FINAL PROGRAM and BOOK OF ABSTRACTS

2018 IEEE 7th Data Driven Control and Learning Systems Conference (DDCLS'18)

Enshi, China
May 25 –27, 2018

Organized by

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

Beijing Jiaotong University

Locally Organized by

Hubei University for Nationalities

Sponsored by

IEEE Beijing Section

IEEE Industrial Electronics Society

ACTA Automatica Sinica

IEEE/CAA Journal of Automatica Sinica (JAS)

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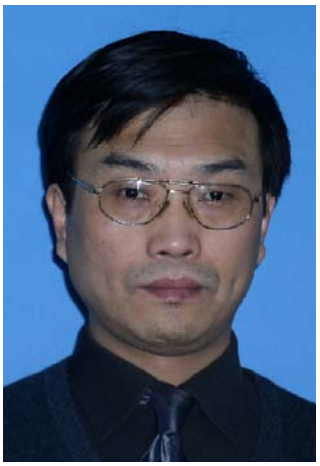
Welcome Message from General Chairs



ZhongshengHou
General Chair of DDCLS'18

Zuyi Dun
General Chair of DDCLS'18

Dear Friends and Colleagues,

On behalf of the Organizing Committee, it is our greatest pleasure to welcome you to the 2018 IEEE 7th Data Driven Control and Learning Systems Conference (DDCLS'18), which is organized by Technical Committee on Data Driven Control, Learning and Optimization (DDCLO), Chinese Association of Automation, and Beijing Jiaotong University, locally organized by Hubei University for Nationalities, sponsored by IEEE Beijing Section, IEEE Industrial Electronics Society, ACTA Automatica Sinica, and IEEE/CAA Journal of Automatica Sinica (JAS). The conference is held at Hualongcheng hotel, Enshi, Hubei Province, China, May 25–27, 2018.

Data driven control and learning systems, together with model-based control methods forming the complete control theory, is an emerging hot research area in the field of automation engineering and in systems & control community. It focuses on 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). In this year, the keywords 'Data Driven Control' has been formally listed with the application code F030110 as a new research domain in the project catalog of the National Natural Science Foundation of China. Further, 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 six workshops, DDCLS'18 continues to attract broad interest throughout the world, with the submission of 282 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 also 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 Hubei University for Nationalities 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'18 technical program comprises 25 regular sessions, 10 invited sessions and 1 best paper award session. Besides the technical sessions, the highlights of the DDCLS'18 are the keynote addresses given by distinguished senior scholars including Prof. Steven X. Ding from Germany, Prof. Håkan Hjalmarsson from Sweden, and Prof. Feng Qian from China. We sincerely appreciate all the contributors, keynote address speakers, invited session organizers, and session chairs for their tremendous efforts towards a top-quality conference.

We also want to thank the large number of volunteers who have made this conference possible. Without you, the monumental task of organizing this conference would be significantly beyond our capabilities.

May you have a wonderful and fascinating stay in Enshi, Hubei Province, China and enjoy the colorful *scenery* and magic foods.

Best wishes

Zhongsheng Hou
General Chair of DDCLS'18

Zuyi Dun
General Chair of DDCLS'18

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 2018 IEEE 7th Data Driven Control and Learning Systems Conference (DDCLS'18) in Enshi, 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'18 has received enthusiastic responses with a total of 282 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 222 papers which are divided into 36 oral sessions for presentation.

Along with the parallel technical sessions, we shall have three keynote addresses to be delivered by eminent researchers. 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 indeed honored to have Prof. Feng Qian (East China University of Science and Technology,), Håkan Hjalmarsson (KTH Royal Institute of Technology), and Prof. Steven X. Ding (University of Duisburg-Essen) as the keynote address speakers. Besides, we are very lucky to have Prof. Chenghong Wang (National Natural Science Foundation of China), Prof. Donghua Zhou (Shandong University of Science and Technology), Prof. Long Wang Peking University) and Prof. Guanghong Yang (Northeastern University) as distinguished lecture speakers in the Forum on Frontier and Hotspot of Automation organized by Acta

Automatica Sinica and IEEE/CAA Journal of Automatica Sinica (JAS). We are confident that their presences 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'18.

To promote the development of Data Driven Control, Learning and Optimization, we will present the "DDCLS Best Paper Award" at DDCLS'18. Based on reviewers' comments and nominations as well as the evaluations of Technical Program Committee members, 15 papers were selected for the consideration of the award by the Best Paper Award Committee. These papers were sent to 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 five finalists will be further assessed by the DDCLS'18 Best Paper Award Committee. The winner of the "DDCLS Best Paper Award" will be determined by the Best Paper Award Committee after assessing the oral 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. Fei Qiao, Prof. Senping Tian, Prof. Qinglai Wei and Prof. Zhanshan Wang, Subject Session Chairs Prof. Zhihuan Song, Prof. Dongbin Zhao, Prof. Xin Xu and Prof. Xisheng Dai, 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'18 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 including many old faces from around the world.

We do hope that you will find your participation in DDCLS'18 in Enshi is really stimulating, rewarding, enjoyable, and memorable.

Mingxuan Sun
Technical Program Chair

Huaguang Zhang
Technical Program Chair

Keynote Address

Keynote Address 1

Prof. Steven X. Ding

University of Duisburg-Essen, Germany

Towards Data-Driven Fault Diagnosis and Fault-Tolerant Control of Dynamic Systems

Saturday, May 26, 2018
08:20-09:20
Multi-Function Hall/多功能大厅

Abstract

In time of industry 4.0 and big data, data-driven schemes are receiving considerable research attention. On the other hand, model-based control and diagnosis framework has been well established in the past decades and successfully applied to dynamic control systems. The focus of this presentation is on the introduction to some recent research efforts towards establishing a data-driven framework for diagnosis and control of dynamic systems on the basis of the well-established system and control theory. It includes some basic ideas, design and implementation schemes as well as the associated mathematic and control theoretic tools.

Biography

Steven X. Ding

Professor Steven X. Ding received Dr.-Ing. degreein electrical engineering from the Gerhard-Mercator University of Duisburg, Germany, in 1992. From 1992 to 1994, he was a R&D engineer at Rheinmetall GmbH, Germany. From 1995 to 2001, he was a full-professor of control engineering at the University of Applied Science Lausitz in Senftenberg, Germany, and served as a vice president of this university during 1998 – 2000. Since 2001, he has been a full-professor of control engineering and the head of the Institute for Automatic Control and Complex Systems (AKS) at the University of Duisburg-Essen. His research interests are model-based and data-driven fault diagnosis, fault tolerant systems and their applications in industry with a focus on automotive systems, chemical processes and renewable energy systems.

Keynote Address 2

Active Application Oriented Learning of Complex Dynamical Systems with Application to MPC

Prof. Håkan Hjalmarsson
KTH Royal Institute of Technology, Sweden

Saturday, May 26, 2018
9:40-10:40
Multi-Function Hall/多功能大厅

Abstract

Data-driven modeling of complex dynamical systems can be very challenging. However, by explicitly considering the quality requirements of the intended use of the model this task can be significantly alleviated. Application oriented experiment design (AOED) is a systematic way to do this. It facilitates identification of system properties that are important for the application at hand, at the same time as it allows simplified model structures to be used since it, for reasons of experimental economy, avoids exciting system properties of little consequence for the application. In this talk we outline the theory for AOED and discuss how to use this technique in an on-line context such that the system is actively better and better probed in a sequential manner as more and more information is acquired. In particular we show how the technique can be integrated in model predictive control.

Biography

Håkan Hjalmarsson

Håkan Hjalmarsson was born in 1962. He received the M.S. degree in Electrical Engineering in 1988, and the Licentiate degree and the Ph.D. degree in Automatic Control in 1990 and 1993, respectively, all from Linköping University, Sweden. He has held visiting research positions at California Institute of Technology, Louvain University and at the University of Newcastle, Australia. He has served as an Associate Editor for Automatica (1996-2001), and IEEE Transactions on Automatic Control (2005-2007) and been Guest Editor for European Journal of Control and Control Engineering Practice. He is Professor at the School of Electrical Engineering, KTH, Stockholm, Sweden. He is an IEEE Fellow and past Chair of the IFAC Coordinating Committee CC1 Systems and Signals. In 2001 he received the KTH award for outstanding contribution to undergraduate education. His research interests include system identification, signal processing, control and estimation in communication networks and automated tuning of controllers.

Keynote Address 3

Smart Manufacturing System for Process Industry

流程工业制造系统智能化 —— 人工智能与流程制造深度融合

Prof. Feng Qian
East China University of Science and Technology, China

Sunday, May 27, 2017
8:00-9:00
Multi-Function Hall/多功能大厅

Abstract

流程工业是能源和基础原材料工业，是我国国民经济和社会发展的支柱产业。经过数十年的发展，我国流程工业的生产工艺和装备水平得到了大幅提升，其经济总量居世界第一位。但我国流程工业部分产品结构性过剩严重、高端制造不足、管理和营销等决策严重依赖知识型工作者、资源与能源利用率不高、安全环保形势严峻、企业运行水平参差不齐等问题依然十分突出。流程工业发展正处于新旧动能迭代更替的过程，如何运用人工智能、大数据、互联网等现代信息技术，推动流程工业企业生产、管理和营销模式的变革，是实现我国流程工业高质量转型发展的核心。

为解决资源、能源与环保的约束问题，提高生产制造水平和效能，我国流程工业亟待践行"中国制造2025"发展战略和"新一代人工智能发展规划"，利用人工智能等现代信息技术，以制造过程高效化与绿色化为目标，从企业生产、管理以及营销全流程优化出发，推进流程工业智能制造，实现制造模式创新与企业变革。报告分析了我国流程工业转型升级的国家重大需求，探讨了以"智能制造+绿色制造—>高端制造"为目标的智能优化制造的愿景，即实现资金流、物质流、能量流和信息流的"四流合一"，利用人工智能等现代信息技术实现工业企业的智慧决策与智能生产。报告深入剖析了当前流程工业企业经营决策层面、生产运行层面、能效安环层面、信息感知层面和系统支撑层面存在的主要问题，为重塑流程工业产业链、供应链、价值链，实现智能化、绿色化、高端化生产，围绕人工智能与流程制造深度融合实现智能优化制造凝练了相关工程科学问题，即（1）生产和经营全过程信息智能感知与协同计算；（2）知识驱动的制造过程决策自动化；（3）制造过程多尺度多目标智能自主调控；（4）全生命周期安全环境足迹监控与风险溯源分析。围绕上述工程科学问题，报告以需求驱动、应用导向为目标，提出了当前流程工业制造系统智能化的主要研究内容和关键技术，并给出了工业应用示例。

