraft systems, multi-vehicle systems, and multi-sensor networks. For cooperative control, the leader-follower consensus tracking has been seen as a more important issue compared with leaderless consensus, since it can save the energy and strengthen flock's orientation and communication. In some real networks, for example the social network, the competition interactions are also existed, where the communications among agents are usually described by signed graphs. Recently, the leaderless bipartite consensus and the leader-follower bipartite consensus tracking are studied for coopetition multi-agent systems, and they focus on how to construct the controllers to guarantee all agents converge to a unprescribed value or a desired state that is the same for all in modulus but not in sign. Backstepping control is one of the most commonly used methods for nonlinear systems, in which the state is designed as the virtual input for each subsystem, and the virtual input and its derivative are needed at the next step design. Since it need to repeat differentiations of virtual signals, so the problem of "explosion of complexity" may emerge. To solve such problem, the dynamic surface control (DSC) approaches were proposed, and the first-order filters were used in its design process, but how to compensate the filtering errors is not considered for DSC, which may result in the desired tracking performance can not be obtained. The command filtered backstepping is also a backstepping based scheme, in which the command filters are introduced at each step of the backstepping design, and the errors compensation scheme is used to eliminate the errors caused by filters. However, to the best of authors' knowledge, few results are available now for command filter based adaptive fuzzy backstepping scheme for coopetition multi-agent networks with nonlinear dynamics and actuator saturation.
So we will study the adaptive bipartite output consensus tracking control for high-order nonlinear coopetition multi-agent systems under input saturation. A distributed fuzzy-based command filtered backstepping method is proposed, which will ensure the bipartite output tracking errors converge into the desired neighborhood and all the closed-loop signals are bounded although the nonlinear dynamics are unknown and the input saturation exists.

▶ SatA02-4 17:00–17:20
Grouped Gene Selection and Classification of Colon Cancer via Robust Sparse Group Lasso
Li, Juntao — Henan Normal Univ.
Liang, Ke — Henan Normal Univ.
Chang, Mingming — Henan Normal Univ.
Chen, Liuyuan — Henan Normal Univ.

Abstract: Colon cancer is a common disease in the population. Selecting disease-related genes and diagnosis has attracted extensive attention in the field of medicine. However, it faces the problems of noise information processing and grouped gene selection in practical application. This paper aims to solve the above problems by developing the robust sparse group lasso. Colon cancer gene expression profile data is firstly decomposed into a low rank clean matrix and a sparse noise matrix. Then, genes are divided into groups by performing weighted gene co-expression network analysis on the clean matrix. By introducing gene reliability and gene significance criterion, robust sparse group lasso model is built and the corresponding algorithm is developed. The experimental results show that the proposed method can select cancer related genes in groups and improve the accuracy of cancer diagnosis.

▶ SatA02-5 17:20–17:40
Data-Driven Nonlinear Iterative Learning Control-Part I: An Optimization-Based Approach
Zhang, Jingyao — Beihang Univ.
Meng, Deyuan — Beihang Univ. (BUAA)

Learning to perform perfect tracking tasks based on measurement data is desirable in the controller design of systems operating repetitively. This motivates the present paper to seek an optimization-based design approach for iterative learning control (ILC) of repetitive systems with unknown nonlinear time-varying dynamics. It is shown that perfect output tracking can be realized with updating inputs, where no explicit model knowledge but only measured input/output data are leveraged. In particular, adaptive updating strategies are proposed to obtain parameter estimations of nonlinearities. A double-dynamics analysis approach is applied to establish ILC convergence, together with boundedness of input, output, and estimated parameters, which benefits from employing properties of nonnegative matrices.

▶ SatA02-6 17:40–18:00
Data-Driven Nonlinear Iterative Learning Control-Part II: Robustness with Respect to Nonrepetitive Uncertainties
Zhang, Jingyao — Beihang Univ.
Meng, Deyuan — Beihang Univ. (BUAA)

This paper aims to solve the robust iterative learning control (ILC) problems for nonlinear time-varying systems in the presence of nonrepetitive uncertainties. A new optimization-based method is proposed to design and analyze adaptive ILC, for which robust convergence analysis via a contraction mapping approach is realized by leveraging properties of substochastic matrices. It is shown that robust tracking tasks can be realized for optimization-based adaptive ILC, where the boundedness of system trajectories and estimated parameters can be ensured, regardless of unknown time-varying nonlinearities and nonrepetitive uncertainties. A numerical example demonstrates the effectiveness of our robust optimization-based ILC results.

SatA03 16:00–18:00 Function Room C
Invited Session: Data-based Cooperative Control of Networked Systems
Chair: Wu, Zhengguang — Inst. of Advanced Process Control
Co-Chair: Che, Weiwei — Shenyang Univ.

▶ SatA03-1 16:00–16:20
Adaptive Strong and Weak Synchronization for Perturbed Complex Networks
Xin-Yuan, Xu — HeFei Univ. of Tech.
Tang, Hao — Hefei Univ. of Tech.
Jin, Xiao-Zheng — Qilu Univ. of Tech.

This paper presents adaptive methods to solve the synchronization problems of dynamic complex networks. Firstly, a complex network model is

designed. Then, in order to achieve strong and weak synchronization, synchronization controllers and adaptive laws are designed. The adaptive laws are used for the renewal of unknown parameters, and the synchronization controller makes its error value in a small range. Then the Lyapunov function is used to prove the theory, and the simulation is used to prove the practice. Both results show that the proposed method can achieve strong synchronization and weak synchronization for nonlinear complex networks.

▶ SatA03-2 16:20–16:40

Robust Adaptive Trajectory Tracking Control of A Class of Disturbed Quadrotor Aircrafts

Wu, Ya-Jun — HeFei Univ. of Tech.
Tang, Hao — Hefei Univ. of Tech.
Jin, Xiao-Zheng — Qilu Univ. of Tech.

This paper explores an approach tracking the trajectory of a class of quadrotor aircrafts based on robust adaptive control against bounded disturbances by compensating for the perturbations. According to the Lyapunov stability theorem, the attitude tracking controller is achieved by using the backstepping technique. A simulation example is illustrated to verify the effectiveness of the designed position trajectory tracking controller and robust adaptive attitude trajectory tracking controller.

▶ SatA03-3 16:40–17:00

Adaptive Exponentially Asymptotic Tracking Control for A One-link Manipulator

Yanjun, Liang — Qingdao Univ.
Li, Yuan Xin — Liaoning Univ. of Tech.

This article addresses the asymptotic tracking issues of a one-link manipulator system. To realize the exponentially asymptotic tracking performance, the exponential term has been introduced into the Lyapunov function and the bounds estimation method and the smooth modification function are used to guarantee the zero-error tracking. In addition, the neural networks (NNs) is devised to cope with the uncertain disturbance and unknown nonlinearlities. At last, a simulation example has been shown to verify the raised scheme.

▶ SatA03-4 17:00–17:20

Asynchronous Control of Positive Markov Jump Systems: A Necessary and Sufficient Condition

Fang, Mei — Engineering Univ.
Wang, Liqing — Zhejiang Univ.
Wu, Zhengguang — Inst. of Advanced Process Control

This paper deals with l_1-gain controller synthesis of positive Markov jump systems (PMJSs) with asynchronous modes. Thanks to the hidden Markov model, the closed-loop systems are modeled as hidden Markov jump systems (HMJSs). The definitions of positivity, mean stability, and l_1-gain are introduced for HMJSs. A necessary and sufficient condition is derived to ensure that the HMJSs are positive and mean stable with l_1-gain γ that can be solvable by linear programming strategy. Two numerical examples are listed to show the effectiveness of our results.

▶ SatA03-5 17:20–17:40

Estimation of the Unreported Infections of COVID-19 Based on An Extended Stochastic Susceptible-Exposed-Infective-Recovered Model

Zhu, Lingyun — Shanghai Univ.
Dong, Wei — ,Shanghai Univ.
Sun, Qing — School of Mechatronical Engineering & Automation, Shanghai Univ.
Hernandez Vargas, Esteban Abelardo — UNAM
Du, Xin — Shanghai Univ.

In this paper, an innovative susceptible-exposed-infective-recovered model is proposed to estimate the true infectivity and lethality of the COVID-19 epidemic in Wuhan, China. Due to the intensity of government's limiting epidemic is changing in different stages, segmented parameters are used in the model.In additation, the generally polynomial chaos method is used to increase the reliability of the model results in the case of parameter estimation. The accuracy and validity of the proposed SEIR model are proved according to the official reported data.Also, according to the epidemic trend reflected by the model , the effectiveness and timeliness can be reflected of the epidemic prevention policies formulated by the government.

▶ SatA03-6 17:40–18:00

Model-Free Adaptive Security Tracking Control for Networked Control Systems

Su, Mengying — Qingdao Univ.
Che, Weiwei — Shenyang Univ.

The model-free adaptive security tracking control (MFASTC) problem of nonlinear networked control systems is explored in this paper with DoS attacks and delays consideration. In order to alleviate the impact of DoS attack and RTT delays on NCSs performance, an attack compensation mechanism and a networked predictive-based delay compensation mechanism are designed, respectively. The data-based designed method need not the dynamic and structure of the system,The MFASTC algorithm is proposed to ensure the output tracking error being bounded in the mean-square sense. Finally, An example is given to illustrate the effectiveness of the new algorithm by a comparison.

SatA04 16:00–18:00 Room D

Regular Session: Statistical Learning and Machine Learning in Automation Field

Chair: Ren, Hongru — Guangdong Univ. of Tech.
Co-Chair: Jin, Feng — Dalian Univ. of Tech.

▶ SatA04-1 16:00–16:20

Manufacturing Big Data Modeling Based on KNN-LR Algorithm and Its Application in Product Design Business Domain

Xiao, Yi — Guangdong Univ. of Tech.
Ren, Hongru — Guangdong Univ. of Tech.
Lu, Renquan — Hangzhou Dianzi Univ.
Cheng, Shen — Guangdong Univ. of Tech.

In product life cycle, it is very important to use the manufacturing big data to build prediction model and apply it to predict whether the design task of the product can be completed within the specified time. Most of the existing prediction models in manufacturing industry are built by a single algorithm or its improved version, and neglect the limitation of using a single forecasting algorithm, which may lead to poor forecasting accuracy. This paper aims to integrate the K-nearest neighbor classification algorithm and the logistic regression algorithm linearly in parallel to obtain the combined model which is called K-nearest neighbor-logistic regression (KNN-LR) in this paper, and use the combined model to predict whether the design task of the product can be completed within the specified time. Experimental results show that compared with the model built by a single algorithm, the combined model has better performance on model evaluation indicators such as accuracy, precision, F1 value, recall and classification error rate.

▶ SatA04-2 16:20–16:40

The Design and Physical Implementation of Tennis Training Robots

Zhang, Guoqian — Lanzhou Univ.
Liu, Mei — Lanzhou Univ.
Li, Shuai — Lanzhou Univ.
Shi, Yang — Yangzhou Univ.

Tennis launching machines available on markets generally have a single function to launch balls from a fixed point. Different from traditional tennis launching machines, a tennis training robot with stereo vision and image processing algorithm is designed in this paper. In specific, trainers can not only use this tennis training robot as a normal tennis launcher, but also switch it into the versus model which offers a vivid experience like fighting against a human player. All these functions are realized with the aid of innovative mechanical structure, stereo vision technology and highly efficient mobile base. The launching construction of this tennis training robot is designed as a three-wheel structure which can emit balls with various spins. Moreover, the introduction of the stereo vision system and the image processing algorithm makes it possible to detect and track the ball. Finally, the tennis training robot is capable of finishing a timely collection of tennis balls with its mobile base.

▶ SatA04-3 16:40–17:00

Auto-Detection of Tibial Plateau Angle in Canine Radiographs Using A Deep Learning Approach

Tonima, Masuda Akter — Concordia Univ.
Hossain, Anim — Concordia Univ.
Dehart, Austin — Innotech Medical Industries Corp
Zhang, Youmin — Concordia Univ.

Stifle joint issues are a major cause of lameness in dogs and it can be a significant marker for various forms of diseases or injuries. A known Tibial Plateau Angle (TPA) helps in the reduction of the diagnosis time of the cause. With the state of the art object detection algorithm YOLO, and its variants, this paper delves into identifying joints, their centroids and other regions of interest to draw multiple line axes and finally calculating the TPA. The methods investigated predict successfully the TPA within the normal range for 80 percent of the images.

▶ SatA04-4 17:00–17:20

Calculation Method of Available Transfer Capacity Based on Graph Convolutional Network

Cai, Zhi — China Electric Power Research Inst.
Li, Yuxuan — China Electric Power Research Inst.
Dai, Sai — China Electric Power Research Inst.
Deyue, Men — China Electric Power Research Inst.

Studying and evaluating the available transfer capacity (ATC) of transmission lines is of great significance when determining the reasonable operation mode of a power grid and optimizing the allocation of power grid resources. With the rapid development of deep learning technology, it is possible to quickly find the most ATC by mining historical data and prior knowledge without relying on physical model. Therefore, an ATC calculation method based on graph convolutional network (GCN) is proposed. The topology information between the nodes of a power grid is represented by adjacency matrix. The proposed algorithm can effectively mine the correlation between the nodal injection power, and map the complex non-linear relationship between ATC and power data with deep graph convolutional architecture. The simulation results show that the calculation accuracy of ATC based on GCN can meet the needs of practical application of power grid.

▶ SatA04-5 17:20–17:40

Anomaly Detection Method Based on Multi-criteria Evaluation for Energy Data of Steel Industry

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

The stability and integrity of the monitoring data in the energy system of the iron and steel industry is of great significance for ensuring the safety of the system. Aiming at the data with periodic characteristics in the steel energy system, an abnormal data detection method based on multi-criteria evaluation is proposed in this study. The data time series is divided according to its periodic characteristics, and each sub-period sequence are evaluated through the quasi-measures established in this paper. Then the outlier detection of the periodic time series is realized through the AFCM (Adaptive fuzzy C-means) of these evaluation results. The simulation results based on the actual operating data of a steel enterprise show that this method can identify the local abnormal state in the original time series and improve the detection efficiency.

▶ SatA04-6 17:40–18:00

Multi-Sensor Fusion Perception System in Train

Gao, Hongfei — Inst. of Automation
Huang, Yongzhen — Watrix Tech. Beijing Co.,Ltd
Li, Haoran — Univ. of Chinese Acad. of Sci.
Zhang, Qichao — Chinese Acad. of Sci.

Environment perception is one of the most crucial modules in a self-driving system. In an open subway environment, pedestrians, equipment boxes and other unknown obstacles often appear. The perception module is required to quickly and accurately recognize the obstacle and measures the corresponding distance data. This paper proposes a detection and ranging fusion method based on one Lidar and two different focal length cameras, which be applied in the subway system, to alert drivers to possible obstacles and assist brake. First, the relative transformation between Lidar and camera is calibrated to find the intrinsic and extrinsic matrices. Modified SSD network is trained on the self-built dataset to detect the potential obstacle and produces the final detection bounding box. Then, rail track segmentation network RailNet is applied to obtain rail shape features, which offers a region of interest (ROI) for sensing systems in point cloud clustering algorithms. Further, the fusion information is utilized to estimate the distance of objects detected by the SSD detector. The proposed method can realize real-time pedestrian detection and range on the on-board embedded platform Jetson Xavier, which satisfies subway environment's perception requirements.

SatA05 16:00–18:00 Room E

Regular Session: Model-free Adaptive Control

Chair: Zhou, Miaolei — Jilin Univ.
Co-Chair: Bu, Xuhui — Henan Polytechnic Univ.

▶ SatA05-1 16:00–16:20

Model-free Adaptive Control for MIMO Nonlinear Systems under Packet Dropout and DoS Attack

Zhao, Xuyang — Henan Polytechnic Univ.
Bu, Xuhui — Henan Polytechnic Univ.
Yu, Wei — Henan Polytechnic Univ.
Liang, Jiaqi — Henan Polytechnic Univ.
Zhang, Wenwen — Henan Polytechnic Univ.

The control problem for multiple-input multiple-output (MIMO) nonlinear systems against stochastically occurring packet dropout and periodic denial-of-service (DoS) jamming attacks is studied in this paper. Firstly, two independent Bernoulli distributions are applied to model random packet dropout and periodic DoS attack. Then combining with the model, a model-free adaptive control (MFAC) algorithm is put forward. Meanwhile, we analyze the stability of the algorithm theoretically and the results indicated that the tracking error is convergent under the presence of packet dropout and periodic DoS attack. Finally, a numerical example results verify the validity of the algorithm.

▶ SatA05-2 16:20–16:40

Data Driven Adaptive Control with Hysteresis Input for A Piezo-Actuated Stage

Wang, Yifan — Jilin Univ.
Zhou, Miaolei — Jilin Univ.

As a core component in the micro/nano-manufacturing, the piezo-actuated stage has superior performance of ultraprecision positioning, fast response and compact size. However, the inherent nonlinearity, such as hysteresis and creep characteristics, in the piezo-actuated stage impacts its positioning precision severely. To eliminate the impact of the nonlinearity of a piezo-actuated stage, a data driven adaptive control method with hysteresis input is proposed in this paper. An unknown nonlinear function with hysteresis input is adopted to depict the piezo-actuated stage. Then, the undetermined parameters of the controller are adjusted online by using the input and output measured data. Finally, the availability of the proposed control method have been demonstrated by a series of experiments compared with a hysteresis inverse compensation-based model reference adaptive control method and a classical model free adaptive control method.

▶ SatA05-3 16:40–17:00

Improved High-Order Model Free Adaptive Control

Xu, Jian — Qingdao Univ. of Sci. & Tech.
Lin, Na — Qingdao Univ. of Sci. & Tech.
Chi, Ronghu — Qingdao Univ. of Sci. & Tech.

Abstract: In this paper, an improved high-order model free adaptive control (IHOMFAC) method is proposed. Considering more information of the previous time, a high-order estimation algorithm is designed, which is different from the traditional high-order MFAC. The design of the control scheme is based on the principle of symmetric similarity, which not only considers more control knowledge of the previous time in the control law, but also uses more information of the previous time in the estimation algorithm, which is conducive to enhancing the control performance. Simulation results show that IHOMFAC has better control performance than the traditional high-order MFAC.

▶ SatA05-4 17:00–17:20

Model Free Adaptive Iterative Learning Fault-tolerant Control for High-speed Trains with Speed and Input Constraints

Gao, Guangzhuo — Beijing Jiaotong Univ.
Jin, Shangtai — Beijing Jiaotong Univ.
Qian, Wang — Qufu Normal Univ.

In this work, a model free adaptive iterative learning fault-tolerant control (MFAILFTC) strategy is proposed to address the speed trajectory tracking problem of high-speed trains (HSTs) with actuator failures as well as speed and traction/braking force constraints. Firstly, an equivalent compact form dynamic linearization (CFDL) data model of the HSTs with actuator failures is derived, and then the RBF neural network (RBFNN) is introduced to approximate fault function. Secondly, the modularized controller design with feedforward iterative learning control(ILC) added on the feedback model free adaptive control (MFAC) is proposed, which makes use of the periodicity of the high-speed trains effectively and improves the control performance greatly. Finally, in order to verify the effectiveness of the proposed strategy, simulation results are presented.

▶ SatA05-5 17:20–17:40

An Active Vibration Control Method for Typical Piping System of Nuclear Power Plant

Zhang, Xiaomeng — Shenyang Ligong Univ.
Sui, Tao — Shenyang Ligong Univ.
Zhang, Haishuai — SHENYANG LIGONG Univ.
Zhang, Yanzhu — Shenyangligong Univ.
Liu, Lu — Northwestern Polytechnical Univ.

Zhang, Shuo Northwestern Polytechnical Univ.

Abstract: This paper proposes a fractional-order PD controller to suppress the vibration of the typical pipeline system of a nuclear power plant. In view of the characteristics of typical pipeline systems of nuclear power plants, mathematical models are established and dynamic equations are derived to make complex systems digitized for analysis and research. A piping system vibration damping controller based on fractional-order PD control is designed. The fractional-order PD controller introduces a differential order on the basis of the traditional integer-order PD controller to improve the matching degree of the model. Under this system structure, the quadratic performance index is designed, and the particle swarm optimization algorithm is used to optimize the controller parameters to optimize the effect of suppressing vibration. The simulation results show that in the typical pipeline system of nuclear power plant, the fractional-order PD controller designed by this method can suppress the vibration of the system better than the traditional integer-order PD controller.

▶ SatA05-6 17:40–18:00

Optimal Adaptive Control for Nonlinear Uncertain Systems

Siyu, Chen Kunming Univ. of Sci. & Tech.
Na, Jing Kunming Univ. of Sci. & Tech.
Huang, Yingbo Kunming Univ. of Sci. & Tech.
Yang, Jun Kunming Univ. of Sci. & Tech.

How to achieve a compromise between the accuracy of parameter estimation and the robustness of system is How to achieve a compromise between the accuracy of parameter estimation and the robustness of system is still a challenging task in adaptive control field. To address this issue, a novel optimal adaptive control (OAC) strategy is proposed for a model reference adaptive control (MRAC) system with uncertain dynamics. To realize this purpose, a low-pass filter operation is first employed for the linearized system to derive the parameter estimation error information. Then, a cost function concerning the tracking error and estimation error is established. Then, the MIT rule is introduced to reconstruct a new optimal adaptive law driven by the parameter estimation error information. In this framework, both the tracking error and parameter estimation error can converge to zero simultaneously. The asymptotic stability of the closed-loop system is analyzed in terms of the Lyapunov theorem. Finally, comparative simulation results are provided to exemplify the effectiveness of the proposed control method.

SatA06 16:00–17:30 Room F

Invited Session: AI and Its Applications on Fault Diagnosis and Image Processing

Chair: Huang, Deqing Southwest Jiaotong Univ.
Co-Chair: Huang, Darong Chongqing Jiao-tong Univ.

▶ SatA06-1 16:00–16:15

The Classification of Motor Imagery EEG Signals Based on the Time-Frequency-Spatial Feature

Deng, Xin Chongqing Univ. of Posts & Telecommunications
Zhang, Boxian Chongqing Univ. of Posts & Telecommunications
Liu, Ke Chongqing Unversity of Posts & Telecommunications
Wang, Jin Chongqing Univ. of Posts & Telecommunications
Pengfei, Yang Chongqing Univ. of Posts & Telecommunications
Hu, Chengxin Chongqing Univ. of Posts & Telecommunications

The effective features of the motor imagery (MI) electroencephalogram (EEG) signals plays a significant role to improve the classification accuracy for the brain-computer interface (BCI) system. Some traditional methods usually extract the frequency or spatial features without considering the related information between different channels that would affect the classification performance. This paper proposes a new method for feature extraction of EEG signals based on the fusion of time-frequency and spatial features. At the beginning, the common spatial pattern (CSP) algorithm is adopted to extract the spatial features. Then the discrete wavelet transform (DWT) and the wavelet packet decomposition (WPD) are used to extract the μ rhythm of the motor imagery EEG signals as the time-frequency features. After that, by combining the spatial and time-frequency features, the time-frequency-spatial feature is formed. Based on different kinds of features, the experimental data are classified by using the support vector machine (SVM), as well as the sparse representation classification (SRC) algorithm with the elastomeric network (EN) and L1 norm, respectively. The experimental results show that the SRC with EN has a better performance on either the time-frequency feature or spatial feature than the SRC with L1 norm does. In contrast, the SVM and the SRC with L1 norm perform better than the SRC with EN based on the time-frequency-spatial feature. The study concludes that the time-frequency-spatial feature cooperating with the certain classifiers can achieve the good classification effect for the MI EEG signals, which not only reduces the operation time but also improves the classification accuracy.

▶ SatA06-2 16:15–16:30

KCF-Match Target Tracking Algorithm for Tracking Swing Angle of Coupler Based on Video

Du, Jiahao Southwest Jiaotong Univ.
Qin, Na Southwest Jiaotong Univ.
Zhang, Yiming Southwest Jiaotong Univ.
Wu, Bi Southwest Jiaotong Univ.
Chen, Shiqian Southwest Jiaotong Univ.

The coupler is an essential component on the train that has the function of connecting and buffering. The actual dynamic performance of the coupler directly influences the safety and comfort of the vehicle. When the heavy haul train passes through the curve, the extreme swing angles of the couplers will seriously threaten the safety of the train. Therefore, the kernelized correlation filter-template matching (KCF-Match) target tracking algorithm is proposed to track the position and calculate the swing angles of the couplers. After the tracked area is selected, the corresponding data of the area are input into the KCF target tracking model for tracking. During the tracking process, if the tracking effects are not satisfied with the given evaluation indexes, the template matching algorithm will be used to track again. Experiments show that KCF-Match target tracking algorithm can achieve 99.8% accuracy rate and 99.9% success rate on the premise of ensuring real-time performance.

▶ SatA06-3 16:30–16:45

An Algorithm Based on ACF and SRG for Abnormality Detection of Bolts on the Subway

Cai, Chongyang Southwest Jiaotong Univ.
Qin, Na Southwest Jiaotong Univ.
Hu, Yuanjiang Guangzhou Yunda Intelligent Tech. Co., Ltd
Li, Jinhan Southwest Jiaotong Univ.

Bolt detection is an essential part of the train inspection system. This paper presents a novel method of wear and looseness detection of the bolt on the subway, based on the depth and intensity maps captured by a 3D line-scan camera. First, this paper adopts the aggregate channel features algorithm to locate the bolt by two steps on the intensity map. Second, by combining the seeded region growing and the random sample consensus algorithm (RANSAC), the method achieves region segmentation in complex environments. RANSAC fits the plane of upper and lower surfaces of the bolt. The difference between the average depth values of inliers with the twice RANSAC is defined as the nut thickness. Third, the wear and looseness detection is realized by comparing it with the historical data. Finally, the 3D image is reconstructed to facilitate human observation. Algorithm verification has been carried out on different trains and locations of bolts. In dynamic operation, the detection success rate is above 94.44 %. The relative detection error of the same vehicle with the latest data is within 0.3mm, proving the effectiveness and robustness of the proposed detection scheme.

▶ SatA06-4 16:45–17:00

Short-Term Traffic Flow Prediction Based on Ensemble Machine Learning Strategies

Zeng, Ximu Chongqing Univ. of Posts & Telecommunications
Wang, Yixiong Chongqing Univ. of Posts & Telecommunications
Deng, Xin Chongqing Univ. of Posts & Telecommunications
Wang, Jin Chongqing Univ. of Posts & Telecommunications

In order to solve the problem of traffic congestion, many city governments have begun to develop intelligent transportation systems. As a research hotspot in the field of intelligent transportation, the short-term traffic flow prediction is of great significance to traffic diversion and route planning. In the recent big data era, the machine learning (ML) algorithms have been applied to mining deep information in the data. However, the performance of a single ML model is usually not good. The ensemble learning can improve accuracy in most cases. In this paper, we propose a new short-term traffic flow prediction model. This paper regards the traffic prediction problem as a regression prediction problem, rather than a time series forecasting problem. The proposed model combines the prediction results of the XGBoost, LightGBM and CatBoost models through the ensemble machine learning strategy. With the experiments on real traffic data in Xi'an city, this paper has obtained the comparison of predictive performance of the models. Compared with single models such

as the ARIMA, LSTM, XGBoost, LightGBM and CatBoost models, the results show the proposed model is more accurate and more suitable for short-time traffic status prediction.

►SatA06-5 17:00–17:15

Finite Element Analysis of Radar Frequency Synthesizer Based on ANSYS

Min, Tang	Chongqing Jiaotong Univ.
Huang, Darong	Chongqing Jiao-tong Univ.
Zhenyuan, Zhang	Chongqing Jiaotong Univ.
Ning, Zhao	China Shipbuilding Industry Corporation
Yu, Zhang	China Shipbuilding Industry Corporation

Temperature field Analysis of Radar frequency synthesizer is important issue the key components of radar in real application scene. In radar system, the problem plays a vital role in ensuring the normal operation of radar. To solve problem, the ANSYS Workbench finite element steady-state thermal analysis method has been introduced to analyze and design the correspongding heat transmission module. In our research, the temperature distribution of frequency syntheses is determined through the finite element heat transfer analysis of frequency syntheses. Combing with the basic idea of finite element, the temperature field is added to the stress field as the load, and the thermal deformation of frequency syntheses is obtained. Some experiment simulating examples have verified the effectiveness of our method.

►SatA06-6 17:15–17:30

A Practical Hybrid Automatic Transmission Model for Commercial Vehicles

Haiyang, Hao	Shaanxi Fast Gear Co.,Ltd
Chen, Haoxing	Shaanxi Fast Gear Co.,Ltd
Huang, Darong	Chongqing Jiao-tong Univ.
Zhenyuan, Zhang	Chongqing Jiaotong Univ.

This study proposes a practical hybrid automatic transmission model for commercial vehicles based on the first-principle modelling approach. The developed plant model consists of three base elements, i.e. hydraulic circuit, multi-plate wet clutches and planetary gear sets. In today’s intelligent transmission control system development framework, plant model plays an important role. It can be used to valid the control algorithm as well as control system in an early stage of the development process, thus shortening development process and improving software quality.

►SatA06-7 17:30–17:45

A KPI-based Performance Management Framework for Commercial Vehicle Automatic Transmissions

Haiyang, Hao	Shaanxi Fast Gear Co.,Ltd
Shi, Yanlong	Shaanxi Fast Gear Co.,Ltd
Huang, Darong	Chongqing Jiao-tong Univ.
Liu, Yang	Inst. of Information Sci. & Engineering

This study proposes a new framework for performance management of commercial vehicle automatic transmissions. Within the proposed framework, performance degradation caused by component failures/malfunctions, low-level control loop attenuations, as well as system-level correlation variations, can be detected at an early stage. In order to avoid further losses/damages to the transmission, online corrective actives are scheduled as well for closing the performance management loop.

►SatA06-8 17:45–18:00

Robust State Estimation for Power Systems Using Quasi-Newton Method

Bai, Yu	Beihang Univ.
Li, Wenling	Beihang Univ.
Li, Xiaoming	Shenzhen Univ.

This article addresses the state estimation problem in power system under non-Gaussian noise environment. This estimator is designed based on maximum correntropy criterion (MCC), which exhibits the robustness with reference to non-Gaussian noise. To avoid computing the inverse matrix of Hessian matrix, the quasi-Newton Broyden-Fletcher-Goldfarb-Shanno (BFGS) method is adopted to propose a centralized power system state estimation algorithm. For the reason of security, privacy and further reducing the computation burden, adapt-then-combine (ATC) strategy is applied to design a distributed state estimation algorithm based on the centralized algorithm. The effectiveness of the proposed method is verified by the numerical results of IEEE 14-bus and IEEE 118-bus systems under uniformly distributed noise, t-distribution noise and impulsive noise.

SatA07 16:00–18:00 Room G

Regular Session: Iterative Learning Control

Chair: Li, Junmin Xidian Univ.

Co-Chair: Ye, Linqi Tsinghua Shenzhen International Graduate School

►SatA07-1 16:00–16:20

Coordinated Fuzzy Adaptive Iterative Learning Control for Nonlinear Multi-agent Systems

Liang, Mengdan	School of Mathematics & Statistics
Li, Junmin	Xidian Univ.
Li, Jinsha	Xidian Univ.

In this work, we design a new fuzzy adaptive iterative control (AILC) scheme for a class of unknown nonlinear leader-following multi-agent systems (MAS), where the influence of unknown input disturbance is considered as well. We adopt the distributed initial learning protocol and use the fuzzy logic system to estimate the unknown function of each agent. Through rigorous analysis, we prove that under the new scheme, all agents track the leader node completely on finite time interval. Finally, one illustrative examples is given to show the effectiveness of the algorithm.

►SatA07-2 16:20–16:40

Reinforcement Learning Tracking Control for Unknown Continuous Dynamic Systems

Ye, Linqi	Tsinghua Shenzhen International Graduate School
Li, Jiayi	Harbin Inst. of Tech.,Shenzhen
Wang, Changliang	Shanghai Acad. of Spaceflight Tech.
Liu, Houde	Tsinghua Univ.
Liang, Bin	Tsinghua Univ.

Reinforcement learning tracking control (RLTC) is proposed to solve the traditional iterative learning control (ILC) problem. For unknown continuous dynamic systems, precision output tracking is achieved for a given trajectory after several times of trials. The controller is composed of a feedback part and a feedforward part, where the feedback part uses linear states feedback to stabilize the system and the feedforward part is a time-dependent signal to ensure precision tracking. The desired trajectory is defined in a finite time interval and the controller is applied repeatedly to the system with the feedforward signal updated by reinforcement learning in each trial. The tracking problem is treated as a black-box optimization problem where the integral quadratic tracking error is a cost to be minimized under input constraints. In order to apply reinforcement learning, the feedforward signal is approximated by spline interpolation of a few representative points distributed uniformly along the tracking time interval. A search strategy based on squeeze theorem is adopted to update the value of the representative points to achieve minimum tracking error cost. The cart pole example illustrates the effectiveness of the proposed method.

►SatA07-3 16:40–17:00

Iterative Learning Control Approach for A Class of 2-D Linear Continuous-discrete Systems

Wan, Kai	Huizhou Univ.
Sun, Xin	Huizhou Univ.

Among available iterative learning control (ILC) results on 2-D dynamical systems, they only focus on the discrete case. This paper first investigates ILC problems of a class of 2-D continuous-discrete systems. We develop convergence of the designed ILC law. With 2-D stability theory, sufficient convergence condition of the designed ILC law is derived. We use an illustrative example to test the feasibility on the designed ILC algorithms.

►SatA07-4 17:00–17:20

Iterative Learning Fault-Tolerant Control for Discrete-time Linear Switched Systems

Gong, Yingjie	Shandong Univ.
Wang, Luyao	Shandong Univ.
Yang, Rongni	Shandong Univ.
Zhu, Yanzheng	Huaqiao Univ.

This paper considers the fault-tolerant tracking control problem based on the iterative learning control (ILC) strategy for a class of discrete-time linear switched systems with actuator faults. By taking advantage of a multiple switched Lyapunov function method and a quadratic performance function, sufficient conditions are proposed to guarantee the asymptotic convergence of the resulting ILC dynamics, and then the ILC law could be further designed. Finally, a numerical example is applied to validate the feasibility of the developed theoretical results.

►SatA07-5 17:20–17:40

Iterative Learning Based Train Stop Control with Initial State Shifts for Urban Rail Transit

Yu, Ruochuan	Beijing Jiaotong Univ.
Tang, Tao	Beijing Jiaotong Univ.
Yin, Chenkun	Beijing Jiaotong Univ.
Xun, Jing	Beijing Jiaotong Univ.
Xi, Jiayi	Traffic Control Tech. Co., Ltd
Zheng, Xiaobin	Beijing Transport Inst.

In this paper, a partitioned terminal iterative learning control (TILC) strategy for urban rail transit with initial state shifts is proposed to solve the accurate stop problem. A supervised machine learning method is used to pre-processing the historical operation data (i.e. the initial speed and the position data pairs in the stopping stage). And for each category the TILC algorithm is applied, realizing the update of the control law in a small range. Simulation results show that the proposed algorithm can achieve the stop accuracy of ±15cm even though the initial state varies over a certain range during the iterations. This meets the general requirement of accurate train stop for urban rail transit (±30cm).

▶ SatA07-6 17:40–18:00

Iterative Learning Enhanced Integral Terminal Sliding Mode Control for Precision Motion Systems

Feng, Zhao	Univ. of Macau
Ling, Jie	Nanjing Univ. of Aeronautics & Astronautics
Wan, Feng	Univ. of Macau
Yang, Zhi-Xin	Univ. of Macau

The rapid development and application of precision motion systems pose a great challenge on tracking performance improvement to complete various industrial or scientific tasks. In this paper, an iterative learning enhanced integral terminal sliding mode control (IL-ITSMC) is developed to further enhance the performance of such systems under repetitive trajectory and disturbance. For the generally used second-order model in precision motion systems, an integral terminal sliding surface is utilized to improve the steady-state performance and robustness to unexpected disturbance. A novel reaching law is also designed to realize the finite-time convergence of the sliding surface. In addition, an iterative learning law is proposed based on the sliding surface to compensate the repetitive term through updating the feedforward control input iteratively. The stability in time domain and convergence in iterative domain are proven theoretically based on the well-known Lyapunov theory, respectively. The simulation results on a pizeo-actuated stage with hysteresis nonlinearity demonstrate that the proposed IL-ITSMC achieves the best tracking performance through comparisons, and the convergence speed is improved significantly in comparison with ITSMC with traditional P-type ILC (PIL-ITSMC) for a 10 Hz sinusoidal repetitive trajectory.

SatA08 16:00–18:00 Room H

Regular Session: Neural Networks, Fuzzy Systems Control in Data Driven Manner (I)

Chair: Li, Sheng — Zhejiang Univ. of Tech.

Co-Chair: Huang, Congzhi — North China Electric Power Univ.,Beijing, China

▶ SatA08-1 16:00–16:20

GWVSeg-Net: An Efficient Method for Gastrointestinal Wall Vascular Segmentation

Xueting, Kong	Zhejiang Univ. of Tech.
Lu, Cheng	Zhejiang Univ. of Tech.
Si, Peng	Zhejiang Univ. of Tech.
Li, Sheng	Zhejiang Univ. of Tech.
Zhu, Jinhui	Second Affiliated Hospital of Medical College of Zhejiang Univ.
He, Xiongxiong	Zhejiang Univ. of Tech.
Ou, Xianhua	Zhejiang Univ. of Tech.

Precisely and automatically segment the blood vessels in the gastrointestinal wall and analyze their distribution state, which is of great significance to reduce or even avoid serious complications such as iatrogenic colonic perforation. In this paper, we propose the novel gastrointestinal wall vascular segmentation network (GWVSeg-Net) to capture a wider range of semantic features and improve the ability of inter-class recognition and intra-class aggregation by using the global pyramid attention module (GPA). In addition, in order to improve the ability of the model to accurately distinguish between mucosal folds and vessels, a new loss function is proposed to train the model. Experimental results show that the proposed method is superior to the existing advanced segmentation networks in the performance of gastrointestinal wall vascular segmentation.

▶ SatA08-2 16:20–16:40

MSB-Net: Multi-Scale Boundary Net for Polyp Segmentation

Dongchao, Wang	Zhejiang Univ. of Tech.
Mingjie, Hao	Zhejiang Univ. of Tech.
Ruirui, Xia	Zhejiang Univ. of Tech.
Zhu, Jinhui	Second Affiliated Hospital of Medical College of Zhejiang Univ.
Li, Sheng	Zhejiang Univ. of Tech.
He, Xiongxiong	Zhejiang Univ. of Tech.

Polyp of intestinal tract is the precursor of colorectal cancer. Accurate computer-aided polyp location and segmentation in colonoscopy is of great importance since it provides valuable information for endoscopists. However, polyps are arduous to be segmented due to their high inter-class similarity, high intra-class variation, and low contrast with surrounding mucosa. To address these challenges, we propose a multi-scale boundary network (MSB-Net) for polyp segmentation. We first focus on the multi-scale feature representation and propose a novel architectural unit to extract intra-stage and contextual information, which is named ResU-Block (RUB). RUBs are connected by the proposed multi-squeeze-and-excitation (Multi-SE) units which can recalibrate the feature information from a multi-scale perspective. We then generate a coarse prediction using the partial decoder, of which the boundary is further refined by a shallow-level attention (SA) module. In addition, we exploit the boundary details using a set of reverse attention (RA) modules, which can progressively establish relationships between regions and boundaries from deep-level features. Comprehensive experiments on five public datasets across five metrics elucidate that our architecture outperforms other SOTA methods by a large margin while maintaining comparable model complexity and inference speed.