Biography

Feng Qian

钱锋，中国工程院院士，过程控制和过程系统工程专家。现任华东理工大学教授、博士导师、副校长，化工过程先进控制与优化技术教育部重点实验室主任，过程系统工程教育部工程研究中心主任，国务院学位委员会控制科学与工程学科评议组成员，中国石油和化工自动化应用协会副理事长。全国政协第十一届、十二届、十三届委员会委员。

他长期从事化工过程资源与能源高效利用的制造系统智能控制和实时优化理论方法与关键技术研究。创新研发了乙烯装置智能控制与优化运行技术和软件，在国内乙烯行业全面推广应用，成效显著；突破了精对苯二甲酸装置全流程优化运行关键技术，实现工业装置大幅度节能降耗；发明的汽油管道调合优化控制技术，实现了调合过程实时优化系统长周期高效运行。研究成果已在数十套大型石油化工装置上成功应用，取得了显著经济和社会效益。先后获得 4 项国家科技进步二等奖、10 项省部级科技进步一等奖等 20 余项省部级科技奖励，授权国家发明专利 40 项，登记国家计算机软件著作权 70 项，获得 2 项中国专利优秀奖、2 项上海市发明创造奖发明专利一等奖，出版专

著 3 部、发表论文被 SCI/EI 收录 300 余篇。研究成果入选中国高校产学研合作十大优秀案例。先后荣获首届新世纪百千万人才工程国家级人选、国家“973 计划”项目首席科学家，国家杰出青年科学基金、入选教育部长江学者特聘教授、何梁何利基金科学与技术创新奖、全国发明创业奖、上海市科技精英、上海市劳动模范等荣誉。

Prof. Feng Qian is Academician of Chinese Academy of Engineering, an expert in Process Control and Process Systems Engineering. He is currently the Vice President of East China University of Science and Technology (ECUST), Director of the Key Laboratory of Advanced Control and Optimization for Chemical Processes under the Ministry of Education and Director of the Process Systems Engineering Research Center under Ministry of Education. He is also a member of the consultation group of Control Science and Engineering Academic Degree Accreditation Committee under the State Council, and the Vice President of China Petroleum and Chemical Industry Association. He is also the member of the 11th, 12th and 13th National Committee of Chinese People's Political Consultative Conference (CPPCC).

Since 1980s, he has been focused on research and development of new theories and key technologies to implement intelligent control and real-time optimization for process manufacturing systems so as to achieve efficient use of chemical process resources and energy. His research team developed novel intelligent control and optimized operation algorithms and software for large scale ethylene plants. These research outcomes have been widely used in the ethylene industry in China and have achieved remarkable economic benefits. His research team also achieved breakthrough in key technologies of the whole terephthalic acid process optimal operation and achieved substantial energy saving and consumption reduction in industry. They also developed the optimal control technology for gasoline pipeline blending, which achieved long cycle and efficient operation of the real-time optimization system for blending process. The research outcomes have been successfully used in dozens of large scale petrochemical plants, and remarkable economic and social benefits have been achieved. His research team has won 4 National Second-Prizes for Progress in Science and Technology and over 20 provincial and ministerial-level Science and Technology awards. His team has 40 national invention patents authorised and 70 pieces of national computer software copyright successfully registered. They also won 2 Chinese patent outstanding awards and 2 First-Prizes of Shanghai Invention Patent Award. He has published 3 monographs and over 300 papers indexed by SCI and EI. The research from his team was selected as the Top 10 cases of the university-industry cooperation. He was among the first batch of national candidates for the New Century Talents Project, the principal scientist of the national "973" Program, winner of the National Science Fund for Distinguished Young Scholars. He was the Changjiang Scholar Professor of Ministry of Education. He is also the winner of Science and Technology Innovation Award of Ho Leung Ho Lee Foundation, the Award of National Invention and Entrepreneurship, Elite of Shanghai Science and Technology and other honors.

第 10 期自动化前沿热点论坛

Keynote Address 4

长程相关随机退化过程的剩余寿命预测方法

Prof. Donghua Zhou
Shandong University of Science and Technology, China

Sunday, May 27, 2017
9:00-9:40
Multi-Function Hall/多功能大厅

Abstract

目前的绝大多数退化模型均建立在退化过程满足 Markov 性的假设下，然而，这一假设严重限制了此类方法的适用范围。通过分析锂电池、轴承和高炉炉壁等实际设备的退化数据，我们发现许多设备的退化过程并不满足 Markov 性，而具有长程相关性。基于此，本报告针对长程相关退化过程的剩余寿命预测开展了系统性研究，给出了有效的剩余寿命预测方法，并进行了应用验证。

Biography

Donghua Zhou

IET/CAA Fellow,上海交通大学博士，浙江大学博士后，曾任北京理工大学副研究员，德国洪堡学者，清华大学自动化系主任。目前任山东科技大学副校长，清华大学教授（双聘）。

主要研究动态系统故障诊断、容错控制与运行安全性评估理论等。已主持国家 973 课题, 863 项目, 国家自然科学基金重大、重点、重大国际合作项目等国家和省部级科研项目 20 余项。已出版学术专著 6 部，在国际学术刊物发表论文 190 余篇。目前任 IFAC 技术过程故障诊断与安全性技术委员会委员，教育部高等学校自动化类教学指导委员会主任，第七届"控制科学与工程"国务院学科评议组成员, 中国自动化学会副理事长、技术过程故障诊断与安全性专业委员会主任等。

曾获国家自然科学二等奖、国家科技进步二等奖、国家级优秀教学成果二等奖各一项。曾获第六届中国青年科技奖、国家杰出青年科学基金、教育部长江学者特聘教授、国家"万人计划"领军人才、山东省泰山学者优势特色学科人才团队领军人才、全国优秀科技工作者称号，并曾任国家自然科学基金会优秀创新群体负责人。

Keynote Address 5

数据驱动的科学

Prof. Long Wang
Peking University, China

Sunday, May 27, 2017
10:00-10:40
Multi-Function Hall/多功能大厅

Abstract

能控性与性能优化问题是多智能体系统协调控制中的重要研究课题。重点介绍能控性的基本问题和特点，并结合智能体自身动力学与邻居交互协议，从拓扑结构角度对该领域当前的研究热点和前沿进行分析，给出急需解决的问题和可行的研究方向。性能优化问题是指给定性能评价指标设计分布式协议或在某类分布式协议下优化通信拓扑的边权重/设计通信拓扑图， 使系统以最优的性能完成既定任务。分别介绍快速一致性、最优控制等相关成果。

Biography

Long Wang

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、演化博弈与群体决策等方面的研究工作，获得国家自然科学奖、国家教委霍英东奖（研究类一等奖）、教育部自然科学奖（一等奖）、国家教委科技进步奖（一等奖）、第一届 Ho Outstanding Paper Award、第一届关肇直控制理论奖等多项奖励。

王龙教授目前担任《控制理论与应用》、《控制与决策》、《信息与控制》、《PLoS ONE》、《IEEE Transactions on Industrial Electronics》编委、北京大学系统与控制研究中心主任、中国仿真学会常务理事、智能物联系统专业委员会主任、北京人工智能学会副理事长、国家出国留学基金评审专家等。

Keynote Address 6

信息物理系统的安全状态估计与控制

Prof. Guanghong Yang
Northeastern University, China

Sunday, May 27, 2017
10:40-11:20
Multi-Function Hall/多功能大厅

Abstract

信息物理系统是一类紧密整合计算机、通讯网络以及物理系统的复杂系统。近几十年来，由于对通讯网络依赖的不断增强，信息物理系统越来越容易受到攻击。报告研究了受到稀疏攻击的信息物理系统的安全状态估计与控制问题。针对仅受到传感器攻击的系统，可通过估计系统状态来实现闭环系统的镇定。由于攻击的存在，一类安全状态估计方法被提出。其基本思想是遍历所有可能未受攻击的测量值来重构出系统状态。而遍历所引起的高计算复杂度问题可以通过引入自适应以及切换机制解决。针对同时受到执行器和传感器攻击的系统，在考虑安全状态估计的同时，安全控制器的设计也是至关重要的。而安全控制器设计的关键是在估计出系统状态的同时，从异常的测量值中提取出执行器攻击信息。最终，通过设计状态-执行器攻击依赖的控制律来实现在存在执行器和传感器攻击的情况下镇定闭环系统。

Biography

Guanghong Yang

东北大学特聘教授、信息科学与工程学院院长、国家自然科学基金创新群体负责人。现任《控制与决策》以及 Journal of Control and Decision 期刊副主编、中国控制与决策会议总主席(CCDC，2010-2018)、中国自动化学会信息物理系统控制与决策专业委员会主任、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、5 个国际学术期刊编委（IEEE TFS 等）、IEEE 控制系统协会哈尔滨分会主席。主要研究方向包括：故障诊断与容错控制、鲁棒控制、非线性控制，信息物理系统分析与控制等。发表学术专著 3 部，SCI 期刊论文 300 余篇， Google 引用 1 万余次，学术引用（H）指数 47，入选爱思唯尔中国高被引学者榜单(2014-2017）。

Keynote Address 7

新一代人工智能助推新一代智能控制

Prof. Chenghong Wang
National Natural Science Foundation of China, China

Sunday, May 27, 2017
11:20-12:00
Multi-Function Hall/多功能大厅

Abstract

从多个角度、多个层面，初步探讨了“智能”与“人工智能”的内涵、特征及相互关系。在此基础上，初步探讨了“自动控制”与“智能控制”的内涵、本质区别及相互关系，最后提出了若干个智能控制方面的前沿问题。上述内容对理解和落实国家新一代人工智能发展规划具有一定的借鉴作用。

Biography

Chenghong Wang

王成红，国家自然科学基金委员会研究员，中国自动化学会副理事长，数据驱动控制、学习与优化专业委员会副主任委员；感兴趣的研究领域涉及控制理论及应用，系统可靠性理论及应用，科技政策与管理等。

Program at a Glance

Saturday, May 26, 2018, Enshi Hualongcheng Hotel (恩施华龙城大酒店)									
8:00-8:20	Opening ceremony, Venue: Multi-Function Hall, Chair: Prof. Xiongxiong He								
8:20-9:20	Keynote Address 1: Towards Data-Driven Fault Diagnosis and Fault-Tolerant Control of Dynamic Systems, *Prof. Steven X. Ding*, Venue: Multi-Function Hall, Chair: Prof. Huaguang Zhang								
9:20-9:40	Tea Break								
9:40-10:40	Keynote Address 2: Active Application Oriented Learning of Complex Dynamical Systems with Application to MPC, *Prof. Håkan Hjalmarsson*, Venue: Multi-Function Hall, Chair: Prof. Chiang-Ju Chien								
10:40-12:00	Panel Discussion：AI vs DDCLS - Future and Development, Prof. Furong Gao, Prof. Kemin Zhou, Prof. Danwei Wang, Venue: Multi-Function Hall, Chair: Prof. Long Wang								
12:00-13:30	Lunch								
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Room7	Room8	Room9
13:30-15:30	SatA01	SatA02	SatA03	SatA04	SatA05	SatA06	SatA07	SatA08	SatA09
	Data driven control (I)	Model-free adaptive control (I)	Iterative learning control (I)	Applications of data-driven methods to complex processes (I)	Reinforcement learning	Data-driven modeling, optimization and scheduling (I)	Statistical learning and machine learning in automation field (I)	ADRC technology and applications (I)	Iterative learning and consensus control
15:30-15:40	Tea Break								
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Room7	Room8	Room9
15:40-18:00	SatB01	SatB02	SatB03	SatB04	SatB05	SatB06	SatB07	SatB08	SatB09
	Best Paper Award Finalist	IS: Data-driven technology in industry	IS: Intelligent learning techniques for autonomous system	Data-driven fault diagnosis and health maintenance (I)	Iterative learning control (II)	IS: Intelligent optimization and control of urban road traffic	Data-driven modeling, optimization and scheduling (II)	IS: Data-driven modeling and optimization	Neural networks, fuzzy systems control methods in data driven manner
18:00-20:00	Dinner								
Sunday, May 27, 2018, Enshi Hualongcheng Hotel (恩施华龙城大酒店)									
8:00-9:00	Keynote Address 3: 流程工业制造系统智能化—— 人工智能与流程制造深度融合, *Prof. Feng Qian,* Venue: Multi-Function Hall, Chair: Prof. Zhongsheng Hou								
9:00-9:40	Keynote Address 4: 长程相关随机退化过程的剩余寿命预测方法, *Prof. Donghua Zhou*, Venue: Multi-Function Hall, Chair: Prof. Zhihuan Song								
9:40-10:00	Tea Break								
10：00-10:40	Keynote Address 5: 数据驱动的科学, *Prof. Long Wang*, Venue: Multi-Function Hall, Chair: Prof. Fei Liu								
10：40-11:20	Keynote Address 6: 信息物理系统的安全状态估计与控制, *Prof. Guanghong Yang*, Venue: Multi-Function Hall, Chair: Prof. Huajing Fang								
11:20-12:00	Keynote Address 7: 新一代人工智能助推新一代智能控制, *Prof. Chenghong Wang*, Venue: Multi-Function Hall, Chair: Prof. Zengqiang Chen								
12:00-13:30	Lunch								
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Room7	Room8	Room9
13:30-15:30	SunA01	SunA02	SunA03	SunA04	SunA05	SunA06	SunA07	SunA08	SunA09
	Data driven control (II)	Model-free adaptive control (II)	ADRC technology and applications (II)	Iterative learning control (III)	IS: Iterative learning identification and control	Data-driven fault diagnosis and health maintenance (II)	Applications of data-driven methods to complex processes (III)	IS: parameter identification, learning, and control for nonlinear systems	IS: Data-driven technologies and application in complex systems
15:30-15:40	Tea Break								
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6	Room7	Room8	Room9
15:40-17:40	SunB01	SunB02	SunB03	SunB04	SunB05	SunB06	SunB07	SunB08	SunB09
	Iterative learning control (IV)	Statistical learning and machine learning in automation field(II)	Applications of data-driven methods to complex processes (II)	Data-driven fault diagnosis and health maintenance (III)	Data-driven fault diagnosis and health maintenance (IV)	Data-driven modeling, optimization and scheduling (III)	IS: Data-driven fault analysis and diagnosis	IS: New trends in data-based modeling, optimization and control	IS: AI and its Applications on Fault Diagnosis
18:00-20:00	Closing Ceremony and Banquet, Chair: Prof. Xiongxiong He								

2018 IEEE 7th Data Driven Control and Learning Systems Conference (DDCLS'18)

Technical Programmes
and
Book of Abstracts

Saturday, 26 May, 2018

SatA01 **Room 1**
Data driven control (I) **13:30-15:30**
Chair: Zhanshan Wang Northeastern Univ.
CO-Chair: Jun Xiang Hubei Univ. for Nationalities

13:30-13:50 **SatA01-1**

Fixed-time Stabilization for Interconnected Systems with Discontinuous Interconnections and Nonidentical Perturbations

Nannan Rong Northeastern Univ.
Zhanshan Wang Northeastern Univ.
Huaguang Zhang Northeastern Univ.

This paper investigates the fixed-time stabilization issue for a class of nonlinear interconnected systems with discontinuous interconnections and nonidentical perturbations. Firstly, according to the differential inclusion theory, the solutions of such discontinuous interconnected system are defined in the sense of Filippov. In addition, an improved fixed-time lemma, in which the regional bound r can be freely chosen in [0, 1], is proposed to realize the fixed-time stabilization and estimate the settling time. Then, through designing a state feedback controller and utilizing generalized Lyapunov functional method, sufficient criteria are derived to guarantee the fixed-time stabilization of the discontinuous interconnected system. Especially, the upper bound of the convergence time is estimated by a fixed time, which is independent of initial conditions. Finally, the proposed methodology and results are verified by an example.

13:50-14:10 **SatA01-2**

A Nonlinear Self-tuning Control Method Based on Neural Wiener Model

Bi Zhang Shenyang Institute of Automation, Chinese Academy of Sci.
XinGang Zhao Shenyang Institute of Automation, Chinese Academy of Sci.
Zhuang Xu Shenyang Institute of Automation, Chinese Academy of Sci.
Ming Zhao Shenyang Institute of Automation, Chinese Academy of Sci.

In this paper, a novel nonlinear adaptive control method based on neural Wiener model is developed to address nonlinear control problems. First the parameterization model with uncertain parameters is derived based on a linear transfer function model followed by neural networks. Then based on the performance index, the adaptive control strategy includes the system parameters identification and the control law calculation. Since the networks are linearly described by some basis functions, the closed-loop stability is guaranteed under mild conditions. Finally, the proposed controller is applied to a pH control problem. Simulation results have shown that the proposed control scheme is effective for its set-point tracking and adaptive ability.

14:10-14:30 **SatA01-3**

Data-driven Sliding-mode Decoupling Control with Time-varying Sliding Surface for Nonlinear Discrete-time Processes

Yongpeng Weng Dalian Maritime Univ.
Ning Wang Dalian Maritime Univ.
Shaowu Li Hubei Univ. for Nationalities.
Xinming Liu Liaoning Technical Univ.

In this paper, a novel data-driven time-varying sliding surface (TVSS) for second-order sliding-mode decoupling control (SSDC) law is proposed to improve tracking control performance of nonlinear discrete-time processes. First, using the extended state observer (ESO) and the non-parametric dynamic linearization technique (NDLT), a decoupled data-driven sliding surface (DSS) is firstly proposed to facilitate the SSDC law design. Then, inspired by the fuzzy logic control (FLC) approach, a TVSS is proposed to further enhance the SSDC law's performance, where the sliding surface slope is updated by the proposed rule base of FLC. In light of the developed sliding surface, a less overshoot and faster dynamic response are obtained without deteriorate the original discontinuous control term. In addition, the chattering phenomenon is also alleviated under this control scheme. Finally, a numerical example is given to evaluate the proposed approach.

14:30-14:50 **SatA01-4**

Routing Algorithm Based on Energy and Hop Number for Linear Distributed WSN

Pengfei Wu Huazhong Agricultural Univ.
Meng Wang Wuhan Univ. of Tech.

Monitoring nodes are usually linear distributed along river and canal in irrigation area, which constructs linear distributed WSN. Aiming at linear distributed WSN, Flooding routing protocol based on energy and hop number (BEH-Flooding) is proposed. This protocol realizes efficient and stable wireless data transmission for irrigation area. According to the principle of same hop number, nodes are divided into multiple levels. In each level, two routing nodes are selected based on the principle of optimal residual energy. In the transmission stage, data packets are only transferred between routing nodes of upper level and routing nodes of lower level. By this, the protocol not only has the robustness of Flooding protocol, but also reduces extra data transmission. The simulation results validate the effectiveness of the proposed routing protocol. This method provides an approach to data acquisition for monitoring system in irrigation area.

14:50-15:10 **SatA01-5**

A Novel Rotor Position Detection Method Using Morphological Wavelet Transform for Brushless DC Motor

Yin Zhang Guangxi Univ. of Sci. and Tech.
Chongyue Liu Guangxi Univ. of Sci. and Tech.
Liping Qin Guangxi Eco-engineering Vocational and Tech. College
Xisheng Dai Guangxi Univ. of Sci. and Tech.