▶ SatA08-3 16:40–17:00

Research on Short Term Photovoltaic Power Prediction Based on ITMBA-BP Algorithm

Cao, Hanwen	Shenyang Inst. of Engineering
Zhao, Yan	Shenyang Inst. of Engineering
Ma, Yanjuan	Shenyang Inst. of Engineering

Photovoltaic power generation, with its clean, low-carbon and sustainable characteristics, is playing an increasingly important role in the formulation of national energy strategies. The photovoltaic power generation is affected by many factors. The traditional prediction method is not accurate to solve the high dimensional optimization problem, and it is easy to fall into the local optimal problem. In this paper, a collaborative algorithm based on improved adaptive T-distribution variation bat algorithm and traditional BP neural network （ITMBA-BP） is proposed. The improved bat algorithm is used to enhance the global coverage and the ability to solve high-dimensional optimization problems. The ITMBA algorithm is used to adjust the structure and parameters of the neural network, which enhances the global search capability of the BP neural network. Use real photovoltaic power plant data to predict and analyze the algorithm proposed in this paper, and compare it with the traditional BP algorithm. The simulation results show that ITMBA-BP algorithm has the advantages of high accuracy and small mean square error. It can effectively predict the change of power generation and has strong practical application value.

▶ SatA08-4 17:00–17:20

Relaxed Nonquadratic Stabilization of Discrete-Time Takagi-Sugeno Systems via An Efficient Switching Law

Lu, Hongyu	Nanjing Univ. of Posts & Telecommunications
Gong, Aimin	Nanjing Univ. of Posts & Telecommunications
Xie, Xiangpeng	Nanjing Univ. of Posts & Telecommunications

This paper investigates the study on further enhancing the stabilization of discrete-time Takagi-Sugeno systems by proposing a new fuzzy switching controller. Compared with the recent result reported in the literature, the proposed fuzzy switching controller is with a richer architecture on normalized fuzzy weighting functions and a much more efficient switching law is developed for on-line activating the best pair of control gain matrices at each sampling instant. As a result, a larger system controllable interval can be obtained and it means that the conservatism of the previous result can be further reduced. In the end, some numerical simulations are provided to verify the effectiveness of the method developed in this paper. Furthermore, the proposed fuzzy switching controller is illustrated to be capable of providing much better control performance than the recent one for the same controllable plant.

▶SatA08-5 17:20–17:40

Intelligent Built-in Test Design of Controller Module by Improved Biologically Inspired Neural Network

Xie, Zhenmeng North China Electric Power Univ.
Hou, Guolian North China Electric Power Univ.
Zhang, Jianhua North China Electric Power Univ., Beijing
Huang, Congzhi North China Electric Power Univ.,Beijing, China

Built-in test (BIT) technology is widely employed in heavy-duty gas turbine control systems for fault recognition. However, it is difficult to obtain an excellent fault diagnostic ability by using the conventional BIT technology, and the false alarm rate is high. In this paper, a design of intelligent BIT based on improved biologically inspired neural network (BINN) is proposed to reduce false alarm. Firstly, massive historical measurement data of controller module is collected and used as training dataset and test dataset. Secondly, intelligent BIT based on improved BINN is designed to deal with the issue of module state identification and reduce false alarm rate. Finally, the effectiveness of proposed approach is validated by the given extensive numerical simulation results and experimental results.

▶SatA08-6 17:40–18:00

Spectrum Attention Mechanism for Time Series Classification

Zhou, Shibo Zhejiang Univ.
Pan, Yu Zhejiang Univ.

Time series classification (TSC) has always been an important and challenging research task. With the wide application of deep learning, more and more researchers use deep learning models to solve TSC problems. Since time series always contains a lot of noise, which has a negative impact on network training, the original data are usually filtered before the training of the network. The existing schemes are to treat the filtering and training as two stages, and the design of the filter requires expert experience, which increases the design difficulty of the algorithm and is not universal. We note that the essence of filtering is to filter out the insignificant frequency components and highlight the important ones, which is similar to the attention mechanism. In this paper, we propose an Spectrum Attention Mechanism (SAM). The network can assign appropriate weights to each frequency component to achieve adaptive filtering. We use $l1$ regularization to further enhance the frequency screening capability of the SAM. We also propose a Segmented-SAM (SSAM) to avoid the loss of time domain information caused by using the spectrum of the whole sequence. In which, a tumbling window is introduced to segment the original data. Then SAM is applied to each segment to generate new features. We propose a heuristic strategy to search for the appropriate number of segments. Experimental results show that SSAM can produce better feature representations to speed up the learning process, and improve the robustness and classification accuracy.

SatA09 16:00–18:00 Room I

Invited Session: Big Data in Smart Grid

Chair: Yu, Yajie Xi'an Jiaotong Univ.
Co-Chair: Cao, Hui Xi'an Jiao Tong Univ.

▶SatA09-1 16:00–16:20

Short-term Prediction of Electricity Consumption in Distribution Network During Peak Summer Period Based on ARIMA Model

Luo, Simin Guangzhou Power Supply Bureau Co., Ltd
Xu, Shuo Guangzhou Power Supply Bureau Co., Ltd
Luan, Le Guangzhou Power Supply Bureau Co.,Ltd
Xu, Zhong Guangzhou Power Supply Bureau Co., Ltd
Zhou, Kai Guangzhou Power Supply Bureau Co.,Ltd
Guo, Qianwen Guangzhou Power Supply Bureau Co., Ltd
Xiao, Yao Xi'an Jiaotong Univ.
Wang, Yu Xi'an Jiaotong Univ.

The short-term prediction of the electricity consumption of the distribution network during the peak summer period is of great significance to the safe and stable operation of the distribution network and to reduce the burden on the grid staff. This paper obtains and organizes the operating data of distribution transformers in a city in southern China, takes the active load rate as the electricity consumption index, and uses ARIMA and PCR models to make short-term electricity consumption prediction. The results show that ARIMA prediction results are significantly better than PCR. The research results of this paper have certain guiding significance for the actual work of distribution network.

▶SatA09-2 16:20–16:40

A High Dimensional Input Data Processing Method for Load Forecasting Model Based on Tensor Partial Least Squares

Feng, Yu Chang'an Univ.
Tian, Chao Huayin Ordance Test Certer of China

Many factors affect the power load prediction which is worthy of attention in power production and management. The factors can be expressed as tensors. Most traditional forecasting models require the inputs are matrics. When the inputs are tensors, data processing is needed. In this paper, a data processing method which is called tensor partial least squares (TPLS) is proposed to transform the input tensor into matrix in the latent space. Two classical and commonly used methods, support vector machine (SVM) and back propagation neural network (PBNN), are selected to test the prediction results. Compared with the traditional data processing method, TPLS can improve the prediction accuracy.

▶SatA09-3 16:40–17:00

Early Warning of Distribution Transformer Based on BP Neural Network Considering the Influence of Extreme Weather

Wang, Hongbin Guangzhou Power Supply Bureau Co.,Ltd
Luan, Le Guangzhou Power Supply Bureau Co.,Ltd
Rao, Yi Guangdong Power Grid Ltd
Yang, Liu Guangzhou Power Supply Bureau CO.,LTD
Zhou, Kai Guangzhou Power Supply Bureau Co.,Ltd
Chen, Jian GuangZhou Power Supply Bureau Co., Ltd

When extreme weather occurs, it may cause grid equipment failures and regional power outages. It can even give rise to a large-scale power outage, which affect people's normal life seriously and bring about irreparable losses. In order to avoid losses and ensure reliability of users' power consumption, researchers have carried out research from two aspects: before and after the occurrence of extreme weather. After the occurrence of extreme weather, the research analysis the cause of key equipments' failure and the emergency restoration has been relatively mature, which already have various methods. However, it is relatively weak for the researches about warning before the occurrence of extreme weather. This paper makes research on disaster prevention measures before the occurrence of extreme weather, and proposes early warning of distribution transformer power supply failure based on BP neural network considering the influence of extreme weather. The method proposed in this paper is easier to promote and apply from the perspective of the distribution network. With BP neural network, taking into account extreme weather and other nonlinear factors, it can more accurately realize the distribution transformer fault warning. Based on a distribution transformer data set, compare the distribution transformer failure warning results with the results of the Logistic regression algorithm and the support vector machine algorithm. It is shown that the BP neural network algorithm results are optimal.

▶SatA09-4 17:00–17:20

Similar-Density-Array-Based Equipment Outage Prediction Method for Distribution Network Considering Weather Factors

Mo, Wenxiong Guangzhou Power Supply Bureau Co.,Ltd
Xu, Zhong Guangzhou Power Supply Bureau Co., Ltd
Zhou, Kai Guangzhou Power Supply Bureau Co.,Ltd
Luan, Le Guangzhou Power Supply Bureau Co.,Ltd
Fan, Weinan Guangzhou Power Supply Bureau Co.,Ltd
Liu, Han Guangzhou Power Supply Bureau Co.,Ltd

Predicting the failure risk of the equipment in distribution network helps to guide operation and maintenance decision-making, which is very useful to boost the resilience against unplanned power failure risks and improve the reliability of distribution network. In this paper, a Similar-Density-Array-Based equipment outage prediction method is proposed to solve the outage prediction problem. In this method, Similar-Density-Array-Based clustering algorithm is used to classify the predictable data and unpredictable data according to the load data and recorded outage data in the power network. Similar-Density-Array-Based equipment outage prediction method is proposed using the Logistic fast minimum error entropy algorithm to predict the failure risk of the equipment considering weather factors. The proposed method is validated in the real distribution dataset. The results proved that the proposed clustering algorithm is effective and the outage prediction method completes the failure risk prediction problem, obtaining good prediction result.

▶SatA09-5 17:20–17:40

Study on the Correlation Model between Extreme Disaster Weather and Distribution Transformer Fault Types

Wang, Yong Guangzhou Power Supply Bureau Co., Ltd
Xu, Zhong Guangzhou Power Supply Bureau Co., Ltd
Zhou, Kai Guangzhou Power Supply Bureau Co.,Ltd

Liu, Junxiang Guangdong Power Grid Co. Ltd
Guo, Qianwen Electric Power Test & Research Inst. Guangzhou Power Supply, Guangdong Power Grid Co., Ltd
Fan, Weinan Guangzhou Power Supply Bureau Co.,Ltd

Nowadays extreme disaster weather have a great impact on the safe operation of distribution transformer. In this paper, an analytic hierarchy process(AHP)-fuzzy comprehensive evaluation method combined with a data mining method based on Apriori algorithm is proposed to build a new disaster weather evaluation system and construct the correlation model between extreme weather conditions and transformer fault types. For the proposed method, the analytic hierarchy process-fuzzy comprehensive evaluation method is firstly used to processed the real data of a certain power grid, and then the disaster weather evaluation system is established to to determine the impact degree of the disaster weather and classify the disaster grade. Lastly the Apriori algorithm is used to mine the real data to obtain the strong association rules and build the correlation model.The proposed model is performed on the field data obtained from a real power grid in South China and the final experimental results prove that the evaluation system and the correlation model are effective and comprehensive.

▶ SatA09-6 17:40–18:00

Blockchain-Enabled Secure and Transparent Cross-Regional Model Updating and Sharing Approach in Smart Grid

Hao, Yuan Xi'an Jiaotong Univ.
Cao, Hui Xi'an Jiao Tong Univ.

With the rapid development of smart grid, the lack of a very accurate and consistent grid model has become a bottleneck for its development. However,the traditional maintenance and sharing methods for grid model can not meet the requirements of the current grid environment since it is centralized and once the central server is attacked, huge loss will be caused. To this end, this paper proposes a blockchain-based architecture for province- prefecture power dispatching system to realize secure and transparent cross-regional model parameters updating and sharing , which can ensure the integrity, consistency and traceability of the grid model applied in each local dispatching center. In this paper, the blockchain technology is used to store, update and share model parameters in a secure way, and different clients have different permissions to access the blockchain network. The implementation of the proposed approach shows that it is a feasible and promising solution for smart grid model communication in a secure way.

Sunday, May 16, 2021

SunA01 08:00–10:00 Room D

Regular Session: Applications of Data-driven Methods to Industrial Processes

Chair: Tian, Huixin — Tianjin Ploytechnic Univ.
Co-Chair: Wang, Yinsong — North China Electric Power Univ.

▶ SunA01-1 08:00–08:20

The Batch Process Fault Monitoring Using Adversarial Auto-encoder and K-Nearest NeighborRule

Li, Zeyu — Beijing Univ. of Tech.
Chang, Peng — Beijing Univ. of Techonlogy
Wang, Kai — Beijing Univ. of Tech.
Wang, Pu — Beijing Univ. of Tech., China

In the industrial batch process monitoring domain,the conventional multivariate monitoring methods may notalways function well in monitoring faults that have bothNon-Linear and Non-Gaussian properties. To enhance themonitoring capability, the adversarial auto-encoder (AAE) wasintroduced to increase the sensitivity to Non-Gaussian anomaliesby projecting non-Gaussian information into a given Gaussiandistribution feature space. At the same time, low-dimensionalfeature space can avoid the problem of ”Concentration ofmeasure” and improve the ability to distinguish minor smallabnormalities. Therefore, A novel statistic index was constructedin the feature space based on the k-nearest neighbor rule (KNN)to improve the ability of minor fault monitoring. The proposedmodel is compared with the traditional multivariate statisticalprocess monitoring methods in numerical examples andpenicillin fermentation platform, which proves that it has bettermonitoring ability for minor magnitude and non-Gaussian faults.

▶ SunA01-2 08:20–08:40

A Soft-Sensor Model for NOx Concentration Based on Enet-GPR

Wang, Yinsong — North China Electric Power Univ.
Chen, Ruijie — North China Electric Power Univ.

The control and optimization of Selective Catalytic Reduction (SCR) system has been one of the research hotspots of thermal power units. Accurate measurement of the Nitrogen Oxide (NOx) concentration at the entrance of SCR is of great significance for SCR control and optimization. Firstly, Elastic Net (Enet) method is used to variable selection. This method improves the penalty coefficient by convex combination of L1 and L2 norm, which has the advantages of ridge regression (RR) and Least Absolute Shrinkage and Selection Operator (LASSO), and overcome the problem of collinearity and group effects in the data when using the LASSO Method. Then, focusing on the advantages of the Gauss process regression (GPR) model , such as the easy acquisition of the super parameters, the flexibility of non parametric inference and the probability significance of output, the Enet-GPR soft-sensor model is established. Field data simulation results show that the proposed method has excellent prediction accuracy and generalization performance.

▶ SunA01-3 08:40–09:00

基于改进*Isolation Forest*算法的高炉异常挖掘

Deng, Hua — Tsinghua Univ.
Zhang, Tongshuai — Tsinghua Univ.
Xiong, Zhihua — Tsinghua Univ.
Ye, Hao — Tsinghua Univ

高炉历史数据挖掘对于建立高炉异常检测所需的模型非常重要，现有研究还比较少。本文采用孤立森林的方法进行高炉历史数据异常炉况的挖掘，但孤立森林方法应用于高炉数据时会导致挖掘结果出现大量时间上不连续的孤立异常数据点，这并不符合高炉运行的实际情况。因此本文在孤立森林算法的基础上，利用移动滑窗将数据样本的异常得分划分为一系列子集，并通过监测每个子集中异常点数量的占比来判断相应的子集是否异常，因而保证了所挖掘出的异常炉况样本的连续性。基于实际高炉历史数据的测试表明，该方法不仅正确识别出了工作日志中有记录的异常炉况，还挖掘出了日志中没有记录的异常炉况数据，并得到现场操作人员的事后确认。

▶ SunA01-4 09:00–09:20

Uncertainty-Aware Data-driven Tobacco Loosening and Conditioning Process Moisture Prediction and Control Optimization

He, Yi — Hongyunhonghe GROUP
Li, Bin — Hongyunhonghe GROUP
Pu, Yi — Hongyunhonghe GROUP
Jin, Wenjing — CyberInsight Tech. Co. Ltd
Zhou, Xunmiao — CyberInsight Tech. Co. Ltd
Jin, Chao — CyberInsight Tech. Co. Ltd

Tobacco loosening and conditioning process is one of the most important processes in cigarette production, the quality of which affects the final product quality largely. The control of water proportion added in this process has been human experience-centric and inconsistent without intensive human tuning. This paper proposes an uncertainty-aware outlet moisture prediction and optimization approach to provide updated water proportion to the PID controller for consistently desirable quality performance and stability. In this research, quantile regression is applied to describe the confidence of prediction, and Monte Carlo simulation is induced in the online optimization to take in the uncertainty. The approach has been applied to a cigarette production line and showed significant improvement compared with human tuning.

▶ SunA01-5 09:20–09:40

Compressor Health Prediction Based on Multi-Source Information Fusion and LSTM

Tian, Huixin — Tianjin Ploytechnic Univ.
Yang, Linzheng — Tiangong Univ.
Wang, Hongyi — Tianjin Polytechnic Univ.
Li, Kun — Tianjin Polytechnic Univ.

Reciprocating compressor is core equipment of petrochemical industry. Accurate state of health monitoring and faults early warning state are very important for the smooth running of a reciprocating compressor. Aiming at the lower accuracy of traditional vibration signal prediction, the LCD-LSTM is used for the accurate and stable vibration signal prediction. The LCD is used to decompose the original vibration signal into many intrinsic scale components(ISCs). And all of the ISCs are predicted by LSTM separately and accumulated as vibration signal predicted result. Meanwhile, in order to overcome the limitation of information in single vibration signal, a multi-source information fusion (MSIF) strategy is designed to build the state of health prediction model with more comprehensive information by considering multiple parameters information related to the main faults. Then a health curve which will reflect and predict the running state of compressor can be obtained. To validate the prediction capacity of the proposed MSIF-LCD-LSTM method, running data of the reciprocating compressor in offshore natural gas exploitation of China National Offshore Oil Corporation is used for modeling and testing. The results of experiments demonstrate that the proposed model has great superiority over other models and good performance of running state detection and faults early warning.

▶ SunA01-6 09:40–10:00

Physics-informed Recurrent Neural Networks for the Identification of A Generic Energy Buffer System.

Lahariya, Manu — Ghent Univ.
Karami, Farzaneh — Ghent Univ.
Develder, Chris — Ghent Univ. - Imec
Crevecoeur, Guillaume — Ghent Univ.

Energy storage is ubiquitous in industrial processes and comes in many forms such as material, chemical, electromechanical buffers. System identification of such energy buffers demands proper estimation/prediction of their physical quantities and unknown parameters. Once these parameters are determined, the identified model can be employed to predict the industrial process dynamics, which finally assist to build efficient control for these processes. This paper proposes physics-informed neural networks-based grey-box modeling methods for the identification of energy buffers. The underlying system dynamics are enforced on the neural network structure to ensure that the identified grey-box model follows the approximate physics. We define two novel grey-box models based on simple and recurrent neural network architectures and test these models for a generic energy buffer. Performance and training time for the proposed grey-box models are compared against a black-box baseline model. Results confirm that imposing the dynamic system’s physics on the network improves the performance, and utilizing a recurrent architecture leads to a further improvement.

SunA02 08:00–10:00 Room E

Invited Session: Data-based Cooperative Control of Networked Systems

Chair: Wu, Zhengguang — Inst. of Advanced Process Control
Co-Chair: Che, Weiwei — Shenyang Univ.

▶ SunA02-1 08:00–08:20

Adaptive Event-triggered Fuzzy Control for DC Motor Servo Systems

Li, Baomin	Liaocheng Univ.
Wang, Xueliang	Liaocheng Univ.
Wang, Linqi	Liaocheng Univ.
Yang, Wenjing	Liaocheng Univ.
Xia, Jianwei	Liaocheng Univ.

In this paper, an adaptive event-triggered fuzzy tracking control problem is studied for direct current (DC) motor servo systems. Fuzzy logic system (FLS) is introduced to deal with the problem of unknown nonlinear functions. Then, an adaptive event-triggered tracking control scheme is proposed by using backstepping design and event-triggered strategy. The proposed event-triggered tracking controller guarantees that the tracking error converges to an arbitrarily small neighborhood of zero and all the signals in the closed-loop system remain bounded. Finally, the effectiveness of the proposed control scheme is proved by a numerical example.

▶ SunA02-2 08:20–08:40

Trajectory Tracking of Nonlinear Complex Network via Pinning Impulsive Control

Jiahao, Zhang	Huazhong Univ. of Sci. & Tech.
Chi, Ming	Huazhong Univ. of Sci. & Tech.
Liu, Zhi-Wei	Huazhong Univ. of Sci. & Techology

In this paper, the tracking problem of nonlinear complex network via pinning impulsive control is studied. A novel approach to trajectory tracking control of a complex network is presented. By applying pinning impulsive controllers to the nodes in the follower network to ensure that the trajectory of target network can be tracked exactly.And a sufficient condition for follower flow to track the target network is obtained through the selection of parameters and the nodes selection at each impulsive instant. The stability of the system is proved with Lyapunov's stability theorem.

▶ SunA02-3 08:40–09:00

Learnability of System Dynamics for A Class of Linear Time-invariant Discrete-time Systems

Liu, Jian	Xidian Univ.
Zheng, Yuanshi	Xidian Univ.

This note is concerned with the learnability of system dynamics for a class of linear time-invariant discrete-time multi-input-multi-output systems. Firstly, we give the definition of learnability of system dynamics. Secondly, we show that the controllability matrix is unconditionally learnable. Finally, by using Hamilton-Cayley Theorem we illustrate that the system matrix and the input matrix are learnable if and only if the controllability matrix is full-row rank.

▶ SunA02-4 09:00–09:20

Consensus Tracking of Second-Order Autonomous Unmanned Systems with Nonlinear Dynamics Using Distributed Adaptive Control

Li, Yanzhou	Guangdong Univ. of Tech.
Wu, Yuanqing	Guangdong Univ. of Tech.
He, Shenghuang	College of Automation
Lu, Yongkang	Guangdong Univ. of Tech.
Zhong, Wenjian	Guangdong Univ. of Tech.

The consensus tracking of second-order autonomous unmanned systems with nonlinear dynamics by using distributed adaptive control is studied in this paper. First, the consensus tracking problem is converted to the stability problem of error dynamic system. Second, the obtained error dynamic system is proved to be asymptotically stable by constructing suitably Lyapunov function. Third, the distributed consensus tracking controller and adaptive control law acting on the network topology are designed to achieve the consensus tracking of second-order autonomous unmanned systems. The theoretical results are verified by some simulations

▶ SunA02-5 09:20–09:40

Non-fragile H_∞ Filtering for Fuzzy Discrete-time Systems with Markovian Jump and Data Loss

Liang, Lun	Zhejiang Univ.

This paper focuses on the design of the non-fragile H_∞ filtering of fuzzy discrete-time systems with Markovian jump and data loss. The system is represented by Takagi and Sugeno (T-S) fuzzy model. The imperfect information transmission from the factory to the filter is modeled by a Bernoulli random binary distribution. A non-fragile and full-order H_∞ filter with additive gain variations is constructed. The sufficient conditions are derived based on mode-dependent and fuzzy-basis-dependent Lyapunov functional methods, which ensure the developed filtering error system is stochastically stable with given H_∞ performance index. The usefulness and effectiveness of the filter design method is certified by a numerical case.

▶ SunA02-6 09:40–10:00

Structural Balance Preserving and Consensus of Uncertain Euler-Lagrange Systems in Cooperation-Competition Networks

Wang, Jia	Hangzhou Dianzi Univ.
Yingxia, Zhou	Hangzhou Dianzi Univ.
Hu, Hong-Xiang	Hangzhou Dianzi Univ.

The structural balance preserving problem is studied in this article for multiple Euler-Lagrange systems in the state-dependent cooperation-competition network. The initial network is structurally balanced and connected, which means that the entire network could be divided into two subnetworks, with cooperation internally and competition externally. By means of the potential function techniques, one kind of classification strategy is applied to handle this problem, where the evolution rules of two kinds of edge sets among agents and the distributed protocol based on a class of potential functions are proposed, respectively. Under this strategy, the multiple Euler-Lagrange systems can maintain the structural balance of cooperation-competition network and achieve bipartite static consensus in the revolution. Finally, a numerical example is delivered to demonstrate the effectiveness of the theoretical analysis.

SunA03 08:00–10:00 Room F

Regular Session: Data-driven Modeling, Optimization and Scheduling

Chair: Liu, Han — Xi'an Univ. of Tech.

Co-Chair: Chen, Xin — Suzhou Univ. of Sci. & Tech.

▶ SunA03-1 08:00–08:20

Robust Variational Bayesian Inference for Jump Markov ARMAX Systems

Chen, Xin	Suzhou Univ. of Sci. & Tech.
Liu, Fei	Jiangnan Univ., China

In this paper, the robust identification problem of the jump Markov systems with colored noise is considered with variational Bayesian inference. The linear dynamic of the individual mode with colored noise is approximated with an autoregressive moving average exogenous model. The outliers are accommodated with the Student's t-distribution. The posterior distributions of the parameters and the variance are provided with the variational Bayesian inference. The point estimation of the transition probability and the degree of freedom of t distribution are also estimated.

▶ SunA03-2 08:20–08:40

Based on the Recursive Identifier of Different Innovation Lengths On-off Detection Strategy of Slow-switching Hammerstein System

Chen, Haichao	China Univ. of Petroleum,Beijing
Wang, Zhu	China Univ. of Petroleum (Beijing)
Liu, Zhihui	China Univ. of Petroleum,Beijing
Chang, Qing	China Univ. of Petroleum,Beijing

For the slow-switching Hammerstein system in an impulsive noise environment, multiple identifiers are used to work together to detect the switching point quickly and accurately, and at the same time obtain the parameter estimates of the sub-model. Recursive identification of multiple innovations can improve the accuracy of the identification results and increase the robustness of the identification algorithm. Recursive identification of short innovations is more sensitive to changes in the system environment. Compare the identification results of the two identification algorithms to determine whether subsystem switching occurs and can resist the interference of impulse noise. During the switching process of the subsystem, the initial identification value generated during the switching process is confirmed to improve the convergence speed and speed up the switching process. Finally, simulation experiments prove the superiority of the proposed switching scheme.

▶ SunA03-3 08:40–09:00

A Hybrid-driven Soft Sensor with Complex Process Data Based on DAE and Mechanism-introduced GRU

Guo, Runyuan	Xi'an Univ. of Tech.
Liu, Han	Xi'an Univ. of Tech.
Wang, Wenqing	Xi'an Univ. of Tech.
Xie, Guo	Xi'an Univ. of Tech.
Zhang, Youmin	Concordia Univ.

With the increasing complexity of industrial processes, process big data inevitably has strong nonlinear, dynamic and noise problems, which restrict the accurate establishment of data-driven or mechanism-driven soft sensor models. Therefore, a soft sensor based on the denoising autoencoder and mechanism-introduced gated recurrent units is proposed. The

denoising autoencoder is used to denoise the data. The mechanism-introduced gated recurrent units are used to introduce the information contained in the mechanism model and extract the dynamic characteristics of the process data by deep learning. This soft sensing method can deal with various problems of complex process data and introduce mechanism model for hybrid-driven modeling, which improves the prediction performance of the soft sensor. The effectiveness and superiority of the method are verified by the industrial case of predicting the thermal deformation of an air preheater rotor.

►SunA03-4 09:00–09:20

A Novel Interval Prediction Method Based on Long Short-term Memory Networks with Adaptive Dropout

Xu, Yuan	Beijing Univ. of Chemical Tech.
Xi, Changchao	Beijing Univ. of Chemical Tech.
Zhang, Yang	Beijing Univ. of Chemical Tech.
Zhu, Qunxiong	Beijing Univ. of Chemical Tech.
He, Yan-Lin	Beijing Univ. of Chemical Tech.

Aiming at the problem of interval prediction for key variables in the process industry, a Long Short-term Memory (LSTM) network based on adaptive Dropout is proposed. Firstly, in order to reduce the complexity of time series data and the mutual influence between time series data of different scales, Empirical Mode Decomposition (EMD) is used to decompose time series data into several Intrinsic Mode Functions (IMF) Weight and trend weight. Secondly, an adaptive Dropout method is proposed in the loop unit of the LSTM model. Some neurons are probabilistically stopped (equivalent to discarding neurons or corresponding weights), and the probability of stopping neurons is adaptively calculated according to the distribution characteristics of the data. Thereby, the LSTM model is improved that the model overfitting is reduced and the dependence between neurons is inhibited, so as to enhance the efficiency of information transmission and the model prediction accuracy. Thirdly, Bootstrap method is introduced to construct the prediction interval, and the comprehensive function of interval evaluation is used to estimate the prediction interval result. Finally, a simulation experiment is made on the Purified Terephthalic Acid (PTA) solvent system. The comparison results show that the proposed interval prediction model can effectively analyze the trend of key variables and has higher prediction accuracy and interval estimation ability.

►SunA03-5 09:20–09:40

Dynamic State Estimation of DFIG Using Square-root Cubature Kalman Filter

Sun, Zhihong	School of Electrical & Electronic Engineering,Huazhong Univ. of Sci. & Tech.
Chen, Yixuan	State Grid Fujian Longhai Power Supply Co.,Ltd

This paper proposes the implementation of dynamic state estimation of Doubly Fed Induction Generator (DFIG) using Cubature Kalman Filter (CKF) and Square-root Cubature Kalman Filter (SRCKF). First, the related research of DFIG dynamic state estimation is reviewed, and then the shortcomings of Extended Kalman Filter (EKF) and Unscented Kalman Filter (UKF) and the advantages of CKF and its extended algorithm are explained. Then, a specific DFIG model is used for simulation analysis. The simulation results compare the performance of UKF, CKF and SRCKF. It shows that SRCKF can avoid the non-positive definiteness of the covariance matrix during CKF iteration, and has better filtering effect.

►SunA03-6 09:40–10:00

Research on Dynamic Target Assignment Method of UAV Swarms Based on Cost Minimization

Xingye, Qiu	Sys. Engineering Research Inst.
Miao, Boya	Sys. Engineering Research Inst.
Yang, Li	Sys. Engineering Research Inst.
Li, Linghao	Sys. Engineering Research Inst.
Liu, Geng	Sys. Engineering Research Inst.
Wu, Yanxia	Sys. Engineering Research Inst.
Liu, Sidong	Sys. Engineering Research Inst.

For synergetic air interception targets of the unmanned aerial vehicle (UAV) swarms, this paper proposes a dynamic target assignment model of UAV swarms based on the cost minimization (DAMCM). Taking comprehensive consideration of factors such as interception feasibility, safely return, importance of targets and so on, we design and calculate the cost of UAVs intercepting different targets, and get the optimal assignment plan by minimizing total cost. The model allows assignment plan to be updated dynamically with good extensibility. In order to solve DAMCM model, an iterative genetic algorithm (iterGA) is designed based on genetic algorithm (GA). Simulation experiments show that DAMCM model can give a reasonable target assignment in line with expectations, and iterGA algorithm can calculate less cost than classical genetic algorithm.

SunA04 08:00–10:00 Room G

Invited Session: Data-Driven Technologies in Robotic Systems

Chair: Wang, Yu Inst. of Automation Chinese Acad. of Sci.

Co-Chair: Zhao, Bo Beijing Normal Univ.

►SunA04-1 08:00–08:20

A Novel Clustering Method Using Variational Autoencoder with Reliable Sample Decision and Balanced K-Means++ for Single-particle Cryo-EM Images

Yan, Yang	Xiamen Univ.
Wu, Jiageng	Xiamen Univ.
Liu, Bowen	Xiamen Univ.
Zheng, Qingbing	Xiamen Univ.
Zhang, Dongxu	Xiamen Univ.
Ge, Shengxiang	Xiamen Univ.
Zhang, Jun	Xiamen Univ.
Xia, Ningshao	Xiamen Univ.

Single-particle cryo-electron microscopy (cryo-EM) is one of the most popular technology in the field of biology molecular structure determination. Clustering for Cryo-EM particle images is very important in the structure reconstruction process, which significantly affected the reconstruction resolution. Because the signal-to-noise-ratio (SNR) of cryo-electron is extremely low, it' s a challenge to improve the clustering accuracy. In this paper, we proposed a novel clustering method that combined a variational autoencoder with reliable sample decision (ReVAE) and balanced K-means++ (BK-means++). ReVAE projects cryo-EM images into low-dimensional latent variables, and BK-means++ is applied to cluster latent variables. Training of ReVAE and clustering of latent variables by BK-means++ are performed jointly and iteratively. The experimental results showed that ReVAE with BK-means++ achieved state-of-the-art results compared to traditional cryo-EM particle images clustering methods.

►SunA04-2 08:20–08:40

Disturbance Observer Based Control for An Underwater Biomimetic Vehicle-Manipulator System with Mismatched Disturbances

Lv, Jiaqi	Univ. of Chinese Acad. of Sci.
Wang, Yu	Inst. of Automation Chinese Acad. of Sci.
Wang, Shuo	Inst. of Automation,Chinese Acad. of Sci.
Wang, Rui	Inst. of Automation, Chinese Acad. of Sci.
Cheng, Long	Inst. of Automation, Chinese Acad. of Sci.
Tan, Min	Inst. of Automation, Chinese Acad. of Sci.

In this paper, a disturbance observer based control (DOBC) framework is proposed to achieve the motion control of an underwater biomimetic vehicle-manipulator system (UBVMS) driven by bionic flippers with mismatched disturbances. First, a disturbance observer is established to estimate the mismatched disturbances in finite time. Then, a novel arctangent non-singularity sliding mode manifold incorporating the disturbance observer is proposed to counteract the lumped mismatched disturbances. The stability of the system is validated by the Lyapunov theory. Finally, various comparative simulations are carried out to validate the performance of our proposed DOBC framework in the presence of mismatched disturbances.

►SunA04-3 08:40–09:00

Omnidirectional Drift Control of An Underwater Biomimetic Vehicle-Manipulator System via Reinforcement Learning

Ma, Ruichen	Institution of Automation Chinese Acad. of Sci.
Wang, Yu	Inst. of Automation Chinese Acad. of Sci.
Wang, Rui	Inst. of Automation, Chinese Acad. of Sci.
Wang, Shuo	Inst. of Automation,Chinese Acad. of Sci.

This paper addresses an omnidirectional drift control method of an underwater biomimetic vehicle-manipulator system (UBVMS). The UBVMS has two biomimetic propellers, they obtain propulsive force by actuating their undulating fins. A system configuration of the UBVMS, the dynamic model of the UBVMS and the kinematics of the undulating fins are given respectively. Then the control problem is formulized and formed into a Markov decision process (MDP). A reinforcement learning method based on the twin delayed deep deterministic policy gradient (TD3) is proposed for this MDP. A control policy is well trained by the reinforcement learning method and tested in eight different simulations. An analysis of the simulation results is given in the end.

▶ SunA04-4 09:00–09:20

Remote Operation with Haptic Force and Virtual Proxy for An Underwater Vehicle-Manipulator System

Ma, Jin — Univ. of Chinese Acad. of Sci.
Wang, Yu — Inst. of Automation Chinese Acad. of Sci.
Wang, Rui — Inst. of Automation, Chinese Acad. of Sci.
Wang, Shuo — Inst. of Automation,Chinese Acad. of Sci.

This paper aims to investigate a smooth teleoperation method for the underwater vehicle-manipulator system. First, a coordinated mapping control method for the vehicle is presented. The haptic force is considered to help assist the operation. Then, two mapping modes are used to teleoperate the manipulator: when the end-effector needs to move in a large area, two virtual points and a spring-damping system are implemented to filter the operator's hand jitter and limit the manipulator's speed; when the end-effector needs to move in a small area, a position increment control method with a small proportional coefficient is used to improve the precision. Finally, the simulation demonstrates the effectiveness of the proposed teleoperation method.

▶ SunA04-5 09:20–09:40

Study on Underwater Simultaneous Localization and Mapping Based on Different Sensors

Yin, Jiye — North China Electric Power Univ.
Wang, Yu — Inst. of Automation Chinese Acad. of Sci.
Cheng, Long — Inst. of Automation, Chinese Acad. of Sci.

Simultaneous localization and mapping (SLAM) is important for autonomous underwater vehicles (AUVs). An AUV can be equipped with corresponding function sensors to obtain the information of underwater environment and its own position. Affected by many factors of water, many sensors that can be used normally on the ground perform poor in the marine scenario. This paper presents a review of the underwater SLAM implemented by different sensors: monocular camera, stereo camera, single-beam sonar, multi-beam sonar, side-scan sonar and laser.

▶ SunA04-6 09:40–10:00

Dynamic Event-triggered Scheme and Output Feedback Control for CPS under Multiple Cyber Attacks

Zhang, Zhigang — Northeastern Univ.
Liu, Jinhai — Univ. of Northeastern
Zhang, Shuo — Northeastern Univ.
Zhu, Hongfei — Univ. of Northeastern

For a cyber physical system under multiple cyber attacksincluding nonperiodic denial-of-service (DoS) attack and stochastic deception attack,we design a dynamic output feedback controller with dynamic event-triggered strategy. We adopts a control strategy based on dynamic trigger conditions, which reduces the number of triggers and saves network resources. Besides, we establish a switched system model to describe the presence of multiple cyber attacks with dynamic event-triggered scheme. Then, according to asymptotic stability theory, dynamic output feedback controller ensuring the switching system stable is designed by using a piecewise Lyapunov-Krasovskii function. Furthermore, the parameters of dynamc event-triggered and controller are derived in a unified framework and sufficient conditions for asymptotic stability can be obtained.

SunA05 08:00–10:00 Room H

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

Chair: Li, Yan — Shandong Univ.
Co-Chair: Zuo, Zhiqiang — Tianjin Univ.

▶ SunA05-1 08:00–08:20

A Combined Model-Based and Data-Driven Fault Diagnosis Method with Gap Metric Technology

Jin, Hailang — TianJin Univ.
Zuo, Zhiqiang — Tianjin Univ.
Wang, Yijing — Tianjin Univ.