By analyzing the relationship between rotor position and phase back electromotive forces of brushless DC motor (BLDCM), a novel method based on morphological wavelet transform (MWT) for BLDCM rotor position detection is proposed in this paper. MWT is used to detect the signal turning points of the source signals, which can technically support the stator winding current commutations of pulse width modulation control circuit. Accurate current commutation point identification of BLDCM is helpful for achieving rotor position detection and position sensorless control of BLDCM. Simulation studies has been done by constructing BLDCM model in MATLAB. Simulation results proved that, the novel rotor position detection method using morphological wavelet transform can accurately detect the rotor position of BLDCM, which can improve the position sensorless control for BLDCM by obtaining the signal turning points of phase back electromotive forces in BLDCM.

15:10-15:30 **SatA01-6**

A Loading Balancing Equi-join Algorithm Based on Key Cost

Jun Xiang Hubei Univ. for Nationalities
Qian Zheng Hubei Univ. for Nationalities
Chao Li Hubei Univ. for Nationalities

MapReduce parallel computing model is widely used in large-scale distributed data processing. However, this model does not support the join operation well. Especially in the face of skewed data, the original partitioning algorithm tends to cause unbalanced load between processing nodes. To solve this problem, a load balancing equi-join algorithm based on key cost is proposed. The algorithm generates more key partitions than the number of processing tasks according to the type of join attributes and calculates the cost information for each partition. By dynamically determining the partition function, the data in the partition is sent to the corresponding node, considering the network transmission cost and disk I/O cost of data and achieving load balancing. Experimental results show that the proposed algorithm has good effect in load balancing in homogeneous clusters.

SatA02 Room 2
Model-free adaptive control I 13:30-15:30

Chair: Xunhui Bu Henan Polytechnic Univ.
CO-Chair: Na Dong Tianjin Univ.

13:30-13:50 **SatA02-1**

An Improved Model-free Adaptive Predictive Control Algorithm for Nonlinear Systems with Large Time Delay

Na Dong Tianjin Univ.
Yu Feng Tianjin Univ.
Xueshuo Han Tianjin Univ.
Aiguo Wu Tianjin Univ.

For control problem of nonlinear time-delay systems, we improve the control input criteria function of the model-free adaptive control by adding the sum of control output error into the control input criteria function. Also, the concept of predictive control has been incorporated into the improved algorithm. Typical linear and nonlinear large time-delay systems are introduced for simulation comparison tests. The simulation results show that the improved model-free predictive control algorithm can achieve stable output, better control effect and faster response. Thus, the effectiveness of this improved model-free predictive control method is fully illustrated.

13:50-14:10 **SatA02-2**

Decentralized Robust Adaptive Output-feedback Control for a Class of Large-scale Stochastic Time-delay Nonlinear Systems

Qian Wang Qufu Normal Univ.
Qiangde Wang Qufu Normal Univ.
Zhengqiang Zhang Qufu Normal Univ.
Chunling Wei Qufu Normal Univ.

The paper solves the problem of decentralized robust adaptive output-feedback control for a class of large-scale stochastic time-delay nonlinear systems. It is shown that under some milder conditions, the closed-loop system is globally stable in probability and the outputs can be regulated to an arbitrarily small neighborhood of the origin in probability.

14:10-14:30 **SatA02-3**

Adaptive Fuzzy Consensus Control for Unknown State-delay Nonlinear Multiagent System

Fei Yan Xidian Univ.
BaoLong Guo Xidian Univ.

This paper focuses on the leader-following consensus control problem of nonlinear multiagent systems. The fuzzy logic systems are used to approximate the system uncertainties which from the unknown nonlinear dynamics and a novel adaptive fuzzy controller is presented by combining the Lyapunov-Krasovskii functionals. With the help of Lyapunov-Krasovskii functionals the state-delay of systems are compensated. A major advantage of the proposed adaptive consensus method is that it can greatly reduce the computation burden. Finally, one simulation example is given to verify the effectiveness of the designed algorithm.

14:30-14:50 **SatA02-4**

Model Free Adaptive Control for a Class of Nonlinear Systems with Output Saturation

Qingfeng Wang Henan Polytechnic Univ.
Xuhui Bu Henan Polytechnic Univ.
Yanling Yin Henan Polytechnic Univ.

This paper considers the problem of model free adaptive control algorithm for a class of nonlinear systems with output saturation constraints. Based on the compact form dynamic linearization data model, a modified model free adaptive control algorithm using saturated system output is constructed. A sufficient condition for guaranteeing the stability of the modified algorithm is given and the convergence of the tracking error is proved. It is shown that the model free adaptive control using saturation output can also guarantee the convergence of the tracking error. The theoretical result is validated by using a numerical example.

14:50-15:10 **SatA02-5**

Model Free Adaptive Perimeter Control for Two-region Urban Traffic System with Input and Output Constraints

Ting Lei Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.

Recent studies on urban traffic systems have shown that there exists a well-defined macroscopic fundamental diagram (MFD) in well-partitioned homogenous regions, which depicts a unimodal and low-scatter relationship between accumulation and trip completion flow. In this paper, a new type of data driven control method called model free adaptive control with input and output constraints (IOC-MFAC) is utilized for perimeter control for two-region urban traffic system, using MFD to choose the desired number of vehicles and generate the output data of the urban traffic system. Different from the protype scheme of MFAC, in this work, the constraints of perimeter control input and the urban traffic system's output are considered. A key advantage of the proposed method is that only the input and output data of the urban traffic system is needed to design the perimeter controller. The effectiveness of IOC-MFAC method is tested via numerical simulation, and the result shows that it works better than some other commonly used perimeter control strategies.

15:10-15:30 **SatA02-6**

Dual-channel Event-triggered Output Feedback Control for Linear System with Unavailable States

Chaoqun Tan Jiangnan Univ.
Fei Liu Jiangnan Univ.

In this technical note, the problem of event-triggered output-feedback control is considered for a linear system whose states are unavailable or partial available. In order to realize the reduction of communication in both the sensor to controller(S-C) and the controller to actuator(C-A) channels, a piecewise linear model is introduced, by which the communication in dual channels can be simultaneously considered. For S-C channel, the event-triggered strategy based on the observer is applied. For C-A channel, classical fixed threshold, relative threshold strategy and switching threshold strategy which combines the benefits of the first two mechanisms are discussed respectively. It is shown that the proposed event-triggered scheme can realize the reduction of communication while guaranteeing the stability of the system. The simulation results also confirmed the superiority of switching threshold strategy.

SatA03 Room 3
Iterative learning control (I) 13:30-15:30

Chair: Chiang-Ju Chien Huafan Univ.
CO-Chair: Yong Fang Shanghai Univ.

13:30-13:50 **SatA03-1**

Point-to-point Iterative Learning Control Based on Updating Reference Trajectory with Constrained Input

Xiangfeng Shen Tsinghua Univ.
Zhihua Xiong Tsinghua Univ.
Yingdong Hong Tsinghua Univ.

The point-to-point tracking control method under constrained input is proposed by using updating-reference and an integrated predictive iterative learning control strategy. A reference trajectory through the desired key points is adopted and updated batch-to-batch, and then the whole system is described as 2D model. By using the integrated predictive ILC, the control method can depress effectively disturbances. For the constrained input, its convex set is abstracted and the procedure of calculating the constrained input is presented in detail. Comparing with gradient based point-to-point control algorithms, updating- reference relaxes the output constraints and the proposed algorithm can lead to faster convergence. Simulation results of a numerical model have demonstrated the effectiveness of the proposed method.

13:50-14:10 **SatA03-2**

Decentralized Iterative Learning Control for Large-scale Interconnected Non-affine Nonlinear Discrete-time Systems

Lili Du Suzhou Univ. of Sci. and Tech.
Qin Fu Suzhou Univ. of Sci. and Tech.

This thesis discusses the decentralized iterative learning control for large-scale discrete-time single-input single -output (SISO) systems, which is interconnected by non-affine nonlinear systems. In view of the structure of the system, the P-type learning algorithm is constructed. Under certain assumptions, the algorithm can make sure that the error precision required in each subsystem is attained through repeated iteration. The given example indicates that the proposed scheme is effective.

14:10-14:30 **SatA03-3**

Quantized Iterative Learning Control for Formation of Multi-agent System

Chenlong Li Shanghai Univ.
Yong Fang Shanghai Univ.
Jialu Zhang Shanghai Univ.

This paper investigates the formation control problem for discrete-time multi-agent systems with switching network topologies and data quantization. It is assumed that the tracking error signals of individual agent are quantized before they are transmitted into the iterative learning controller. However, quantification of data can lead to quantization error, which seriously impacts the performance of multi-agent systems. Based on the nearest neighbor interaction rule, a quantized iterative learning approach is given to overcome the quantization error in the occasion of switching network topologies, and guarantee the accurate formation of multi-agent systems simultaneously. Simulation results are provided to verify the effectiveness of the proposed method.

14:30-14:50 **SatA03-4**

A Fractional-order Design Approach for the Notch Filter in RC of CVCF PWM Inverter

Qiangsong Zhao Zhongyuan Univ. of Tech.
Nanjing Univ. of Aeronautics & Astronautics
Yongqiang Ye Nanjing Univ. of Aeronautics & Astronautics
Shengjun Wen Zhongyuan Univ. of Tech.
Sainan Chen Zhongyuan Univ. of Tech.
Xiaohui Lu Zhongyuan Univ. of Tech.

LC filter in PWM inverter can suppress the high frequency harmonics caused by dead zone to obtain a better sinusoidal output voltage waveform. However, the resonance of LC filter with no load may deteriorate the system stability. In order to solve the resonance problem, a zero-phase notch filter in repetitive control (RC) system has been put forward to damp the resonance. Nevertheless, the resonant frequency of conventional integer-order zero-phase notch filter can only be designed at some specific frequencies which may not be the resonant frequency of LC filter. In this paper, a fractional-order zero-phase notch filter with any desired notch frequency is proposed to exactly align the resonance of LC filter. The notch frequency of novel fractional-order zero-phase notch filter based on finite-impulse-response (FIR) filter is designed according to the resonant frequency of LC filter. The simulation results of a single phase inverter system verify that the single phase inverter system can achieve wider stability region of inverter system and lower THD.

14:50-15:10 **SatA03-5**

Design and Analysis of Adaptive Iterative Learning Control for Iteration-varying Nonlinear Systems

Chiang-Ju Chien Huafan Univ.
Ying-Chung Wang Huafan Univ.
Feng-Li Lian National Taiwan Univ.

Design of iterative learning controller for continuous-time nonlinear systems with iteration-varying uncertainties is studied in this paper. The iteration-varying uncertainties include initial resetting tracking error, iteration-varying external disturbance, iteration-varying desired trajectory and iteration-varying system parameters. The iteration-varying uncertainties are not required to take any special structure and the uncertain bounds are not necessarily small. All the iteration-varying uncertainties are compensated by an adaptive iterative learning controller with a projection-type adaptive law. We show that the system output can converge to the desired one as close as possible after suitable numbers of learning trials. Compared with the existing papers studying the similar problems, this approach can be used to solve the iterative learning control issue with more general class of nonlinear uncertain systems and achieve better learning performance.

15:10-15:30 **SatA03-6**

Iterative Learning Control for Singular System with an Arbitrary Initial State

Mengji Chen Hechi Univ.
Yinjun Zhang Hechi Univ.
Air Force Engineering Univ.
Jianhuan Su Hechi Univ.

In this paper, a class of a class linear singular system with an arbitrary initial state was proposed based on singular value decomposition. A novel generalized theoretical result is presented by using the D-type learning law. We established the convergence conditions of algorithm. By the matrix theory, we give rigorous convergence proof. The effectiveness of the theoretical result is illustrated in two application examples.

SatA04 Room 4

Applications of data-driven methods to complex processes (I) **13:30-15:30**

Chair: Zhihuan Song Zhejiang Univ.
CO-Chair: Yalin Wang Central South Univ.

13:30-13:50 **SatA04-1**

Bayesian Regularized Gaussian Mixture Regression with Application to Soft Sensor Modeling for Multi-mode Industrial Processes

Jingbo Wang Zhejiang Univ.
Weiming Shao Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

The Gaussian mixture regression (GMR) is an effective approach to predicting those difficult-to-measure quality variables for industrial processes with multiple operating modes. However, the GMR easily gets stuck into overfitting in the scenario of insufficient labeled samples, particularly when the dimensionality of the secondary variables is high. To alleviate this issue, this paper proposes the Bayesian regularized GMR (BGMR), and applies it to soft sensor modeling. In the BGMR, an alternative model structure, which explicitly considers the functional dependency between the primary and secondary variables, is presented to facilitate the Bayesian regularization that is widely used for

anti-overfitting. In addition, an efficient learning procedure is developed for the BGMR based on the expectation-maximization algorithm. The performance of the BGMR is evaluated through two case studies including a numerical example and a real-life industrial process, which demonstrates the effectiveness of the proposed approach.

13:50-14:10 **SatA04-2**

A Comparative Study of Adaptive Soft Sensors for Quality Prediction in a Refining Hydrocracking Process

Xiaofeng Yuan Central South Univ.
Jiao Zhou Central South Univ.
Yalin Wang Central South Univ.

Soft sensors have played important roles in modern refining industry, which can provide significant information for process monitoring, control and optimization. However, the prediction performance often gradually deteriorates due to process time-varying problem caused by reasons like catalyst deactivation. Hence, it is necessary to update soft sensor models in order to sustain good prediction accuracy. In this paper, a comparative study of adaptive soft sensors is carried out for quality prediction in a real hydrocracking process. Recursive partial least squares (RPLS), moving window RPLS (MWRPLS), locally weighted partial least squares (LWPLS) and moving window LWPLS (MWLWPLS) models are built to predict the 10% boiling point of the aviation kerosene product. The results show that RPLS and MWRPLS can provide better prediction performance.

14:10-14:30 **SatA04-3**

A Novel Soft Sensing Method for Transient Processes Regression Utilizing Locally Weighted PLS

Yuchen He China Jiliang Univ.
Chenyang Liu China Jiliang Univ.
Binbin Zhu China Jiliang Univ.
Jiusun Zeng China Jiliang Univ.

This paper develops a novel soft sensing method using locally weighted Partial least squares (PLS) for transient processes regression. Industrial transient processes cannot be described using merely one model and therefore the regression model should be updated according to the online system condition. Different from previous just-in-time (JIT) methods using Euclidean distance, a supervised approach is proposed involving both process data X and quality data Y to finish sample selection tasks. The locally weighted PLS is adopted to depict the relation between X and Y. The performance of the novel soft sensing structure is validated by an industrial process.

14:30-14:50 **SatA04-4**

Energy Saving and Management of the Industrial Process Based on an Improved DEA Cross-model

Zhiqiang Geng Beijing Univ. of Chemical Tech.
Ju Bai Beijing Univ. of Chemical Tech.
Qunxiong Zhu Beijing Univ. of Chemical Tech.
Yuan Xu Beijing Univ. of Chemical Tech.
Yangming Han Beijing Univ. of Chemical Tech.

Data envelopment analysis (DEA) has been commonly used in the energy saving of enterprise plants. Nevertheless, when the traditional DEA model analyzes the effectiveness of decision-making units (DMUs), over 1/3 of the DMUs' efficiency values are 1, so the traditional DEA model cannot distinguish the cons and pros of the DMUs. And although the DEA cross model (DEACM) is able to differentiate the cons as well as pros of the effective DMUs, it can't obtain the improvement direction of the ineffective DMUs. Therefore, an energy saving and management method based on an improved DEACM, which can use the higher efficiency distinction to identify the efficiency state of the DMUs, is proposed in this paper. Meanwhile, the improvement direction of the ineffective DMU can be found by the self-evaluation of the improved DEACM. Finally, the improved DEACM is utilized to save and manage the energy configuration of the PTA solvent system in the industrial process. The experimental results reveal that the practicality and effectiveness of the proposed method are verified, and in addition, the efficiency discrimination is well. Moreover, the proposed model can find the direction of the quantitative targets of energy saving to improve the energy efficiency of PTA production.

14:50-15:10 **SatA04-5**

Markov Parameters Sequence Identification Oriented Data-driven LQ/H_∞ Robust Preview Control

Kezhen Han Univ. of Jinan
Xiju Zong Univ. of Jinan
Shi Li Univ. of Jinan

In this paper, the data-driven robust preview control problem is addressed based on Markov parameters sequence identification and augmented modelling technique. The involved analysis and synthesis are composed of three parts. First, data-based state-space model is established by augmenting input/output data, finite window previewable signals and tracking errors. Then, the Markov parameters sequence is identified, which enables the determination of data model matrices. In the following, the mixed linear quadratic (LQ) and H1 criterions are used to optimize the robust preview control gains, and the specified preview control policy containing data feedback control, integral operation and preview action is finally obtained. The application to injection velocity control of injection molding process verifies the effectiveness of proposed results.

15:10-15:30 **SatA04-6**

The DC Bus Voltage Control Based on Virtual Inertia for SST

Dazhong Ma Northeastern Univ.
Sen Lin Northeastern Univ.
Qifu Cheng Northeastern Univ.
Qiuye Sun Northeastern Univ.

Three-stage solid state transformer adopts three independent control units, so when the system power changes, the regulation of DC bus voltage stabilization is important. A DC bus voltage control Strategy based on virtual inertia is proposed for AC/DC converter in this paper. On the basis of traditional voltage/current double closed-loop controller, the virtual inertia control loop and the DC current feed-forward loop are introduced. In order to effectively suppress the voltage fluctuation of the DC bus in the case of the fluctuation of the system power, the inertia of the DC bus is enhanced by adding virtual capacitance. In order to reduce the influence on the DC voltage caused by load current changing, the voltage stability of the DC bus is enhanced by adding the DC current feed-forward link. Single phase shift control of load current feed-forward is adopted for DAB, which decreases the fluctuation of the DC bus voltage and increases the dynamic response time of the DC bus voltage. Finally, the simulation results verify the effectiveness of the proposed control strategy.

SatA05 Room 5
Reinforcement learning (I) 13:30-15:30

Chair: Dazi Li Beijing Univ. of Chemical Tech.
CO-Chair: Hao Tang Hefei Univ. of Tech.

13:30-13:50 **SatA05-1**

Cooperative Adaptive Control for Consensus of Leader-following General Linear Multi-agent Systems in Directed Communication Topology

Benkai Li Inst. of Automation, Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Qinglai Wei Inst. of Automation, Chinese Academy of Sci.
Derong Liu Guangdong Univ. of Tech.

This paper investigates the consensus problem for leader-following multi-agent systems with general linear dynamics in directed communication topology. The fixed directed communication topology is considered. To adjust the coupling weights of neighboring agents, an adjacent state feedback protocol with an adaptive law is developed. LaSalle's invariance principle is used to analyze the stability. The consensus for multi-agent systems under directed communication topology containing a directed spanning tree with the leader as the root can be realized. The design method is based on Riccati inequality as well as algebraic graph theory. Finally, two examples are shown to illustrate the performance of the present controller.

13:50-14:10 **SatA05-2**

Adaptive Natural Policy Gradient in Reinforcement Learning

Dazi Li Beijing Univ. of Chemical Tech.
Zengyuan Qiao Beijing Univ. of Chemical Tech.
Tianheng Song Beijing Univ. of Chemical Tech.
Qibing Jin Beijing Univ. of Chemical Tech.

In recent years, the policy gradient method in intensive learning has attracted wide attention with its good convergence performance. At the same time, regulation of hyper parameters is also a matter of concern. Based on the advantages of Actor-Critic structure (AC), the Natural-Gradient Actor-Critic algorithm (NAC) in the discount model is studied in this article. Then the Natural-Gradient Actor-Critic with ADADELTA (A-NAC) algorithm is proposed. The use of ADADELTA is adapted to adjust the learning rate in the actor network, and further improves the convergence speed of the NAC algorithm. Simulation results show that NAC/A-NAC have better learning efficiency and faster convergence rate than regular gradient AC methods.

14:10-14:30 **SatA05-3**

Reinforcement Learning Control for Consensus of the Leader-follower Multi-agent Systems

Mingli Chiang National Taiwan Univ.
Ansheng Liu National Taiwan Univ.
Lichen Fu National Taiwan Univ.