Fault diagnosis technology has become a significant research topic in various industrial systems due to the increasing requirements for higher reliability and safety. In recent years, the main direction in terms of system reliability is concentrated on the large amplitude of faults via the model-based method. In general, the model-based fault detection and isolation (FDI) is an effective tool for an accurate system model, especially the actuator and sensor faults. However, there may exist incipient fault, which is easily covered by modeling uncertainty, external disturbances, or measurement noises. It is difficult to guarantee the trade-off between the robustness against the disturbances and the sensibility for the faults. Hence, the model-based method has certain limitations for incipient fault. Though the degree of a system deviation from its normal state is relatively inconspicuous when an incipient fault occurs at an early stage, it may still pose a significant security risk to the system over time. If the incipient faults can be accurately detected and isolated earlier by an effective FDI technique, the system will be regularly maintained and overhauled. By doing so, people can reduce or avoid the occurrence of catastrophic faults. Therefore, a data-driven gap metric fault detection and isolation (DDGMFDI) method is expected to detect and isolate incipient faults. Residual generator plays a key role in fault diagnosis in terms of the model-based method, which mainly consists of two categories: deterministic model framework and stochastic model framework. For the former, a lot of work has been done in this field. In parallel with the development of deterministic model method, the stochastic framework has also captured wide attention since 1970s. A common fault detection approach was first presented based on the Kalman filter to generate residual signals, and then the faults can be detected via the changes of the mean for the residual signals. A slice of statistical tools, such as χ^2 testing, cumulative sum algorithm, multiple hypothesis testing, and generalized likelihood ratio test, were further applied to check the possibility of a fault occurrence. Meanwhile, the parameter estimation method via system identification technique is also powerful for stochastic fault diagnosis. With the rapid development of information and communication technology, a huge amount of input/output data of the industrial process can be stored. Thus, the data-driven FDI approach has attracted wide attention. Roughly speaking, the gap metric is used to measure the distance between two closed subspaces in Hilbert space. In other words, it can predict the variations of a system closed-loop characteristics when a component fault occurs. As we know, the component faults may be caused by certain parameter variation. Such variation will have certain impact on the zero-pole distribution of the closed-loop system. Further, it may affect the closed-loop characteristics. In order to analyze directly the influence of parameter variation on the system, a performance index that quantifies this effect is essential. Fortunately, the gap metric can exactly measure the impact of the variations caused by certain component faults. Meanwhile, the gap metric technique is also critical for stability analysis in robust control. There has been a lot of progress of the gap metric for fault detectability, fault isolability, and threshold computation. More recently, the data-driven calculation of the gap metric between two linear time-invariant systems was suggested through the data-driven realization of the stable image representation. With the above preparations, a novel DDGMFDI approach is proposed for incipient component faults in this study. The overall structure diagram of the FDI system is plotted in Fig. 1. For actuator and sensor faults, an adaptive Kalman filter combining with the generalized likelihood ratio method is applied in our study. For component faults, especially incipient faults, the model-based scheme may be not a good choice due to the existence of disturbances or noises. Hence, a novel data-driven gap metric strategy is presented. The design of the appropriate fault cluster center model and radius via gap metric technique is put forward to enhance the isolability of the incipient faults.

▶ SunA05-2 08:20–08:40

Optimistic Fault Diagnosis of Discrete Event Systems Modeled with Labeled Petri Nets

Zhu, Guanghui — Xuchang Univ.

This paper deals with the fault diagnosis problem of discrete event systems modeled with labeled Petri nets. Its main contributions are threefold. First, depending on whether a diagnosis function examines the fault transitions that possibly occur after the last observed event, we formally divide the diagnosis functions into two types: optimistic and pessimistic, which aims to facilitate the discussion and research of different diagnosis approaches. Second, a framework is proposed, which extends a given diagnosis approach for Petri nets to the case of labeled Petri nets by computing and combining the diagnosis results for observable transition sequences corresponding to an observed word. Third, we convert a basis-marking-based approach that is originally pessimistic to the optimistic case and prove the correctness of this conversion.

▶ SunA05-3 08:40–09:00

A Visualized Quality Grading Method for Multi-index Products

Wang, Peiming — Huazhong Univ. of Sci. & Tech.
Wang, Zhaojing — Huazhong Univ. of Sci. & Tech.
Yang, Weidong — Huazhong Univ. of Sci. & Tech.
Wang, Yanwei — Wuhan Inst. of Tech.

Zheng, Ying Huazhong Univ. of Sci. & Tech.

A graphical system for quality assessment is highly demanded in current manufacturing industry. It is typically difficult to grade products by multi-index quality data according to specification limits, especially when there is a complex correlation between indexes. This work introduces a visualized quality grading framework to solve the problems, which includes adopting Yoe-Johnson transformation and kernel principal component analysis to augment the insufficient quality data with correlations, and then visualizing the data through a modified 3D Kiviat diagram. The confidence region of each quality grade is determined respectively on the diagram to evaluate online products. The proposed methodology is tested on a semiconductor manufacturing and the result demonstrates its effectiveness and reliability.

►SunA05-4 09:00–09:20

A Novel Lifecycle Operation Performance Evaluation Framework for Plant-Wide Industrial Processes

Zhang, Xueyi Univ. of Sci. & Tech. Beijing
Zhang, Kai Univ. of Sci. & Tech. Beijing
Peng, Kaixiang Univ. of Sci. & Tech. Beijing
Zhang, Chuanfang Univ. of Sci. & Tech. Beijing
Ma, Liang Univ. of Sci. & Tech. Beijing

In the modern complex industrial process, such as hot strip mill process (HSMP), the safety and optimality of the production process may deteriorate and operation performance will be degraded due to the wear of equipment, mode conversion and random disturbances. If the process is not adjusted and maintained, there may be more serious faults resulting in greater economic losses and potential safety hazards. Hence, it is essential to develop comprehensive operation performance evaluation. In this paper, a novel lifecycle operation performance evaluation framework based on multi-step total projection to latent structures (T-PLS) is proposed, which is used to deal with normal or faulty performance evaluate problems in the plant-wide HSMP. Firstly, HSMP can be divided into upstream, midstream and downstream by the actual process. Then, the T-PLS monitoring model is established gradually in each stream. Based on the pre-designed transmission rules of fault prior information, comprehensive statistical indexes are constructed to judge whether the process is in normal or faulty operation state. After that, the lifecycle performance evaluations are realized by different evaluation rules. Finally, the feasibility and effectiveness of the proposed method are illustrated through a real HSMP.

►SunA05-5 09:20–09:40

Operation State Assessment and Prediction of Distribution Transformer Based on Data Driven

Fan, Min Chongqing Univ.
Gang, Peng Chongqing Univ.
Bo, Zhang China Electric Power Research Inst.
Meng, Zhou China Electric Power Research Inst.
Shitao, Jia Chongqing Univ.

With the rapid development of Power Internet of Things, power grid monitoring data and analysis methods are increasing, so real-time dynamic monitoring of power equipment becomes possible. This paper presents a data driven method for evaluation and trend prediction of distribution transformer operation state. The key features reflecting dynamic change of operation state are extracted from voltage and current data of distribution transformer, and characteristic data flow is input into dynamic evaluation model to make real-time portrait description of distribution transformer operation state. According to time order and change trend of characteristic data flow, Long Short-Term Memory network (LSTM) is used to analysis regulation of characteristic data, and Support Vector Regression model (SVR) for its prediction. The future characteristic data flow is obtained, which is input into the dynamic evaluation model to realize the future operation trend prediction of the distribution transformer. Finally, examples are given to illustrate the feasibility, advanced nature and applicability of the method.

►SunA05-6 09:40–10:00

Battery Fault Diagnosis Scheme Based on Improved RBF Neural Network

Liu, Zhenyu Shandong Univ.
Li, Yan Shandong Univ.

In this paper, the fault diagnosis scheme for battery is investigated by an improved radial basis function (RBF) neural network. First, the causes of battery faults and the difficulties of fault diagnosis are analyzed. Second, by using the characteristics of experimental data, the subtractive clustering method (SCM) is employed to determine the number of hidden layer neurons, center vector, and expansion coefficient in the RBF neural network. Then, a battery fault diagnosis scheme is designed based on the proposed improved RBF neural network. The simulation results show that the designed scheme can accurately diagnose the type of battery fault with a fast training speed.

SunA06 08:00–10:00 Room I

Invited Session: Learning-based Adaptive Control and Applications (I)

Chair: Na, Jing Kunming Univ. of Sci. & Tech.
Co-Chair: Chen, Qiang Zhejiang Univ. of Tech.

►SunA06-1 08:00–08:20

Adaptive Nonsingular Terminal Sliding Mode Attitude Tracking Control of Rigid Spacecraft

Xie, Shuzong College of Information Engineering, Zhejiang Univ. of Tech.
Shi, Huihui Zhejiang Univ. of Tech.
Tao, Meiling Zhejiang Univ. of Tech.
Chen, Qiang Zhejiang Univ. of Tech.
Wu, Chun Zhejiang Univ. of Tech.

This paper proposes an adaptive nonsingular terminal sliding mode control scheme for attitude tracking of rigid spacecrafts. A novel nonsingular terminal sliding mode surface is constructed and an auxiliary function is developed in the controller design to avoid the singularity problem. Then, a finite-time controller is designed to ensure the finite-time convergence of the attitude tracking error and angular velocity error, and the lumped uncertainty including inertia uncertainties and external disturbances is compensated by the adaptive update law. With the proposed control scheme, no prior knowledge on the bound of uncertainty is required and the finite-time stability of the entire closed-loop system is analyzed with a rigorous theoretical proof. The effectiveness of the proposed scheme is demonstrated through an illustrative example.

►SunA06-2 08:20–08:40

Internal Reconstruction Gradient Blind Estimation Method for Hammerstien-like System

Li, Linwei Beijing Inst. of Tech.
Xianglong, Liu Beijing Jiaotong Univ.
Fengxian, Wang Zhengzhou Univ. of Light Industry
Ren, Xuemei Beijing Inst. of Tech.

Most of the Block-oriented nonlinear system identifications focus on the memoryless nonlinear sub-model, there are relatively few researches on nonlinear submodels with memory. In this work, we study the blind identification of Hammerstein-like system with memory nonlinearity. By force of the half-substitution technology, the estimation model of the Hammerstein-like system is written as a compact form in which the bulk-parameters are escaped, the high time-consuming is avoided. To achieve the parameter estimation, the system order information is obtained by using determinant ratio scheme. In algorithm design, we applied internal reconstruction idea to revise the multi-innovation gradient scheme in which the innovation length obstacle is addressed. For the unmeasurable variable, we use the reference model method to realize indirect measurability of unmeasurable variable. Finally, the effectiveness of the developed estimator is demonstrated based on the numerical example.

►SunA06-3 08:40–09:00

Study on the Measuring system for the Position of Industrial Robots' End-effectors based on Monocular Vision

Yan, Zizheng Kunming Univ. of Sci. & Tech.
Gao, Guanbin Kunming Univ. of Sci. & Tech.
Na, Jing Kunming Univ. of Sci. & Tech.
Liu, Fei Kunming Univ. of Sci. & Tech.

The requirement of intelligent manufacturing technology for the accuracy of industrial robots becomes higher and higher. To improve the accuracy of industrial robots, kinematic calibration as a valid method is generally used, which requires the data of the end-effector's position. Unlike the existing method mainly depend on precision instruments such as laser trackers, a measurement system for the position of industrial robot's end-effector based on monocular vision is proposed, which includes an industrial camera, a standard sphere. The industrial camera is installed on the end-effector of the industrial robot, which is used to measure the position of the standard sphere placed near the base of the industrial robot. The data of the ray from the optical center of the camera to the standard sphere's center are acquired by moving the industrial robot with different poses. With the error model of the robot established, an

objective function based on the kinematic model and the distance from the ray to the standard sphere is obtained, optimization methods are used to identify the kinematic parameters of the industrial robot.

▶ SunA06-4 09:00–09:20

Neural-Network-Based Adaptive Funnel Control for Strict-Feedback Systems with Tracking Error and State Constraints

Cheng, Yun Beijing Inst. of Tech.
Ren, Xuemei Beijing Inst. of Tech.

In order to deal with the error/state constraints of the strict-feedback systems with the unknown quantization paremeters and disturbances, an adaptive control strategy based on funnel variables and neural networks (NNs) is proposed. The original strict-feedback systems is transformed into a new systems without constrains by some funnel variables, and then a dynamic surface control (DSC) is used to stabilize the transformed systems, which guarantees the tracking error in a preset ferformance funnel and states in some bounded regions. The unknown disturbances are estimated and compensated by the NNs, and the quantization error of the control input is also considered by an adaptive way. Furthermore, the feasibility conditions of the virtual controllers in barrier Lyapunov function (BLF) are removed. The convergence of the transformed control systems is proved through the Lyapunov theory. Lastly, some simulations illustrate the effectiveness of the proposed control strategy.

▶ SunA06-5 09:20–09:40

Unconstrained Lower Limb Motion Recognition by Angle Assisted Annotation-Based Surface EMG Sequential Labelling

Li, Zhuorong Yunnan Univ.
Tao, Dapeng Yunnan Univ.
Wu, Yiqiang Yunnan Univ.

Surface electromyography(sEMG)-based lower limb motion recognition has developed rapidly in a variety of applications and attracts extensive attentions. However, most of existing work focuses on single lower limb motion recogition(SLLMR) and ignores the importance of unconstrained lower limb motion recognition(ULLMR). In this paper, we propose a novel angle assisted annotation-based surface electromyography sequential labelling (A3-SESL) framework to solve ULLMR task. Specifically, A3-SESL is composed of labelling phase and learning phase. In term of labelling phase, due to difficulty of direct sEMG annotation, we introduce joint angle information to assist sEMG labelling. In term of learning phase, we first use labelled sEMG data to establish unconstrained lower limb motion sEMG (ULLM-sEMG) dataset, and then an light-weight temporal concolutional network is designed to perceive the latent difference information in supervised learning manner. Comprehensive comparision experimental results demonstrate the ability of proposed framework in recognizing lower limb motion

▶ SunA06-6 09:40–10:00

Building Health State Recognition Method Based on Multi-channel Convolution Neural Network Fusion

Su, Tingli Beijing Tech. & Business Univ.
Li, Jian Beijing Tech. & Business Univ.
Yang, Aiqiang Beijing Tech. & Business Univ.
Jin, Xuebo Beijing Tech. & Business Univ.
Kong, Jianlei School of Computer & Information Engineering
Bai, Yuting Beijing Tech. & Business Univ.

The identification of the health status of buildings has been paid more and more attention by all sectors of the society. The early warning of catastrophes or the assessment of the damage degree and residual life of building structures after catastrophes has become a hot issue for scholars from all over the world. In order to improve the performance of building health state recognition, a novel framework based on multi-channel convolution neural network fusion is proposed in this paper. By combining the output results of different convolution neural networks, temporal information and spatial information are used to achieve the accurate classification of building health status. Eventually, with the data collected by the sensor during the earthquake, the proposed framework is proved to be effective and superior.

Poster Session SunA07
May 16, 8:00–10:00
Corridor

Chair: Song, Yang Shanghai Univ.
Co-Chair: Dong, Na Tianjin Univ.

▷ SunA07-01

Building Energy Optimization Based on Biased ReLU Neural Network

Xinglong, Liang Harbin Inst. of Tech., Shenzhen
Li, Hongyi Harbin Inst. of Tech., Shenzhen
Xu, Jun Harbin Inst. of Tech., Shenzhen

Buildings account for nearly 40% of global energy consumption. Given the rapid development of artificial intelligence technology there is an opportunity to develop a new generation of smarter building controllers. In this work, we propose a building energy optimization method based on artificial intelligence modeling method, which has low modeling cost and satisfactory accuracy. Specifically, the Biased ReLU neural network is used to predict the building energy consumption and room temperature. Then, based on the above two predictions, the set temperature of the air conditioner is optimized to save energy through model predictive control (MPC). The genetic algorithm is used to solve the MPC problem. Finally, the co-simulation of EnergyPlus and Matlab is realized. The results show that the proposed strategy is effective.

▷ SunA07-02

Controllability of Multiagent Systems Based on Unidirectional Strongly Connected Cycle Graphs

Zhang, Zhiwei Qingdao Univ.
Ji, Zhijian Qingdao Univ.

In this paper, the controllability of multi-agent systems based on a class of directed topological structures under path and unidirectional strongly connected cycle graphs is studied by the Kalman rank criterion. On the one hand, for paths and unidirectional strongly connected cycles, under the premise of choosing a leader, sufficient and necessary conditions are presented for determining the locations of leaders under which the controllability can be realized. The results show that the leader selected at the first end of the path graph can make it controllable, however, the leader can be selected arbitrarily in the unidirectional strongly connected cycle. What's more, the controllability of path-cycle graph is studied. Each path-cycle graph is formed by connecting the last node of the path graph to any node in the cycle graph. Interestingly, we find its controllability is equivalent to that of a path graph when leader is selected specially. On the other hand, a necessary condition for the controllability of the system is obtained when a node of an unknown topology is connected to an arbitrary node of an unidirectional strongly connected cycle graph. Specifically, the necessary condition is that there is a leader in the unknown topology to receive external control input.

▷ SunA07-03

RMPC Fault-tolerant Control for Flexible HSV with Polytopic LPV Model

Yang, Xiaohe Tianjin Univ.
Lv, Weijie Tianjin Univ.
Hu, Chaofang Tianjin Univ.
Hu, Yongtai Flight Automatic Control Research Inst.

In this paper, a robust fault-tolerant controller is designed for flexible air-breathing hypersonic vehicle (HSV) with actuator fault and external disturbance. Firstly, the polytopic linear parameter variable (LPV) model of flexible HSV is established through Jacobian linearization and tensor product (TP) method. The integral terms of height error and velocity error are introduced to eliminate the steady state error, and the extended system is constructed. The actuator loss of effectiveness fault is separated from the control input and lumped into disturbance term together with the external disturbance. And the extended polytopic LPV faulty system is obtained. Secondly, the fault-tolerant controller is designed based on robust model predictive control (RMPC). The state feedback control law is obtained by solving the linear matrix inequality (LMI) optimization problem. Norm bounded theory is introduced to suppress the lumped disturbance term of the real system. The disturbed and undisturbed state are guaranteed to be in the same invariant set. Finally, numerical simulations have demonstrated the fault-tolerant performance of the developed controller.

▷ SunA07-04

A Data-driven Trajectory Tracking Control Method Based on Adaptive Fourier Decomposition for Linear Discrete Systems

Li, Junkang Shanghai Univ.
Fang, Yong Shanghai Univ.
Ge, Yu Shanghai Univ.

Data-driven control methods are a hot issue in the field of control in recent years. In this paper, a trajectory tracking control algorithm based on adaptive Fourier decomposition is proposed for linear discrete systems by using the adaptive and fast convergence characteristics of adaptive Fourier decomposition. The algorithm implements the data-driven output control of the system without using the model information. And the entire algorithm process has no parameters needed to be selected, which

makes the algorithm fully adaptive. The simulation verifies the effectiveness of the proposed algorithm.

▷ SunA07-05

Structural Controllability Analysis Based on Network Topology

Sun, Shuhui	Qingdao Univ.
Ji, Zhijian	Qingdao Univ.

In this paper, the structural controllability of leader-follower systems defined on digraph is discussed. Firstly, by the aid of the leader-follower partition, we analyze the topological characteristics of network systems without ”dilation”. Inspired by these topological characteristics, we divide the digraph into leader subgraph and follower subgraph, and by analyzing the topological characteristics of follower subgraph, a sufficient condition for the system to be structurally controllable if and only if there is no ”dialtion” in the follower subgraph under the premise of directed spanning tree (forest) with leader(s) as root node(s) is given. Furthermore, we analyze the topological structure of a kind of systems, and the sufficient conditions for the systems to be structurally controllable with the follower subgraph is strongly connected is intuitively given, and the sufficient conditions for the systems to be structurally controllable with the digraph is leader-follower connected is also given, meanwhile, we also present a way to construct a digraph under structural controllability. Finally, the structural controllability of directed tree graph is briefly analyzed, the selection mechanism of leaders and the lower bound of the number of leaders under strong structural controllability are given.The above results reflect the effect of system topology on (strong) structural controllability.

▷ SunA07-06

Fuzzy Control of Discrete Nonlinear Systems with Backlash

Sun, Guofa	Qingdao Univ. of Tech.
Du, Hui	Qingdao Univ. of Tech.
Wang, Gang	Qingdao Univ. of Tech.

For a class of nonlinear discrete-time systems with input backlash, the fuzzy backlash model is used to replace the backlash inverse model, and the fuzzy backlash model is approximated by the linear combination of linear term and disturbance like term. The internal unknown function and external unknown disturbance of the closed-loop system are defined as the total disturbance of the system, and the discrete-time high-order sliding mode differentiator is used as the precise disturbance observer, and the total disturbance was controlled by an adaptive controller. Finally, Lyapunov theorem is used to prove the stability of the controller, and a simulation example is used to verify the feasibility of the scheme.

▷ SunA07-07

Denoising Control of Temperature Tracking for LiBr-H2O Absorption Refrigeration System

Dong, Na	Tianjin Univ.
Chang, Jianfang	Tianjin Univ.
Lv, Wenjin	Tianjin Univ.
Zhu, Shuo	Tianjin Univ.

To alleviate the noise in the temperature tracking of the LiBr-H2O absorption refrigeration system, denoising model-free adaptive control algorithm has been proposed in this paper. Firstly, the improved tracking differentiator is mainly used to alleviate the phase delay. Secondly, the model-free adaptive control with single input and single output has been extended to dual input and single output, equipped with the improved tracking differentiator, the denoising control of temperature tracking for LiBr-H2O absorption refrigeration system has been constructed. Thirdly, the stability of denoising model-free adaptive control algorithm has been proven. Finally, the proposed algorithm is applied to the mathematical model and actual system, the experimental results prove the rapidity and immunity of the proposed algorithm in different systems.

▷ SunA07-08

Implementation of Adaptive Self-Organizing Fuzzy Wavelet Neural Network: Modeling AC Servo System

Hou, Runmin	Nanjing Univ. of Sci. & Tech.
Shi, Difen	Nanjing Univ. of Sci. & Tech.
Hou, Yuanlong	Nanjing Univ. of Sci. & Tech.
Qiang, Gao	Nanjing Univ. of Sci. & Tech.

In this paper, an adaptive self-organizing fuzzy wavelet neural network (ASOFWNN) controller is investigated for AC servo system, aims to deal with nonlinear problem and time-varying disturbance. In order to acquire better performance, an improved self-organizing wavelet neural network (SOWNN) is proposed as the consequent part fuzzy rule in the training process. Innoviate with adaptive learning, adaptive gradient algorithm (AGA) is used to optimize the parameters in SOFWNN. Furthermore, the Lyapunov approach is implemented to verify the stability of the system. Finally, simulation and experimental results proved that compared with fuzzy wavelet neural network (FWNN), novel ASOFWNN shows fast convergence rate and more precise modeling performance.

▷ SunA07-09

Model-Free-Adaptive-Control for Moving Object Detection in RGB Video Sequence

Sun, Guoqing	Qingdao Univ.
Hou, Zhongsheng	Beijing Jiaotong Univ.

Moving object detection in video sequences is an important topic in the field of computer vision. The video background image extraction is the key step in most moving object detection methods. The traditional background image extraction methods are easy to cause model distortion when the video scene cannot meet its assumptions or model conditions. In this paper, the background image extraction method is proposed using model free adaptive control. The method combines RGB three channel history and current data of pixels to represent and update background image. The proposed method that under different video sequences is compared with the traditional background image extraction methods. The results show that the method can extract the color background image and separated the color foreground image, and the foreground image is closer to the ground truth image of the video target.

▷ SunA07-10

Research on Frequency Regulation Control Strategy of Wind Turbine Based on Disturbance Adaptiveness

Liu, Hongqing	China Univ. of Mining & Tech.
Xiong, Liansong	Xi’an Jiaotong Univ.
Cao, Hui	Xi’an Jiao Tong Univ.
Li, Mingxian	StateGrid Jiaxing Power Supply Company
Liu, Xinghua	Xi’an Univ. of Tech.
Yang, Lei	Xi’an Univ. of Tech.

To solve the frequency problem caused by high wind power penetration, control strategies such as rapid power compensation (RPC) have been adopted to release the frequency regulation capability of new energy sources quickly. However, when the wind turbine (WT) adopts the RPC strategy to participate in the system frequency regulation, it cannot adapt to the random disturbance. In this paper, a disturbance adaptive rapid power compensation （ARPC） strategy is proposed. When the system is disturbed, the signal excitation method is used to estimate the external disturbance. According to the estimated disturbance, the WT rotational inertia is quickly used to compensate for the grid’s unbalanced power. When the system frequency deviation and the rate of change of frequency (RoCoF) evaluation indexes meet the threshold requirements, the control strategy switches from ARPC to droop control, which can ensure the WT exit frequency regulation smoothly, and further reduce the frequency deviation and improve the frequency quality. Finally, analyzing the operation mode and determining the relevant switching logic, the proposed ARPC strategy’s detailed implementation is developed. Simulation results proved the effectiveness and advancement of the ARPC based strategy.

▷ SunA07-11

Extended-State-Observer Based Finite-Time Control for Spacecraft Attitude Tracking on SO(3)

Shi, Zhongjun	Shanghai Acad. of Spaceflight Tech.
Shao, Changbao	Shanghai Inst. of Satellite Engineering
Zhang, Jianqiao	Shanghai Inst. of Satellite Engineering
Zhao, Yanbin	Shanghai Inst. of Satellite Engineering

This paper addresses the spacecraft attitude tracking control problem in the presence of model uncertainties, external disturbances, and actuator saturation by proposing a finite-time controller integrated with an extended-state-observer (ESO). More specifically, in view of the aforementioned drawbacks, the attitude dynamics are developed on the Special Orthogonal group SO(3) directly, and the system total disturbance is reconstructed by using anti-windup technique. It should be noted that singularities and ambiguities associated with other attitude representations are avoided in the developed model. Then, a finite-time ESO is designed to observe the disturbance. Based on the estimated information, a coordinate-free fast terminal sliding mode controller (FTSMC) is developed to ensure the finite-time stability of the closed-loop system. The stability of the closed-loop system is proved using Lyapunov stability theory. Finally, numerical simulations are conducted to demonstrate fine performance of the finite-time observer and the controller for the attitude

tracking control system.

▷ SunA07-12

Research on Autocad Data Extraction Algorithm Based on 3D Printing Technology in Construction Industry

Wang, Renren	Qilu Univ. of Tech.,Jinan
Ning, Yaxiao	Qilu Univ. of Tech.
Lu, Hong Qian	Qilu Univ. of Tech.
Chen, Hongwei	.Ji Nan Building Source Cement Products Co.LTD, Jinan, China

In order to accurately extract AutoCAD drawing information when 3D printing in the construction industry, this paper proposes a method for extracting information from AutoCAD format files. In this way, 3D printing equipment can directly use this information for work.

▷ SunA07-13

Cascade Smith Control of SCR Flue Gas Denitrification System Based on Active Disturbance Rejection

Pu, Cuiping	Kunming Univ.

Selective catalytic reduction (SCR) denitrification system has complex reaction process, which is characterized by large inertia, large delay, strong disturbance and uncertainty. In order to improve the robustness of traditional linear active disturbance rejection controller (LADRC), an improved active disturbance rejection controller (ILADRC) is designed by adding an identical linear extended state observer(LESO) and introducing the estimated error value of total disturbance. In order to better solve the problem of large delay in SCR denitrification system, Smith predictor is used to offset the delay of output variables before entering LESO. Smith-ILADRC control of SCR denitrification system is designed. The tracking performance, anti-jamming performance and robustness of Smith-ILADRC are simulated under the action of external disturbance and the change of model parameters. The results show that the tracking performance and anti-jamming ability of Smith-ILADRC are obviously improved.

▷ SunA07-14

Fault Diagnosis of Rod Pump Oil Well Based on Support Vector Machine Using Preprocessed Indicator Diagram

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With the continuous development of the petroleum industry, rod pumping has been vigorously developed and widely used in the petroleum industry, so the fault diagnosis of rod pumping wells has become very important. Today, most of the fault diagnosis for pumping wells is based on analyzing the indicator diagram. The indicator diagram can effectively reflect the working status of the rod pump pumping well. By observing the indicator diagram, various failures of the pumping well can be judged, and corresponding measures can be taken to solve the relative failure. This is of great significance to ensure the safe, stable and efficient production of pump devices. This paper takes indicator diagram as the research object, and uses support vector machine (SVM) to identify and classify indicator diagrams to diagnose the fault types of pumping wells. A series of preprocessing is adopted for the indicator diagram, and the improved Fourier descriptor is used for feature extraction to establish a sample database of indicator diagrams. The experimental results show that this indeed improves the accuracy of SVM learning, increases the fault recognition rate, and provides a guarantee for the safe operation of rod pumping wells.

▷ SunA07-15

Fault Hybrid Propagation of Power System in More Electric Aircraft

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In practical avionic system, an incipient fault may propagate from one component to other components under both discrete factor and continuous factor, which is named as fault hybrid propagation. To deduce reasonable fault propagation path in this paper, a structure including discrete propagation sub-model, continuous propagation sub-model, and interface sub-model, is utilized to build the fault hybrid propagation model. The discrete propagation sub-model is established according to the cross-link relationship between components, while the continuous propagation sub-model is deduced according to the operation data based on energy operator. And the interface sub-model is introduced to convert the influence caused by continuous factor to the discrete propagation model. Based on the fault hybrid propagation model, most likely fault propagation path can be inferred based on failure propagation intensity. The proposed method is verified in the power system in a more electric aircraft.

▷ SunA07-16

Early Warning of Intermittent Failure Based on Hybrid Algorithm

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Yang, Jing	Xi'an Univ. of Tech.
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In this paper, the early warning of intermittent failure in complex industrial system is studied. Firstly, a target label generation strategy is proposed to preprocess the data. Secondly, combining RF with sliding window, a RF intermittent fault early warning model based on sliding window was constructed. Then, the ANT colony algorithm was used to fuse ARMA with RF based on sliding window, and a intermittent fault warning model based on hybrid algorithm was constructed. Finally, an argon air separation system is taken as an example to simulate these models, and the effectiveness and feasibility of the proposed method are verified.

▷ SunA07-17

The Research of Aero-engine Digital Twin Model Based on Model-driven and Data-driven Fusion Method

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With the rapid development of multi-field physical modeling, sensor network, big data processing and analysis and other information technologies, digital twin technology is gradually applied in the field of complex equipment operation and maintenance. Aero-engine is a typical complex equipment. The accurate monitoring in operation and performance degradation assessment and prediction are the key problems in maintenance. According to the definition of digital, the paper puts forward the concept of aero-engine digital twin and constructs an aero-engine digital twin model based on precise physical models, historical data and sensors data. The aero-engine digital twin model can predict the physical properties and can be applied to accurate monitoring in operation and performance degradation assessment and prediction

▷ SunA07-18

Bearing Health Monitoring Based on the Improved BilSTM-CRF

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Bearing Remaining Useful Life (RUL) prediction has important meaning in the mechanical maintenance. However, the existing RUL algorithms cannot achieve stable prediction. Therefore, an improved bearing health monitoring algorithm based on Bidirectional Long Short-Term Memory (BiLSTM) integrating Conditional Random Field (BiLSTM-CRF) is proposed. The empirical mode decomposition (EMD) algorithm is used to decompose the bearing diagnostic signal into several intrinsic mode function (IMF) components. Moreover, the effective IMF component is selected to reconstruct the signal by combining the cross-correlation coefficient and kurtosis criterion. Through the reconstructed signal extracting the time-frequency features into a feature vector, the feature data with lower dimension can be got. Then, the feature with lower dimension as inputs and RUL status as the output are used to train the BiLSTM-CRF model, which can achieve more accurate predictions. Finally, the XJTU-SY bearing data is used to verify the effectiveness of the proposed algorithm. Experiments show that this proposed method can get the best performance comparing with the convolutional neural networks and the Long Short-Term Memory.

▷ SunA07-19

Servo DC Motor Fault Diagnosis Driven by Multi-source Heterogeneous Data

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According to the requirement of the on-line fault diagnosis of the servo DC motors used in TT&C antenna, which is applicated in aerospace exploration, noise reduction and power spectrum analysis with wavelet packet are studied in this paper. The ability of feature extraction and pattern recognition are the characteristics of wavelet packet noise reduction, which are applied to analyze the motor' s current signals in different branches, thus the characteristic parameters of the fault motors can be shown clearly. We proposed a servo DC motor fault diagnosis model based on informatization theory, which improves the reliability of fault diagnosis result, and the accuracy of data screening increases from 70.5% to 92%. The result shows that the fault diagnosis model can trigger alarm accurately, it is also effective and superior in fault location.

▷ SunA07-20

Research and Application of A Novel RPCA- SVME Based Multiple Faults Recognition

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In the modern industrial process, the likelihood of the occurrence of multiple faults is higher than that of a single fault. Comparing with single faults, the multi-faults problem has higher coupling and complexity, thus it is quite important to establish an effective multi-faults recognition model to ensure process safety. In this paper, a multi-fault recognition model based on reconstructed principal component analysis (RPCA) algorithm and support vector machine ensemble (SVME) classifier is proposed to satisfy the needs. First, obtain the principal component information from the original high-dimensional data space. Second, to solve the loss of local feature information, reconstruct the local structural error of the feature space through the inverse mapping matrix, and then align the error to obtain the reconstructed coordinates. Third, based on the One vs. One (OvO) ensemble strategy, an SVME classifier is constructed for multiple faults recognition. Finally, to verify the performance of the proposed RPCA-SVME model, the simulation experiments are made on a Circle dataset and the Tennessee Eastman process (TEP). The comparison results show that the proposed method can guarantee higher diagnostic accuracy and macro_F1 score.

▷ SunA07-21

Monitoring of Wastewater Treatment Process Based on Slow Feature Analysis Variational Autoencoder

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The wastewater treatment process（WWTP） is a complex nonlinear, uncertain and dynamic physical and biochemical reaction process. The non-linearity, uncertainty and dynamicity of the WWTP increase the difficulty of extracting data features, and also make it difficult to monitor the faults in this process. Aiming at the problems of non-linearity, uncertainty and dynamicity, a slow feature analysis variational autoencoder (SFAVAE) process monitoring model is proposed. With the dynamicity of WWTP data taken into account, the slow feature analysis algorithm (SFA) is used to extract the slowly changing dynamic features of wastewater data. The variational auto-encoder (VAE) can impose Gaussian distribution restrictions on its hidden layer features, so that it can simultaneously learn nonlinear and certain features that obey the Gaussian distribution to deal with the nonlinearity and uncertainty of data. Finally, the hidden layer space of the VAE model is used to construct hidden layer feature statistics Z^2 to realize process monitoring. Compared with the principal component analysis (PCA), independent component analysis (ICA), kernel principal analysis (KPCA) and VAE models, the experimental results of the benchmark simulation model 1 (BSM1) model show that the SFAVAE model has higher effectiveness in process monitoring.

▷ SunA07-22

Transfer Learning Based Rolling Bearing Fault Diagnosis

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In recent years, transfer learning has been an important method to address the problem that labeled data are rarely in the real world. In many industry scenarios, collected labeled sample signals are usually not in the same data distribution. A major assumption for traditional learning and deep learning based bearing fault diagnosis methods is the training data and testing data must follow the same data distribution. However, this assumption may not hold in reality. To address the different distribution problem, this paper proposed an unsupervised approach for bearing fault diagnosis based on transfer learning. The correlation alignment (CORAL) algorithm is used to align data distribution of domains in the proposed approach, then the proposed approach applies statistical algorithms to extract shallow features and wavelet scattering network to extract deep features. The 1 nearest neighbors (1-NN) classifier is trained with the feature vector matrix of source domain, which is able to classify the unlabeled samples of target domain presenting the effectiveness of the proposed approach. Different experiments were carried out to demonstrate the performance of the proposed approach. The experiment results show that the proposed model is superior to other bearing fault diagnosis methods.

▷ SunA07-23

Defect-sensitive Testing Data Analysis Method for Industrial Robots Quality Inspection

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Industrial robots play important parts in modern industries to increase factory capacity and guarantee final product quality. The qualified industrial robot product is critical to promise the OEE (overall equipment efficiency) at customer site. Therefore, quality inspection is the indispensable part in robot manufacturing. To guarantee superior robot quality and excellent customer experience, the defect-sensitive testing method is proposed to detect robot defect issues, including defects of incoming materials and problems of robot assembly. Two main technologies applied here to improve defect sensitive are segmentation of running cycle and integration of physical model and data model. The results from the testing data analysis method could not only show the pass or not information of the detected robot, but also guide how to fix the problem if any defect issue is detected. This could sharply reduce dependence on expert knowledge and personal experience.

▷ SunA07-24

Quality-Relevant Process Monitoring Based on Improved Concurrent Canonical Correlation Analysis

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How to use existing technology to improve product quality while ensuring production stability and safety has become a hot topic in various fields. Being one of the most powerful multivariate analysis tools in process monitoring, canonical correlation analysis (CCA) is an exploratory statistical method that emphasizes the correlation between a set of poly dimensional data obtained at the same experimental level. For overcoming the drawbacks of CCA, a concurrent canonical correlation analysis (CCCA) modeling method was put forward, which decomposes the input and output variables into five segments. However, CCCA based quality-related process monitoring scheme would make ambiguous decisions due to the decomposition is incomplete. It is intended that this paper will explore an improved concurrent canonical correlation analysis (ICCCA) technique used for process monitoring. Specifically, a CCA model is established where the latent structure of process data is extracted. Subsequently, an algorithm of total principal component regression (TPCR) is implemented grounded on the established CCA model. Complete decomposition of the input and output variables into six parts was performed for quality-related process monitoring. Taking the Tennessee Eastman process (TEP) as an industry benchmark, the superiority of ICCCA is verified by comparing it with other monitoring methods.

▷ SunA07-25

Reactive Power Optimization for Power System with Distributed Generations Using PSO Hybrid SCA Algorithm

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As more and more distributed generations (DGs) are introduced into the power system, the original power flow distribution and voltage quality are changed. Particle swarm optimization (PSO) has been attested to be an effective way to solve reactive power optimization in electrical power system, but it is prone to fall into the local optimization solution and premature convergence. Aiming at these weaknesses, an improved PSO which

hybrid sine cosine algorithm (SCA) is proposed. SCA can attract and reject the particles because of the character of sine and cosine functions. This can guarantee the diversity of PSO, and the convergence speed and accuracy are improved effectively. The effectiveness of algorithm is verified by simulations on IEEE 14-bus system including a DG. The results show that the proposed algorithm can obtain a better optimization effect and faster convergence speed.

▷ SunA07-26

Research on Optimal Scheduling of Semiconductor Manufacturing System Based on Characteristic Petri Net Model

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The production process of semiconductor manufacturing system is very complex. To establish a reliable scheduling model of semiconductor manufacturing system is very important for testing the whole production line system, evaluating different scheduling schemes, and optimizing production resource scheduling. In this paper, a model of semiconductor manufacturing system based on characteristic Petri net is proposed. By simplifying the non main characteristic elements of Petri net model of semiconductor manufacturing system, the model can effectively overcome the danger of model scale expansion brought by basic Petri net in the case of complex system. Finally, the modeling of semiconductor manufacturing system and its calculation example are realized by the above modeling method.

▷ SunA07-27

Blockchain-based Energy Transaction Model for Multiple Energy Hubs

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Promoting the effective use of energy with energy hub(EH) is an important part of the construction of the Energy Internet.In this paper,an energy transaction model for the Multiple Energy Hub System(MEHS) based on blockchain technology is proposed,which is a distributed system composed of multiple energy hubs.Firstly, the concept of the EH and the current research and application of the energy hub technology are introduced.Then the definition, structure, classification, consensus mechanism, and the smart contract of blockchain technology are described.The feasibility of applying blockchain technology to the energy network is analyzed. Thirdly, the model structure and energy transaction framework based on blockchain technology are established.Meanwhile,a series of algorithms that give transaction priority are designed.Finally,the model of MEHS based on blockchain technology is given in detail,and compared with the traditional scheduling model to illustrate the superiority of using blockchain technology.

▷ SunA07-28

Identification of An ARMAX Model Based on A Momentum-accelerated Multi-error Stochastic Information Gradient Algorithm

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The ARMAX model is widely used in industrial modeling. However, the traditional stochastic information gradient algorithm for ARMAX identification needs less computation, but its convergence speed is too slow. In order to accelerate the algorithm, we propose a two-step algorithm based on gradient acceleration strategy. The first step is to replace the error scalar with the error vector, and the second step is to introduce a momentum related to the gradient. The simulation results show that the proposed algorithm can obtain more accurate estimation and the convergence speed is greatly improved.

▷ SunA07-29

Time Delayed Feedback Control for A Class of Hyper-chaotic Systems

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We study the dynamic behavior of a new type of hyper-chaotic system and use the method of time delay control to achieve the purpose of the control system. This paper analyzes the stability and existence of the equilibrium point and discusses the cross-sectional conditions under which the balance point has Hopf bifurcation.Then we give the time delay value of the periodic solution generated by the system equilibrium point. Numerical examples are given to verify the theoretical results.

▷ SunA07-30

Evaluation of Smart Energy System Based on Machine Learning

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In the context of the gradual shortage of fossil energy and serious pollution, the voice of energy transformation is increasing year by year. With the development of Internet and artificial intelligence, the smart energy is getting more and more attention, and it is also the key direction of the upgrading of the world energy industry. In this process, in order to better understand its development and effectively guide the future construction and development of smart energy, appropriate and reasonable evaluation is essential. In the past few years, some researchers have put forward some evaluation methods for smart energy systems, and have achieved some good results. However, only traditional evaluation methods are used which are more subjective. Therefore, the application of machine learning method in the evaluation of smart energy system is worth trying and studying. Starting from the requirements of energy system and human development, this paper first introduces the emergence and development of smart energy and its evaluation methods. Simultaneously indicating the necessity of evaluation. Then the formation of the evaluation index system is briefly introduced. Secondly, machine learning algorithm models such as support vector machines, decision trees, and BP neural networks used are introduced respectively. Finally, experiments are carried out to train the model, and then comparing and analyzing the results. The final results show that the machine learning method plays a good role in the research of smart energy system evaluation, which is worthy of further research.

▷ SunA07-31

3D Shape Descriptor by Principal Component Analysis Embedding for Non-rigid 3D Shape Retrieval in A Learning Framework

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In this paper, we propose a 3D shape descriptor which can be used for applications such as non-rigid 3D shape analysis and retrieval. We start with the calculation of the Wave Kernel Signature (WKS) and the scale-invariant Heat Kernel Signature (siHKS) of surface points belong to a 3D shape. Then we combine them together and obtain their principle components by PCA (principle component analysis), which are employed as our own point signatures. We take a weighted average of all the point signatures over a 3D surface to obtain our own shape descriptor. Different from other approaches, we employ shape curvature as the element of weight in the construction of the shape descriptor. Moreover, our shape descriptor is also trained in a machine learning framework and applied to a non-rigid 3D shape retrieval task. The experimental results turn out that our 3D shape descriptor is feasible and efficient for tasks such as non-rigid 3D shape analysis, non-rigid 3D shape matching and 3D shape retrieval, etc..

▷ SunA07-32

Pattern Recognition of Traction Energy Consumption for Urban Rail Transit by Using Symbolic Aggregate Approximation

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In the urban rail transit system, the traction energy consumption accounts for 40%-60% of the total energy consumption. There is a large amount of traction energy consumption data in time series format recorded by energy meters. Accurate analysis of traction energy consumption based on time series is in urgent demand for energy saving. In order to analyze the law of traction energy consumption, this paper proposes a pattern recognition method for traction energy consumption based on SAX (Symbolic Aggregate approXimation). The original time series of traction energy consumption is transformed by SAX and the sub-patterns are obtained. The traction energy consumption patterns are recognized by using K-means algorithm. To show the effectiveness and efficiency, we apply the proposed method to a data set from Beijing Subway, and find 3 representative patterns. We find that the recognized patterns of traction energy consumption appears coherence with the major services prescribed in the rolling stock scheduling plan. By calculating the similarity and comparing with these representative patterns, the days that differ from the typical patterns are judged as anomalies.

▷ SunA07-33

An Adaptive Clustering Algorithm Based on Boundary Detection

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To solve the problem that the partition clustering algorithm usually needs to specify the number of clusters artificially and the poor clustering effect on nonconvex datasets, this paper proposes an adaptive clustering algorithm based on boundary detection (BAC). BAC algorithm searches the boundary points of each cluster according to the global distribution characteristics of all samples in the sample space, then connects the boundary points to form the boundary shape closure of the cluster, and finally propagates the cluster labels of the boundary points to the non boundary points according to the nearest neighbor principle. BAC algorithm finds the number of clusters adaptively by searching the number of boundary shapes in the sample space, and it is not sensitive to the shape of clusters, so it can detect clusters with complex shapes. Experimental evaluation is carried out on a large number of datasets, and compared with K-means, K-means++ and DPC algorithms. The results show that the clustering performance of BAC algorithm is better than other algorithms.

▷ SunA07-34

Optimal Tracking Control for Uncertain Singularly Perturbed Systems

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In this paper, the problem of tracking control for uncertain singularly perturbed systems is studied. Firstly, the uncertain singularly perturbed system and the uncertain external system are combined to form an augmented system, and the optimal tracking problem is transformed into a new standard linear quadratic optimization problem. Then, based on the minimum principle, the minimum value of quadratic performance index and the tracking optimal controller of the system are obtained. For the controller with a feasible approximate solution of the generalized Riccati equation, the design method of the controller can be obtained in the form of linear matrix inequality (LMI). Finally, a numerical example is given to demonstrate the viability and rightness of the proposed conclusion.

▷ SunA07-35

Cluster-based Generative Adversarial Network Imbalanced Data Generation Method

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Data imbalance is widespread in data mining. However, the imbalance of data makes the minority recognition rate low but the cost of misclassification is high. In order to improve the minority recognition rate, this paper proposed a data generation method for balance imbalanced data set. First, the minority data is clustered and divided into sub-categories, next it built a GAN model to generate each sub-category data separately to improve the quality of data generation and balance the number of majority and minority categories, and also alleviate the imbalance within the minority category. Then, this paper built a costsensitive convolutional neural network model for classification.Finally, experiments on the UCI public data set show that we proposed method has a good classification performance.

▷ SunA07-36

Decision Making for Overtaking of Unmanned Vehicle Based on Deep Q-learning

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Overtaking decision under dynamic environment is one of the key research directions. Traditional methods are difficult to solve such a complex optimization decision-making problem. In recent years, reinforcement learning algorithm is developing continuously, which can be applied to solve the overtaking decision problem of unmanned vehicles. Reinforcement learning generates new data through the continuous interaction between agent and environment, and feeds back to the agent for corresponding learning behavior, so as to improve its own behavior strategy. In this paper, Deep Q-learning (DQN) is used to solve the overtaking decision-making problem on one-way through two lanes. A one-way through two lane traffic environment is built in Python to train and test the algorithm.

▷ SunA07-37

Model-based Ensemble Reinforcement Learning with Soft Proximal Policy Optimization

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At present, model-free reinforcement learning has been widely used in games, robot control and other fields, and has achieved good results. However, these algorithms require a large number of samples to achieve good performance, which limits the application of model-free reinforcement learning methods in real-world domains. Model-based reinforcement learning can use fewer samples, but requires careful tuning. In this article, we use a neural network ensemble model to learn the dynamics, and incorporate model predictive control as the basic control framework. The dynamic model is also used to train an initial model-free neural network to achieve a combination of sampling efficiency and performance. We evaluated our method on the MuJoCo experimental platform. The results show that, compared with other model-free and model-based methods, our approach achieves better task performance while having excellent sample efficiency.

▷ SunA07-38

Study on Initial Value Problem for Fractional-order Kalman Filters of Linear Continuous-time Fractional-order Systems

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To realize the state estimation of linear continuous-time fractional-order systems, the fractional-order Kalman filter (FOKF) is designed to solve problem on the initial value influence. By using the model transformation, an equivalent equation is obtained such that the state estimation of the transformed model is independent of the initial value. The dimension of the equivalent equation is the same as that of the original system, and the proposed FOKF algorithm based on equivalent equation can effectively reduce the initial value influence on the state estimation. Finally, the effectiveness of the solutions for initial value problem for FOKF is validated by the given simulation example.

▷ SunA07-39

Indoor Localization and Trajectory Tracking System Based on Millimeter-Wave Radar Sensor

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In this paper, we propose a novel indoor location scheme base on Frequency Modulated Continuous Wave (FMCW) radar to realize high precision positioning. Firstly, to achieve complete spatial motion information, the 3D-FFT algorithm is utilized to measure range, velocity, and angle of arrival (AOA) parameters. In particular, considering the non-linear problem in the conventional Kalman filter process, we proposed an extended Kalman filter (EKF) based tracking method to achieve high tracking accuracy. Finally, the extensive experiments demonstrate that the proposed system is able to achieve the minimum mean error of 0.6974 m, which is better than the existing schemes.

▷ SunA07-40

Real-time Modeling of Photovoltaic Strings under Partial Shading Conditions

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Partial shading is unavoidable in photovoltaic (PV) systems. However, there still lacks an abstract modeling and simulation for PV strings under partial shading conditions. This paper proposes a modified Tubo search algorithm to find the locations of turning points in current-voltage (I-V) curve. PV model parameters are then identified by a particle swarm optimization algorithm with the location and search history of turning points. The proposed model can effectively approximate the actual PV string. The feasibility and accuracy of the proposed method are verified through simulation and experimental results.

▷ SunA07-41

Unsupervised Feature Learning with Data Augmentation for Control

Valve Stiction Detection

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This paper proposes an unsupervised feature learning approach on industrial time series data for detection of valve stiction. Considering the commonly existed characteristics of industrial time series signals and the condition that sometimes massive reliable labeled-data are not available, a new time series data transformation and augmentation method is developed. The transformation stage converts the raw time series signals to 2-D matrices and the augmentation stage increases the diversity of the matrices by performing transformation on different timescales. Then a convolutional autoencoder is used to extract the representative features on the augmented data, these new features are taken as the inputs of the traditional clustering algorithms. Unlike the traditional approaches using hand-crafted features or requiring labeled-data, the proposed strategy can automatically learn features on the time series data collected from industrial control loops without supervision. The effectiveness of the proposed approach is evaluated through the International Stiction Data Base (ISDB). Compared with traditional machine learning methods and deep learning (DL) based methods, the experimental results demonstrate that the proposed strategy outperforms the other methods. Besides performance evaluation, we provide a visualization process of feature learning via principal component analysis.

▷ SunA07-42

Model Predictive Control Based on FSP-ADT Switching Sequence Constraint

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Qin, Ying — Shanghai Univ.

In this paper, we study the contractive set and model predictive control (MPC) problems for discrete-time switched linear systems, where the switching signals are under the constraint of fixed starting point average dwell time (FSP-ADT). The calculation method for terminal contractive set which is regarded as the terminal constrained set of the MPC problem is given. In addition, the algorithms and properties of all truncated FSP-ADT switching sequences in the predictive time domain are provided. From the perspective of the stability of the closed-loop switched system, what the terminal cost function should satisfy with regard to performance index are presented. Finally, the feasibility and the effectiveness of the proposed calculation method is proved by reliable numerical simulations.

▷ SunA07-43

Feature Context Aggregation Network with Edge Enhance for Endoscopic Gastrointestinal Bleeding Images Segmentation

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Accurate segmentation of gastrointestinal(GI) bleeding area is helpful to identify a variety of GI diseases such as ulcers, polyps, tumors, which is of great significance to assist doctors in precise diagnosis. However, the existing methods are affected by GI bubbles, which leads to the problems of hole and fuzzy edge in the segmentation results. To solve these two problems and improve segmentation accuracy, we propose a new deep learning method to extract the context information and the edge information of GI bleeding area by using Context Information Aggregation Module(CIAM), Feature Attention Module(FAM) and Edge Enhancement Module(EEM). The proposed method is evaluated on a public dataset and achieve 86.069% in mean intersection over union(IoU), which shows better performance than the most advanced GI bleeding segmentation methods.

▷ SunA07-44

Soft Measurement of Effluent Ammonia Nitrogen Based on DAK-FNN

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Aiming at the problem of real-time and accurate measurement of effluent ammonia nitrogen in wastewater treatment process, a data and knowledge-driven fuzzy neural network (DAK-FNN) method is proposed for the effluent ammonia nitrogen, which can effectively combine the existing knowledge of the source scene with the data of the current scene. First, the source scene has a large amount of historical data, and the reference model can be pre-trained through the dynamic structural adjustment and the parameter learning. Then, a model with a good performance can be established and the hidden knowledge in the historical data is obtained as a guide for the target model. In the current scene, the idea of transfer learning is adopted to transfer the knowledge of the reference model to the target model, and the parameters of the target model are fine-tuned through the online learning method to solve the problem of insufficient real-time data of effluent ammonia nitrogen. Finally, the effectiveness of the proposed method is verified using the numerical simulation and effluent ammonia nitrogen prediction experiment. Simulation results show that the proposed DAK-FNN method can obtain much higher online prediction accuracy and better real-time performance compared with other methods.

▷ SunA07-45

Multilayer Self-Organizing Impulse Neural Network for Handwritten Digit Recognition

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Zhang, Dingxue — Yangtze Univ.
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This paper proposes a multi-layer self-organizing impulse neural network. By adding an improved lateral inhibition mechanism and neuron model, the novel network can extract more information from the pictures, thus improving the expressive ability and elevating the recognition accuracy of the classification model. Besides, we replace the topology of the excitation layer and the inhibition layer with a recurrent connection structure. Several experiments have been carried out based on the proposed neural network and proved that the network can well complete the task of handwritten digit recognition. By tuning the network parameters, the recognition accuracy can reach 92.8%, which is at a high level in the same type of network. Besides, we also verified the robust performance of the network by randomly reducing the number of synapses and the number of neurons. It turns out that the network can still achieve high recognition accuracy after randomly discarding some neurons or synapses.

▷ SunA07-46

EFAG-CNN: Effectively Fused Attention Guided Convolutional

Jing, Cao — Zhejiang Univ. of Tech.
Jiafeng, Yao — Zhejiang Univ. of Tech.
Zhibo, Zhang — Zhejiang Univ. of Tech.
Shan, Cheng — Zhejiang Univ. of Tech.
Li, Sheng — Zhejiang Univ. of Tech.
Zhu, Jinhui — Second Affiliated Hospital of Medical College of Zhejiang Univ.
He, Xiongxiong — Zhejiang Univ. of Tech.
Qianru, Jiang — Zhejiang Univ. of Tech.

Wireless capsule endoscopy (WCE) has been widely used in the detection of digestive tract diseases because of its painlessness and convenience. Accurate classification of WCE abnormal images is very crucial for the diagnosis and treatment of early gastrointestinal tumors, while it remains challenging due to the ambiguous boundary between lesions and normal tissues. In order to overcome the above limitations, a three-branch effectively fused attention guided convolutional neural network (EFAGCNN) which imitates the practical diagnosis process is proposed. Specifically, global features and local images with suppressed background noise are generated by branch1 and local features are extracted by branch2 based on the local images. What s more, an effective attention feature fusion module (EAFF) is devised and inserted into branch3 to make the final prediction, which helps adaptively capture more discriminative features for classification. EAFF can integrate the representative features from branch1 and branch2 better than other methods. Furthermore, we propose a joint loss function to enhance the classification performance of branch2. Extensive experimental results demonstrate that the overall classification accuracy of the proposed method on the public Kvasir dataset reaches 96.50%, which is superior to the state-of-the-art deep learning methods.

▷ SunA07-47

Fault Classification of Industrial Processes Based on Generalized Zero-Shot Learning

Huang, Jiacheng — HuZhou Univ.
Li, Zuxin — Huzhou Univ.

Ye, Lingjian Huzhou Univ.
Zhou, Zhe Huzhou Univ.

In the process industry, the supervised learning methods cannot classify the unseen faults (i.e., those faults without training samples to participate in the establishment of the model). Although Zero-Shot Learning (ZSL) has been proposed and successfully solved the problem of unseen fault classification, it failed to classify the seen faults (i.e., those faults participate in the establishment of the model). To overcome their shortcomings, in this paper, a generalized Zero-Shot Learning (GZSL) method is proposed to classify all the faults including the seen and the unseen faults by only using the samples of the seen fault and the human-defined fault semantic attribute description information. We use a gating mechanism based on Conditional Variational Autoencoder (CVAE) and a binary classifier to distinguish the online sample into the classes of the seen and unseen faults. Thus, the GZSL problem can be transformed into a supervised fault classification problem and a ZSL fault classification problem. Firstly, we train a CVAE to generate pseudo unseen fault samples and seen fault samples. Secondly, a binary classifier is trained to classify the online samples into seen and unseen categories. Finally, the specific category of the online samples will be determined by the supervised method and ZSL method, respectively. We validate our approach on the Tennessee-Eastman benchmark process.

SunB01 10:10–12:10 Room D
Invited Session: Deep Learning for Industrial Big Data Analytics

Chair: Ge, Zhiqiang Zhejiang Univ.
Co-Chair: Yuan, Xiaofeng Central South Univ.

▶SunB01-1 10:10–10:30
Lognormal and Gamma Mixed Negative Binomial Model for Defects Prediction in Steel Products

He, Bocun Zhejiang Univ.
Wei, Chihang Zhejiang Univ.
Zhu, Zheren Zhejiang Univ.
Zhang, Xinmin Zhejiang Univ.
Song, Zhihuan Zhejiang Univ.

In steel industry, variations in the manufacturing process cause various defects in products. Thus, it is important to forecast the instance of defects in real time. However, ordinary probability models are not adequate enough to describe the observed defect count data due to the nonnegative integers characteristics, high imbalanced distribution, and overdispersion. To explicitly account for these distinctive characteristics, the present work proposes an online quality forecast system developed on the lognormal and Gamma mixed negative binomial (LGNB) model. LGNB incorporates the lognormal and Gamma distributions to account for the random effect and dispersion in the data. In addition, the drawbacks of the ordinary negative binomial (NB) model such as low robustness and biased parameter estimation against data with large dispersion are conquered by the LGNB model. The efficacy of the LGNB model was validated via its application to the defect data of an ironmaking plant. The results show that the LGNB model improves the forecast accuracy as compared to the PLS, Poisson, and NB models, respectively.

▶SunB01-2 10:30–10:50
Yarn-dyed Shirt Cut Pieces Defect Detection Using Attention Vector Quantized-Variational Autoencoder

Zhang, Hongwei Zhejiang Univ.
Liu, Shuting Xi'an Polytechnic Univ.
Ge, Zhiqiang Zhejiang Univ.
Li, Pengfei Xi'an Polytechnic Univ.

For yarn-dyed shirt cut defects detection problems in production process, this paper proposes a yarn-dyed shirt cut de-fects detection method based on attention vector-quantized variational autoencoder reconstructed model and residual analysis. To solve the actual problem that the defect sample quantity scarce, defect categories imbalances, high cost and poor generalization ability of artificial design defect features. Firstly, for a certain yarn-dyed shirt cut, salt and pepper noise is artificially added to the defect-free samples to construct a training data set, and then a reconstruction model based on the attention vector quantized variational autoencoder is established and trained. Secondly, a residual map between the original image and the correspondingly reconstructed image is calculated. Finally, the defective area could be detected and located by thresholding and opening operation processing. Experimental results on several yarn-dyed shirt cut pieces data sets show that the proposed method can effectively reconstruct the yarn-dyed shirt cut pieces, de-tect and locate the defect area of yarn-dyed shirt cut pieces quickly.

▶SunB01-3 10:50–11:10
Stacked Attention-based Autoencoder with Feature Fusion and Its Application for Quality Prediction

Yuan, Xiaofeng Central South Univ.
Feng, Lu Central South Univ.
Wang, Yalin Central South Univ.
Wang, Kai Central South Univ.

In recent years, deep learning like stacked autoencoder (SAE) has been widely used in soft sensor modeling for industrial process quality prediction. However, the original SAE based models cannot extract the quality-relevant features due to the unsupervised feature learning, which may even cause negative impact on the final prediction. To cope with this problem, a novel stacked attention-based autoencoder (SAAE) is proposed. By introducing quality information and attention mechanism to the pre-training process, the quality-relevant features can be obtained and simultaneously their importance can be distinguished. Furthermore, to fully utilize these features, feature fusion strategy is integrated with the SAAE method. Finally, a hydrocracking industrial process is used to validate the effectiveness of the proposed SAAE method.

▶SunB01-4 11:10–11:30
Data-Driven Predictive Model for Mixed Oil Length Prediction in Long-Distance Transportation Pipeline

Li, Xu Chinese Univ. of Petroleum (East China), Qingdao
Han, Wenxue China Univ. of Petroleum, Qingdao, China
Shao, Weiming China Univ. of Petrolieum
Chen, Lei China Univ. of Petroleum(East China)
Zhao, Dongya China Univ. of Petroleum

During the sequential transportation of refined oil pipelines, mixed oil in the intersection area of two different types of oil needs to be identified and cut. Therefore, prediction of the length of the mixed oil (LMO) is of significance for scheduling and optimization purposes. Presently, the models used for such tasks are all developed by first-principles (FP), which suffer from the limitations of strong assumptions and ignorance of important features. In this paper, we first explore the application of pure data-driven predictive models for predicting the LMO, which is able to deal with the drawback of the FP-based models. Then, the performance of the FP-aided data-driven models are further investigated. Two fundamental data-driven learning models, namely the partial least squares (PLS) and the deep neural network (DNN) are employed to construct the regression models. The performance of the PLS and DNN, as well as those of the FP-aided PLS and DNN are evaluated using real-life dataset from the database of long-distance pipelines.

▶SunB01-5 11:30–11:50
Fiber Optic Speckle Recovery Based on Lightweight Adversarial Network

Zhang, Yanzhu Shenyangligong Univ.
Zhang, Haishuai SHENYANG LIGONG Univ.
Zhang, Xiaomeng Shenyang Ligong Univ.
Pu, Jixiong Huaqiao Univ.
Wang, Xiaoyan Huaqiao Univ.

Abstract: When light with object information passes through a multi-core fiber, the speckle pattern is obtained. The reconstruction of the original image from the speckle pattern is crucial. In this paper, we propose a lightweight adversarial network for reconstruct image from the speckle pattern. Combining the characteristics of U-Net network and Mobile-Net, a lightweight Mobile–U-Net network is formed to reduce the number of network parameters by using depth separable convolution to realize fast reconstructing image. The adversarial network is also introduced to restrain the quality of the restored image and solve the quality problem of the restored image further. Thus, a high-quality reconstructing image can be achieved.

▶SunB01-6 11:50–12:10
Phase Space Reconstruction and Time Series Prediction of A Nonlinear Financial System

Li, Yue Nankai Univ.
Chen, Zengqiang Nankai Univ.
Shijian, Cang Tianjin Univ. of Sci. & Tech.

As a mechanism for trading financial assets and determining the price of financial assets, the financial market plays an important guiding role in the development of the social economy. To explore the essential characteristics of the financial market and analyze its potential development laws, this paper takes a classical financial system as an example to reconstruct the chaotic attractor of the system based on a one-dimensional

series. We adopt the C-C method to calculate the optimal delay time and embedding dimension that are two important indicators used to reconstruct the chaotic attractor. Furthermore, the BP neural network is used to predict the financial market trend. We discuss the predicted outputs for the BP neural network with different numbers of neurons or hidden layers. Numerical results show that the proposed BP neural network is effective to predict market trends based on the existing data.

SunB02 10:10–12:10 Room E

Invited Session: Control and Filtering of Markov Jump Systems

Chair: Wu, Zhengguang Inst. of Advanced Process Control
Co-Chair: Che, Weiwei Shenyang Univ.

▶ SunB02-1 10:10–10:30

Event-triggered Secure Group Consensus of Second-order Multi-agent Systems under Periodic DoS Attacks

Liu, Peiming Univ. of Sci. & Tech. Beijing
Huang, Zhizong Lanzhou Fumei Electronic Tech. Co., Ltd, Lanzhou
Guo, Xianggui Univ. of Sci. & Tech. Beijing

In this paper, an event-triggered group consensus pinning control strategy is proposed for the second-order nonlinear multi-agent systems (MASs) with directed communication graph under periodic denial-of-service (DoS) attacks, which does not require the MASs to satisfy the in-degree balance condition. On this basis, the state error systems under periodic DoS attacks are established. In addition, it should be pointed out that the control strategy includes the selection method of pinning nodes under the group consensus framework. Furthermore, the sampled-data-based event-triggered mechanism (ETM) reduces the excessive consumption of system resources. Finally, simulation examples are given to verify the effectiveness of the control strategy under periodic DoS attacks with different duration.

▶ SunB02-2 10:30–10:50

Memory-Based PI-Type Sampled-Data Consensus Control for Nonlinear Multiagent Systems with Time-Varying Delays

Yang, Jin Univ. of Electronic Sci. & Tech. of China
Zhong, Qishui Univ. of Electronic Sci. & Tech. of China
Shi, Kaibo Univ. of Electronic Sci. & Tech. of China
Zhong, Shouming Univ. of Electronic Sci. & Tech. of China
Han, Sheng Univ. of Electronic Sci. & Tech. of China

In this paper, the sampled-data consensus problem of nonlinear multiagent systems (MASs) with time-varying delays is investigated. Compared with the widely used sampled-data controller, a proportional integral type (PI-type) protocol utilizing the information of neighbors considering the effects of memory delay is adopted. Then, by adequately considering characteristic about the time-varying delays, an improved time-varying quadratic type of Lyapunov-Krasovskii functional (LKF) is developed. Besides, augmented state vectors and two-sided looped-functional approach are adopting to constructed the LKF, some relaxed matrices in the LKF are not necessarily positive definite. Furthermore, some sufficient criteria are derived to ensure the consistency of the MASs. By solving a series of linear matrix inequalities, the desired memory PI-type sampled-data control gain matrices are obtained. Finally, the numerical examples are presented to illustrate the theoretical results.

▶ SunB02-3 10:50–11:10

Iterative Learning Control for Nonlinear Systems with Iteration-Varying Trial Lengths Using Modified Reference Trajectories

Wu, Xingzheng Nanjing Tech Univ.
Wang, Xianming Nanjing Tech Univ.
Qin, Wen Nanjing Univ. of Tech.
Liwei, Li Northeastern Univ.
Sun, Zhenxing Southeast Univ.
Shen, Mouquan Nanjing Tech Univ.

In this work, a nonlinear uncertain system' s iterative learning control (ILC) with randomly varying iteration lengths is discussed. Based on existing adaptive iterative learning control schemes , by using a modified reference trajectory, instead of assuming the identical initial condition, the alignment condition which is widely used in ILC problems can be satisfied when the iteration lengths is not fixed. An illustrative example is presented in the end to demonstrate the convergence of tracking error.

▶ SunB02-4 11:10–11:30

Consensus of Nonlinear Multiagent Systems with Transmission Delays and Deception Attacks via Sampled-Data Control

Han, Sheng Univ. of Electronic Sci. & Tech. of China
Zhong, Qishui Univ. of Electronic Sci. & Tech. of China
Shi, Kaibo Univ. of Electronic Sci. & Tech. of China
Yang, Jin Univ. of Electronic Sci. & Tech. of China

The consensus issue for the nonlinear multiagent systems (MASs) with transimission delays subjected to deception attacks is addressed based on sampled-data control. Due to the universality of cyber attacks, this paper considers a kind of deception attacks which occur randomly at sampling instant and can modify the communication information. By employing the two-sided looped-functional method, an augmented Lyapunov-Krasovskii functional (LKF) is constructed to fully utilize the information on the sampling interval, which makes some free matrices be not necessarily positive definite. Then, the sufficient criteria are presented to ensure the consensus of MASs with deception attacks. Furthermore, the controller gain matrix and the maximal sampling interval are obtained based on the decoupled approach. Finally, the numerical example is exploited to verify the effectiveness of our results.

▶ SunB02-5 11:30–11:50

Global Event-triggered Attitude Consensus of Multiple Rigid Body Systems with Additive Quaternion Errors

Zhang, Fan Beihang Univ.
Meng, Deyuan Beihang Univ. (BUAA)
Wu, Yuxin Beihang Univ.

In this extended abstract, we introduce an event-triggered mechanism-based attitude protocol for the global consensus of multiple rigid body systems. As a result of the presentation of the quaternion, the initial attitude condition can be relaxed to the global scope. Meantime, the nonunique mapping problem of the quaternion presentation can be dealt with well. Through the rigorous analysis, it is proved that the proposed protocol with the event-triggered mechanism can effectively drive the rigid bodies to the identical attitude.

▶ SunB02-6 11:50–12:10

An Intelligent Recommendation System for Performance Equipment Operation and Maintenance via Deep Neural Network and Attention Mechanism

Li, Huimin Zhejiang Univ. of Tech.
Chen, Yongyi Zhejiang Univ. of Tech.
Zhang, Dan Zhejiang Univetsity of Tech.
Wu, Lifeng Zhejiang Dafeng Industry Co. LTD

The theater has a huge number and variety of performing arts equipment, so the artificial maintenance will take a great time and energy. How to reduce the cost of manual maintenance is particularly important. This paper proposes an intelligent recommendation system for performance equipment operation and maintenance based on deep learning network and attention mechanism. First, according to the research main goal, the performance equipment is used to construct dataset and a preprocess scheme is adopted for the raw data, then we use the deep neural network to train the feature data, and integrate the attention mechanism into the recommendation system. Attention mechanism can increase attention to important information. Finally, through the cosine similarity between the calculated features, the recommended results are generated. An illustrative example is given to show the effectiveness of main results.

SunB03 10:10–12:10 Room F

Regular Session: Data Driven Control

Chair: Zhang, Guoshan Tianjin Univ.
Co-Chair: Li, Xiangyang South China Uni. of Tech

▶ SunB03-1 10:10–10:30

Adaptive and Robust Tracking for Radar Maneuvering Targets

Shi, Jiantao Tsinghua Univ.

The robustness and stability of maneuvering target tracking algorithms based on Kalman filtering are not satisfactory. The state estimation results are relatively ineffective when there exists model uncertainties or turning maneuvers during the target moving. In extreme cases, this may lead to filter divergence. According to this issue, a novel adaptive robust tracking algorithm for radar targets has been proposed in this paper. By using strong tracking filtering strategy, an adaptive fading factor is introduced to adjust the matrix gain in real time for dealing with the model uncertainties and ensuring the tracking effect. The simulation results show that this algorithm has better stability and tracking effect for maneuvering targets.

▶ SunB03-2 10:30–10:50

A Discrete-time Integral Sliding Mode Control Method Based on Iterative Dynamic Linearization Data Model

Hou, Mingdong Shandong Jiaotong Univ.

Tian, Jie — Shandong Women Univ.

A data-driven integral sliding mode control scheme is proposed for a class discrete-time repetitive nonlinear system in this article. First, an iterative dynamic linearization data model is established in the iterative domain based on iterative dynamic linearization technology, which is only related to the online data of the system. Then, considering the time and iterative domain at the same time, an iterative integral sliding mode surface is designed, and an iterative integral sliding mode controller is proposed. Moreover, the stability of the proposed scheme is proved by theoretical analysis. Finally, the effectiveness of the proposed scheme is verified by simulation research. Comparative results with optimal iterative learning controller demonstrate that the proposed controller can provide the minimize the control effort and less tracking error.

▶ SunB03-3 10:50–11:10

Data Driven Tracking Control for A Class of Unknown Nonlinear Time-Varying System Using Improved PID Neural Network and Cohen-Coon Approach

Hao, Jun — Tianjin Univ.
Zhang, Guoshan — Tianjin Univ.

In this paper, data driven tracking control based on improved proportional-integral-derivative (PID) neural network and Cohen-Coon approach (IPIDNN-CC) is proposed for a class of completely unknown nonlinear time-varying system (NTVS). This hybrid algorithm only uses the input/output (I/O) data of NTVS online and initial control parameters of IPIDNN-CC can be properly determined only via system open loop response. Thus, IPIDNN-CC algorithm can ensure that initial control parameters can be converged based on gradient descent algorithm. Compared with traditional PIDNN, adaptive scaling factor is employed in the proposed improved PIDNN and the problem of PIDNN weights initialization is solved. Moreover, the stability of closed loop system based on IPIDNN-CC algorithm is proven based on Lyapunov stability theory. The simulations are carried out to demonstrate the correctness and superiority of the proposed algorithm.

▶ SunB03-4 11:10–11:30

A Discrete Operational Point Control-based Adaptive Dynamic Coordination Control Strategy for HEV

Qi, Fei — Beijing Inst. of Tech.
Ma, Yue — Beijing Inst. of Tech.
Liu, Jiaxin — Beijing Inst. of Tech.
Li, Zhilin — Beijing Inst. of Tech.
Hu, Qiang — Beijing Inst. of Tech.

Abstract This paper proposes a limited discrete operation points control strategy for series hybrid electric tracked-vehicle. First, to optimize the control parameters of rule-based energy management strategy, particle swarm optimization algorithm is employed. the optimization results were applied to determine the optimal switch strategy between operation points of the engine. Second，a dynamic adaptive strategy is also proposed to achieve the coordinated control of the engine generator set. Finally, with combination of above parts, a detailed energy management strategy and coordinated control system was proposed. The results demonstrate that the discrete operation points control strategy combined with coordinated control strategy can improve the electricity power supply performance, decrease the fluctuations of the system and stabilize the bus voltage and guarantee robust control performance.

▶ SunB03-5 11:30–11:50

Accurate Trajectory Tracking Control of Unknown Autonomous Underwater Vehicles: A Data-driven Predictive Approach

Nan, Dong — Dalian Maritime Univ.
Weng, Yongpeng — Dalian Maritime Univ.
Liu, Yi — Dalian Maritime Univ.
Wang, Xin — Heilongjiang Univ.

The adaptive tracking control of autonomous underwater vehicles (AUVs) under the conditions of unavailable kinetic dynamics is considered via developing a new data-driven adaptive predictive control (DAPC) method. By deploying the non-parametric DLT, a new data-based predictive model is first designed such that the unknown kinetic dynamics and nonlinearities in AUV system are efficiently handled. Then, a data-based predictive control law is further devised, and thereby the dynamics of the entire closed-loop AUV system can be appropriately regulated. Finally, numerical simulations pertaining to an underwater vehicle is given to validate the efficiency of the devised method.

▶ SunB03-6 11:50–12:10

Active Disturbance Rejection Based Iterative Learning Control for Direct Torque Control of Switched Reluctance Motor Drive

Ai, Wei — South China Univ. of Tech.
Wu, Mingchao — South China Univ. of Tech.
Li, Xinling — South China Univ. of Tech.
Li, Xiangyang — South China Uni. of Tech

Aiming at the problem of large torque ripple in switched reluctance motor (SRM), this paper designs a novel direct torque controller using active disturbance rejection based iterative learning control (ADR-ILC). Direct torque control (DTC) scheme shuns the complicated torque-to-current conversion as required in indirect torque control scheme. Without complex real-time implementation or an accurate model of SRM magnetization characteristics, the ADR-ILC method is used to improve the performance of DTC in SRM. The torque sharing function (TSF) is used to distribute the given torque to each phase, where the DTC based on ADR-ILC calculates the required PWM duty cycle value for the converter of SRM. Simulation results show the effectiveness of DTC based on ADR-ILC to achieve constant torque control of SRM.

SunB04 10:10–12:10 Room G

Regular Session: Neural Networks, Fuzzy Systems Control in Data Driven Manner (II)

Chair: Liu, Shan — Zhejiang Univ.
Co-Chair: Li, Dazi — Beijing Univ. of Chemical Tech.

▶ SunB04-1 10:10–10:30

Mask-based Object Pose Estimation with Domain Transfer

Ying, Yongkang — Zhejiang Univ.
Liu, Shan — Zhejiang Univ.

Object pose estimation is important for robots to understand and interact with the real world. This problem is challenging because the various objects, clutter and occlusions between objects in the scene. Deep learning methods show better performances than traditional problems in this problem but training a convolutional neural network needs lots of annotated data which is expensive to obtain. This paper proposes a general method by using domain transfer technology to efficiently solve object pose estimation problem. Besides, the proposed method obtains mask to achieve high quality performance by combing an instance segmentation framework, Mask R-CNN. We present the results of our experiments with the LineMOD dataset. We also deploy our method to robotic grasp object based on the estimated pose.

▶ SunB04-2 10:30–10:50

Multi-fusion Network for Single Image Deraining

Guo, Huanlei — Zhejiang Univ. of Tech.
Wang, Jie — Zhejiang Univ. of Tech.
Zhou, Tingwei — Zhejiang Univ. of Tech.
Wenkang, Huang — Zhejiang Inst. of Economics & Trade
Yuan, Junqing — Zhejiang Univ. of Tech.
He, Xiongxiong — Zhejiang Univ. of Tech.

Single image deraining is regarded as an important research direction in image processing. To tackle the over-smoothing effect caused by the overlapping between rain streaks and the background, we propose a multi-fusion network for single image deraining. A novel local feature fusion block and a global feature fusion block are explored to fuse the high-level features with the low-level ones and correct the low-level representations. By stacking multiple fusion blocks, the proposed network can fully utilize the high-level information and extract powerful feature maps of rain streak layers. In addition, based on the prediction difficulty, a curriculum learning strategy is further explored to make the training process easier. Extensive experiments demonstrate that our network performs favorably against other deraining approaches.

▶ SunB04-3 10:50–11:10

Parameter Estimation of the Hammerstein Output Error Model Using Multi-signal Processing

Zhu, Xinjian — Jiangsu Univ. of Tech.
Li, Feng — Jiangsu Univ. of Tech.
Li, Chenghao — Chongqing Univ.
Jia, Li — Shanghai Univ.
Cao, Qingfeng — Yangzhou Univ.

In this paper, a parameter estimation method based on multi-signal processing is proposed for the Hammerstein output error model. The multi-signal processing are designed to completely separate the parameter estimation problem of nonlinear block and linear block for the Hammerstein output error model. Firstly, based on input and output data of binary signal, the parameters of the linear block are identified by the auxiliary model recursive least square method, the unmeasurable intermediate

variable information problem is effectively handled using auxiliary model technology. In addition, based on input and output data of random signal, model error probability density function technology is applied to estimate parameters of the nonlinear block, which can control the space state distribution of the model error, and make the model error distribution tend to normal distribution. The results show that the proposed parameter estimation method can effectively estimate the parameters of the Hammerstein output error model.

▶ SunB04-4 11:10–11:30

Feedback-based Graph Convolutional Networks

Wenkang, Huang — Zhejiang Inst. of Economics & Trade
Guo, Huanlei — Zhejiang Univ. of Tech.
Wang, Jie — Zhejiang Univ. of Tech.
Yuan, Junqing — Zhejiang Univ. of Tech.
He, Xiongxiong — Zhejiang Univ. of Tech.
Ding, Jiajun — Zhejiang Univ. of Tech.

Applying graph convolutional networks to efficient nodes classification is still a hot spot in the research area of artificial intelligence. In order to fully exploit the neuron information in the graph model, we propose a feedback-based graph neural network, where the graph network takes the information of the known labels and the output of the model as the targets to optimize the network. Then, a top-down manner is adopted to select neurons associated with the target and remove the ones with negative contribution weights through a gating mechanism. The experimental results on benchmark datasets show that our proposed networks remarkably outperform the comparison methods.