This paper considers the optimal consensus of multi-agent systems using reinforcement learning control. The system is nonlinear and the number of agents can be large. The control objective is to design the controllers for each agent such that all the agents will be consensus to the leader agent. We use the Actor-Critic Network and the Deterministic Policy Gradient method to realize the controller. The policy iteration algorithm is discussed and many simulations are provided to validate the result.

14:30-14:50 **SatA05-4**

Simulation Model for the AGC System of Isolated Microgrid Based on Q-learning Method

Penghu Wang Hefei Univ. of Tech.
Hao Tang Hefei Univ. of Tech.
Kai Lv Hefei Univ. of Tech.

The automatic generation control (AGC) in isolated microgrid with multiple distributed energy resources is concerned in this study. First, the load frequency control (LFC) model of an isolated microgrid, which contains diesel engine generators, super-magnetic magnetic energy storage, wind turbines and photovoltaic power system, is established through the analysis of the power generation characteristics of each distributed generation (DG). The LFC model of an isolated microgrid is built by MATLAB/Simulink with diesel generators as frequency control units. Based on the AGC principle of power grid, the AGC controller of the microgrid system is designed by the Q learning algorithm based on the discount compensation model to complete the frequency control. The simulation results verify the feasibility of the isolated microgrid model, showing the

efficient dynamic performance of Q controller by compared with PI controller.

14:50-15:10 **SatA05-5**

Sampled-data Control for T-S Fuzzy Systems with Quantized Signals

Xiaojing Han Yanshan Univ.
Ningwei Cheng Yanshan Univ.
Yuechao Ma Yanshan Univ.

This paper deals with the problem of sampled-data control for T-S fuzzy systems with quantized signals. Based on the constructed Lyapunov-Krasovskii functional (LKF), Jensen's inequality and Free weight matrix, some sufficient conditions are obtained in the form of linear matrix inequalities (LMIs). By combining the input delay approach and dynamic quantizer, the sampled-data controller is designed to guarantee that T-S fuzzy systems with quantized signals is asymptotically stable. Finally, a numerical example is presented to verify the feasibility and effectiveness of the proposed methods.

15:10-15:30 **SatA05-6**

An Intelligent Car Temperature Control System

Xiongnan He Northeastern Univ.
Songchen Jiang Northeastern Univ.
Qiuye Sun Northeastern Univ.

Nowadays, more and more residential cars apply various of services of energy saving to help themselves improve performances and decrease cost. As for the car air conditioning, some put forward ideas that using neuron-fuzzy method can precisely control the cooling capacity, the other hold the view that power line communication based photovoltaic (PV) system can effectively manage the energy. In this paper, it aims to deal with the shortcomings that aforementioned do not take the realistic environment and the neuron-fuzzy method's disadvantages into consideration. As a result, this paper comes up an intelligent car temperature control system(ICTCS), which comparing with conventional temperature control systems, has two main advantages-one is using three criterions, namely light intensity outside cars(I), temperature inside cars(T) and sunshine incident angle(α), to judge what kind of environment the car is in on earth and decide car cooling capacity over , the other is applying neuron-fuzzy system to train the comprehensive temperature to try its best to decrease faster. It will refrigerate in different stalls in the standard of difference between temperatures inside cars and calculated most suitable temperature. Applying the above system into actual experiments, we can find under the premise that cooling effect stays nearly the same, the energy consumption gets decreased, which is to say, the ICTCS gets good results.

SatA06 Room 6

Data-driven modeling, optimization and scheduling (I)

13:30-15:30

Chair: Huijin Fan Huazhong Univ. of Sci. and Tech.
CO-Chair: Yong Chen Univ. of Electronic Sci. and Tech. of China

13:30-13:50 **SatA06-1**

Design Optimization of Permanent Magnet Brushless Direct Current Motor Using RBF Neural Network

Darong SORN Univ. of Electronic Sci. and Tech. of China
Yong Chen Univ. of Electronic Sci. and Tech. of China

This paper is about a methodology for the optimization of a Permanent Magnet Brushless Direct Current (PM-BLDC) motor. The most advantage of this proposed method is its mathematical modeling effectiveness. In specific, it is focused on multi-objective optimization by using a Radial Basis Function (RBF) Neural Network simulated in the Matlab environment. The aim of this optimization process was to maximize the efficiency and to minimize the permanent magnet mass, active mass, and volume of the motor. In order to verify results, two-dimensional models were developed and thoroughly analyzed using Finite Element Analysis (FEA) in Ansys-Maxwell. Moreover, the comparison of the RBFNN and Genetic Algorithm (GA) results were also figured out in this paper and the comparison showed that the RBFNN has better ability in finding the optimal solutions and also has better computational time consume than GA.

13:50-14:10 **SatA06-2**

Controlled Variables Adaptation to Improve Process Optimality Using Historical Operating Data

Wanqing Tao Zhejiang Univ.
Lingjian Ye Zhejiang Univ.
Feifan Shen Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

The selection of controlled variables (CVs) plays an important role in the process optimality and is highlighted in the methodology of self-optimizing control. In general, the self-optimizing control deals with expected disturbances via controlling CVs selected, while the unknown disturbances encountered in practice are not accounted for. A recent two-layer control architecture integrating self-optimizing control and modifier adaptation is able to handle both types of disturbances, which is however not effective in cases when the unknown disturbance are frequent. The controlled variable adaptation strategy proposed in this paper utilizes information in the historical operating data, endowing the self-optimizing control layer an ability of handling either disturbance mentioned above, in the aid of the upper modifier adaptation. Such transformation is beneficial to improve the process

optimality because the self-optimizing control works in a much faster time-scale than the modifier adaptation. The Williams-Otto reactor is investigated to show the proposed methodology.

14:10-14:30 **SatA06-3**

A New Method to Detect the License Plate in Dynamic Scene

Chunliang Zhao Qingdao Univ. of Sci. & Tech.
Yuanyuan Hao Qingdao Univ.
Shulin Sui Qingdao Univ. of Sci. & Tech.
Shujiao Sui Qingdao Univ. of Sci. & Tech.

License plate detection includes license plate positioning, segmentation characters, character recognition. The recognition rate of license plates under dynamic scenes is affected by many factors. Each process deviation may affect the overall system recognition rate, and the accuracy of each part is affected by many factors, in order to reduce this error, we combine the advantages of a variety of algorithms to propose a comprehensive detection model. In the license plate positioning phase, we propose HSV space and morphological methods; in the segmentation character phase, we propose the maximum adjacent character horizontal center distance segmentation method; in the character recognition stage, we choose to use the CNN algorithm. In the final simulation test, there are a set of 1 errors in the 30 groups of license plate recognition, the accuracy is higher.

14:30-14:50 **SatA06-4**

RRT Based Path Planning for Autonomous Parking of Vehicle

Kaiyu Zheng Zhejiang Univ.
Shan Liu Zhejiang Univ.

Path planning is one of the most issues in the automatic parking system for vehicle. This paper presents a path planning method based on rapidly-exploring random tree (RRT) with non-holonomic constraint and kinematics model of vehicle. First, the kinematics model of car parking according to the vehicle kinematics equation is set up, and the non-holonomic constraints are put forward. Based on this model, the RRT algorithm is used to search parking path with the constraints. And then, to optimize the search efficiency, two strategies--target preference and bi-RRT are used and also the cost function is added for optimization. Besides, because of the new detected obstacles, a replanning method is used to replan the path using the feature of the RRT algorithm. Finally, the performance of the proposed method is verified on a simulation model based on matlab.

14:50-15:10 **SatA06-5**

Robust Stability Analysis of Lurie Nonlinear Discrete System with Time-varying Delay via Scaled Small Gain Theorem

Chaoqun Guo Qilu Univ. of Tech.
Hongqian Lu Qilu Univ. of Tech.
Yue Hu Qilu Univ. of Tech.
Xingping Liu Qilu Univ. of Tech.
Hongwei Chen Ji Nan Building Source Cement Products Co. LTD.

This paper is concerned with the robust stability of lurie nonlinear discrete time-varying delay system. The initial lurie nonlinear discrete system with time-varying delay is converted into two interconnected subsystems by using a model transformation. One of the subsystems has no uncertainty and delay and could be analyzed stability by Lyapunov-Krasovskii functional method. Then use an input-output (IO) approach which is an application of the scaled small gain theorem to obtain the stability condition of the lurie nonlinear discrete system. A numerical example is provided to demonstrate the applicability of the presented method.

15:10-15:30 **SatA06-6**

An Improved Nonlocal Patch-based Image CS Algorithm with SBI

Wenkang Guan Huazhong Univ. of Sci. and Tech.
Huijin Fan Huazhong Univ. of Sci. and Tech.
Li Xu Akita Prefectural Univ.
Yongji Wang Huazhong Univ. of Sci. and Tech.

In image compressive sensing field, nonlocal patch-based CS methods have achieved an impressive improvement on the recovery quality. In [8], a new structural group sparse representation (SGSR) modeling has been proposed, which enforces image sparsity and self-similarity simultaneously under a unified framework in an adaptive group domain. The works greatly confine the CS solution space while in a cost of time consuming or an unsatisfactory quality. In this paper, by taking the advantage that the Split Bregman Iteration (SBI) converges faster and requires only a small memory footprint, an improved SGSR algorithm is to be proposed with SBI embedded. Experimental results show that our improved SGSR CS algorithm outperforms much better than the original one, and is not only competitive to some state-of-the-art image CS algorithm to our best knowledge, but also with a lower time consuming.

SatA07 **Room 7**

Statistical learning and machine learning in automation field (I) **13:30-15:30**

Chair: Dongbin Zhao Chinese Academy of Sci.
CO-Chair: Yi Liu Zhejiang Univ. of Tech.

13:30-13:50 **SatA07-1**

A Prediction Approach on Energy Consumption for Public Buildings Using Mind Evolutionary Algorithm and BP Neural Network

Yang Gao Beijing Institute of Residential Building Design & Research Co.