▶ SunB04-5 11:30–11:50

Grasping Detection Based on YOLOv3 Algorithm

Li, Zhiyuan — Zhejiang Univ.
Liu, Shan — Zhejiang Univ.

In order to achieve multi-object grasping detection, this paper draws on the YOLOv3 algorithm, which has good performance in the field of object detection, and designs a grasping detection model based on deep learning. This model can recognize and locate multi-object in real time, and can predict the grasping point and the grasping deflection angle at the same time, which can realize end-to-end object positioning and grasping detection. For the specific application scenario, the corresponding dataset is automatically produced through data enhancement, which greatly saves the cost and time of manual collection and labeling. In the actual scene, we identify and locate the object and estimate the grasping point and grasping deflection angle of the object at the same time. 99.5% of the targets can be detected on the self-made data set. This method can greatly improve the accuracy of grasping detection in a specific scene.

▶ SunB04-6 11:50–12:10

Maximum Entropy Inverse Reinforcement Learning Based on Behavior Cloning of Expert Examples

Li, Dazi — Beijing Univ. of Chemical Tech.
Du, Jianghai — Beijing Univ. of Chemical Tech.

This study proposes a preprocessing framework for expert examples based on behavior cloning (BC) to solve the problem that inverse reinforcement learning (IRL) is inaccurate due to the noises of expert examples. In order to remove the noises in the expert examples, we first use supervised learning to learn the approximate expert policy, and then use this approximate expert policy to clone new expert examples from the old expert examples, the idea of this preprocessing framework is BC, IRL can obtain higher quality expert examples after preprocessing. The IRL framework adopts the form of maximum entropy, and specific experiments demonstrate the effectiveness of the proposed approach, in the case of expert examples with noises, the reward functions that after BC preprocessing is better than that without preprocessing, especially with the increase of noise level, the effect is particularly obvious.

SunB05 10:10–12:10 Room H

Regular Session: Data-driven Fault Diagnosis and Health Maintenance (II)

Chair: Yang, Ying — Peking Univ.
Co-Chair: He, Yan-Lin — Beijing Univ. of Chemical Tech.

▶ SunB05-1 10:10–10:30

Improved Fault Detection Using Kantorovich Distance and Neighborhood Preserving Embedding Method

Wang, Yang — Huazhong Univ. of Sci. & Tech.
Yang, Weidong — Huazhong Univ. of Sci. & Tech.
Wang, Yanwei — Wuhan Inst. of Tech.
Fan, Huijin — Huazhong Univ. of Sci. & Tech.
Zheng, Ying — Huazhong Univ. of Sci. & Tech.

Traditional data-driven fault detection methods based on Euclidean distance usually lack the measurements of data distribution, thus they are not sensitive to small faults in the processes. Kantorovich distance measures the distance between two distributions, and can directly reflect the slight differences between two distributions. In this paper, Kantorovich distance is combined with neighborhood preserving embedding(NPE) algorithm to achieve the fault detection. Firstly, the training dataset is divided into two subsets. Two NPE models are established separately for the two subsets, and the residuals are obtained. Secondly, the threshold is calculated based on the Kantorovich distance matrix by employing a moving window on the two subsets. Thirdly, the monitoring index is determined for test data using Kantorovich distance. The effectiveness of the proposed fault detection method is verified by a numerical example.

▶ SunB05-2 10:30–10:50

Novel Mahalanobis Distance Based Fault Diagnosis Using Discrimination Neighborhood Preserving Embedding for Industrial Process

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

With the advancement of technology, the data collected by sensors have high-dimensional, non-linear characteristics. These data are difficult to be processed by traditional fault diagnosis methods. In this paper, an advanced fault diagnosis method based on discrimination neighborhood preserving embedding of Mahalanobis Distance (DNPE-M) was proposed. The proposed new method solves the problems of classification accuracy and data overlapping. Firstly, the high-dimensional and nonlinear data are dimensionally reduced by discrimination neighborhood preserving embedding based on the Mahalanobis Distance. Secondly, the fault data are classified using the integrated learning classifier AdaBoost. Finally, the Tennessee Eastman (TE) chemistry dataset is used to verify. The results of the experiments show that the proposed DNPE-M improves the performance of fault diagnosis accuracy.

▶ SunB05-3 10:50–11:10

A Novel Framework for Hierarchical Fault Detection under the Supervision of Key Performance Indicators

Liu, Ruijie — Peking Univ.
Yang, Ying — Peking Univ.

This paper proposes a novel key performance indicators (KPIs) supervised hierarchical fault detection framework for model-free linear dynamic systems. In the ground process layer, a bank of residual generators are constructed with the aid of the subspace identification method, based on which the faulty process variables are isolated and the corresponding fault distribution matrix is derived. In the upper KPIs supervised layer, the dynamic relationship between the high level KPIs and the low level process variables is identified and the fault detection is realized by checking the geometric property of the fault distribution matrix transmitted from the ground layer. A numerical example is provided in the end to demonstrate the effectiveness of the proposed fault detection framework.

▶ SunB05-4 11:10–11:30

Intelligent Fault Diagnosis of Chemical Process Based on Twin Convolution Deep Neural Network of Wavelet Transform

Yu, Ting — Inner Mongolia Univ. of Tech.
Qi, Yongsheng — Inner Mongolia Univ. of Tech.

Abstract: with the modern chemical process becoming more and more complex and comprehensive, the operating conditions and operating environment are becoming more and more changeable, which not only improves the production efficiency of enterprises, but also increases the probability of process failure. Many traditional diagnosis methods need a lot of labeled data to establish effective models, but it is difficult to collect enough labeled data in the actual industrial scene. In addition, in many traditional diagnosis methods, the frequency change of chemical process is hardly considered, which greatly affects the diagnosis performance. To solve the above problems, an intelligent fault diagnosis algorithm based on wavelet transform twin convolution neural network is proposed. Firstly, the fault data is transformed by wavelet transform to extract the dynamic changes of amplitude and frequency, and then transformed into dynamic time-frequency graph as the input of depth network;secondly, the pooling layer and convolution layer of convolution neural network with strong feature extraction ability are used to construct twin network to map the image data to low dimensional space, and the similarity is compared

based on Euclidean distance, and the results show that the algorithm is effective The classification of fault types and new fault self-learning are discussed. Finally, through the simulation of chiller data,it is verified that this method can not only identify the known faults, but also accurately identify the unknown faults in the case of incomplete data modeling, realize fault self-learning, and enhance the intelligence of the diagnosis process.

►SunB05-5 11:30–11:50

A Dynamic Fault Detection Method for Nonlinear Process

Sun, Chengyuan — Northeastern Univ.
Yin, Yizhen — Northeastern Univ.
Ma, Hongjun — Northeastern Univ.

The data-driven methods based multivariate regression have become popular in the area of fault detection due to the development of the computer technique. However, some traditional data-driven methods only consider the statical operating environment that the dynamic relationship in the variables will be ignored to bring some false detection results. In this study, an approach called the dynamic fault detection (DFD) is proposed to solve dynamic behavior under the nonlinear case. From the view of the best KPIs, the proposed method divides the variables into two orthogonal subspaces by the improved kernel principal component regression to judge whether the happened fault is relevant to the KPIs or not. Finally, in the numerical simulation, the effectiveness of the DFD approach is demonstrated by comparing it with three nonlinear methods.

►SunB05-6 11:50–12:10

Degradation-trend-dependent Remaining Useful Life Prediction for Bearing with BiLSTM and Attention Mechanism

Chen, Yanan — Wuhan Univ. of Sci. & Tech.
Liu, Zhenxing — WuHan Univ. of Sci. & Tech.
Zhang, Yong — Wuhan Univ. of Sci. & Tech.
Zheng, Xiujuan — Wuhan Univ. of Sci. & Tech.
Jin, Xie — Wuhan Huaxia Univ. of Tech.

Rolling bearing is an important basic component widely used in mechanical equipment, and its remaining useful life (RUL) prediction is one of the important technologies to realize the health management and predictive maintenance. It can be found in this paper that the degradation law of bearings can be divided into fast degradation and slow degradation after the degenerate point. Based on this important fact, the main exploration is listed into the following parts: Firstly, the root mean square (RMS) is selected as the monitoring indicator from the original signal, and it can be used to judge the degradation mode and determine the incipient degradation time (IDT) according to the 3 criterion; Secondly, relative transformation is chosen to transform the selected degenerate feature, and input the proposed bidirectional long short-term memory (BiLSTM) with attention mechanism, then the RUL is predicted accurately. Finally, experimental verification is carried out on the validation dataset in the PRONOSTIA, and the comparison with other approaches demonstrate that the proposed method achieves better performance.

SunB06 10:10–12:10 Room I

Invited Session: Learning-based Adaptive Control and Applications (II)

Chair: Chen, Qiang — Zhejiang Univ. of Tech.
Co-Chair: Wang, Shubo — Qingdao Univ.

►SunB06-1 10:10–10:30

Repetitive Control of Two-mass Systems Based on the Singular Perturbation Technique and Periodical Disturbance Observer

Zheng, Dongdong — Beijing Inst. of Tech.
Li, Weixing — Beijing Inst. of Tech.
Ren, Xuemei — Beijing Inst. of Tech.

In this paper, a repetitive learning control strategy for two mass systems is proposed based on the singular perturbation technique (SPT) and an periodical disturbance observer (PDOB). Firstly, the original higher order system is decomposed into two lower order subsystems using the SPT. Then PDOBs are designed for each subsystems, and sliding mode controllers are designed using the estimation results to achieve exponential convergence. Compared to other methods where the controller is designed based on the high order system model, the developed control method combines the SPT and PDOB together, thus the controller design problem is simplified and the control accuracy is improved because the periodic nature of the system is exploited. Furthermore, to reduce the oscillation at the beginning of each period when the PDOB is employed, a new repetitive learning law is developed, where an additional parameter is introduced to adjust the damping effect during the disturbance observation. The stability of the PDOB and the closed-loop system is analyzed via the Lyapunov approach and the effectiveness of the proposed PDOB and controller is verified by simulations.

►SunB06-2 10:30–10:50

Adaptive Tracking Control of Flexible Joint Manipulator with Output Constraints

Nan, Yurong — Zhejiang Univ. of Tech.
Zhao, Shichao — Zhejiang Univ. & Tech.
Ding, Kexin — Hangzhou Polytechnic
Chen, Qiang — Zhejiang Univ. of Tech.

This paper proposes an adaptive tracking control scheme for the uncertain model flexible joint manipulators with output constraints to achieve satisfactory performance. A time-varying arctangent barrier Lyapunov function (TABLF) is first designed to ensure the system output constraints are not violated. By combining backstepping, the negative feedback controller is designed to guarantee the errors remain within the allowable range of the constraints. The unknown dynamic observers are employed to approximate the uncertainties in the system, and a tracking differentiator (TD) is applied to obtain the differentiation of the virtual control laws in the back stepping design. Finally, the comparative simulations are given to illustrate the effectiveness of the proposed scheme.

►SunB06-3 10:50–11:10

Fault Diagnosis of Satellites under Variable Conditions Based on Domain Adaptive Adversarial Deep Neural Network

Gu, Yuxing — Nanjing Univ. of Aeronautics & Astronautics
Mao, Zehui — Nanjing Univ. of Aeronautics & Astronautics
Yan, Xing-Gang — Univ. of Kent
Liang, Hanyu — Sci. & Tech. on Space Intelligent Control Laboratory
Liu, Wenjing — Beijing Inst. of Control Engineering
Liu, Chengrui — Sci. & Tech. on Space Intelligent Control Laboratory

Fault diagnosis of satellite attitude control system is an important task to ensure the safe and reliable operation of on-orbit satellites. At present, most fault diagnosis methods are to diagnose independent identically distributed(i.i.d) task objects. However, even if the same device works under different working conditions, the distribution domain of the collected data almost always changes. At the same time, the training of fault diagnosis model under full working conditions can increase the model complexity and training time, and there may unknown working conditions. In view of the above situation, this paper proposed a domain adaptive adversarial deep neural network based fault diagnosis method. By combining the feature extractor, label classifier and domain classifier with the convolutional neural network and gradient inversion layer (GRL), the effective label classification can be achieved while the resolution of different domains can be reduced. We achieved feature extraction of the classification learning task in the source domain and transfer of the classification task between the two domains. The effectiveness of the diagnosis model is verified in the ground simulation data of a certain satellite under different conditions.

►SunB06-4 11:10–11:30

Adaptive Parameter Estimation for Nonlinear Systems with Relaxed PE Condition

He, Haoran — Kunming Univ. of Sci. & Tech.
Na, Jing — Kunming Univ. of Sci. & Tech.
Huang, Yingbo — Kunming Univ. of Sci. & Tech.

This paper presents a novel adaptive parameter identification method based on an augmented regression for linearly parameterized nonlinear systems, which relaxes the persistence excitation (PE) condition. By setting filter operations, an augmented system is constructed. Then, the augmented system is fused to decouple the estimated parameters. Furthermore, an adaptive estimator based on the parameter estimation error is designed to guarantee that the parameters exponentially converge to the true values. In this parameter estimation framework, not only the required PE condition can be relaxed but also the parameter estimation performance can be improved. Finally, comparative simulation results are provided to illustrate the effectiveness of the proposed method.

►SunB06-5 11:30–11:50

Unknown System Dynamics Estimator Based Control for Bilateral Teleoperation Systems

Baorui, Jing — Kunming Univ. of Sci. & Tech.
Hao, Duan — Kunming Univ. of Sci. & Tech.
Na, Jing — Kunming Univ. of Sci. & Tech.

Wang, Shubo Qingdao Univ.

In this paper, we propose a novel control scheme for bilateral teleoperation system subject to the unknown system dynamics. To realize this purpose, the low-pass filter operation is introduced to construct a simple yet robustness unknown system dynamics estimator (USDE). With the help of the proposed USDE, not only the effect of unknown system dynamics can be eliminated but also the acceleration signal can be avoided. Moreover, one salient feature of the proposed USDE is that it only has one tuning parameter, which is more straightforward compared with traditional estimators. The convergence of the estimation error and the stability of the closed-loop control system are rigorously proved via the Lyapunov theorem. Finally, simulation is carried out to demonstrate the superior performance concerning the movement synchronization and transparency.

▶ SunB06-6 11:50–12:10

Rudder Health Monitoring and Data Visualization Based on Feature Extraction

Zhou, Yajing Nankai Univ.
Sun, Mingwei Nankai Univ.
Hao, Mingrui Harbin Inst. of Tech.
Chen, Zengqiang Nankai Univ.

In order to monitor the health status of the rudder, this paper proposes a health monitoring method based on deep neural network through feature extraction. First, sufficient samples are obtained by data preprocessing. Then the feature dimension is reduced by using autoencoder, and the health monitoring can be carried out by combining with Softmax classifier. After proper tuning and comparison, proper network structure parameters can be obtained. Two kinds of images can be plotted by using the feature extraction of encoder to provide explicit contrast between the normal and abnormal rudders. The effectiveness of the proposed method can be demonstrated by numerical simulations.

Poster Session SunB07
May 16, 10:10–12:10
Corridor

Chair: Song, Bing East China Univ. of Sci. & Tech.
Co-Chair: Ji, Zhijian Qingdao Univ.

▷ SunB07-01

PredNet Based Sequence Image Disturbance Processing of Fused Magnesium Furnaces

Zhang, Yang Northeastern Univ.
Yang, Chao Northeastern Univ.
Liu, Qiang Northeastern Univiersity

Disturbance processing is necessary for image based deep learning of abnormal diagnosis for fused processes, e.g., fused magnesium furnace (FMF), since the disturbance of water mist, furnace body, and environmental will inevitably affect the visual image relevant to the identification of working conditions. To address this issue, this paper proposes a new predictive neural network (PredNet)-based unsupervised learning method for sequence image processing of fused magnesium furnace. This method consists of a residual extraction of original sequence image, a feature learning of disturbance via PredNets, and a single frame de-mean operation. Finally, the proposed method is compared to the one using original data and the one using residual extraction method using the collected sequence image from the furnace shell of a real FMF. The application results demonstrate the effectiveness of the proposed method.

▷ SunB07-02

Multi-TV Scheduling in MTVS by Using An Improved Genetic Algorithm

Li, Yiming Zhejiang Univ.
Zhu, Ke Zhejiang Univ.
Zhang, Zhiwen ZheJiang Univ.
Jiafeng, Ma ZJU
Zhang, Jianming Institution of Cyber-Sys. & Control

This paper addresses a multiple track vehicle (TV) scheduling problem with time window constraints (MTVSPTW) from medical supply transporting process in medical track vehicle system (MTVS). We establish a mathematical model to describe multi-TV scheduling in MTVS, which is close to the actual situation in real hospital. Based on this model, we propose a new hybrid algorithm for the MTVSPTW that executes genetic algorithm in combination with the large-scale neighborhood search algorithm (LNS–GA). Numerical experiments verify the effectiveness of the proposed method.

▷ SunB07-03

Modeling of Aggregation Process Based on Feature Selection Extreme Learning Machine of Atomic Search Algorithm

Wu, Chao Donghua Univ. (Songjiang Campus)
Ren, Lihong Donghua Univ.
Hao, Kuangrong Donghua Univ.

Polymerization process is a process in the production of polyester fiber, and its reaction parameter intrinsic viscosity has an important influence on the properties of the final polyester fiber. In this paper, a feature selection extreme learning machine model based on binary encoding atomic search algorithm is proposed and applied to the polymerization process of polyester fiber production. Firstly, the distance measure of KNN algorithm, combined with binary coding, and ASO algorithm are used to select features of industrial data to obtain the optimal data set. According to the data set,ASO algorithm is used to optimize the weight and threshold of extreme learning machine and the activation function of the improved extreme learning machine. A prediction model with root mean square ersror as fitness function was established and applied to polyester production process.The simulation results show that the model has good prediction accuracy, which can be used for reference in the follow-up industrial production.

▷ SunB07-04

Cooperative Formation for Multiple Mobile Robots Based on Data-driven Iterative Learning Control

You, Dongya Henan Polytechnic Univ.
Bu, Xuhui Henan Polytechnic Univ.
Hou, Rui Henan Polytechnic Univ.
Yan, Kanghua Henan Polytechnic Univ.
Geng, Jiahao Henan Polytechnic Univ.

This paper presents a double closed-loop iterative learning control (ILC) strategy for the formation problem of wheeled mobile robots (WMRs). A formation algorithm based on distributed iterative learning is designed by introducing the leader-follower formation mode and the directed graph into the outer loop algorithm. Considering that the traditional robot control algorithm relies on the precise vehicle dynamics model, a velocity tracking algorithm based on data is proposed. The dynamic linearization method is used to transform dynamics into the data model based on the system input and output. In the inner loop algorithm, a finite-time velocity tracking algorithm for iterative domain updates is analyzed and designed according to the data model. The theoretical analysis of the convergence for position error and velocity tracking error is given, and the effectiveness of the double-closed loop formation strategy is verified by simulation.

▷ SunB07-05

Controllability Analysis of Diffusion Coupled Multi-agent System under Signed Networks

Zhao, Lanhao Qingdao Univ.
Ji, Zhijian Qingdao Univ.

In this paper, the controllability of diffusion coupled multi-agent systems under signed networks is studied. Firstly, the upper bound of the controllable subspace of the system is given based on the generalized almost equitable partition and the restriction on the coefficient matrix of the system. Compared with the previous similar conclusions, the influence of the choice of coefficient matrix on the conclusion is discussed and a necessary condition for the controllability of the system is given: all the cells in the partition are trivial when the system is controllable. Secondly, an algorithm for computing the leader-isolated maximal generalized almost equitable partition is presented. In addition, it is proved that the controllability of the general linear diffusion coupled multi-agent system is equivalent to the controllability of the corresponding all positive network if leaders are selected from the same vertex set under the condition of structural balance, but independent of the selection of system coefficient matrix.

▷ SunB07-06

Attitude Tracking Control of 3-DOF Helicopter Based on Command Filter and Neural Network Techniques

Liu, Liang Bohai Univ.
Su, Yibo Bohai Univ.
Lu, Jiaming Bohai Univ.

This paper proposes the attitude tracking controller design scheme for the 3-DOF helicopter with unknown model uncertainties and external disturbances by combining command filter with neural network techniques. On the basis of backstepping design method, the unknown model uncertainties and external disturbances are firstly reconstructed by adopting

command filter. Then, neural network technique is used to approximate the reconstructed model uncertainties and external disturbances to realize the attitude tracking control of the 3-DOF helicopter. Finally, the stability of the closed-loop tracking control system of the 3-DOF helicopter is verified by Lyapunov stability theory. Simulation results verify the effectiveness of the proposed method.

▷ SunB07-07

SCA-SVM Fault Diagnosis of Analog Circuits Based on Transfer Learning

Yu, Danlu	Bohai Univ.
Zhang, Aihua	Bohai Univ.

The classification algorithm of SCA-SVM is applied to the fault diagnosis of analog circuits by transfer learning. In this thesis, a challenging research task of fault diagnosis is proposed, which considers modeling under the condition that a small number of target fault samples can be used for training. The classification algorithm of SVM is applied to fault diagnosis of analog circuits. A fault diagnosis method for analog circuits based on sine and cosine algorithm（SCA） is proposed in order to solve the problem of low fault diagnosis samples and low accuracy. SCA-SVM algorithm is used for fault diagnosis of analog circuits. Overall, compared with back-propagation algorithm (BP) genetic algorithm (GA) learning vector quantization algorithm (LVQ) and principal component analysis (PCA), SCA performance in few-shot learning (FSL) is better than other algorithms.

▷ SunB07-08

A Novel Electric Vehicle Braking Energy Recovery Method Based on Model Free Adaptive Control Algorithm with Input and Output Constraints

Liu, Shida	Beijing Jiaotong Univ.
Li, Zhen	North China Univ. of Tech.
Ji, Honghai	North China Univ. of Tech.
Hou, Zhongsheng	Beijing Jiaotong Univ.
Fan, Lingling	Beijing Information Sci. & Tech. Univ.

This study focus on the problem of pure electric vehicle’ s braking energy recovery with the uncertain dynamic external factors. For this problem, a novel model free adaptive control with input and output constraints (IOC-MFAC) method is introduced. The dynamic process can be considered as a nonlinear two inputs and two outputs system with hydraulic braking torque and motor braking torque as inputs and braking energy and braking deceleration as outputs. By using IOC-MFAC, the constraints of limitation of current and voltage on the maximum motor braking torque and the constraints of the vehicle’ s comfort on braking deceleration are considered. Consequently, the recovered energy is controlled in a stable range while guaranteeing the energy recovery to prolong the storage battery’ s operating life. The major advantages of IOC-MFAC are that not only the controller is designed only with input and output data of the regenerative brake control system, but also the constraints of the system inputs and outputs are considered. Further, the efficiency of IOC-MFAC is verified with a series of numerical simulations.

▷ SunB07-09

Design of Distributed Model Free Adaptive PID Controllers for Heterogenous Nonlinear Multi-agent Systems

Xiong, Shuangshuang	Beijing Information & Tech. Univ.
Hou, Zhongsheng	Beijing Jiaotong Univ.
Fan, Lingling	Beijing Information Sci. & Tech. Univ.

In this note, two kinds of distributed model free adaptive PID controllers are proposed to solve the consensus tracking problem for a class of unknown heterogenous nonaffine nonlinear discrete-time multi-agent systems based on the technique of dynamic linearization of controlled plant and ideal controller. Only the input/output data information of agent itself and its neighbours are used in the parameter estimation law of the designed adaptive PID controller. A simulation is given to illustrate the theoretical results.

▷ SunB07-10

Model Free Adaptive Predictive Tracking Control for Robot Manipulators with Uncertain Parameters

Wu, Huiying	Beijing Jiaotong Univ.
Jin, Shangtai	Beijing Jiaotong Univ.
Yin, Chenkun	Beijing Jiaotong Univ.
Zheng, Jianmin	Univ. of Jinan
Hou, Zhongsheng	Beijing Jiaotong Univ.

In this paper, a model-free adaptive predictive tracking control method is proposed for the robotic manipulators with uncertain parameters. The compact form dynamic linearization method is used to transform the nonlinear robotic manipulator into a dynamic linearized data model. Then, the model free adaptive predictive tracking control algorithm is designed based on the robot manipulator data model. As a data-driven control method, the proposed control algorithm does not need accurate system model information, merely uses the input and output data of the robot manipulator. Numerical simulations are carried out for PUMA560 robotic manipulator, and the effectiveness of the designed algorithm is verified by the simulation results.

▷ SunB07-11

Data Fusion Method and Its Application Analysis in Rocket Data Processing

Sun, Guang	China Acad. of Launch Vehicle Technolog
Wang, Xiaoding	China Acad. of Launch Vehicle Tech.

Viewing the development of aerospace at home and abroad, the intelligence, autonomy, and reusability of launch vehicle have become an important direction for the development of delivery technology. The health management technology of the launch vehicle is an important means to realize the above development direction, and data fusion plays an important role as a part of the health management technology. This paper analyzes the existing commonly used data fusion levels and fusion algorithms, fully considers the characteristics of rocket data, and proposes a data fusion strategy with three data fusion structures and five data fusion algorithms.

▷ SunB07-12

Model Predictive Control-based Stability Performance Recovery

Wang, Jia	College of Engineering, Peking Univ.
Yang, Ying	Peking Univ.

This paper studies the stability performance recovery for linear systems with input and output constraints. In particular, the model predictive controller is formulated based on the nominal model to cope with constraints. The multiplicative fault-induced performance degradation is detected by the stability margin. For the purpose to recover the stability performance, the model of the faulty plant is identified with the aid of the process data, then, the model predictive controller is reconfigured based on the identified model.

▷ SunB07-13

Quality-related Process Monitoring of Industrial Processes Based on Key Variable-Slow Feature Analysis

Xie, Jiamin	East China Univ. of Sci. & Tech.
Song, Yi Meng	Zhengzhou Univ.
Lv, Xiaolong	Shandong Wendeng Pumped Storage Co., Ltd
Shi, Hongbo	East China Univ. of Sci. & Tech.
Song, Bing	East China Univ. of Sci. & Tech.

In the industrial production, for the close-loop control, not all faults will affect product quality. To detect quality related fault effectively, a novel method named key variable-slow feature analysis (KV-SFA) is proposed in this work to extend the SFA algorithm to the domain of online quality-related fault detection. Firstly, key quality related process variables are selected via the combination of the least absolute shrinkage and selection operator (LASSO) method and the mechanism knowledge. Secondly, the SFA is conducted in the key variables space to extract slow features for establishing fault detection model. Then, the monitoring statistics are constructed and the control limits are estimated. Finally, the validity and effectiveness of the proposed KV-SFA method are proved through an industrial process.

▷ SunB07-14

Novel Discriminant Locality Preserving Projections Based on Improved Synthetic Minority Oversampling with Application to Fault Diagnosis

He, Yan-Lin	Beijing Univ. of Chemical Tech.
Liang, Lilong	Beijing Univ. of Chemical Tech.
Xu, Yuan	BEIJING Univ. OF CHEMICAL Tech.
Zhu, Qunxiong	Beijing Univ. of Chemical Tech.

Nowadays, chemical processes are becoming more complex, and so the safety requirement is getting higher and higher. Intelligent and effective fault detection and diagnosis are becoming more and more important. However, complex industrial systems generate high-dimensional data, which has bad influence on fault detection and diagnosis. Thus, it is necessary to handle industrial data with high dimensionality. Discriminant Locality Preserving Projections (DLPP) has attracted much interest as a dimensionality reduction method. However, there is a small size sample problem when the data dimension is higher than the number of data classes. Under this condition, DLPP cannot achieve acceptable performance in reducing data dimension. In order to solve this problem,

this paper proposes a novel DLPP based on improved Synthetic Minority Oversampling Technique (SMOTE-DLPP). The improved SMOTE is used to sample the original data set to generate new data sets so that the number of data classes is basically the same as the number of data dimension. Simulation results on the Tennessee Eastman process (TEP) show that the proposed SMOTE-DLPP can achieve acceptable performance in fault diagnosis.

▷ SunB07-15

State of Health Estimation of Lithium-ion Batteries Based on Indirect Health Indicators and Gaussian Process Regression Model

Ye, Yifu	Huzhou Univ.
Zhou, Zhe	Huzhou Univ.
Cai, Zhiduan	Huzhou Univ.
Zhang, Zongjie	Huzhou Univ.
Li, Zuxin	Huzhou Univ.

Achieving accurate and reliable battery state of health (SOH) estimation is significantly important to ensure the reliability and safety of the electrical system operation. The capacity and internal resistance are often used as direct health indicators (HIs) for degradation modeling and SOH estimation of lithium-ion batteries. However, it is difficult to directly measure the battery capacity in online applications due to the complex operating environment. In addition, the measurement of battery resistance is very expensive on-line. In this paper, a new method combining indirect HIs and Gaussian process regression (GPR) model is presented for battery health conditions prediction. First, considering the whole charge-discharge process of lithiumion battery and the influence of temperature, the appropriate and easy to measure indirect HIs are extracted from the curves of current, voltage and temperature. Then, the important indirect HIs are selected to describe comprehensively the aging of battery performance, and the correlation analysis methods are used to analyze the correlation between indirect HIs and SOH. Next, a GPR model is built based on the extracted indirect HIs for battery SOH estimation. Experimental results show that the proposed approach can provide accurate and effective online SOH estimation information of lithium-ion battery

▷ SunB07-16

Application of EEMD and Cloud Similarity Measurement in Gearbox Failure Feature Extraction

Xin, Chi	Chongqing Jiaotong Univ.
Zhao, Ling	Chongqing Jiaotong Univ.
Huang, Darong	Chongqing Jiao-tong Univ.
Jiaxing, Gong	Chongqing Jiaotong Univ.

The gearbox is widely used in mechanical equipment. Due to the complexity of their working environment, gears, bearings, etc. will have varying degrees of damage, fracture and other problems, and they will not work. In this paper, the algorithm combining EEMD and cloud similarity is used to filter the sensitive IMF components in the gearbox fault signal to help feature extraction achieve better results. First, the gearbox signal is decomposed by EEMD to obtain a series of intrinsic mode function (IMF) with frequencies ranging from high to low. Then use the proposed cloud model similarity measurement method to identify the false IMF components and delete them, and the sensitive IMF is obtained. The simulation results show that the modified method is feasible.

▷ SunB07-17

An ECT-PCA-based Fault Detection Method for Winding Asymmetry of Marine Current Turbine Generator

Xie, Tao	Shanghai Maritime Univ.
Wang, Tianzhen	Shanghai Maritime Univ.

The traditional detection methods of motor winding asymmetry often analyze the zero-sequence component. However, due to the different types of motors, the collection methods are also different. The marine current turbine (MCT) has a complicated sealing method due to the harsh marine environment, and its working conditions are frequently changed by the influence of the marine current flow rate, which makes it challenging to extract the fault characteristics. This paper proposes a novel method, called ECT-PCA, to detect MCT generator winding asymmetry, which includes: acquiring the stator three-phase current and using the extended Concordia transform (ECT) to obtain the modulus signal; dividing the modulus signal into an equal-length sample, and performing Fourier transform to obtain the frequency domain amplitude; Then establishing a PCA fault detection model, finally uses T2 and SPE statistics to detect whether the winding asymmetry or not. An experimental platform based on the MCT prototype was built to verify the effectiveness of the proposed method.

▷ SunB07-18

A New Integrated Health Management for Quadrotors Based on Deep Learning

Weiyi, Kong	Beijing Inst. of Tech.
Shaobo, Bian	Beijing Inst. of Tech.
Xiaoyan, Li	Beijing Inst. of Tech.
Wang, Chunyan	Beijing Inst. of Tech.
Wang, Jianan	Beijing Inst. of Tech.

In this paper, the health management problem for quadrotors based on deep learning technique is investigated. First, the fault diagnosis and health monitoring techniques based on machine learning are introduced before the research. Then, the dynamic model of the quadrotor is analyzed and the most important relationship between the IMU and motor outputs are given. Afterwards, the high-coupling and nonlinear link between units are mapped into an implicit network APN based on LSTM neural network. Predictions and train are made based on the data set collected from the practical and HITL flight log. Finally, the feasibility of the health management is verified through the fault simulation and the a possible solution is given against the common error.

▷ SunB07-19

A Gear Fault Diagnosis Method Based on EEMD Cloud Model and PSO_SVM

Yunui, Ou	Chongqing Jiaotong Univ.
Huang, Darong	Chongqing Jiao-tong Univ.
Chong, Hu	Chongqing Micro Identification Tech. Co.Ltd
Haiyang, Hao	Shaanxi Fast Gear Co.,Ltd
Jiaxing, Gong	Chongqing Jiaotong Univ.
Zhao, Ling	Chongqing Jiaotong Univ.

Aiming at the difficulty in identifying small fault of gear, a gear diagnosis method was proposed based on integrated empirical mode decomposition (EEMD), cloud model, support vector machine, and particle swarm optimization (PSO-SVM). Firstly, the vibration signal was decomposed into several IMF components by EEMD, and the backward cloud generator calculation was performed on the IMF components to obtain the digital characteristics of the cloud model. Then, the digital features obtained and the frequency domain features and time-domain features obtained after linear reconstruction were constructed as feature vectors, which were dimensionalized by principal component analysis. Finally, the features after dimensionality reduction are input into PSO-SVM for classification training and testing. The results show that this method can effectively complete gear fault diagnosis and has a higher recognition rate.

▷ SunB07-20

Fault Detection of Chemical Process Based on Functional Kernel Entropy Component Analysis

Chen, Ma	NanTong Univ.
Qiu, Aibing	Nantong Univ.
Shang, Liangliang	Nantong Univ.
Li, Peiqi	Nantong Univ.
Zhang, Hao	Nantong Univ. School of Zhangjian

In order to reduce the influence of data nonlinearity and noise on industrial process fault detection, a functional kernel entropy component analysis (FKECA) for industrial process fault detection is proposed. Firstly, using the function data analysis strategy, by introducing the rough penalty term in the curve fitting process, the industrial process data is transformed into functional data, which can effectively eliminate the abnormal value and noise interference, and make up for the missing data. Secondly, the functional data is mapped to the high-dimensional linear feature space through the radial basis function. Thirdly, the entropy cumulative contribution in descending order is proposed to determine the number of principal components, and the monitoring statistics and control limit are calculated. Finally, the fault detection method of nonlinear process in noise environment is verified. The proposed method is applied to Tennessee Eastman process. The results show that compared with principal component analysis (PCA) and functional principal component analysis (FPCA), the proposed method not only can effectively filter out noise and outliers, but also can improve fault detection rate in a certain extend.

▷ SunB07-21

Adaptive Iterative Learning Control for Leader-following Multi-agent Systems with Unknown Control Directions under Directed Graph

Qin, Simeng	Xidian Univ.

Li, Jinsha Xidian Univ.

In this paper, a leader following consensus problem for a first-order multi-agent system without priori knowledge of the control direction is studied by using adaptive iterative learning control. For the uncertainty of control direction, the Nussbaum-type gain function is proposed. The adaptive iterative learning control protocols are designed to achieve leader-following consensus under directed graph. The protocols ensure that all following agents can follow the leader agent perfectly within a finite interval as the number of iterations increases. Finally, an example proves the validity of the results.

▷ SunB07-22

Iterative Learning Reliable Control for A Kind of Discrete-time Nonlinear Systems with Stochastic Transmission Attenuation and Offset Fault in Actuator

Yang, Xuan Xi'an Polytechnic Univ.
Ruan, Xiaoe Xi'an Jiaotong Univ.
Yan, Geng Xi'an Polytechnic Univ.

This paper focuses on the reliability of the iterative learning control strategy for a kind of repetitive discrete-time models subject to transmission attenuation and offset fault produced in actuator. The attenuation is a random multiplier with respect to both time and iteration index and the fault is an additive stochastic disturbance. So, the real control input is modelled by multiplying a stochastic variable with the original control signal and adding a random bounded-disturbance function. By resorting to the time-weighted norm technique, the tracking performance is analyzed in the statistical sense and the sufficiency of convergence is established. To illustrate the effectiveness and reliability of the proposed results, numerical experiments are carried out.

▷ SunB07-23

Adaptive Iterative Learning Control for Hybrid Parameterized System with Input Saturation and Time-Delay

Wang, Yanjie Qingdao Univ. of Sci. & Tech.
Zhang, Ruikun Qingdao Univ. of Sci. & Tech.

In this manuscript, an adaptive iterative learning control method is proposed for a class of nonlinear hybrid parameterized systems with input saturation and state delay. The hybrid parameterized system contains the time-varying and time-invariant parameters simultaneously. According to the properties of input saturation and state delay in the single-input and single-output nonlinear hybrid parameterized systems, an adaptive iterative learning controller is designed to deal with the nonlinear problems caused by input saturation and state delay. Meanwhile, a Lyapunov-Krasovskii type composite energy function is constructed to prove the convergence of state tracking error. Finally, the correctness and effectiveness of the control method is verified by a numerical simulation.

▷ SunB07-24

Prediction of Social Ownership of Typical Household Appliances Based on Improved Grey Models

Sun, Xiaoan Jiangnan Univ.,China
Luan, Xiaoli Jiangnan Univ., China
Liu, Fei Jiangnan Univ., China

With the advent of complicated system of electronic and electrical household appliances, the prediction of the social ownership based on a single time series does not conform to its nonlinear growth law. In the present study, the main factors affecting the social ownership of household electronics and electrical appliances are initially investigated based on the grey relational model. Then the main influencing factors are considered to construct a multiple grey prediction model. Moreover, the model is optimized by various intelligent algorithms to improve prediction accuracy. Finally, the model accuracy is evaluated through the social ownership data of four typical household appliances in Jiangsu province. The optimized model is applied to predict the social ownership of household appliances in Jiangsu province in the period 2020 to 2022. The results of this article may provide a basis for promoting the resource utilization of e-wastes and assisting managers to improve electronic waste recycling.

▷ SunB07-25

An Improved Virtual Sample Generation Method Based on Quadrat Density Method and Quantile Regression for Small Sample Size Problem

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

The gradual realization of automation has caused explosive growth of data and increased the amount of researchable data. However, due to the low probability of occurrence and high difficulty in obtaining, representative data is lacking. One of the effective ways to solve this problem is virtual sample generation (VSG). In this study, a novel VSG method is put forward. The sample squares are divided in the input space according to Dominance Analysis, and the virtual inputs are generated by using the Quadrat Density Method in reverse. The corresponding virtual output is predicted by Gaussian Process Regression. Through Quantile Regression, analyze the correlation between input variables and output variables. The generated virtual samples are screened, and the virtual samples that do not meet the correlation relationship are eliminated. In order to verify the effectiveness of the proposed method, experiments are carried out on two numerical simulations and a real-world application from a cascade reaction process for high-density polyethylene. The results show that the method proposed in this paper is superior to other methods.

▷ SunB07-26

An Optimal Path-planning Algorithm for Unmanned Rollers with Constraints on Roller Attitude

Xie, Hui Tianjin Univ.
Jiang, Kecheng Tianjin Univ.
Song, Kang Tianjin Univ.

The unmanned roller (UR) is promising in improving the compaction quality and efficiency simultaneously. When transiting from on work site to another, a well-designed path-planning algorithm is essential for the efficient operation of rollers between two sites. Existing path planning algorithms barely consider the vehicle attitude at the destination and the kinematic constraints, limiting the efficiency in the initial phase of operation in a new work site. Therefore, in this paper, an improved RRT* algorithm is proposed. By combining Dubins curve with RRT* algorithm, the algorithm enforces the roller to maintain an optimal attitude (orientation) when approaching the entrance of the next work site, by manipulating the target path. In addition, a smooth and achievable path is generated, by setting-up the upper bound of the curvature based on kinematic and steering dynamic models then fitting the target path using the B-spline. The proposed algorithm is tested in both simulation and experiments, confirming its effectiveness.

▷ SunB07-27

非高斯随机分布系统的决策优化与控制

Yin, Liping Nanjing Univ. of Information Sci. & Tech.
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电力系统的运行过程中面临着许多的不确定性，如何保证电力系统运行效率和稳定性的同时最大化节约花费成本，一直是系统操作人员关心的问题。电力系统运行过程一般分为决策层、回路控制层和运行优化层。本文针对电力系统决策层操作过程中操作人员熟练程度的评定和量化问题及控制层中存在非高斯干扰问题，考虑了决策层操作人员决策的不确定性和控制回路受到干扰时对电力系统运行优化的影响，提出了一种基于脑电信号(EEG)特征的实时分析方法来判断决策层是否引入不确定性；给出了在不同条件下使用的优化控制算法。首先利用小波变换法将预处理之后的脑电信号分离成不同的脑电波节律分别为 delta，theta，alpha，beta 和 gamma；其次通过小波熵来确定特征，采用支持向量机与卷积神经网络进行特征分类，根据结果我们可以判断操作人员的熟练程度，从熟练程度来决定在决策层是否需要引入随机不确定性，并且根据其经验值的大小，考虑引入不同的优化策略；然后建立性能指标函数，由于性能指标函数受到随机因素和随机输入约束的影响，在这种情况下，性能指标函数是随机的，常用的基于均值和方差的控制方法已经不能完整的描述系统的特性；这里我们基于随机分布控制理论，构建带随机约束的性能指标函数，其中性能指标函数可以描述为实际输出的概率密度函数和期望输出概率密度函数之间的距离的方式；一般的情况下，我们采用基于输入 -输出模型的输出 PDF 控制算法，但是在目标概率密度函数不可测的情况下，拟采用最小熵控制方法。

▷ SunB07-28

A New Variable Selection Algorithm for LSTM Neural Network

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Zhang, Mengyan Qilu Univ. of Tech. (Shandong Acad. of Sci.)
Sun, Kai Qilu Univ. of Tech. (Shandong Acad. of Sci.)

This paper proposes an accurate and reliable input variable selection algorithm by embedding a nonnegative garrote (NNG) algorithm into long short term memory (LSTM) neural network to perform data-driven modeling on a highly nonlinear and dynamic time-delay dataset. Firstly, an LSTM deep neural network is trained, and a well-trained LSTM network is obtained by optimizing the parameters of LSTM through a grid search

algorithm. Secondly, the initial input weights of LSTM are compressed accurately by the NNG algorithm, and block cross-validation is applied to the optimization calculation process to achieve input variable selection. Finally, the performance of the algorithm is verified by the improved Friedman time-delay artificial datasets. Simulation results show that the algorithm could construct a more simplified and better predictive model than other traditional algorithms.

▷ SunB07-29

An Improved Method for Cloth Pattern Cutting Based on Holistically-nested Edge Detection

Yu, Naigong	Beijing Univ. of Tech.
Zhang, Zhen	Beijing Univ. of Tech.
Xu, Qiao	Beijing Univ. of Tech.
Essaf, Firdaous	BEIJING Univ. OF Tech.
Lin, Jia	Beijing Univ. of Tech.

Image edge detection is the basis for precise positioning and accurate cutting of cloth pattern contours. Compared with the commonly used traditional edge detection methods, the Holistically-nested Edge Detection has clearer and more continuous detection results including the reduction of the false detection rate. However, this method extracts a coarser thick outline. In order to extract a high-precision cloth pattern outline, clearly distinguish the main body of the pattern from the background, provide convenience for the follow-up cutting machine for accurate cutting, this paper proposes an improved method for edge detection of cloth pattern cutting based on the holistically-nested Edge Detection method. The edge refinement and smoothing process are added, where the edge detection, edge refinement, and edge smoothing of the clothes images are carried out in sequences, so that the extracted cloth pattern contour is continuous, smooth, and detailed, allowing the respect of the cutting requirements of the cutting machine and the requirements of the factory production.

▷ SunB07-30

Deep Neural Network Classification of EEG Data in Schizophrenia

Guo, Zhifen	Northeastern Univ.
Wu, Lezhou	Northeastern Univ.
Li, Yun	Northeastern Univ.
Li, Beilin	Northeastern Univ.

Schizophrenia(SZ) is a disease of unknown etiology and pathogenesis and is ranked by the World Health Organization as one of the top ten diseases contributing to the global burden of disease. Studying the internal physiological differences between EEG of schizophrenia patients and normal individuals is important for diagnosing and treating schizophrenia in order to determine objective physiological diagnostic criteria. The EEG data of patients with schizophrenia were preprocessed and markers were extracted. The convolutional neural network was used to characterize the difference of distributed structure of data for classification and the classification results were given. The accuracy of the classification was 92%, and the disease classification was effectively performed using deep learning networks.

▷ SunB07-31

A Multi-feature Fusion Model Based on BRB of Health State Prediction for Aeroengine Gas Path System

Yin, Xiaojing	Changchun Univ. of Tech.
Peng, Shouxin	Changchun Univ. of Tech.,
Zhang, Bangcheng	Changchun Univ. of Tech.
Shi, Guangxu	Changchun Univ. of Tech.
Zhang, Yu	Changchun Univ. of Tech.

The health of an aeroengine gas path system is essential to the reliable flight of the aircraft. Due to the complexity and coupling of aeroengine gas path systems, the establishment of a dynamic and comprehensive model for the health state prediction is difficult. It is very necessary to establish the prediction model by fusing multiple features instead of using a single feature such as exhaust temperature. A belief rule base (BRB) shows outstanding performance in modeling complex systems. This paper proposes a multi-feature fusion model based on BRB of health state prediction for aeroengine gas path system. In this model, firstly, the health characteristics of the aeroengine gas path system with different physical characteristics is taken. Secondly, a time series prediction model of the health characteristics based on BRB is established. Finally, the evidence reasoning (ER) algorithm is used to fuse these health characteristics to achieve the comprehensive health states prediction of the aeroengine gas path system. The BRB health state prediction model combines both quantitative information and expert knowledge to remedy deficiency of effective data and improve the prediction accuracy. Considering the initial parameters given by experts are subjective and may not be appropriate for engineering practice. The projection covariance matrix adaptive evolution strategy (P-CMA-ES) is selected as the optimization algorithm for training the initial parameters. Finally, a certain type of aeroengine is taken as a case to verify the effectiveness of the proposed model. The results show that the health state prediction model based on BRB with multi-feature fusion can accurately predict the health states of aeroengine gas path system.

▷ SunB07-32

Abnormal Behavior Analysis Strategy of Bus Drivers Based on Deep Learning

Liu, Shida	Beijing Jiaotong Univ.
Wang, Xuyun	North Univ. of Tech.
Wang, Li	North China Univ. of Tech.
Zhang, Xiaoping	North China Univ. of Tech.
He, Zhonghe	North China Univ. of Tech.

Aiming at the bus driving safety problems caused by the abnormal behavior of the bus driver during the driving process, this paper proposes a deep learning-based analysis strategy for the abnormal behavior of the bus driver. The program defines the abnormal behaviors of bus drivers and categorizes them into behaviors such as smoking, drinking, and making phone calls. The YOLOv5 (You Only Look Once-Version 5) convolutional neural network algorithm is used as the core technique, and the abnormal behavior data of the drivers in the actual bus is used to produce the abnormal behavior data of the bus drivers. Collected and carried out automatic detection experiments to test the feasibility and effectiveness of drivers' abnormal behaviors. The experimental results show that the detection of abnormal behaviors of bus drivers is fast and accurate, the scheme is feasible and effective, and the detection effect can meet the application requirements.

▷ SunB07-33

Electrical Insulator Defect Fault Detection Method Based on Yolov5

Feng, Zhiqiang	Hubei MinZu Univ.
Guo, Li	Hubei Minzu Univ.
Li, Runze	Hubei Univ. for Nationalities
Darong, Huang	Chongqing Jiaotong Univ.

With the continuous improvement of China's power system, the use of insulators has been very common.Due to longterm exposure to the outside, it is inevitable to cause defects of insulators.In this paper, an insulator defect detection method based on yolov5 is proposed.The accuracy rate can reach 86.8%,map@0.5 up to 95.5%.This method can be used to identify and locate the insulator defects, and reduce the maintenance burden and task of the staff.

▷ SunB07-34

A Heavy-tailed Distribution Data Generation Method Based on Generative Adversarial Network.

Zhang, Xiaoyu	Beijing Univ. of Chemical Tech.
Zhou, Jinglin	College of Information Sci. & Tech.,Beijing Univ. of Chemical Tech.

Heavy-tailed distribution widely exists in economic, financial, industrial and other data. The tail of heavy-tailed distribution is thicker than that of Gaussian distribution. Generative adversarial networks (GANs) is a data generation model, which is mainly used for image generation. The traditional GANs method usually assumes that the samples follow Gaussian distribution, so it is often not used directly in the heavy-tailed distribution data. In this paper, a generative adversarial network HTGAN for industrial heavy-tailed data is proposed. By improving the method of data preprocessing, the distribution of hidden variable Z is changed to T distribution. This method is applied to the fault data of TE process data. Compared with the traditional GAN method, the superiority of this method in industrial heavy tail data generation is proved.

▷ SunB07-35

A Semantic Relation Graph Reasoning Network for Object Detection

Shu, Xiao	Harbin Inst. of Tech., Shen Zhen
Liu, Rui	Harbin Inst. of Tech.,Shen Zhen
Xu, Jun	Harbin Inst. of Tech., Shenzhen

Object detection is a basic task in computer vision, and it plays an important role in the fields of robotics, security, and autonomous driving. However, the object detection algorithms at present usually extract the features of a single region and then perform detection, ignoring the semantic context between objects and scenes, which will produce bad effect in detection. In order to use the semantic context between objects

and scenes, this paper considers object detection as a graph reasoning problem. In this paper, we obtain the prior knowledge of the co-occurrence among the objects and between objects and scenes through statistics of the dataset, then we mainly use two modules to extract the semantic relationship between objects and scenes. The first one extracts the prior knowledge between objects through of graph convolutional networks(GCN), and introduces the graph attention networks(GAT) to learn hidden knowledge about the semantic context relationship between objects adaptively, and by concating these knowledge then use them for detection. The second one uses MLP to generate S-L coefficients and multiplies the scene features and the S-L coefficients to obtain scene-object related features for object detection. We have conducted experiments to verify our method on the PASCAL VOC dataset, and the experiments show that our method can effectively improve the accuracy of object detection.

▷ SunB07-36

Formation Consensus of Stochastic Multi-agent System Based on Probability Density Compensation

Wang, Jing	North China Univ. of Tech., China
Zhang, Xuerou	Beijing Univ. of Chemical Tech.
Zhou, Jinglin	College of Information Sci. & Tech.,Beijing Univ. of Chemical Tech.

Due to the randomness of multi-agent system, it is difficult to achieve strict formation consensus, generally, not all agents in the system can obtain global information. Therefore, this paper designs a distributed controller to make multi-agent system achieve formation consensus in the sense of probability, which combines two parts of sliding mode controller and probability density function compensator. Sliding mode controller is used for rough tuning, so that the formation of agents can be controlled within a certain range. Probability density function compensator uses the minimum entropy criterion to train the weights, so as to realize the compensation of the random part of the system and play the role of fine tuning. The control algorithm minimizes the entropy of the system output error and optimizes the control effect. Finally, the simulation results show the effectiveness of the proposed method.

▷ SunB07-37

LiNet: A Neural Network with Data Augmentation for Liquor Quality Classification

Tang, Hao	Beijing Univ. of Chemical Tech.
Tian, Kexin	Univ. of Wisconsin-Madison
Zhu, Haijiang	Beijing Univ. of Chemical Tech.

In recent years, Chinese Liquor is widely loved by consumers in the world. Therefore, the quality of Chinese Liquor has also attracted much attention. In order to establish a fast and accurate method for identifying the quality of liquor, this paper proposes LiNet, which is a novel neural network to classify different quality liquors. For the purpose of extracting the characteristics of different quality liquors, we used Ion Mobility Spectroscopy (IMS) to analyze different quality liquors and constructed a feature vector based on the ion mobility spectrum signal of liquor. Due to industrial production reasons, the dataset is small, LiNet leverages the Generative Adversarial Networks to enhance the dataset. Considering that IMS data is time series data and has temporal and spatial correlation, LiNet uses 1-D CNN and 1-D transposed CNN to implement the Stacked Auto Encoder to learn the feature of IMS data of Chinese Liquor. Experimental results show that our proposed model achieves premium performance to other state-of-the-art approaches.

▷ SunB07-38

Qualitative Analysis and Quantitative Calculation of Crude Oil Drilling Fluid Mixtures Based on Raman Spectroscopy

Wang, Guoliang	Liaoning Shihua Univ.
Wang, Yang	Liaoning Petrochemical Univ.

As a well-developed molecular spectroscopic analysis technique, laser Raman spectroscopy has been widely used in the analysis of a variety of substances. Treat measure for the detection of oil content in the mixture, this article through the analysis of the existing Raman spectra, using wavelet analysis to extract the spectral feature, according to Pearson correlation coefficient, and puts forward an improved algorithm based on data to eliminate, eliminate some abnormal data points, and then using the partial least square method to complete the treatment measure material concentration of qualitative analysis and quantitative calculation. Through the comparison of experiments, the accuracy is guaranteed in a certain range, and the running speed of the model is improved, which proves the effectiveness of the method.

▷ SunB07-39

Equipment Life Prediction Method Based on Multi-source Data

Yan, Mingsheng	Shenhua Zhonghai Shipping(Tianjin) Co., Ltd
Han, Baohong	Shenhua Zhonghai Shipping(Tianjin) Co., Ltd
Duan, Pengfei	Shenhua Zhonghai Shipping(Tianjin) Co., Ltd
Li, Zhi	Shenhua Zhonghai Shipping(Tianjin) Co., Ltd
Zhu, Huimin	Zhendui Industrial Intelligent Tech. Co., Ltd
Li, Qizhong	Zhendui Industrial Intelligent Tech. Co., Ltd

Based on Kalman smoothing to synthesize multi-source data, the degradation model of Weiner process drift coefficient changing with time is established. The analytical expression of model parameter estimation is given by EM algorithm. Combined with the actual test data, the life of marine propulsion system gearbox is predicted. Compared with the traditional method and test results, the method is proved to be more accurate, which is of great significance to the life prediction of ship propulsion system related equipment.

▷ SunB07-40

Directivity and Effective Diameter Measurement Method of the Hydrophone in Ultrasound Field

Hu, Song	Beijing Univ. of Chemical Tech.
Zhu, Haijiang	Beijing Univ. of Chemical Tech.

The directivity model of hydrophone describes the frequency response of the hydrophone at different incident angles, which can be used for estimation of the effective diameter of the hydrophone. This parameter is very important because of the correction of the spatial average effect and the accurate measurement of the sound field parameters. At present, the nominal diameter of most commercial hydrophones is difficult to meet the requirement that the effective radius of hydrophone should be less than or equal to 1 / 4 of the acoustic wave wavelength, which may result in large errors because of spatial averaging. To solve this problem, this paper studies an effective diameter measurement method based on three kinds of hydrophone directivity models. In this method, the received signals of the hydrophone at different angles are measured, and the directional response model of hydrophone is established by least square method according to rigid baffle (RB), un-baffled (UB) and soft baffle (SB) model. The influence of directional models on effective diameter measurement is evaluated at different frequencies. The experimental results show that the directivity response data of hydrophone are not only matched with one model at different frequencies, but the directivity model closest to the data points should be selected to estimate the effective diameter of hydrophone.

▷ SunB07-41

Real-Time Optimization of Fermentation Processes Using Economic DNN-Based Model Predictive Control Strategy

Wu, Jie	Jiangnan Univ.
Liu, Fei	Jiangnan Univ., China

Real-time optimization technology has become a powerful tool in improving yield of fed-batch fermentation processes. However, the existing studies were based on unstructured models which only reveal the approximate macroscopic description of fermentation processes and regardless of the intracellular metabolic flux information. Deep neural network (DNN) is suitable for modeling relationship between manipulated variables and metabolic flux. An economic DNN-based model predictive control has been proposed to realize real-time optimization of fermentation processes. Simulation results on a penicillin fermentation process fully illustrate the effectiveness of the proposed strategy

▷ SunB07-42

Dark Web Traffic Detection Method Based on Deep Learning

Haoyu, Ma	Chongqing Jiaotong Univ.
Jianqiu, Cao	Chongqing Jiaotong Univ.
Mi, Bo	Chongqing Jiaotong Univ.
Huang, Darong	Chongqing Jiao-tong Univ.
Zhenyuan, Zhang	Chongqing Jiaotong Univ.
Liu, Yang	Inst. of Information Sci. & Engineering

Network traffic detection is closely related to network security, and it is also a hot research topic now. With the development of encryption technology, traffic detection has become more and more difficult, and many crimes have occurred on the dark web, so how to detect dark web traffic is the subject of this study. In this paper, we proposed a dark web traffic(Tor traffic) detection scheme based on deep learning and conducted experiments on public data sets. By analyzing the results of the experiment, our detection precision rate reached 95.47%.

▷ SunB07-43

Data-Driven Co-simulation of Adaptive Coordinated Control Algorithm in Urban Traffic Signal Timing

Ji, Honghai — North China Univ. of Tech.
Yin, Hu — NCUT
Wang, Li — North China Univ. of Tech.
Liu, Shida — Beijing Jiaotong Univ.
Fan, Lingling — Beijing Information Sci. & Tech. Univ.

This paper proposes a new data-driven adaptive cooperative control algorithm, which calculates the green time of the next cycle through the queue length, greatly reduces the queue delay, realizes the queue strength balance control of multi-directional traffic flow, and achieves the purpose of reducing traffic congestion. This new collaborative recursive algorithm has three new characteristics: it only uses the queuing vehicle data collected by geomagnetic coil to regulate the new cycle in real time. It can reduce the vehicle congestion caused by fully saturated and oversaturated scenarios. Adjusting the parameters can adapt to different urban traffic flow scenarios. Based on the open source advantages and parameter controllability of SUMO simulation platform, The algorithm is carried out, which compared with the traditional fixed timing control and inductive timing control. The numerical analysis and experimental results show the advantages of the method.

▷ SunB07-44

The Analysis of COVID-19 Transmission on Diamond Princess Cruise Ship

Xi, Zhouhui — Qingdao Univ.
Meng, Delin — Qingdao Univ.
Zhao, Jijun — Qingdao Univ.

This paper takes the COVID-19 transmission on the Diamond Princess Cruise Ship as an example to study the transmission dynamics of COVID-19 in a relatively closed environment, and to evaluate control measures that can greatly reduce the transmission of COVID-19. The Agent-Based Modeling (ABM) method is used to simulate the transmission process, and the Latin Hypercube Sampling is applied for parameter estimation in ABM. The simulation results show that most of the infected cases on the Diamond Princess Cruise Ship were transmitted between passengers. However, at the beginning of the quarantine, most infected passengers were infected by crew members rather than other passengers. Due to the nature of their work, the crew members played a key role in the early spread of the epidemic on the cruise ship. If the lab testing was strengthened for crew members at the beginning of the quarantine, and the infected crew members were disembarked on time, the final total number of infected would be greatly reduced. Furthermore, if this measure is supplemented with other measures such as increasing the frequency of washing hand by crew members, strengthening hygiene for the process of distributing foods, strengthening deck surface cleaning which can reduce the probabilities of transmission from a crew member to a passenger and between passengers while on deck, the final number of infected would be further highly reduced.

▷ SunB07-45

Analysis on the Impacting Factors of Hand, Foot and Mouth Disease Incidence Using Random Forest

Meng, Delin — Qingdao Univ.
Xi, Zhouhui — Qingdao Univ.
Zhao, Jijun — Qingdao Univ.

Hand, foot and mouth disease (HFMD) has circulated in China and caused yearly outbreak. In order to find the impacting factors that affect HFMD incidence, we used Random Forest to examine the association between HFMD incidence and potential variables of 31 provinces in mainland China. We also use the K-means clustering algorithm to check our results. Our analysis results revealed that: 1) average temperature is the one that affects HFMD incidence the most among all climatic variables. Among all 31 provinces in mainland China, average temperature is the primary impacting factor in 24 provinces. 2) transmission patterns of HFMD cannot be fully explained by geographical proximity; climate variables alone cannot explain the spread of HFMD. 3) Population flux also plays an important role in affecting HFMD incidence, especially in China's four municipalities.

▷ SunB07-46

Modeling and Control for 3D Output Stochastic Distribution System Based on 2D PDF Models

Yang, Jingqi — Beijing Univ. of Chemical Tech.
Zhou, Jinglin — College of Information Sci. & Tech.,Beijing Univ. of Chemical Tech.

This paper presents a novel modeling and control method for 3D output probability density function (PDF) of stochastic distributed systems. Firstly, considering the boundary constraints of the output PDF, linear B-spline functions are used to approximate the PDF of the system output variables, and the linear dynamic models of the X-axis and Y-axis are established respectively. Afterwards, on the basis of the 2D PDF models, a 3D PDF model is established. A controller is designed by optimizing the quadratic performance index, which makes the output PDF track the desired PDF effectively. Finally, an example is used to illustrate the effectiveness of the algorithm, and the expected results are achieved.

SunC01 13:30–15:30 Room D

Invited Session: System Modeling, State and Parameter Estimation (I)

Chair: Zhu, Fanglai — Tongji Univ.
Co-Chair: Zhang, Junfeng — Hangzhou Dianzi Univ.

▶ SunC01-1 13:30–13:50

Randomly Occurring Cluster Synchronization of Complex Networks via Adaptive Pinning Control

Jiang, Chenhui — Jiangnan Univ.
Ding, Dong — Jiangnan Univ.
Zhang, Jiancheng — Tongji Univ.
Tang, Ze — Jiangnan Univ.

The article studies the cluster synchronization for a kind of nonlinear coupled complex networks with time-varying delay. Considering the networks may subject to certain uncertainties, the model of complex networks consisting of nonidentical systems with randomly occurring disturbance which described by Bernoulli stochastic variable is established. Secondly, a kind of pinning feedback controllers under randomly occurring disturbance is proposed in order to not only synchronize the systems in the same clusters but also weaken the mutual influence among clusters, which will be imposed on the systems in current cluster which have directed connections with the systems in the other clusters. Then, sufficient conditions for the realization of the cluster synchronization are derived in terms of the QUAD function class, the NCF function class and the Lyapunov stability theorem. Furthermore, the optimal feedback control gain is obtained by designing the adaptive updating laws. Finally, a numerical experiment is presented to illustrate the effectiveness of theoretical analysis.

▶ SunC01-2 13:50–14:10

Saturated Adaptive Pinning Control and Consensus of Discontinuous Multi-Agent Systems

Wang, Jiafeng — School of Internet of Things Engineering, Jiangnan Univ.
Ding, Dong — Jiangnan Univ.
Zhang, Jiancheng — Tongji Univ.
Tang, Ze — Jiangnan Univ.

This paper studies the consensus problem for a kind of multi-agent systems with nonlinear and discontinuous dynamics through distributed adaptive control. By applying saturation strategy, the control signal is limited into a reasonable range in order to simulate the practical applications. Then utilize the Gaussian error function and the differential mean value theorem to simulate the saturation effect. By designing the adaptive updating law, appropriate control gain is finally obtained. According to Filippov differential inclusion and measure selection theorem as well as Lyapunov stability theorem, sufficient conditions for achieving the consensus of multi-agent systems are derived. Ultimately, the validity of our conclusion is verified by establishing a numerical simulation.

▶ SunC01-3 14:10–14:30

A Novel Set-Theoretic Interval Observer for Discrete Linear Time-Invariant Systems

Xu, Feng — Tsinghua Univ.
Yang, Songlin — Tsinghua Shenzhen International Graduate School
Wang, Xueqian — Tsinghua Univ.

This paper proposes a novel robust state estimation method for discrete linear time-invariant (LTI) systems by using the positive system theory and the set theory to achieve an expected balance between computational complexity and robust state estimation conservatism. The proposed method partitions an equivalent system into two subsystems, where the first subsystem owns a nonnegative subsystem matrix and the second subsystem has a subsystem matrix including possible negative elements of the system matrix of the equivalent system. In this way, the design of interval observers is divided into two steps. The first step is to

design an interval observer for the first subsystem based on the positive system theory. The second step is to design a zonotopic set-valued observer for the second subsystem based on the set theory. Consequently, a so-called set-theoretic interval observer (SIO) of the whole system can be synthesized by integrating the interval estimations and set-valued estimations of the two subsystems together. At the end, a numerical system is used to illustrate the effectiveness of the proposed SIO.

▶ SunC01-4 14:30–14:50

Observability Keeping in Observer Design of Descriptor System and Its Form

You, Renyang	Suzhou Univ. of Sci. & Tech.
Guoliang, Xiang	SUZHOU Univ. OF Sci. & Tech.
Zhang, Wenyang	Suzhou Univ. of Sci. & Tech.
Tang, Mingzhu	Suzhou Univ. of Sci. & Tech.
Guo, Shenghui	Suzhou Univ. of Sci. & Tech.

In the process of observer designing of descriptor systems, some system transformations are usually used to transform the descriptor systems into standard normal ones. However, some originally observable systems are not observable after these system transformations. For some standard normal systems with unknown interference, descriptor system form is also often constructed to design observers by using an augmented state vector. And the observability is also not always keeping in the latter transformations. The loss of observability will lead to a wrong observer, and usually it is inapparent. An extra constraint is added into the transformation matrices, and the observability can be guaranteed. Furthermore, the calculate process of the matrices is given. Two examples are shown to illustrate the correctness and the effectiveness of the presented methods

▶ SunC01-5 14:50–15:10

Optimal Controller Design for State Estimation of Boolean Control Networks

Chen, Yantao	Henan Polytechnic Univ.
Yang, Junqi	Henan Polytechnic Univ.
Cui, Lizhi	Henan Polytechnic Univ.Electrical
Zhu, Junjie	Henan Polytechnic Univ.

In this paper, a kind of optimal controller is proposed to estimate the state of Boolean control networks (BCNs). Different from the standard observer, the optimal state estimation is completed by designing the control input instead of directly using it, where the maximum-minimum method is employed such that the state of BCNs can be uniquely estimated in possible short time steps. A set observer is first proposed to estimate the state of BCNs at any time steps. Based on the set observer, an initial output-dependent reconstructible state tree is developed, where an algorithm is provided to generate the nodes of such tree and can be implemented offline. The optimal control sequence for uniquely determining the state of BCNs is derived from the reconstructible state tree by a breadth-first search algorithm, where the output of BCNs is dynamically employed. An example is given to illustrate the applicability and usefulness of the developed methods.

▶ SunC01-6 15:10–15:30

Data-Driven Fault Symptoms Generation and Augmentation for Satellite Attitude Control System

Ma, Youdao	Harbin Inst. of Tech.
Zhang, Wenhan	Harbin Inst. of Tech.
Liu, Xinyang	Harbin Inst. of Tech.
Wang, Zhenhua	Harbin Inst. of Tech.
Shen, Yi	Harbin Inst. of Tech.

This paper studies the data-driven fault symptoms generation and augmentation for satellite attitude control system via an approximate model technique and a generative adversarial network. An approximate model is determined to fit the input and output data of satellite attitude control system. Based on the designed model, a small number of addictive fault symptoms and multiplicative fault symptoms are generated. To obtain abundant symptom data, the generative adversarial network is introduced to augment the fault symptoms. Finally, numerical simulation results are presented to demonstrate the effectiveness of the proposed method.

SunC02 13:30–15:30 Room E

Invited Session: Reinforcement Learning and Optimal Control

Chair: Wu, Zhengguang Inst. of Advanced Process Control

Co-Chair: Che, Weiwei Shenyang Univ.

▶ SunC02-1 13:30–13:50

Real-time Reachable Set Estimation for Markov Jump Systems with Time-varying Delay

Zhang, Liang	Bohai Univ.
Cao, Yuning	Harbin Engineering Univ.
Feng, Zhiguang	Harbin Engineering Univ.

The problem of real-time reachable set estimation (RSE) for a class of Markov jump systems is studied in this paper. A method is proposed for estimating real-time reachable set of the Markov jump systems with known inputs, bounded disturbances and non-zero initial conditions. By utilizing the linear matrix inequalities (LMIs) and the Lyapunov stability theory, sufficient conditions for estimating the real-time reachable set of Markov jump systems are given, and the reachable set of the resulting systems is mean-square (M-S) bounded by the prescribed ellipsoid. The validity of the theoretical analysis is verified by numerical simulation.

▶ SunC02-2 13:50–14:10

Finite-time Stabilization for SOSM Dynamics Subject to Time-varying Output Constraint

Ding, Chen	Jiansu Univ.
Ma, Li	Jiangsu Univ.
Ding, Shihong	Jiangsu Univ.
Mei, Keqi	Jiangsu Univ.

The paper concentrates on the problem of second-order sliding mode (SOSM) controller design with mismatched term and time-varying Output Constraint. By designing a novel time-varying Barrier Lyapunov Function (BLF) and using the modified adding a power integrator (API) technique, a SOSM control algorithm, which is able to cope with the closed-loop system simultaneously with and without time-varying output constraint, has been developed. The rigorous mathematical proof shows that with the time-varying output constraint, the presented control strategy ensures the finite-time stability of the considered system. Lastly, the effectiveness of the presented algorithm is demonstrated by an illustrative example.

▶ SunC02-3 14:10–14:30

HILONet: Hierarchical Imitation Learning from Non-Aligned Observations

Liu, Shanqi	Zhejiang Univ.
Cao, Junjie	Inst. of Cyber Sys. & Control, Zhejiang Univ. State Key Laboratory of Industrial Control Tech.
Chen, Wenzhou	College of Control Sci. & Engineering
Wen, Licheng	Zhejiang Univ.
Liu, Yong	Inst. of Cyber-Sys. & Control

It is challenging learning from demonstrated observation-only trajectories in a non-time-aligned environment because most imitation learning methods aim to imitate experts by following the demonstration step-by-step. However, aligned demonstrations are seldom obtainable in real-world scenarios. In this work, we propose a new imitation learning approach called Hierarchical Imitation Learning from Observation(HILONet), which adopts a hierarchical structure to choose feasible sub-goals from demonstrated observations dynamically. Our method can solve all kinds of tasks by achieving these sub-goals, whether it has a single goal position or not. We also present three different ways to increase sample efficiency in the hierarchical structure. We conduct extensive experiments using several environments. The results show the improvement in both performance and learning efficiency.

▶ SunC02-4 14:30–14:50

Containment Control for Multi-agent Systems with Differentially Private Protocols

Yang, Zewei	Yangzhou Univ.
Zhang, Wenbing	Yangzhou Univ.

This paper studies the containment control problem for a class of discrete-time multi-agent systems with fixed topology by introducing differential privacy mechanism. Firstly, we present a private containment control algorithm such that private initial values of followers can be protected, and moreover, followers' states can be driven into the convex hull formed by leaders' states along with the evolution rules. Secondly, for the proposed algorithm, we carry on the mean square convergence analysis of measurement error between followers and convex combination of leaders, we also verify the differential privacy and study the upper bound of convergence accuracy. Finally, some numerical examples are simulated to verify our theoretical results.

▶ SunC02-5 14:50–15:10

Adaptive Optimal Setpoint Tracking Control of Unknown Linear Continuous-time Systems

Zhao, Jianguo	China Univ. of Mining & Tech.
Zhang, Hengjin	China Univ. of Mining & Tech.

Yang, Chunyu China Univ. of Mining & Tech.

This paper presents a novel adaptive optimal setpoint tracking control method for unknown linear continuous-time systems with constant disturbances using adaptive dynamic programming (ADP). Compared with the existing works, the proposed ADP-based tracking control and disturbance rejection framework has the following advantages: 1) By defining a new performance index, its boundedness is guaranteed without additional discount factor and thus the influence of discount factor on the stability of the closed-loop system is eliminated; 2) According to Lyapunov theory, we prove that the tracking error converges to zero rather than the bounded tracking error of the existing results; 3) It is not to assume that the knowledge of the output matrix is known and a complete model-free tracking control scheme is achieved; 4) The external disturbance input is not required to be measurable, so the proposed method has more practical engineering application. Finally, the feasibility and effectiveness of the proposed tracking controller are verified by the rougher flotation operational processes simulation.

▶ SunC02-6 15:10–15:30

Face Verification Technology Based on FaceNet Similarity Recognition Network

Gu, Fengwei Harbin Engineering Univ.
Lu, Jun Harbin Engineering Univ.
Xia, Guihua Harbin Engineering Univ.
Feng, Zhiguang Harbin Engineering Univ.

The background complexity of face images is high in actual scenes, and there are a series of problems such as illumination and occlusion, which greatly reduces the performance of the face verification model. This paper proposes a face verification algorithm FaceNetSRM based on the FaceNet similarity recognition network to improve the performance of the face verification model and the accuracy of Chinese face verification. Firstly, the deep convolutional neural network framework in FaceNet is determined, and the similarity recognition module is used to replace the Euclidean distance module in FaceNet. Then, the CASIA-WebFace face dataset and the self-made face dataset C-facev1 are used to train the face verification algorithm of this article. Finally, the trained model is tested and evaluated on the face dataset LFW and CASIA-FaceV5 to show the effectiveness of the face verification method in this article, and the face verification effect of the algorithm is compared with the face verification effect of FaceNet. The experimental results show that the face verification accuracy rate of the FaceNetSRM algorithm in this paper is 1.5% higher than that of FaceNet, and the accuracy rate of Chinese face verification is improved by 2.8%. The algorithm has good robustness and generalization ability, which can be applied in face verification systems.

SunC03 13:30–15:30 Room F

Invited Session: Data-driven Modeling and Adaptive ILC

Chair: Chen, Qiang Zhejiang Univ. of Tech.
Co-Chair: Kong, Ying Zhejiang Univ. of Tech.

▶ SunC03-1 13:30–13:50

A Finite Time Neural Network Model for Solving Time-varying Matrix Inequality Problem

Kong, Ying Zhejiang Univ. of Tech.
Hu, Tanglong Zhejiang Univ. of Sci. & Tech.

Time-varying matrix inequalities are frequently encountered in many mathematical calculations and engineering applications. To solve time-varying problems in an effective way, a special recursive Zhang neural network (ZNN) is proposed. However, the convergent time of ZNN tends to be infinity. To accelerate the convergent speed, a recurrent neural network model with finite convergent property (FTNN) is presented and is used to solve the linear time-varying matrix inequality problem. Additionally, convergence and stability of the proposed FTNN model are analyzed. Finally, simulations about the FTNN network model shows that the convergence performance of FTNN model is superior than that of ZNN model.

▶ SunC03-2 13:50–14:10

Least Squares Algorithms and Their Repetitive Consistency

Bi, Hongbo Quzhou Univ.
Sun, Mingxuan Zhejiang Univ. of Tech.
Chen, Qiang Zhejiang Univ. of Tech.

This paper presents a learning identification method for stochastic systems with time-varying parametric uncertainties. The systems undertaken perform tasks repetitively over a pre-specified finite-time interval, and a least squares learning algorithm is derived on the basis of the repetitive operations. The learning identification method applies to periodically time-varying systems. It is shown that the estimates converge to the time-varying values of the parameters, and the complete estimation can be achieved under repetitive PE condition, a sufficient condition for establishing repetitive consistency of the learning algorithms.

▶ SunC03-3 14:10–14:30

Discrete-Time Dead-Beat Terminal Sliding-Mode Control with Multi-Periodic Disturbances Compensation

Wu, Lingwei Taizhou Univ.

In this paper, a novel dead-beat terminal sliding mode control scheme with multi-periodic disturbances compensation is developed for a class of uncertain discrete-time systems. A dead-beat reaching law and a novel sliding variable with the nonlinear saturation function are given for the controller design. The performance improvement is accomplished by applying a multi-periodic disturbances compensator. The steady-state error band and absolute attractive layer bound of the tracking error dynamics are analyzed in detail, in order to characterize the attractivity and steady-state performance with respect to control parameter values. Simulation results are given to verify the effectiveness of the proposed method.

▶ SunC03-4 14:30–14:50

Iterative Learning Identification for A Class of Wiener Nonlinear Time-varying Systems

Zhong, Guomin Zhejiang Univ. of Tech.
Qile, Yu Zhejiang Univ. of Tech.
Chen, Qiang Zhejiang Univ. of Tech.
Sun, Mingxuan Zhejiang Univ. of Tech.

In this paper, iterative learning identification algorithms are proposed to estimate the time-varying parameters in multi-input-single-output (MISO) Wiener nonlinear time-varying systems. The regression model of the Wiener system is built by using the polynomial expansion of the nonlinear inverse function. Then, two iterative learning algorithms, including iterative learning gradient identification and iterative learning least squares identification, are presented to estimate the time-varying parameters of the regression model. The convergence performance of the iterative learning identification algorithms is analyzed, and numerical simulations are provided to verify the effectiveness of the proposed algorithms.

▶ SunC03-5 14:50–15:10

Repetitive Learning Control for Nonlinear Systems Subject to Time Delays

Li, He Zhejiang Univ. of Tech.
Chen, Qiang Zhejiang Univ. of Tech.
Kong, Ying Zhejiang Univ. of Tech.

This paper presents a repetitive learning control scheme for a class of nonlinear systems with time-delay nonlinearities and fractional uncertainties. The control design is conducted through the direct parametric estimation and the adaptive bounding technique. The desired control input is taken as the parametric uncertainty with regressor one, and the direct estimation is adopted. The time-delay nonlinearity with the fractional uncertainty is tackled as the nonparametric uncertainty, where the bounding function is learned in order to reduce the requirement for the knowledge about the system dynamics. The upper bound of the control input gain is the only prior information requested in this scheme. The convergence of the tracking error is obtained and the boundedness of the variables in the closed-loop system is guaranteed. The numerical simulations are carried out to illustrate the effectiveness of the proposed RLC scheme.

▶ SunC03-6 15:10–15:30

Adaptive Iterative Learning Control for Non-Equal Length Tasks in the Presence of Initial Errors

Sun, Mingxuan Zhejiang Univ. of Tech.
Zou, Shengxiang Zhejiang Univ. of Tech.
Zhan, Yizhao Zhejiang Univ. of Tech.
He, Xiongxiong Zhejiang Univ. of Tech.

Both non-equal trail lengths and initial condition problems are practical challenges to learning control of robotic and mechatronic systems. Iterative learning to update input is still desired, because of the repetitive motion nature of the controlled objects. This paper concerns with the adaptive iterative learning control method for performing the non-identical tracking tasks, where the time scaling technique is used to normalize the non-equal trial lengths, while the error-tracking approach is adopted for coping with initial errors. Theoretical results for the performance analysis are presented in detail. The uniform convergence of the tracking error is examined, while the boundedness of the variables in the closed-loop is characterized. The proposed control design method does not require

the magnitude transformation, and removes the assumption of identical initial conditions. The time scaling technique is effective for assuring the expected tracking performance for the non-equal-length tasks in the presence of initial errors.