Xudong Liu Univ. of Sci. and Tech. Beijing
Xiaoli Li Beijing Univ. of Tech.
Liu Gu Univ. of Sci. and Tech. Beijing
Jiaru Cui Univ. of Sci. and Tech. Beijing
Xu Yang Univ. of Sci. and Tech. Beijing

This paper proposes a prediction approach on energy consumption for public buildings based on mind evolutionary algorithm and BP neural network. The actual real-time data of some layer in a public building can be obtained online by our implemented building monitoring system, then several key factors which affect building energy consumption can be analyzed and determined by correlation analysis method. By using the mind evolutionary algorithm, the ideal weighted values and threshold values of BP neural network is calculated, which can solve its problems of low efficiency and slow convergence. Finally, the performance and effectiveness of the proposed forecasting model is demonstrated through a case study of a building energy consumption monitoring system from practical engineering.

13:50-14:10 **SatA07-2**

Adaptive Fuzzy Control of Nonlinear Systems Based on T-S Fuzzy Hyperbolic Model

Naizheng Shi Xi'an Modern Control Tech. Research Inst.
Junmin Li Xidian Univ.
Pei Li Xi'an Modern Control Tech. Research Inst.
Haitao An Xi'an Modern Control Tech. Research Inst.
Chong Wang Xi'an Modern Control Tech. Research Ins.

This paper proposes a design scheme of stable fuzzy control for a class of nonlinear systems, which can be modeled by a T-S fuzzy hyperbolic model. Firstly, the parallel distributed compensation (PDC) method is employed to design the fuzzy controller for the system without considering the error caused by fuzzy modeling, Data-driven modeling and optimization and the sufficient conditions of stability are given in the form of linear matrix inequalities (LMI). Then the error caused by fuzzy modeling is considered and the method of adaptive control is used to reduce the effect of the modeling error, simultaneously, dynamic performance of the closed-loop system is improved. By Lyapunov stability criterion, the resulting closed-loop system is proved to be asymptotically stable. Finally, an illustrative example is provided to illustrate the effectiveness of the results proposed in this paper.

14:10-14:30 **SatA07-3**

Human Action Recognition Based on Dense Sampling of Motion Boundary and Histogram of Motion Gradient

Min Fan Chongqing Univ.
Qi Han Chongqing Univ.
Xi Zhang Chongqing Nanan Power Supply Co.
Yaling Liu Chongqing Univ.
Huan Chen Chongqing Univ.
Yaqian Hu Chongqing Univ.

In order to realize accurate recognition of human action, feature expression of motion information is a very crucial step. Aiming at the problem that the dense sampling used for action recognition will be affected by interference factors, such as camera motion and background information redundancy, this paper proposes the human action recognition method based on dense sampling of motion boundary and motion gradient histogram. Firstly, the dense sampling strategy based on motion boundary is incorporated into the improved dense sampling to eliminate a large number of invalid sampling points and reduce the number of trajectories. Next, in order to fully excavate the internal relationship of human movement between time and space, histograms of motion gradients based on time and space derivation is introduced to capture motion information in video, which is integrated with dense features to enhance the feature expression. The experiment results on two challenging datasets show that the proposed method improves the human action recognition accuracy effectively in the case of accelerating the speed of algorithm.

14:30-14:50 **SatA07-4**

Online Semi-supervised Quality Prediction Model for Batch Mixing Process

Mingtao Zhang Taizhou Vocational and Technical College
Bocheng Chen Zhejiang Univ. of Tech.
You Wu Shanghai Entry-Exit Inspection and Quarantine Bureau
Weiwei Deng Shanghai Entry-Exit Inspection and Quarantine Bureau
Xuelei Zhang Shanghai Entry-Exit Inspection and Quarantine Bureau
Yi Liu Zhejiang Univ. of Tech.

Current soft sensors for the Mooney viscosity prediction in rubber mixing processes only utilized the limited labeled data. By exploring the unlabeled data, a novel soft sensor, namely just-in-time semi-supervised extreme learning machine (JSELM), is presented to online predict the Mooney viscosity with multiple recipes. It integrates the just-in-time learning, extreme learning machine (ELM), and the graph Laplacian regularization into a unified online modeling framework. When a test sample is inquired online, the useful information in both of similar labeled and unlabeled data is absorbed into the JSELM model to enhance its prediction performance. Moreover, an efficient model selection strategy is formulated for online construction of the JSELM prediction model. The superiority of JSELM is validated via the industrial Mooney viscosity prediction.

14:50-15:10 **SatA07-5**

Overview of Image Segmentation and Its Application on Free Space Detection

Xiaodong Zhao Chinese Academy of Sci.

North China Univ. of Tech.
Qichao Zhang Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Dongbin Zhao Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Zhonghua Pang North China Univ. of Tech.

With the development of deep learning technique, image segmentation has received spreading attention in the computer vision field. It has a wide range of applications such as scene understanding, autonomous driving and so on. For the image segmentation, we can divide it into the semantic segmentation and instance segmentation, where a high-quality segmentation label for each instance is required for the latter method. In this paper, we sort out the popular structures of semantic segmentation and introduce the instance segmentation briefly. In the experiments, three main semantic segmentation methods are tested and analyzed based on the opened CamVid dataset, and the experiments for free space detection based on two popular segmentation methods are given.

15:10-15:30 **SatA07-6**

A Second-order Hidden Markov Model Based Web Services Selection

Yuan Lu Bohai Univ.
Zhichun Jia Bohai Univ.
Xiang Li Bohai Univ.
Xing Xing Bohai Univ.

Over the last few decades, the cloud computing is rapidly developing. How to quickly and accurately find the suitable web services for users is facing more and more challenges. The quality of service becomes an essential parameter to discriminate the web services with the same function. In this paper, we propose an effective services selection method based on QoS parameters. Our method uses the second-order Hidden Markov Model (HMM) to model the business process of web services and select the optimal web services for the execution of user requests. The technique we present can solve the measurement problem of the web service behaviors according to the given threshold values of the throughput and response time. By ranking the candidate services with the similar functionality, the top service is selected to run in the business process for meeting the user needs. Finally, we conduct the simulation experiments to demonstrate our method using QWS database. The result shows our method is effective.

SatA08 Room 8
ADRC technology and applications I 13:30-15:30

Chair: Haoping Wang Nanjing Univ. of Sci. & Tech.
CO-Chair: Xiangyang Li South China Univ. of Tech.

13:30-13:50 **SatA08-1**

LADRC-Smith Controller Design and Parameters Analysis for First-order Inertial Systems with Large Time-delay

Yongshuai Wang Nankai Univ.
Zengqiang Chen Nankai Univ.
Mingwei Sun Nankai Univ.
Qinglin Sun Nankai Univ.

In the process of modern industrial control, systems with large time-delay are typical problems. Thus in order to get better control effect, it is productive by combining advanced control methods with traditional Smith predictor. The aim of this paper is to present the LADRC (linear active disturbance rejection control)-Smith controller design and parameters analysis for first-order inertial systems with large time-delay, along with the discussion of frequency response and parameters perturbation for systems. To be specific, it is proved that the system is stable when parameters of plant are exactly known. Moreover, a sufficient stable condition is obtained when parameters of plant change. Besides, the step response, stability margin and capability of disturbance rejection are compared when plant has a different degree of perturbation, and these results make great sense to design the LADRC-Smith controller and regulate parameters for time-delay systems.

13:50-14:10 **SatA08-2**

Active Disturbance Rejection Control for Active Suspension System of Nonlinear Full Car

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

In this paper, a full car model with seven degrees of freedom is established for the research of active suspension system, and a virtual prototype is built in Adams to compare and validate it, in particular. Then active disturbance rejection control (ADRC) is applied for the control system. The suspension system is complex for its nonlinearities from the springs, dampers, and irregular excitations from road surface. This paper considers the nonlinear characteristics and complex behavior of real vehicles, and uses extended state observer (ESO) to estimate and eliminate them from the controlled system. After decoupling the full car system, three ADRC controllers are designed to balance the vertical vibration, rolling and pitching movement, respectively, thus producing four active control forces of each suspension by matrix transformation. The simulation results are compared with fuzzy PID controlled system, which show that ADRC has good performance over nonlinearities, perturbations and bounded uncertainties.

14:10-14:30 **SatA08-3**

ADRC with Feedfoward Control for Time-delay Systems

Xiangyang Li South China Univ. of Tech.
Wei Ai South China Univ. of Tech.
Senping Tian South China Univ. of Tech.

A novel Active disturbance rejection control (ADRC) with

feedforward control is proposed for time-delay systems. The feedforward control, which is inspired by the classic Smith predictor, is added to the original ADRC scheme and tuned to improve the reference tracking performance. The ADRC is mainly tuned to reject total disturbance including model uncertainties and external disturbance. The feedforward control does not change the poles of the main closed-loop system and the stability of the main closed-loop system depends on the conventional ADRC whose stability has been solved theoretically. A first-order plus time-delay (FOPTD) system is used in simulation study where the increasing system order method for time-delay system is used in ADRC. Simulations for reference tracking, external disturbance and variations of time-delay, time-constant and process gain of the plant show that the proposed ADRC with feedforward control provides more effective tracking performance and disturbance rejection abilities than the conventional ADRC for time-delay systems.

14:30-14:50 **SatA08-4**

Implementation of an Active Disturbance Rejection Controller on Piezoelectric Actuators

Miaolei Zhou Jilin Univ.
Linlin Su Jilin Univ.

This paper investigates the trajectory tracking problem of piezoelectric actuators (PEAs) in the presence of the hysteresis behavior. The hysteresis nonlinearity, an inherent nonlinear characteristic of PEAs, vastly exacerbates the control performance. To overcome this problem, the Krasnoselskii-Pokrovskii model is adopted to describe the hysteresis behavior of PEAs. Then an active disturbance rejection controller (ADRC) is proposed to improve control accuracy during the trajectory tracking. The key characteristics of the proposed strategy are that both hysteresis nonlinearity and system uncertainties are estimated by means of extended state observer, and the controller is independent of the objects. Finally, the simulation results illustrate that the ADRC technique is valid in damping the hysteresis and enhancing the trajectory tracking performance of PEAs.