SunC04 13:30–15:30 Room G
Invited Session: Learning-based Control and Its Applications
Chair: Li, Xiao-Dong Sun Yat-sen Univ.
Co-Chair: Li, Xuefang National Univ. of Singapore

▶ SunC04-1 13:30–13:50
Learning Feedforward Control for Industrial Manipulators
Liu, Chengyuan Univ. of Nottingham
Popov, Atanas Univ. of Nottingham
Turner, Alison Univ. of Nottingham
Shires, Emma Univ. of Nottingham
Ratchev, Svetan Univ. of Nottingham

In this work, an iterative learning control (ILC) algorithm is proposed for industrial manipulators. The proposed ILC algorithm enables the coordination between ILC, inverse dynamics, and the feedback controller. The entire control scheme has ability of compensating both repetitive and non-repetitive disturbances; guaranteeing the control accuracy of the first implementation; and improving the control accuracy of the manipulator progressively with successive iterations. The convergence of the proposed control algorithm is analysed using Lyapunov-like composite energy function. A case study on a four degree of freedom industrial manipulator is demonstrated to illustrate the effectiveness of the proposed control scheme. By implementing the ILC algorithm, the maximum root mean square error of the control accuracy is improved from 0.0262 rad to 0.0016 rad within ten iterations.

▶ SunC04-2 13:50–14:10
Path Tracking Control of Autonomous Vehicles via Adaptive Iterative Learning Control
Li, Hongbo Sun Yat-sen Univ.
Li, Xuefang National Univ. of Singapore

In this work, path tracking control of autonomous vehicles (AVs) are studied under the framework of adaptive iterative learning control (AILC). In order to facilitate the controller design, the nonlinear vehicle dynamics are firstly transformed into a parametric form by utilizing proper variable transformations. Then a robust adaptive learning control approach is developed to achieve the path tracking tasks. Furthermore, to deal with the actuator constraints, an input-dependent auxiliary system is employed to work together with the proposed learning controller, which thus helps to reduce their influence to the control performance. The convergence analysis for the proposed method is also provided by virtue of the Lyapunov-like theory. It has been shown that with the proposed AILC approach, a good path tracking performance can be ensured in the presence of system uncertainties, exteranl disturbances and input constraints. A numerical example is illustrated to verify its effectiveness.

▶ SunC04-3 14:10–14:30
Reinforcement Learning Enhanced Iterative Learning for Path Tracking Control of Autonomous Vehicles
Lai, Qifeng Sun Yat-sen Univ.
Li, Xuefang National Univ. of Singapore

With the growing demand for driving safety, energy saving and environmental protection, the development of autonomous vehicles (AVs) has drawn a lot of attention from both academia and industry, and great achievements have been made in the past years. Among various autonomous driving technologies, path tracking control is one of the most fundamental and important control function of AVs, which concerns the design of a steering control strategy for tracking of a reference trajectory generated by the path planning module. In literature, in order to improve the path tracking performance of AVs, many approaches have been reported, most of which are model-based control strategies and their control performance depend on the accuracy of system models. However, in realistic driving environments, vehicle dynamics may suffer from various uncertainties, high nonlinearities, external disturbances, etc., which challenge the model-based control methods and thus lead to dissatisfactory control performance. While owe to the development of information and sensing technology, huge amounts of operational data can easily be collected. Thus, it would be practical important if we can make use of these data in modelling and controller design of AVs. As a representative of data-driven control methods, iterative learning control (ILC) is a kind of effective control method targeting at trajectory tracking problems. By taking the advantages of system repetition, it is able to fully utilize the past control experience to improve the current control performance iteratively. While its performance will be degraded significantly if there exists non-repeatable factors. Motivated by the above observations, a learning-based adaptive path tracking scheme is proposed in the present work by integrating ILC and reinforcement learning control (RLC), where RLC is responsible for dealing with various non-repeatable factors caused by driving environments. With the proposed approach, a high precision path tracking performance can be achieved in absence of accurate vehicle models and in presence of various system uncertainties and external disturbances. In contrast to existing works that employ pure ILC or RLC, the novelties and contributions of the present work can be summarized as follows: (1) A novel adaptive learning-based path tracking control algorithm is proposed for AVs. (2) The proposed method can make use of learning ability in iteration domain to guide RLC when it explores. Therefore, the learning efficiency as well as the rate of convergence of RLC will be improved. (3) With the integration of RLC, the learning ability and robustness of ILC will be enhanced significantly by utilizing the great adaptability of RLC to driving environments. The convergence and effectiveness of the proposed method has been verified by a preliminary numerical simulation and they will be further analyzed theoretically in the future.

▶ SunC04-4 14:30–14:50
An Adaptive ILC Method for Non-parameterized Nonlinear Continuous Systems to Track Iteration-dependent Trajectory
Ding, Yaqiong Sun Yat-Sen Univ.
Li, Xiao-Dong Sun Yat-sen Univ.

This paper proposes an adaptive Iterative Learning Control (ILC) method for non-parameterized nonlinear continuous systems to track iteration-dependent reference trajectory. The adaptive ILC method releases the general requirement in adaptive ILC community that the control gain matrices of the plants are real asymmetric or even positive-definite. Under the iteration-dependent reference trajectory and unknown external disturbance, the proposed adaptive ILC controller with a simple structure, which includes only two iterative variables, is able to guarantee the convergence of ILC tracking errors. A numerical example is used to verify the effectiveness of the proposed Adaptive ILC method.

▶ SunC04-5 14:50–15:10
Adaptive Neural Network Control of An Uncertain Robotic Manipulator with Input Constraint and External Disturbance
Zhang, Heng Shanghaitech Univ.
Wang, Yang ShanghaiTech Univ.

This paper investigates the control problem of an uncertain robotic manipulator under the effect of bounded external disturbance and input constraint. A novel Neural Network (NN) controller is proposed to achieve asymptotic tracking of the desired trajectory. The model uncertainty is lumped together with external disturbance and compensated by the NN term of the proposed adaptive controller, while the boundedness of input is ensured via an auxiliary system and a projection operator. The ISS property of the closed-loop system and the boundedness of input are rigorous proved. Finally, we show the effectiveness of the proposed controller in the numerical study.

▶ SunC04-6 15:10–15:30
Recent Advances in Iterative Learning Control with Fading Channel
Shen, Dong Renmin Univ. of China
Jiaxi, Qian Jilin Univ.

With the rapid development of communication technology, network control is widely used. In the process of wireless transmission, a signal may be affected by the attenuation channel. In this paper, we review the recent advances in learning control with fading channels. We first study the case that the fading channel statistics are known, then we turn to the unknown case. We also make some comparisons among these results to illustrate the newly developed techniques. This review paper may assist the readers in understanding the progress of the researches on the design of fading channel algorithms as well as the related issues in multiplicative randomness.

SunC05 13:30–15:00 Room H
Invited Session: ADRC and Its Advance in Motion Control
Chair: Yang, Zhijun Guangdong Univ. of Tech.
Co-Chair: Chen, Sen Shaanxi Normal Univ.

▶ SunC05-1 13:30–13:45
The Estimation Error of Extended State Observer in Rigid-Flexible Coupling Motion Stage
Huang, Ruirui Guangdong Univ. of Tech.

Su, Liyun Guangdong Univ. of Tech.
Wei, Yutai Guangdong Univ. of Tech.
Yang, Zhijun Guangdong Univ. of Tech.

The rigid-flexible coupling motion stage (RFCMS) uses the elastic deformation of the flexure hinges to compensate the position error caused by the friction dead zone, and the disturbance to the working stage is converted from friction to elastic disturbance. After the observer estimates and compensates the elastic disturbance, the working stage can be equivalent to a frictionless system. However, due to the friction to the rigid frame in RFCMS and the machining error of the flexure hinges, as well as the measurement deviation, there will be errors in the measurement and the estimation of the observer, which affect the final position accuracy of RFCMS. This paper theoretically analyzes the influencing factors of the estimation error in extended state observer (ESO), and quantitatively studies the estimation performance of ESO, in order to provide a theoretical basis for the control scheme of RFCMS.

▶ SunC05-2 13:45–14:00

Modified ADRC Design for Rigid-flexible Coupling Rotary Stage with Filters

Wei, Yutai Guangdong Univ. of Tech.
Yang, Zhijun Guangdong Univ. of Tech.
Bai, Youdun Guangdong Univ. of Tech.

High-precision rotary stages are applied in many fields, but the bearing friction has a negative impact on tracking performance. Rigid-flexible coupling rotary stage, a novel structure for rotary stage, can convert the friction disturbance into elastic force with flexure hinges. In order to avoid the effect of elastic force, active disturbance rejection control (ADRC) is adopted in this paper for its excellent disturbance rejection ability and independence of accurate modelling. In view of the resonance and high-frequency noise of the system, notch and lead filters are combined with ADRC, which is called modified ADRC. The experimental results show that the modified ADRC has a good effect on eliminating elastic force disturbance, and also has the ability to suppress resonance and high-frequency noise.

▶ SunC05-3 14:00–14:15

Active Disturbance Rejection Control Oriented Rigid-flexible Coupling Rotary Stage Design

Huang, Jianbin Guangdong Univ. of Tech.
Yang, Zhijun Guangdong Univ. of Tech.
Wei, Yutai Guangdong Univ. of Tech.
Huang, Xiaohong Guangdong Univ. of Tech.
Bai, Youdun Guangdong Univ. of Tech.

High precision rotary stages are widely used in the field of optical radar, laser satellite communications and the national defense. However, due to the influence of bearing friction, the stick-slide phenomenon causes the problem of speed fluctuation and large return error. In this paper, a design method for a rigid-flexible coupling rotary stage is proposed, which is designed as flexible hinges linked rotary shaft and rotary stage, friction is acting on the rotary shaft, and the drive torque and detection elements are installed on the rotary stage. Friction disturbance is converted into elastic deformation disturbance, which reduce the perturbation bandwidth and make it easier to estimate and compensate. On the other hand, the elastic deformation disturbance can be obtained directly according to stiffness and damping by measuring the deformation range and rate of flexible hinges. The deviation caused by manufacturing error and nonlinearity is estimated and compensated by ADRC. Results show that the precision are improved by more 5 times only by changing the structure design.

▶ SunC05-4 14:15–14:30

Development of Dual Feedback Active Disturbance Rejection Control Driver

Yang, Zhijun Guangdong Univ. of Tech.
Ke, Bangwei Guangdong Univ. of Tech.
Kuang, Junpeng Guangdong Univ. of Tech.
Su, Liyun Guangdong Univ. of Tech.
Sun, Han Guangdong Univ. of Tech.

Friction is the main reason that affects the accuracy of the mechanical bearing positioner. The rigid-flexible coupling stage adopts an active disturbance rejection control strategy that regards elastic vibration as a disturbance. It can convert unmeasurable friction into easily measurable elastic deformation to ensure the positioning of the micro-stage accuracy. When the Active Disturbance Rejection Control (ADRC) algorithm is used to deal with the errors caused by mass manufacturing and the geometric nonlinearity of large deformations, dual-channel synchronous feedback and low-delay disturbance calculation compensation are required. Therefore, this article develops a hybrid ARM+FPGA architecture active disturbance rejection control driver for the rigid-flexible coupling stage's needs. The integrated drive and control system includes FPGA to realize dual-channel synchronous feedback, ARM to realize position loop, speed loop, active disturbance rejection calculation, and Intelligent Power Module(IPM) to realize current amplification. FPGA has the characteristics of high-speed real-time data acquisition and parallel work, which can realize dual-channel real-time synchronous feedback. Coupled with ARM's powerful computing and flexible control capabilities, the active disturbance rejection control driver of the hybrid ARM+FPGA architecture can meet the control needs of the rigid-flexible coupling stage. This paper verifies the feasibility of the drive system scheme by controlling the rotary stage and the motor.

▶ SunC05-5 14:30–14:45

Improved Repetitive Control with Model-Assisted Extended State Observer for Optoelectronic Tracking System

Nie, Kang Chinese Acad. of Sci.
Li, Zhijun Chinese Acad. of Sci.
Guo, Tong Inst. of Optoelectronic Tech., Chinese Acad. of Sci.
Mao, Yao Chinese Acad. of Sci.

The optoelectronic tracking system is a high-precision tracking and positioning device. The uncertainties and disturbances exist in the working process, especially on the moving optoelectronic platforms in recent years. To sufficiently achieve the required motion performance, the suppression of disturbances and the robustness against uncertainties are of increasing importance. In this paper, we propose an improved repetitive control (IRC) method with model-assisted extended state observer to develop high-precision control performance. IRC can mitigate the magnitude amplification of the non-periodic disturbances caused by conventional repetitive control (CRC). This two-degree-of-freedom control framework is used with one degree to further estimate and eliminate broadband disturbances and the other to further reject periodic disturbances. And it only requires the error, input, and output signals of the system without depending on the accurate model parameters. Finally, the effectiveness of the proposed method is verified by simulation and experiment, and the improved performances on estimation accuracy and disturbance suppression are compared in the tip-tilt mirror system.

▶ SunC05-6 14:45–15:00

Practical Cascade Control for Supercavitating Vehicle

Zhou, Yu Nankai Univ.
Sun, Mingwei Nankai Univ.
Zhang, Jianhong Beijing Inst. of Aerospace Tech.
Liu, Lehua Beijing Electro-Mechanical Engineering Inst.
Chen, Zengqiang Nankai Univ.

Supercavitating vehicles, compared with other underwater vehicles, have amazing high speeds. However, the supercavitating vehicles have the unique tail-slap phenomenon in motion due to the lack of buoyancy and the existence of the planing force. In addition, there are large and unpredictable uncertainties in the hydrodynamics of the supercavitating vehicle because of the approximate understanding of this kind of mechanics. All these together impose big challenge to the controller design. In this paper, the longitudinal model of the supercavitating vehicles is adopted to carry out control investigation. A cascade control strategy is designed to coordinate depth control and avoid the planing force. In the outer-loop, the depth is controlled by the classical proportional-integral-derivative (PID) method; in the inner-loop, the control of longitudinal velocity and pitch rate use the linear active disturbance reject control (LADRC). The feasibility of the method is verified by mathematical simulation. The simulation results demonstrate the effectiveness and the superiority of the proposed strategy.

▶ SunC05-7 15:00–15:15

Trajectory Tracking Control of High-Altitude Wind Power Parafoil

Long, Xinyu Nankai Univ.
Sun, Mingwei Nankai Univ.
Piao, Minnan Nankai Univ.
Liu, Shengfei Nankai Univ.
Chen, Zengqiang Nankai Univ.

In order to attenuate the influence of the uncertainties of high altitude parafoil and environment on trajectory tracking control, active disturbance rejection control (ADRC) is used to regulate the trajectory of the high-altitude wind power parafoil. Linear extended state observer

(LESO) is designed to estimate and compensate for nonlinear disturbances of the system. The simulation results show that this method has good control precision and fast-tracking velocity.

▶ SunC05-8 15:15–15:30

A New Three-dimensional Guidance Law Based on Reduced-order Extended State Observer for Highly Maneuvering Targets

Pengjuan, Ma — ShaanXi Normal Univ.
Chen, Sen — Shaanxi Normal Univ.
Zhao, Zhiliang — Shaanxi Normal Univ.

In terminal guidance phase, this paper proposes a new three-dimensional guidance law in order to achieve high-precision interception against the highly maneuvering targets. Firstly, a reduced-order extended state observer is proposed to estimate the line-of-sight angle rate and the total disturbances composed of internal nonlinear dynamics and external disturbances. Secondly, using only the line-of-sight angle as the output signal, a three-dimensional guidance law based on the reduced-order extended state observer is designed to actively compensate for the total disturbances and guarantee the closed-loop system stability. Moreover, this paper rigorously investigates the stability of the closed-loop control system. Different from the existing analysis of extended state observer based method, the paper carefully investigates the concrete bound of system states to overcome the challenges in analyzing the total disturbance. Simulation results illustrate the effectiveness of the proposed method.

SunC06 13:30–15:30 Room I

Invited Session: Process Data Analytics and Deep Learning

Chair: Liu, Yi — Zhejiang Univ. of Tech.

Co-Chair: Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.

▶ SunC06-1 13:30–13:50

A Novel Soft-Sensor Method Combining Dynamics and Time-Lag

Hu, Fuhai — Central South Univ.
Chen, Ning — Central South Univ.
Chen, Jiayao — Central South Univ.
Gui, Weihua — Central South Univ.
Yang, Chunhua — Central South Univ.

Dynamic and time lag are the two main characteristics of industrial process data, and it is a huge challenge to establish a soft-sensing model considering these two characteristics. In this paper, a new soft-sensor method combining dynamics and time-lag is proposed. The method is based on a dynamic autoregressive latent variable model (DALM) for predicting quality variables in industrial processes. First, the dynamic probability latent variable equation, which combines probabilistic representation and dynamic modeling capabilities, is constructed between the hidden variables and the process variables. Based on this framework, the latent variable autoregressive technique is adopted to extract the process information under the known sampling time-lag by simulating the high-order Markov chain. The feasibility of the proposed method is tested on an industrial case. Detailed comparisons verify the effectiveness and superiority of the proposed model.

▶ SunC06-2 13:50–14:10

A Photovoltaic MPPT Method Based on Mnemonic Enhancement Optimization with the Use of Past Experience Data

Xia, Tao — Wenzhou Univ.
Zhang, Zhengjiang — Wenzhou Univ.
Guiting, Hu — Wenzhou Univ.
Huang, Shipei — Nanjing Univ. of Sci. & Tech.
Yan, Zhengbing — Wenzhou Univ.

The output characteristics of photovoltaic cells are easily affected by the external environment, so the study of maximum power point tracking (MPPT) technology is of great significance for improving the energy conversion efficiency of photovoltaic cells. Aiming at the problem that the traditional perturbation observation based MPPT method cannot consider the tracking speed and vibration amplitude at the same time, a mnemonic enhancement optimization (MEO) based MPPT method is proposed. This method preserves the past experience data of MPPT, and uses the experience data to estimate a good starting point for MPPT when the external environment changes. BP neural network and interpolation can be applied for the estimation of a good starting point, which can speed up the procedure of MPPT. Compared with other methods through simulations, the results demonstrate that the proposed method can significantly improve the tracking speed and adapt to severe weather.

▶ SunC06-3 14:10–14:30

Generative Manifold Learning Thermography for Non-destructive Evaluation of Defects in Composite Materials

Liu, Kaixin — Zhejiang Univ. of Tech.
Fan, Yu — Suzhou Big Vision Medical Imaging Tech. Company
Kuan, Zhang — Zhejiang Univ. of Tech.
Yang, Jianguo — Zheijiang Univ. of Tech.
Yao, Yuan — National Tsing Hua Univ.
Liu, Yi — Zhejiang Univ. of Tech.

In the non-destructive evaluation of infrared thermography, the thermographic data modeling and analysis steps play an important role in improving the inspection results. However, thermal image analysis still faces challenges such as a small number of informative images and difficulty in extracting defect features. In this work, a novel generative manifold learning thermography (GMLT) method for defect detection of composite materials is proposed. In detail, the spectral normalization generative adversarial network is used as a data augmentation strategy to generate more informative thermal images. Sequentially, the MLT-based thermographic data analysis method is adopted to extract and visualize defects in the thermal images. Experiments on carbon fiber reinforced polymers verify the effectiveness and advantages of the proposed method.

▶ SunC06-4 14:30–14:50

Adaptive PID Control for Time-varying Fermentation Processes

Wang, Zhiwen — Liming Vocational Univ.
Chen, Chongcheng — Liming Vocational Univ.
Chen, Xiaoling — Liming Vocational Univ.
Li, Dagang — Liming Vocational Univ.
Feihu, Zeng — Liming Vocational Univ.

Abstract: PID controller is a common control regulator for industrial processes and is widely used in chemical processes. However, conventional proportional-integral-derivative controller has been found insufficient for nonlinear and time-varying fermentation processes. In this work, an auto-turing neuron PID (ANPID) method based on particle swarm optimization is proposed to handle the time-varying fermentation process. Specifically, the PSO method is first adopted to initialize the parameters of PID. Then, an ANPID controller is utilized to adaptively manipulate the process. The design advantage of ANPID is that its control parameters can be updated using useful historical information. Consequently, the time-varying behavior can be captured and good control performance can be achieved. Simulation results illustrate that the proposed controller can obtain better performance than traditional PID.

▶ SunC06-5 14:50–15:10

Terminal Temperature Prediction of Molten Steel in LF Furnace Based on Stacking Model Fusion

Wang-Feng, Zhou — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Chen, Zeng — ShangHai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Lilan — Shanghai Univ.

Ladle Furnace (LF) is a kind of refining equipment outside the furnace, and the end temperature of its molten steel is an important factor affecting the quality of later finished steel. Aiming at the characteristic that it is difficult to continuously measure the temperature of molten steel in LF, based on the field data of Baosteel's LF furnace, a two-layer structure Stacking integrated model framework is designed, the first layer contains four base learners: ridge regression algorithm, support vector regression, random forest, and XGBoost, the second layer uses the XGBoost model. Based on five modeling methods of ridge regression algorithm, support vector regression, random forest, XGBoost and Stacking designed, after analyzing and selecting the main factors affecting the LF temperature, the prediction models of the LF furnace molten steel endpoint temperature were established. The experimental results show that compared with a single model, the prediction effect and stability of the Stacking model combining ridge regression algorithm, support vector regression, random forest, and XGBoost have been significantly improved. The prediction model can not only reflect the effect of different factors on LF, but also, it can predict the end temperature of LF molten steel relatively accurately. The prediction accuracy of the end temperature of molten steel at ±10℃ can reach more than 80%.

▶ SunC06-6 15:10–15:30

Root Cause Diagnosis of Plant Wide Oscillations Based Fuzzy Kernel

Granger Causality

Li, Xiangzhi — Shanghai Univ.
Wang, Jian-Guo — Shanghai Key Lab of Power Station Automation Tech., Shanghai Univ.
Shao, Huimin — Shanghai Univ.
Yao, Yuan — National Tsing Hua Univ.
Liu, Lilan — Shanghai Univ.

Plant-wide oscillations are common phenomenon in large-scale industrial processes, which once generated in one unit and can spread along flows in the whole plant, then cause product quality degradation or safety problems; thus, it is very important to diagnose the root cause. Owing to the Nonlinear characteristics of plant-wide oscillations, the kernel Granger causality is used to the solve nonlinear problem that the conventional Granger cannot deal with well, but its running speed is relatively slow. Therefore, a fuzzy kernel granger causality method is proposed in this paper for root cause diagnosis to save operation time. Through a nonlinear numerical example, the effectiveness of the proposed method is proven. In the root cause diagnosis of industrial cases, the method also can successfully and efficiently find the correct root point.

SunD01 15:40–17:10 Room D

Invited Session: System Modeling, State and Parameter Estimation (II)

Chair: Zhu, Fanglai — Tongji Univ.
Co-Chair: Guo, Shenghui — Suzhou Univ. of Sci. & Tech.

▶ SunD01-1 15:40–15:55

Functional Interval Observer for Discrete-time Switched System under Stealthy Attacks

Fan, Jianwei — Soochow Univ.
Huang, Jun — Soochow Univ.
Zhang, Yueyuan — Inst. of Automation
Che, Haochi — Soochow Univ.

This paper deals with functional interval observer design for discrete-time switched systems under stealthy deception attacks. First, the boundaries of the attack are obtained by designing interval observers. Then a two-step method to design the functional observers by zonotope is presented. For the first step, an H∞ functional observer is presented and as the second step, the zonotope method is applied to obtain the boundaries of states. An illustrative example provided in the last section demonstrates the effectiveness of the proposed method

▶ SunD01-2 15:55–16:10

Robust Zonotopic-Based Interval Fault Estimation for Multi-agent Systems with Unknown but Bounded Noise

Meng, Zhou — North China Univ. of Tech.
Xue, Tong Lai — North China Univ. of Tech.
Wang, Jing — North China Univ. of Tech., China
Chang, Wang — Beijing Aerospace Automation Research Inst.

This paper investigates the issue of robust interval fault estimation for multi-agent systems with unknown but bounded uncertainty by zonotopic method, instead of obtaining the accurate fault estimation results by point-based strategy, this paper also achieve the estimation set containing the real augmented state that is consistent with the measurement noises and disturbances, which can provide more information in practice. First, an augment multi-agent system is obtained by treating the actuator fault as an auxiliary state vector. Then, a unified global system description is generated based on undirected graph theory and an unknown input observer is designed using the global relative output estimation error vector. Under the assumption that the uncertainties are bounded in zonotopes, the observer matrices are achieved by zonotopes method which makes the P-radius of the global augmented state estimation error zonotope is not increased. Next, the upper and lower boundaries of the augmented stated are calculated at each time instant via interval hull technique. Finally, simulation results illustrated by a multi-agent systems with four linearized model of VTOL aircraft are given.

▶ SunD01-3 16:10–16:25

Security Control of Cyber-Physical Systems under Denial-of-Service Sensor Attack: A Switching Approach

Zhao, Younan — Tongji Univ.
Zhu, Fanglai — Tongji Univ.

This paper presents an observer-based security control scheme for a Cyber-Physical System (CPS). In the considered system, the feedback channel of the CPS may suffer from Denial-of-Service (DoS). To begin with, a time-delayed switching CPS model is constructed according to two different attack situations. And then, based on the switching model, an observer-based controller is designed in the cyber-layer. Meanwhile, the stability of the closed-loop system is analyzed based on H∞ stability of switching systems in view of Average Dwell Time (ADT). At last, the performance of the proposed security control scheme is illustrated by an numerical example in Simulation.

▶ SunD01-4 16:25–16:40

Study on Gradation and Classification of Faults for Permanent Magnet Synchronous Motor Systems Based on V-gap Metric

Jiang, Yan — Foshan Univ.
Yu, Wei — Foshan Univ.
Wen, Yu — Guangzhou Huali Sci. & Tech. Vocational College
Wen, Chenglin — Hangzhou Dianzi Univ.

Permanent magnet synchronous motor has become the mainstream motor of electric vehicle, elevator and other drive systems due to its high torque density, high efficiency and high reliability. Most of the existing gradation and classifications of faults in permanent magnet synchronous motor systems use the Euclidean metric method, which is extremely dependent on the physical magnitude of each component and difficult to portray the intrinsic changes of the system. In this paper, normal and fault models for permanent magnet synchronous motor systems are established under normal and different degrees of abnormal operating conditions, and classify different degrees and types of faults in a hierarchical manner based on the inter-system v-gap metric values. The simulation experiments apply the v-gap metric to the permanent magnet synchronous motor system to achieve a hierarchical classification for different degrees and different types of faults.

▶ SunD01-5 16:40–16:55

Observer Design Based on Fractional-order Model of Permanent Magnet Synchronous Motor

Wang, Zhipeng — Foshan Univ.
Yu, Wei — Foshan Univ.
Wen, Yu — Guangzhou Huali Sci. & Tech. Vocational College
Wen, Chenglin — Hangzhou Dianzi Univ.

Permanent magnet synchronous motor has become the mainstream motor of electric vehicle, elevator and other drive systems due to its high torque density, high efficiency and high reliability. The existing motor model-based fault diagnosis method does not consider the fractional characteristics of the motor, then it is difficult to effectively detect the motor's minor faults. The more accurately mathematical model describes the dynamic relationships of the system, the better performance of model-based fault diagnosis. Effective fault diagnosis relies on effective residual generation, and residual generation relies on the design of observer, so designing an effective state observer to generate residuals is the basis for achieving fault diagnosis. In this paper, two full-dimensional state observers are designed based on integer-order and fractional-order models for permanent magnet synchronous motors with fractional-order characteristics, and it is shown through simulation that more effective residual generation can be obtained based on the fractional-order model.

▶ SunD01-6 16:55–17:10

Leader-follower Consensus Control of Linear Multi-agent Systems with Unknown Disturbances

Ma, Li — Tongji Univ.
Zhu, Fanglai — Tongji Univ.

In this paper, a leader-follower asymptotic consensus control strategy is designed for a class of linear multi-agent systems with unknown external disturbances. In such a design, a reduced-order observer which can produce the asymptotical system state estimation by decoupling the unknown disturbances is presented firstly. Meanwhile, with the help of a state equivalent transformation, an interval observer is set up, and then a novel disturbances reconstruction is obtained, which is decoupled from the control input and can approach the unknown disturbances asymptotically. Subsequently, in terms of the relative estimated states between neighbors and its own disturbance reconstruction information, the consensus control protocol is proposed for each agent. It is displayed that the leader-follower consensus issue can be tackled under the developed control protocol. Finally, a simulation example is given to verify the feasibility of the presented control method.

▶ SunD01-7 17:10–17:25

Event-Triggered Fault Detection Filter for Positive Semi-Markovian Jump Systems

Li, Qiang — Hangzhou Dianzi Univ.
Zhang, Junfeng — Hangzhou Dianzi Univ.

Zhang, Shitao Hangzhou Dianzi Univ.

This paper designs an L1 fault detection filter for positive semi-Markovian jump systems with disturbances based on event-triggering scheme. First, an event-triggering strategy is presented in terms of linear inequality and a fault detection filter is proposed. Then, an augmented fault detection system is constructed. Using stochastic copositive Lyapunov function and linear programming, the filter matrices are designed for guaranteeing the positivity and stochastic L1 stability of the considered system. One illustrative example is provided to verify the effectiveness of the results in this paper.

▶ SunD01-8 17:25–17:40

Analyses of Extended Structurally Balanced Properties under Directed Signed Networks via An Algebraic Method

Du, Wen Univ. of North Texas
Wei, Yusheng Univ. of North Texas
Du, Mingjun Qilu Univ. of Tech. (Shandong Acad. of Sci.)

This paper aims at revealing the relationship between the structural balance property of a node and the right eigenvector of the Laplacian matrix associated with the zero eigenvalue through an algebraic view. First, we rewrite the Laplacian matrix in a lower triangular form, based on which we give the mathematical expression of the right eigenvector associated with zero eigenvalue. Second, according to the mathematical expression of the right eigenvector, we derive that for a node with structurally balanced neighbors, it is a structurally unbalanced (respectively, balanced) node if and only if its corresponding entry in the right eigenvector is less than (respectively, is equal to) one. Finally, due to the fact we obtained above and the definition of the structurally balanced node, we give that a node is a structurally unbalanced (respectively, balanced) node if and only if its corresponding entry in the right eigenvector is less than (respectively, is equal to) one.

SunD02 15:40–17:10 Room E

Invited Session: Data-driven Robust Control

Chair: Wu, Zhengguang Inst. of Advanced Process Control
Co-Chair: Che, Weiwei Shenyang Univ.

▶ SunD02-1 15:40–15:55

Adaptive Sliding Mode Trajectory Tracking Control of Automated Guided Vehicles with Sideslip Angle

Gao, Jian Univ. of Sci. & Tech. Beijing
Wang, Heng Univ. of Sci. & Tech. Beijing
Quan, Wei Univ. of Sci. & Tech. Beijing
Li, Qing Univ. of Sci. & Tech. Beijing
Wang, Xuanzhi Univ. of Sci. & Tech. Beijing

This paper studies the problem of trajectory tracking control for automated guided vehicles (AGVs). A novel control framework is proposed to deal with the nonlinear nonholonomic constrained systems with uncertainties. Firstly, an adaptive backstepping control law based on the AGV trajectory tracking model is designed to estimate sideslip angle online, which guarantees the kinematics system stability. Secondly, torque control inputs are designed by sliding mode strategy such that the linear velocity and angular velocity follow desired values accurately. The stability analysis shows that trajectory tracking errors are convergent and bounded. Finally, a simulation example is presented which demonstrates the effectiveness of the proposed approach.

▶ SunD02-2 15:55–16:10

Data-Driven for Affine Nonlinear System via Adaptive Control and LDI Technology

Tu, Yidong Anhui Univ.
Chen, Huan An Hui Univ.
He, Shuping Anhui Univ.

This paper investigates a novel optimal control scheme for affine nonlinear systems. With the complexity of Hamilton-Jacobi-Bellman function and the linear differential inclusion based on the neural network model is used to linearize the affine system, Meanwhile, a data-driven policy iterative algorithm is proposed to solve the relevant optimal solution. Finally, a simulation example is given to demonstrates the feasibility and applicability of the designed algorithm.

▶ SunD02-3 16:10–16:25

A 2-Dimensional Linear Non-minimum Phase Estimator Based on Dynamic Exceeded Regressor

Que, Haoyi Shenzhen Polytechnic
Sun, Pei Shenzhen Polytechnic
Su, Hongye Zhejiang Univ., China
Xu, Zhaowen Zhejiang Univ.

In the paper, we proposed a 2-dimensional non-minimum phase linear regressor, to verify that in the procedure of dynamic extended regressor and mixing, with bounded functions of time, which persistence of excitation(PE) condition is absent, the parameter estimation errors could converge to 0. And a proposition of available form is given for the systems to meet the requirements of the dynamical extended regressor. Numeral and simple pendulum examples examine the results and simulations show the effectiveness.

▶ SunD02-4 16:25–16:40

Model-Free Adaptive Control for Vehicle-Following Systems with Acceleration Uncertainties

Zhou, Changren QingDao Univ.
Che, Weiwei Shenyang Univ.
Chao, Deng Neu

In this paper, we propose a model-free adaptive control (MFAC) method to solve the vehicle-following problem for multi-vehicle systems. The considered system is affected by the nonlinear acceleration uncertainties and the unknown bounded inputs, which will lead to the performance degradation and the modeling difficulty of the vehicle system. To solve the problem, the MFAC method is used to establish an equivalent data model based on the input/output (I/O) data of the vehicle. Then, an adaptive controller is designed to control the vehicle such that all spacing errors are ultimately uniformly bounded. Finally, a numerical example is presented to testify the effectiveness of the developed method.

▶ SunD02-5 16:40–16:55

Passivity Analysis of Markov Jump Inertial Neural Networks Subject to Reaction-Diffusion

Sun, Lin Anhui Univ. of Tech.
Wang, Xuelian Anhui Univ. of Tech.
Qin, Yuqing Anhui Univ. of Tech.
Su, Lei Anhui Univ. of Tech.
Shen, Hao Anhui Univ. of Tech.
Wang, Jing Anhui Univ. of Tech.

This paper considers the passivity analysis of inertial neural networks with Markov jump parameters and reaction-diffusion terms. The original second-order differential system, by utilizing a suitable variable transformation, is transformed into a first-order one. The focus is on investigating the passive property of Markov jump reaction-diffusion neural networks. Then, based on Lyapunov stability theory, some sufficient criteria in terms of linear matrix inequality are established to guarantee the desired passive performance of neural networks.

▶ SunD02-6 16:55–17:10

Learning-based Event-triggered Adaptive Optimal Output Regulation of Linear Discrete-time Systems

Zhao, Fuyu Northeastern Univ.
Gao, Weinan Florida Inst. of Tech.
Liu, Tengfei Northeastern Univ.
Jiang, Zhong-Ping New York Univ.

In this paper, a data-driven event-triggered output-feedback control approach is proposed to solve the problem of adaptive optimal output regulation for uncertain discrete-time linear systems when only the output information is available. A crucial strategy is to develop a novel co-design scheme for the event-triggering mechanism and the data-driven optimal controller. Theoretical analysis and an application to a LCL coupled inverter-based distributed generation system demonstrate the effectiveness of the proposed learning-based, event-triggered, adaptive optimal controller design with output feedback.

▶ SunD02-7 17:10–17:25

Event-Triggered Adaptive Controller Design with Reduced-Order Observer for Constrained Nonlinear Systems

Wang, Lijie Qingdao Univ.
Liu, Yang Guangdong Univ. of Tech.
Li, Hongyi Guangdong Univ. of Tech.

This paper addresses the adaptive tracking control problem for a class of strict feedback nonlinear systems subject to input saturation and output constraint. By utilizing the designed event-triggering mechanism, the control input signals of the system are sampled aperiodically, which can reduce the number of transmissions as possible. Meanwhile, the closed-loop performance is still preserved. In addition, taking the input saturation error as the input of the constructed auxiliary system, a number of auxiliary signals are generated to deal with the effect of asymmetric

input saturation. Note that partial state in the considered system is unavailable, then a more simple reduced-order observer is introduced to estimate them. Finally, simulation results on a one-link manipulator system are presented to demonstrate the feasibility of the proposed control scheme.

▶ SunD02-8 17:25–17:40

Distributed Control Problems for Directed Signed Networks Subjected to External Interventions

Du, Mingjun — Qilu Univ. of Tech. (Shandong Acad. of Sci.)
Chen, Baicheng — Qilu Univ. of Tech.

This paper investigates the distributed control problems of directed signed networks under the influence of external interventions. The dynamic behaviors and converged values of signed networks are provided. When signed networks are structurally balanced, the bipartite consensus objective can be achieved and their terminal values have a relationship with the external interventions. However, when signed networks are structurally unbalanced, the states of all agents can converge to zero and the external interventions have no effect on the state stability of signed networks. Simulation examples are given to demonstrate the effectiveness of our developed results.

SunD03 15:40–17:40 Room F

Invited Session: Interdisciplinary Data Driven Methods

Chair: Chen, Yiyang — Soochow Univ.
Co-Chair: Ying, Haojiang — Soochow Univ.

▶ SunD03-1 15:40–16:00

Optimal Iterative Learning Control of Quantized Signals Based on Encoding-Decoding Method

Huang, Yande — Jiangnan Univ.
Zhuang, Zhihe — Jiangnan Univ.
Tao, Hong-Feng — Jiangnan Univ.
Chen, Yiyang — Soochow Univ.

This paper considers optimal iterative learning control (ILC) to solve the trajectory tracking problem of systems using a network to transmit signals. Assuming that the relative quantization error of the logarithmic quantizer is white noise uniformly distributed in a known range, a cost function in the sense of mathematical expectation is established to deal with the relative quantization error, so as to obtain an iterative update law. By combining the logarithmic quantizer with the encoding and decoding method, the system can iteratively achieve high-precision tracking with limited communication capacity. Simulations based on an electromechanical control system model is provided to validate the proposed method.

▶ SunD03-2 16:00–16:20

A Data-Driven Intelligent Medical Management System via Neural Networks

Jinhui, Yang — Chongqing Tech. & Business Univ.
Jianhui, Wang — Chongqing Tech. & Business Univ.
Xuhong, Cheng — Chongqing Tech. & Business Univ.
Guo, Zhiwei — Chongqing Tech. & Business Univ.
Yu, Shen — Chongqing Tech. & Business Univ.
Xu, Gao — Chongqing Tech. & Business Univ.

For human health, medical diagnosis plays an irreplaceable role, conventional medical diagnosis methods cannot ensure the accuracy of diagnosis due to the interference of various external factors. Therefore, this paper proposes a data-driven intelligent medical management system via neural networks(MMS-ID). The essence of this method is to predict the survival time of cancer patients with the aid of gradient boosting decision tree (GBDT) and hybrid neural network model. Firstly, GBDT screens the feature factors of matching conditions according to the set value domain, and inputs them into the neural network. Subsequently, a hybrid neural network that combines the convolutional neural network (CNN) and the long short-term memory (LSTM) model is employed to predict survival length of cancer patients. Finally, the stability of MMS-ID is analyzed and compared with a series of baseline methods. A series of experiments prove that MMS-ID has excellent performance.

▶ SunD03-3 16:20–16:40

Iterative Learning Fault-tolerant Control for Uncertain Batch Process with Actuator Fault

Wang, Lei — Jiangnan Univ.
Yang, Huizhong — Jiangnan Univ.
Tao, Hong-Feng — Jiangnan Univ.

A closed-loop iterative learning fault-tolerant control scheme is proposed for batch process with actuator faults, in which the system parameters have uncertainties simultaneously. Firstly, the batch fault-tolerant controller is designed based on the two-dimensional (2D) system theory, and the batch process of iterative learning control is transformed to an equivalent 2D Roesser model. Then the sufficient conditions for the existence of the controller are analyzed in terms of linear matrix inequality (LMI) technique, and the control gain matrices are derived from the convex optimization problems with LMI constrains. Under these conditions of all additive uncertainties on system parameters and admissible failure, the proposed controller can ensure the closed-loop fault-tolerant performance along time. Finally, the simulation on injection molding nozzle pressure control simulation indicate that the proposed method achieve the design objective well, and show excellent fault tolerance performance.

▶ SunD03-4 16:40–17:00

A Neural Network Approach to Subjective Human Face Perception Classification Based on Social Characteristics

Ying, Haojiang — Soochow Univ.
Chen, Yiyang — Soochow Univ.

Human can perceive rich information from a given face quickly and effortlessly. However, the detailed computational mechanism of face perception is still unclear. Psychologists have studied the face perception using psychophysics and neuroimaging methods for decades, but are still far from forming a converged view of classifying the perception of facial characteristics. One reason is that the facial characteristics are somewhat intertwined but the degree to which is not fully clarified. On the other hand, although having agreements on the association between facial traits and perceived social characteristics, people still perceive faces with a certain level subjectivity. In this study, the authors takes the advantage of neural network to propose an algorithm for human face perception classification. The performance of this algorithm is evaluated based on the elements of a database consisting of human face social characteristics, and the experimental results confirm its classification accuracy.

▶ SunD03-5 17:00–17:20

Multi-dimensional Data Analysis Platform (MuDAP): A Versatile Analysis Toolbox for Multi-dimensional Perception Data

Chen, Yiyang — Soochow Univ.
Qiu, Lin — Nanyang Technological Univ.
Ying, Haojiang — Soochow Univ.

Human perception is always formed by information from multiple sources with complex inner structures. When viewing a face, for instance, human vision system would automatically perceive its identity, expression, and social characteristics. However, considering the fact that many social characteristics are indeed intertwined with each other, previous researchers typically use mathematical methods like principal component analysis (PCA) to reduce data dimension for later analysis. However, correctly using PCA is hard even with statistics softwares. This paper introduces a new versatile data analysis platform, which is powered by state-of-the-art computer science technique, to propose a new analysis method dealing with multiple dimensional data analysis. The algorithm utilizes most of the available data and offers a new way to analyze and visualize the data. This platform is easy to use for researchers who are not familiar with neural network and would be practical to researchers from different disciplines dealing with human data.

▶ SunD03-6 17:20–17:40

Square Root Recursive Davidon Least Square Estimation for Feedforward Neural Networks

Sun, Mingwei — Nankai Univ.
Chen, Zengqiang — Nankai Univ.

Please see the attached file.

SunD04 15:40–17:10 Room G

Invited Session: Repetitive Control and Its Recent Advance in Practice

Chair: Quan, Quan — Beihang Univ.
Co-Chair: Ye, Yongqiang — Nanjing Univ. of Aeronautics & Astronautics

▶ SunD04-1 15:40–15:55

An Enhanced Fuzzy Repetitive-Control Design and Optimisation Method Based on 2D Performance Index

Zhang, Manli — China Univ. of GeoSci.
Wu, Min — China Univ. of GeoSci.
Tian, Shengnan — Inst. of Automation
She, Jinhua — Tokyo Univ. of Tech.

This paper concerns the design and optimisation of two-dimensional (2D) repetitive control of nonlinear systems based on the Takagi-Sugeno (T-S) fuzzy model. First, a continuous-discrete 2D model of nonlinear

repetitive-control systems based on T-S fuzzy model is constructed by utilizing the 2D characteristics of continuous control and discrete learning actions in the repetitive-control process. Next, a fuzzy Lyapunov-Krasovskii functional derives the linear-matrix-inequality-based stability condition with a low conservatism. Two positive and two nonzero parameters in the fuzzy Lyapunov-Krasovskii functional tune the control and learning actions. Then the particle swarm optimisation algorithm based on a 2D performance index searches for the best parameter combination, resulting in the optimal 2D controller gains. A numerical example is given to demonstrate the effectiveness of the method.

► SunD04-2 15:55–16:10

The Problem of Identification Parameter Data Saturation in Repetitive Control and Its Solution

Yongpan, Song — North Univ. of Tech.
Zeng, Shuiping — North China Univ. of Tech.
Yutao, Zhang — North Univ. of Tech.

In the repetitive control of tracking periodic signals based on the principle of internal model, the control effect has a great relationship with the parameters of the controlled system. If the system is affected by noise and causes the internal parameters to change, failure to obtain the repeated control of the internal parameters in time will cause the system to lose stability. Therefore, how to quickly identify the parameters of the controlled system is particularly important in the field of repetitive control. In the actual process, the traditional least square method is often used to identify the parameters of the controlled system. However, the convergence of the algorithm to parameter identification is very slow. Once the controlled system parameters are changed, the parameter information provided by the new data cannot be updated in time, and the convergence of the identification results is very slow. In order to overcome the data saturation phenomenon of the least squares algorithm, this paper uses three methods of forgetting factor algorithm, variable gain matrix algorithm, and introducing additional matrix R algorithm to improve the traditional least squares identification algorithm, and verified these three through MATLAB simulation. Effectiveness of the method. Compared with traditional methods, the improved three identification methods can speed up the convergence of parameter identification and improve the accuracy of parameter identification.

► SunD04-3 16:10–16:25

Fractional-Order New Generation of 6k±1-Order Repetitive Control for Three-phase Grid-connected Converters

Wang, Wei — Jiangnan Univ.
Lu, Wenzhou — Jiangnan Univ.
Zhou, Keliang — Wuhan Univ. of Tech.
Fan, Qigao — Jiangnan Univ.

This paper proposed a fractional-order new generation of 6k±1-order repetitive control scheme (FO-NG-6k±1 RC). FO-NG-6k±1 RC is composed of NG-6k±1 RC and a Farrow structure fractional delay filter based on Taylor series expansion. Since 6k±1 RC/FO-NG-6k±1 RC occupies less digital memory space, it has better dynamic performance than CRC/FO-CRC, which is more suitable for the control of three-phase power systems dominated by the 6k±1-order harmonics. By updating filter coefficients online in real time, FO-NG-6k±1 RC can quickly and effectively deal with the frequency variations of grid-connected converters, and has good frequency adaptability. Through a simulation example applied to a three-phase grid-connected inverter, the effectiveness and superiority of the proposed FO-NG-6k±1 RC control scheme are fully verified.

► SunD04-4 16:25–16:40

A Frequency Adaptive PIMR-Type Repetitive Control for A Grid-Tied Inverter

Zhao, Qiangsong — Zhongyuan Univ. of Tech.
Chen, Sainan — Zhongyuan Univ. of Tech.
Ye, Yongqiang — Nanjing Univ. of Aeronautics & Astronautics

A proportional integral multiresonant-type repetitive control (PIMR-type RC) has not only a better harmonic suppressing performance but also a faster error convergence rate. However, the harmonics suppressing performance of PIMRtype RC will significantly decrease when the grid fundamental frequency fluctuates in a large range. In this paper, an improved frequency adaptive PIMR-type RC (FA-PIMR-type RC) is proposed to cope with the frequency fluctuation in a large range. The improved PIMR-type RC is based on fractional delay filter which can be approximately realized by finite impulse response (FIR) filter. The varying fractional delay filters ensure that the resonant frequencies can match the actual reference frequency and harmonic frequencies. The synthesis, stability analysis, and parameters design criteria of the proposed FA-PIMR-type RC are given in this paper. The experimental results show that the improved PIMR-type RC can track grid reference signal, suppress harmonic signals and have good error convergence rate under grid frequency fluctuation.

► SunD04-5 16:40–16:55

Double-fractional OPIMR Controller for A Single-phase Grid-tied Inverter

Liao, Wudai — Zhongyuan Univ. of Tech.
Yifei, Sun — Zhongyuan Univ. of Tech.
Zhao, Qiangsong — Zhongyuan Univ. of Tech.
Chen, Shasha — Zhongyuan Univ. of Tech.

The odd PIMR-type (OPIMR) controller can provide high gains at the fundamental frequency and its odd harmonic frequencies, and has a wider bandwidth and a faster response speed compared with PIMR controller. However, OPIMR controller with integer order phase compensation may be overcompensation or under-compensation and the performance of tracking and suppression decreases in face of a low-sampling frequency and a fluctuation fundamental frequency. Therefore, a double-fractional OPIMR (DF-OPIMR) controller is proposed in this paper. The fraction-order approximation of delay link N under the fluctuation of grid frequency makes the DF-OPIMR controller more adaptable to the change of power grid frequency. The DF-OPIMR controller with a fractional item zm has a precise phase compensation. In this paper, the stability of DF-OPIMR controller is analyzed, and the simulation is given to demonstrate the effectiveness and feasibility of the scheme.

► SunD04-6 16:55–17:10

Suppression of Space-induced Periodic Disturbances Using Modified ILC Algorithm

Wu, Aijing — Harbin Inst. of Tech.
Huo, Xin — Harbin Inst. of Tech.
Liu, Qingquan — Harbin Inst. of Tech.
Ma, Jie — Harbin Inst. of Tech.

This paper aims to devise a modified iterative learning control (ILC) algorithm with orthogonal projection to enhance the space-induced periodic disturbances rejection performance. Iterative learning control is known as an effective technique for improving the performance of systems that require repetitive work, using the error signal from the previous cycle to update the control input. To make problem tractable, based on structural information about the plant and the disturbances, we determine some basis functions which concentrate the repetitive error. Here, the error signals caused by the disturbances are extracted by projecting the overall error signals onto a subspace spanned by these basis functions. Moreover, a data-driven approach is proposed to design the learning gain. In the end, numerical simulations are provided to demonstrate the efficacy and effectiveness of the proposed algorithm.

► SunD04-7 17:10–17:25

On Digital Periodic Controllers

Zhou, Keliang — Wuhan Univ. of Tech.

In this paper the Internal Model Principle (IMP) based periodic controllers is present, which refers to a family of algorithms that incorporate a periodic signal model to enable perfect periodic signal compensation, such as resonant control, repetitive control, and so on. A universal way to the analysis and design of digital periodic control systems is presented. A numerical case study is given to demonstrate the validity of the proposed method.

► SunD04-8 17:25–17:40

Generalized-reduced-order-extended-state-observer-based Adaptive Repetitive Control for Brushless DC Motor

Gao, Dongxu — Hunan Univ. of Sci. & Tech.
Zhou, Lan — Hunan Univ. of Sci. & Tech.
Pan, Changzhong — Hunan Univ. of Sci. & Tech.
Liao, Changchao — Hunan Univ. of Sci. & Tech.

This paper presents a method of designing a generalized-reduced-order-extended-state-observer-based (GROESO-based) adaptive repetitive control system for a brushless DC motor with time-varying parameter uncertainty and unknown nonlinear dynamics. In this system, GROESO-based control is used to estimate and compensate the mismatched nonlinear dynamics, model-reference adaptive control (MRAC) is used to suppress the matched parameter uncertainty, and repetitive controller undertakes the task of tracking periodic reference input signal. By appropriately choosing a disturbance compensation gain for GROESO-based control and adaptive parameters for MRAC, the influ-

ences of the nonlinear dynamics and parameter uncertainty are effectively attenuated. A feedforward compensator for repetitive control is also designed. Simulation results show that the designed brushless DC motor servo system achieves both satisfactory disturbance-rejection and tracking performances.

SunD05 15:40–17:10 Room H
Invited Session: High Order Differential Feedback Control and ADRC
Chair: Qi, Guoyuan Tiangong Univ.
Co-Chair: Chen, Zengqiang Nankai Univ.

▶ SunD05-1 15:40–15:55
Accurate Homing Control of Parafoil Delivery System Based on Active Disturbance Rejection Control
Sun, Hao Nankai Univ.
Sun, Qinglin Nankai Univ.
Tao, Jin Nankai Univ.
Chen, Zengqiang Nankai Univ.

In order to realize the accurate homing control of the parafoil delivery system, in this paper, firstly an eight-degree of freedom model of the parafoil delivery system is built. Then, an active disturbance rejection controller is designed for the accurate trajectory tracking. The control system, including the embedded controller, ground station, steering engine and power plant, is built for the flight test. The detailed simulation results and the flight experiments prove the correctness of the proposed controller. The tracking and landing errors are all less than 20m.

▶ SunD05-2 15:55–16:10
Load Frequency Active Disturbance Rejection Control for An Interconnected Power System via Deep Reinforcement Learning
Wang, Yongshuai Nankai Univ.
Chen, Zengqiang Nankai Univ.
Sun, Mingwei Nankai Univ.
Sun, Qinglin Nankai Univ.

Load frequency control is an important issue in power systems, so focusing on the typical two-area interconnected power system with non-reheat turbines, this paper designed the learning active disturbance rejection controller to achieve intelligent and adaptive tuning of control parameters, in which the deep reinforcement learning is adopted to adapt to unexpected uncertainties and faults, even a new environment. Finally, numerical simulations show the better performance of the learning controller, and the strong capability to deal with uncertainties and disturbances comparing with the general LADRC controller.

▶ SunD05-3 16:10–16:25
ESO Accuracy Problems, Proposal of Compensation Function Observer for Nonlinear System and Applications
Qi, Guoyuan Tiangong Univ.
Li, Xia Tiangong Univ.
Chen, Zengqiang Nankai Univ.

The observation or estimate of the unknown model function and disturbance of nonlinear system has much-attracted attention for the control methods being independent of the model. The accuracy of observation of unknown function is greatly essential, which relates to the stability, convergence of tracking, and robustness of closed-loop systems. The extended state observer (ESO) has been widely applied in model-free control. In the ESO, three factors: structure, innovation usage and unknown character of nonlinear functions, causing the problems of low type and accuracy of observation of unknown functions are identified. A simple linear compensation function observer (CFO) is proposed. The CFO adopts the derivative form overcoming the structure problem of the ESO, fully uses the available innovation, and then introduces a compensator of the unknown function. The filtering implementation of the compensator counteracts the effect of the time-varying nonlinear unknown model to make the error equation behave with desired poles, and recursively uses the gained innovation to update the observation. The compensator in CFO acts the role of integrator, which integrates the gained innovation to increase the type of system. The convergence of observation function to the unknown function for the CFO is theoretically proved. The CFO is a Type-III system that is the highest type for a third-order system. Yet, the ESO is a Type-I system, which makes the CFO have a qualitative leap over the ESO in accuracy improvement for the specific functions and fast change functions. The chaotic Duffing system and chaotic attitude system of a small-scale unmanned aerial vehicle (UAV) helicopter are conducted to test performances of both the ESO and the CFO. The CFO is a decoupling model-free scheme in terms of observation and control. It is capable of observation of nonlinear function, including lumped disturbance, coupling effect, uncertainties, unmodeled parts for both SISO and MIMO nonlinear systems. And its performance of function observation is highly improved over that of ESO for the second-order systems of tested systems.

▶ SunD05-4 16:25–16:40
Model-free Attitude Control for Quadrotor UAV via An Improved High Order Differential Feedback Control Scheme
Li, Xia Tiangong Univ.
Qi, Guoyuan Tiangong Univ.
Guo, Xitong Tiangong Univ.
Ma, Shengli Tiangong Univ.
Zhao, Xu Tiangong Univ.

Quadrotor unmanned aerial vehicle (QUAV), as vertical take-off and landing aircraft with hovering capability, has received growing attention due to its capability to outperform most of other types of helicopters on the issues of maneuverability, survivability, simplicity of mechanics. However, the QUAV system implements 6 DOF by controlling the speed of the four rotors, resulting in a strong coupling between the attitude rotation and translational motion. Moreover, attitude rotation is the foundation of translational motion control, which requires both accuracy and rapidity. Besides, the quadrotor system highly nonlinear with some parameters being dependent on the characteristics of the flight and sensitive to disturbance, which will inevitably lead to errors in modeling. Therefore, the development of specialized controllers that could consider the quadrotor's modeling nonlinearities and unknown uncertainties while reacting to external disturbance is desired. In the actual quadrotor attitude systems, the classic PID controller is still widely used since it does not depend on the system precise mathematical model but only the given reference and measurable system output. In particular, the cascade PID improves the oscillation problem of single-stage PID due to angular velocity control. However, the PID control will produce the steady-state error when the system is subjected to constant unknown external disturbance, so the general PID is not robust. To estimate and compensate for total disturbance such as unknown uncertainties and external disturbances of the attitude system, the model-free control based on the observer is a suitable choice to enhance the system's robustness. In recent years, the active disturbance rejection control (ADRC) technology based on extended state observer (ESO) has attracted wide attention, but the estimation accuracy of ESO is limited by bandwidth, and the differential information of a given reference is usually ignored, which will reduce the tracking accuracy of the system. Meanwhile, the high order differential feedback control (HODFC) based on the high order differentiator (HOD) and a control filter is also a method with strong anti-disturbance ability. However, the original HOD, which only depends on the system measurable output but does not consider the influence of the system control input, is used to extract the differential and high order differential of the signal. The control filter indirectly compensates for the total disturbance. According to our best knowledge, the HOD has not been used to estimate total disturbance. Based on the above observation, a double closed-loop cascade control strategy is proposed in this paper for the attitude tracking control of QUAV. The PID is used to control the angle tracking reference in the outer loop. A novel model-free controller based on an improved HOD is used to ensure the angular velocity tracking the desired in the inner loop. An improved HOD is proposed to estimate total disturbance and angular accelerations based on the control input and measured angular velocity. Based on the estimated total disturbance, an improved high order differential feedback control (IHODFC) is designed to stabilize the closed-loop system. The convergence analysis of the observer shows that the improved HOD can greatly reduce the bandwidth compared with the ESO without reducing the accuracy of the estimation. The experimental verification platform based on Pixhawk demonstrates the effectiveness of the proposed cascade control strategy using IHODFC. Compared with the inner loop general PID, ADRC and HODFC methods, the proposed IHODFC has smaller tracking errors, faster error convergence speeds, and stronger disturbance rejection.

▶ SunD05-5 16:40–16:55
High Order Differentiator Based Model-independent Sliding Mode Control and Its Application in Quadrotor UAV
Yu, Xinchen Tiangong Univ.
Qi, Guoyuan Tiangong Univ.

Sliding mode control (SMC) has been widely used in nonlinear systems because of its good robustness, simple algorithm, and easy online implementation. In recent years, with the development of composite materials, power systems, sensors, and other technologies, the research

of unmanned aerial vehicle (UAV) systems represented by quadrotors has been rapidly developed. The design and research of the quadrotor UAV control system have increasingly become the focus of attention. The control output obtained by the traditional sliding mode controller contains the information of the system model. However, the quadrotor UAV dynamic model has strong nonlinearity and coupling, causing great difficulties in modeling. Even if a more accurate mathematical model is established, it will inevitably be affected by internal structure and external interference during actual flight. Previously, a high-order differentiator (HOD) for estimating signal derivatives of different orders, and a model-free control high-order differential feedback control (HODFC) based on the estimated signal derivatives were proposed. They have been successfully applied to the control systems of the UAV and the robotic arms. This paper combines traditional SMC technology with HOD, proposes a model-independent sliding mode control (MISMC) based on HOD, and applies it to the position and attitude control of quadrotor UAV. The fourth-order HOD is used to accurately estimate the derivatives of the reference signal and the actual output signal of each channel. The unknown part of the controlled model is compensated by the second derivative of the output signal and the filtered signal of the control output. The designed control quantity obtained by MISMC only needs the given signal and the output signal collected by the sensor. It does not need other information in the model of the system and realizes independent model control. Besides, this paper proves the Lyapunov stability of fourth-order HOD and MISMC. Simultaneously, the range of parameter selection is determined, so that the MISMC scheme used in UAVs is easier to operate. To prove the performance and effectiveness of the proposed MISMC, numerical simulation results have been obtained and compared with the corresponding results of PID control and HODFC.

▶ SunD05-6 16:55–17:10

Model Predictive Control Based on High Order Differentiator and Its Application in Quadrotor Trajectory Control

Zhao, Xu — Tiangong Univ.
Qi, Guoyuan — Tiangong Univ.
Li, Xia — Tiangong Univ.
Guo, Xitong — Tiangong Univ.
Ma, Shengli — Tiangong Univ.

Abstract: UAV technology has a wide range of application scenarios in military, rescue, 3D map modeling and other fields. In the process of trajectory control, the environment perception, planning and decision-making methods of UAVs are closely related to UAV control. The quadrotor UAV has the advantages of simple structure, strong maneuverability, low cost and wide application. Therefore, this article uses the quadrotor UAV model to simulate in MATLAB. Since the quadrotor system is highly nonlinear, some of its parameters depend on flight characteristics and are sensitive to interference, which will inevitably lead to steady-state errors. However, due to the internal kinematics and dynamics of the quadrotor trajectory tracking control, if the kinematics and dynamics constraints cannot be effectively reflected in the control process, a good control effect cannot be obtained. In the actual QUAV position control system, because the PID controller does not rely on the system's precise mathematical model, it is still widely used. However, due to its independent model characteristics, the PID controller cannot integrate the kinematics and dynamics. The constraints are reflected effectively, so its robustness is poor. Therefore, we use the model predictive control (MPC) controller to control the position of the drone. The model predictive control (MPC) is a form of control, in which the current state of the UAV is taken as the initial state, and the current control effect is obtained by solving the finite level open-loop optimal control problem at each sampling time. Optimization produces the best control sequence and applies the first control in the sequence to the drone. An essential advantage of this kind of control is that it can cope with strict restrictions on controls and states. The MPC has its natural advantages in multi-model constraint processing after combining with a high order differentiator (HOD). The HOD is used to extract the differential information of each order of the signal. The stability, single parameter and high-precision characteristics of the HOD are analyzed using the root locus. The MPC uses the given and output signal differential information extracted by the HOD. And the HOD is used to process positioning information to obtain UAV position and speed information. The main work of this paper is to use HOD to process the UAV's position information, obtain its position and speed information, and use this information to design a HOD based MPC to control the UAV's trajectory.

▶ SunD05-7 17:10–17:25

Root Locus and b_0 Selection of First-Order Linear Active Disturbance Rejection Control Systems

Jin, Huiyu — Xiamen Univ.
Kaicheng, Huang — Xiamen Univ.

This paper investigates first-order linear active disturbance rejection control (LADRC) with root locus approach. It re-proves that for the first-order plant, if b_0 has a correct sign, then the stability of the LADRC system can be guaranteed by tuning parameters, no matter the plant is stable or not. With theoretical analysis and numerical examples, it shows b_0 can be viewed as a tuning parameter and tuning b_0 along root locus may improve the system's performance.

▶ SunD05-8 17:25–17:40

On Observability Analysis and Observer Design for A Class of Nonlinear Uncertain Systems with General Elastic Vibration Dynamics

Zhang, Xiaoyan — Chinese Acad. of Sci.
Xue, Wenchao — Chinese Acad. of Sci.
Zhao, Yanlong — Chinese Acad. of Sci.

This paper focuses on the observability analysis for a general class of rigid-flexible coupling systems constituted of rigid-body mode and elastic vibration modes with uncertain dynamics and disturbances. And the measured output is a linear combination of rigid-body mode and elastic vibration modes. Firstly, the necessary and sufficient condition of the observability for such system is given. Secondly, the general extended state observer design is proposed to estimate the states of both rigid-body mode and elastic vibration modes as well as "total disturbance". Next, the convergence of estimation errors of the general extended state observer is discussed. Then, under unobservable case, a compressed extended state observer is designed to estimate the states and the "total disturbance" acting on rigid-body mode and the corresponding estimation errors are studied. In addition, the theoretical results are demonstrated via the simulation on a rigid-flexible coupling system.

SunD06 15:40–17:10 Room I

Invited Session: RNN for Computing and Its Applications

Chair: Jin, Long — Lanzhou Univ.
Co-Chair: Sun, Zhongbo — Changchun Univ. of Tech.

▶ SunD06-1 15:40–15:55

A Cluster Water Quality Parameter Collection and Cloud Analysis System Based on A Non-Equidistant ROGM (1,1)

Lian, Yufeng — Changchun Univ. of Tech.
Li, Binglin — Changchun Univ. of Tech.
Sun, Hongliang — Changchun Municipal Engineering Design & Research Inst.
Sun, Weining — Changchun Municipal Engineering Design & Research Inst.
Zhang, Xuesong — CRRC Changchun Railway Vehicles Co.,Ltd

This paper presents a cluster water quality parameter collection and cloud analysis system, which is based on a NEROGM (1,1) to predict water quality accurately with non-equidistant stochastic oscillation sequences. Taking into account the non-equidistant characteristics of original data for water quality, a non-equidistant transformation is given to make a non-equidistant sequence become an equidistant sequence. Combining with the prediction capability of the traditional ROGM (1,1) for equidistant stochastic oscillation sequence, a NEROGM (1,1) is proposed to predict water quality. The water quality parameters can be collected centrally by Modbus to model NEROGM (1,1)s for different water quality parameters. The prediction data obtained by NEROGM (1,1) can be transmitted to cloud analysis system by 4G network. With the water quality parameters in Jilin province different areas, a cluster water quality parameter collection and cloud analysis system is carried out, and the effectiveness and feasibility is demonstrated. The cluster water quality parameter collection and cloud analysis system will provide guiding significance for water environment management.

▶ SunD06-2 15:55–16:10

LS-SVM Combined with ZNN for Predicting the Continuous Motion Joint Angle of Lower Limb

Zhang, Xin — Changchun Univ. of Tech.
Liu, Keping — Changchun Univ. of Tech.
Li, Chunxu — Univ. of Plymouth
Yi, Jiang — Medicine of the Second Hospital of Jilin Univ.
Duan, Xiaoqin — Medicine of the Second Hospital of Jilin Univ.
Sun, Zhongbo — Changchun Univ. of Tech.

In this paper, a method fusing least squares support vector machine (LS-

SVM) with Gaussian kernel function and zeroing neural network (ZNN) is proposed to forecast the continuous motion of lower limb. The surface electromyography (sEMG) signal contains human behavior information and directly reflects the movement intention. In the experiment, the sEMG signal of the lower limbs when the tester is doing leg extension exercise is collected and the real knee joint angle is recorded at the same time. Then the raw sEMG is subjected to a series of preprocessing, and the corresponding muscle activation is gained by calculation. The muscle activation is used as input to the LS-SVM model, and the output to the model is the knee joint angle. LS-SVM transforms the original problem into solving linear equations. When the amount of data is relatively large, the traditional solution method is very time-consuming, and the proposed ZNN method is able to solve the problem, thus speeding up the convergence speed and greatly reducing the learning time. Finally, the back propagation neural network (BPNN) model is utilized to form a comparative experiment. The numerical results indicate that a more stable and better performance is reflected in the raised method, which provides a valuable reference for the research of joint continuous estimation.

▶ SunD06-3 16:10–16:25

An Iterative Learning Algorithm Based on RBF Neural Network in Upper Limb Rehabilitation Robot

Zaixiang, Pang	Changchun Univ. of Sci. & Tech.
Tongyu, Wang	Changchun Univ. of Sci. & Tech.
Shuai, Liu	Changchun Univ. of Tech.
Zhanli, Wang	Changchun Univ. of Tech.
Zhang, Xiyu	,Changchun Univ. of Tech.
Hao, Yan	Changchun Univ. of Technolog

Aiming at the non-linearity and uncertainty of patient spastic disturbance in the trajectory tracking control of upper limb rehabilitation robot, an iterative learning control algorithm is proposed based on RBF neural network. This paper considers repetitive nature of the rehabilitation robot system, the algorithm combines a single hidden layer feedforward neural network with iterative learning. In the upper limb rehabilitation process, the algorithm accelerate the convergence speed of the trajectory tracking error, and quickly suppress the interference in the interference environment. The Lyapunov stability theory is used to prove the globally asymptotic stability of the closed-loop system, then simulation proves the feasibility and effectiveness of the proposed algorithm.

▶ SunD06-4 16:25–16:40

A Gradient Neural Network for Online Solving the Time-varying Inverse Kinematics Problem of Four-wheel Mobile Robotic Arm

Zhou, Yanpeng	Changchun Univ. of Tech.
Liu, Keping	Changchun Univ. of Tech.
Li, Chunxu	Univ. of Plymouth
Wang, Gang	Changchun Univ. of Tech.
Liu, Yongbai	Changchun Univ. of Tech.
Sun, Zhongbo	Changchun Univ. of Tech.

In this paper, a gradient neural network (GNN) is presented, analyzed and discussed to solve the time-varying inverse kinematics solution of the four-wheel mobile robotic arm, which can approximate the time varying inverse kinematics solution. A monolithic kinematics model of mobile robotic arm is established, and the inverse kinematics solution can synchronously coordinate the control of the mobile platform and the robotic arm to accomplish the task of the end-executor. Besides, the computer numerical results are provided to attest validity and high exactitude of GNN model in settling the time-varying inverse kinematics of a four-wheel mobile robotic arm.

▶ SunD06-5 16:40–16:55

New Stochastic Gradient Descent Algorithm via Lagrange-type 1-step-ahead Numerical Differentiation

Luo, Wendi	Lanzhou Univ.
Liu, Mei	Lanzhou Univ.
Chen, Liangming	Univ. of Chinese Acad. of Sci.
Bo, Peng	Chinese Acad. of Sci.

The method that stochastic gradient descent (SGD) algorithm uses to update the undetermined parameter in the iterative process can be viewed as a rudimentary forward Euler method in the perspective of numerical differentiation. In order to overcome the connatural imperfection of the forward differentiation rule and computation error of the SGD algorithm, a new algorithm is obtained by substituting the original updating rule in SGD with the Lagrange-step 1-step-ahead differentiation rule. In addition, extensive experiments between the original SGD algorithm and the modified algorithm are conducted to analyze the convergence. Empirical results demonstrate that Lagrange-step 1-step-ahead can not be used to the SGD algorithm and the new algorithm does not converge. Theoretical analysis is given to explain this result.

▶ SunD06-6 16:55–17:10

Design and Implementation of A Novel Quadruped Robot

Lin, Wenqi	Lanzhou Univ.
Bo, Peng	Chinese Acad. of Sci.
Jin, Long	Lanzhou Univ.

Legged robots have unparalleled advantages over the traditional four-wheel and crawler ones. Particularly, they possess higher maneuverability in complex environments and can play a more significant role in military and emergency missions. To adapt the legged robot to the above situations, the primary task is to make the robot move freely like a human or animal, but this is a complicated and expensive project. The paper is dedicated to designing a novel and cheap quadruped robot and developing a complete and adequate control system. The overall design architecture is proposed, focusing on ease of manufacture and low cost of manufacture. Specifically, the control system runs on stm32, and the movement of the quadruped robot is controlled by a direct current motor that can be driven towards different directions by manipulating the terminal control device. Among the quadruped robots of similar performances, the quadruped robot BlackDog is cheaper and more stable in walking, and its structure is simple and easy to be implemented.

▶ SunD06-7 17:10–17:25

MKE Scheme for the Control of Dynamic Constrained Redundant Robots Based on Discrete-time Neural Network

Liu, Baiyang	Lanzhou Univ.
Su, Dan	Lanzhou Univ.
Liu, Mei	Lanzhou Univ.
Shi, Yang	Yangzhou Univ.
Li, Shuai	Lanzhou Univ.

It is necessary to make physical constraints on the joints for the redundant robot motion control in order to avoid damage. In this paper, a discrete-time neural network model with minimum kinetic energy as the performance index is proposed, which has predominant convergence performance. Then, a solution in robot motion control is studied and further transformed into a dynamic quadratic programming (QP) with equality and inequality constraints. In addition, for solving the formulated QP problem, a continuous-time neural network model is designed by introducing the Lagrange multiplier method, and a discrete-time neural network model is obtained by the Euler forward difference formula. Moreover, the simulations on robot motion control are carried out, and the simulative results further substantiate the superiority, thus extending a solution for motion control of redundant robots with double-bound constraints.

▶ SunD06-8 17:25–17:40

Multiple Object Tracking and Trajectory Recognition Based on Deep Learning

Zhang, Zhen	Nantong Univ.
Jiang, Ping	Nantong

In automobile plastic parts factory, the workers need to check every automotive plastic assembly whether the fastening buckle is missing. This manual method is inefficient. To solve this problem, the space and channel attention mechanism is applied to YOLOv3-tiny network, which uses K-means clustering to find the best suitable size of anchor box. This algorithm has significantly improved detection accuracy in fastening buckles in comparison with original YOLOv3 algorithm, and the speed has increased by 3 times. Threshold segmentation and Hu comparison method are adopted to correct the confidence of the detection target with weight, so as to filter out the false target. Finally, the Lucas-Kanade optical flow method and the Delay-precision mechanism are used to realize the tracking and recognition of the fastening buckle of the automobile plastic assembly. In the experiment of fastening buckle video sequence, the MOTA(Multiple-Object Tracking Accuracy) of this algorithm is about 3.9%～7.6% higher than other algorithms. In 200 experiments, the recognition accuracy of automotive plastic components and fastening buckles reaches 100%.

Program at a Glance

Friday, May 14, 2021, Tongli Lakeview Hotel, Suzhou (苏州同里湖大饭店)									
14:00	Lobby			Function room B					
14:00-17:00	Register			Pre-Conference Workshop: MFAC Progress and Applications					
Saturday, May 15, 2021, Tongli Lakeview Hotel, Suzhou (苏州同里湖大饭店)									
8:00-8:30	Opening ceremony, Venue: *International Hall and Function room A+B+C (Synchronous Network),* Chair: Prof. Jing Wang								
8:30-9:20	Keynote Address 1: Applications and Development Trend of Key Technologies for Multi-robots Collaboration, Prof. *Yaonan Wang*, Chair: Prof. Chenghong Wang								
9:20-9:40	Tea Break and Photo								
9:40-10:30	Keynote Address 2: Control of Linear Systems Subject to Actuator Saturation: from Model-based Design to Reinforcement Learning Control, Prof. *Zongli Lin*, Chair: Prof. Mingxuan Sun								
10:30-11:20	Keynote Address 3: Fault Diagnosis, Prediction and Fault-Tolerant Control Technology for Traction Drive System of High-Speed Train, Prof. *Bin Jiang*, Chair: Prof. Xiongxiong He								
11:20-12:20	Panel Discussion: Control Science in the Era of Big Data and Artificial Intelligence, Prof. *Yaonan Wang*, Prof. *Chenghong Wang*, Prof. *Bin Jiang*, Prof. *Long Wang*, Chair: Prof. Zhongsheng Hou								
12:20-13:30	Lunch								
Time/Room	Function room A+B+C (Synchronous Network)								
13:30-14:20	Keynote Address 4：Digital Twins for Distributed Fault Detection in the Process Industry, Prof. *Thomas Parisini*, Chair: Prof. Huaguang Zhang								
Time/Room	Function room B			Function room A			Function room C		
14:20-15:00	Distinguish Lecture 1: Fault Diagnosis Technology for Brake Control System of High-Speed Trains, Prof. *Xiao He*, Chair: Prof. Zengqiang Chen			Distinguish Lecture 2: Stabilization of Boolean Control Networks, Prof. *Zhengguang Wu*, Chair: Prof. Youqing Wang			Distinguish Lecture 3: Cooperative Control and Its Applications of Unmanned Autonomous Systems, Prof. *Hongyi Li*, Chair: Prof. Jing Na		
15:00-15:40	Distinguish Lecture 4: Filtered Repetitive Control with Nonlinear Systems, Prof. *Quan Quan*, Chair: Prof. Xuhui Bu			Distinguish Lecture 5: Online Operating Performance Assessment of Hydrocracking Process Under Uncertain Information, Prof. *Yalin Wang*, Chair: Prof.Deqing Huang					
15:40-16:00	Tea Break								
Time/Room	Function room B	Function room A	Function room C	Room D	Room E	Room F	Room G	Room H	Room I
16:00-18:00	SatA01	SatA02	SatA03	SatA04	SatA05	SatA06	SatA07	SatA08	SatA09
16:00-18:00	Best Paper	IS: Distributed learning and control for MAS	IS: Data-based cooperative control of networked systems	Statistical learning and machine learning in automation field	Model-free adaptive control	IS: AI and its Applications on Fault Diagnosis and Image Processing	Iterative learning control	Neural networks, fuzzy systems control in data driven manner (I)	IS: Big Data in Smart Grid
18:00-20:00	Dinner								
Sunday, May 16, 2021, Tongli Lakeview Hotel, Suzhou (苏州同里湖大饭店)									
Time/Room	Function room B	Room D	Room E	Room F	Room G	Room H	Room I	Corridor	
8:00-12:30	Forum	SunA01	SunA02	SunA03	SunA04	SunA05	SunA06	SunA07	
8:00--10:00	Industrial Control Practice Forum Chair: Prof. Ronghu Chi	Applications of data-driven methods to industrial processes	IS: Data-Based Cooperative Control of Networked Systems	Data-driven modeling, optimization and scheduling	IS: Data-Driven Technologies in Robotic Systems	Data-driven fault diagnosis and health maintenance (I)	IS: Learning-based adaptive control and applications (I)	Poster session (I)	
10:00-10:10	Tea Break								
Time/Room	Function room B	Room D	Room E	Room F	Room G	Room H	Room I	Corridor	
10:10-12:10	Forum	SunB01	SunB02	SunB03	SunB04	SunB05	SunB06	SunB07	
10:10-12:10	Laoshan Academic Forum Chair: Prof. Zhongsheng Hou	IS: Deep learning for industrial big data analytics	IS: Control and filtering of Markov jump systems	Data driven control	Neural networks, fuzzy systems control in data driven manner (II)	Data-driven fault diagnosis and health maintenance (II)	IS: Learning-based adaptive control and applications (II)	Poster session (II)	
12:10-13:30	Lunch								
Time/Room	Room D	Room E	Room F	Room G	Room H	Room I			
13:30-15:30	SunC01	SunC02	SunC03	SunC04	SunC05	SunC06			
13:30-15:30	IS: System modeling, state and parameter estimation(I)	IS: Reinforcement learning and optimal control	IS: Data-driven modeling and adaptive ILC	IS: Learning-based control and its applications	IS: ADRC and its Advance in Motion Control	IS: Process Data Analytics and Deep Learning			
15:30-15:40	Tea Break								
Time/Room	Room D	Room E	Room F	Room G	Room H	Room I			
15:40-17:40	SunD01	SunD02	SunD03	SunD04	SunD05	SunD06			
15:40-17:40	IS: System modeling, state and parameter estimation(II)	IS: Data-driven robust control	IS: Interdisciplinary data driven methods	IS: Repetitive Control and its Recent Advance in Practice	IS: High order differential feedback control and ADRC	IS: RNN for computing and its applications			
18:00-20:00	Closing Ceremony and Banquet, Chair: Prof. Dong Shen								