14:50-15:10 **SatA08-5**

Application of ADRC in Stability Control of Tank Gun System

Yang Lei China North Vehicle Research Inst.
Jing Xu China North Vehicle Research Inst.
Qiang Hao China North Vehicle Research Inst.

Overcoming the disturbance of vehicle body is an important function of the tank gun control system. Therefore, the tank artillery can be stabilized to a given angle in space. However, due to the change of load factors such as inertia, friction and clearance, the stability precision of the gun control system cannot be further improved, and hitting probability will drop under the condition of tank high speed maneuverability. In this paper, the tank gun control system and the disturbance model were analyzed, and the active disturbance rejection controller was designed. The control performance of this active disturbance rejection controller was verified by MATLAB simulation and the experiments of analog prototype. The results showed that the application of the ADRC is more effective than the traditional PID controller in improving the stability precision of gun control system.

15:10-15:30 **SatA08-6**

Active Disturbance Rejection Based Iterative Learning Control in Variable Air Volume Central Air-Conditioning System

Shiying Lu South China Univ. of Tech.
Wei Ai South China Univ. of Tech.
Xiangyang Li South China Univ. of Tech.

The Variable Air Volume (VAV) Central Air-Conditioning (CAC) system is a complicated system with non-linearity, large-time delay and strong inertia, thus it is difficult to design an effective controller. Iterative Learning Control (ILC) takes good effect in controlled process with characteristics repeatability and periodicity, but it cannot cope with uncertain disturbance explicitly. A creative algorithm, Active Disturbance Rejection based Iterative Learning Control(ADRC-Based ILC) is proposed to improve ILC's performance in VAV control system. ADR-Based ILC helps to compensate the disturbance explicitly caused by ambient temperature, heat from people and machines and make it to a higher control precision and a higher energy-efficiency. An accurate model of VAV system is built in TRNSYS platform, where ADR-Based ILC is proved to be much more effective than fuzzy PID and ILC.

SatA09 Room 9
Iterative learning and consensus control 13:30-15:30

Chair: Xiongxiong He Zhejiang Univ. of Tech.
CO-Chair: Dong Shen Beijing Univ. of Chemical Tech.

13:30-13:50 **SatA09-1**

Iterative Learning Consensus for Discrete-time Multi-agent Systems with Measurement Saturation and Random Noises

Chen Liu Beijing Univ. of Chemical Tech.
Dong Shen Beijing Univ. of Chemical Tech.

This paper investigates the consensus tracking problem for a class of multi-agent systems with measurement saturation and random noises. A distributed iterative learning control algorithm is proposed by utilizing the input signals and the measured output information from previous iterations. The considered multi-agent systems has a fixed topology of the communication graph and the desired trajectory is only accessible to a subset of agents. With the help of a decreasing gain sequence, it is proved that the input sequence will converge to the

desired one in almost sure sense as the iteration number goes to infinity. Simulation results are given to verify the effectiveness of the proposed algorithm.

13:50-14:10 **SatA09-2**

Self-triggered MPC for Tracking of Constrained Wheeled Robots with Additive Disturbance

Qun Cao Beijing Institute of Tech.
Yuanqing Xia Beijing Institute of Tech.
Zhongqi Sun Beijing Institute of Tech.
Hongru Jiang Beijing Institute of Tech.
Xiaopeng Liu Institute of Telecommunication Satellite

In this paper, we present a self-triggered model predictive control (MPC) scheme for unicycle robots with coupled input constraint and bounded external disturbances. Firstly, based on Lyapunov theory, a self-triggered mechanism is developed to the aim of reducing the computation load of MPC. Secondly, by designing a robust terminal region and proper parameters, stability of the closed-loop system as well as a sub-optimal performance are guaranteed. In addition, we compare the given self-triggered MPC scheme with the traditional one. Finally, numerical simulations are given to demonstrate the effectiveness of the proposed strategy.

14:10-14:30 **SatA09-3**

Resilient Consensus with Switching Networks and Double-integrator Agents

Jinbo Huang Zhejiang Univ. of Tech.
Yiming Wu Hangzhou Dianzi Univ.
Liping Chang Zhejiang Univ. of Tech.
Xiongxiong He Zhejiang Univ. of Tech.
Sheng Li Zhejiang Univ. of Tech.

In this paper, we investigate the resilient consensus problem for the second-order multi-agent system communicating via switching networks. The term resilient means the control protocols should consider the presence of attacks by some malicious agents. Assuming that the maximum number of malicious agents in the neighborhood of each agent is bounded and known, we propose a local neighbors' information-based distributed consensus protocol suitable for time-varying topologies to deal with the malicious attacks. It is shown that if the union of communication graphs over a bounded period satisfies certain network robustness property, the states of all normal agents can be guaranteed to reach an agreement resiliently. Numerical simulations are provided to illustrate the effectiveness of the theoretical results.

14:30-14:50 **SatA09-4**

Distributed Convex Optimization Consensus in Multi-agent Network Subject to Equality Constraints

Daduan Zhao Southwest Univ.
Tao Dong Southwest Univ.
XiaoLi Li Southwest Univ.
Yan Li Shandong Univ.

This paper investigates the distributed convex optimization consensus problem for multi-agent network subject to equality constraints, where each agent is assigned with an individual cost function which is coercive and convex. A novel optimization consensus algorithm based on the gradient projection operator and the method of exploiting penalty is proposed. Moreover, it is proved that for any initial state, the algorithm can guarantee a consensus, and in the mean while reach the minimizer of the aggregate cost functions within the constraint set. Finally, a numerical simulation is given to illustrate the effectiveness of the proposed optimization consensus algorithm.

14:50-15:10 **SatA09-5**

Iterative Learning Control for Discrete Singular Systems with Randomly Varying Trial Lengths

Jiahuan Liu South China Univ. of Tech.
Huiping Tian Guangdong Women's Polytechnic College
Senping Tian South China Univ. of Tech.
Xiangyang Li South China Univ. of Tech.

This paper researches iterative learning control for a class of singular systems with randomly iteration varying lengths. Based on an equivalence decomposition of discrete singular systems, a new learning algorithm with a stochastic variable and moving average operator is used to cope with the state tracking problem under non-uniform trial lengths circumstance. The stochastic variable is include both in tracking error and control input. Furthermore, the convergence condition of the proposed learning scheme is put forward and strictly proved. In the end, a numerical example is presented to demonstrate the effectiveness of the theoretical results.

15:10-15:30 **SatA09-6**

High-order Distributed Consensus in Multi-agent Networks

Zunshui Cheng Qingdao Univ. of Sci. and Tech.
Tiansun Wang Qingdao Univ. of Sci. and Tech.
Youming Xin Qingdao Univ. of Sci. and Tech.

We deals with high-order distributed consensus protocols in multi agent networks. It is shown that the inner coupling strengths play a key role in reaching consensus for high-order systems. Scheme for choosing coupling strengths are derived for the third-order consensus and the fourth-order consensus. We found that high-order consensus cannot be achieved even if inner coupling strengths are very large when they were selected incorrectly. The high-order consensus of complex networks is particularly targeted. This result helps investigate large scale multi-agent networks.

SatB01 Room 1
Best Paper Award Finalist 15:40-18:00
Chair: Danwei Wang Nanyang Technological Univ.
CO-Chair: Zengqiang Chen Nankai Univ.

15:40-16:00 SatB01-1

Finite-level Quantized Iterative Learning Control by Encoding-decoding Mechanisms

Chao Zhang Beijing Univ. of Chemical Tech.
Dong Shen Beijing Univ. of Chemical Tech.

This paper studies the zero-error tacking problem of finite-level quantized iterative learning control using an encoding- decoding method, where both measurement and actuator side quantization and transmission are considered. In particular, the system output is encoded, quantized, transmitted and decoded in sequence for input updating of the next iteration. Then the generated input is transmitted through networks following the same procedure as the output transmission for plant input updating. The zero-error convergence of the proposed scheme is strictly proved and a numerical simulation is provided to demonstrate the effectiveness of the proposed scheme.

16:00-16:20 SatB01-2

A Novel Scalable Semi-supervised GMM and Its Application for Multimode Process Quality Prediction with Big Data

Le Yao Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Weiming Shao Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

In this paper, a novel variational inference semi-supervised GMM (VI-S2GMM) model is firstly proposed for multimode process predictive modeling with semi-supervised data. Since all the labeled and unlabeled data samples are involved in each iteration of parameter updating, an intractable computing problem occurs when facing a high-dimension and large-scale dataset. To tack this problem, a scalable Stochastic Variational Inference semi-supervised GMM (SVI-S2GMM) is further proposed for massive semi-supervised data. Through taking advantage of stochastic gradient optimization algorithm to maximize the Evidence of Lower Bound (ELBO), the VI-based algorithm becomes scalable. In SVI-S2GMM, only one or a mini-batch of samples are randomly selected to update parameters in each iteration, which is more efficient than VI-S2GMM. In this way, a large number of unlabeled process data can be useful in the modeling, which will benefit the parameter identification. The SVI-S2GMM is then exploited for the prediction of quality-related key performance index (KPI). Two modeling cases with large scale of semi-supervised datasets demonstrate the feasibility and effectiveness of the proposed algorithms.

16:20-16:40 SatB01-3

Adaptive Event-Triggered Control for Nonlinear Systems with Output Constraint

Lei Liu Liaoning Univ. of Tech.
Yanjun Liu Liaoning Univ. of Tech.

In this paper, the event-triggered adaptive neural network-based tracking control problem is investigated for a class of single-input single-output (SISO) nonlinear systems in strict-feedback form. In the considered systems, there exist unknown functions which are approximated by radial basis function neural networks (RBFNNs). Moreover, the output constraint problem is also taken into account, which is solved by exploiting a barrier Lyapunov function. In order to save resources, the event-triggered control method is developed by using the backstepping technique. Then, the boundedness of all variables appearing in the systems is obtained, as well as the tracking error stays in a small neighborhood of the origin. In the end, a simulation example is employed to show the effective of the proposed scheme.

16:40-17:00 SatB01-4

Optimal Finite-time Tracking Control for a Class of Unknown Nonlinear System Based on Input-Output Data

Ruizhuo Song Univ. of Sci. and Tech. Beijing
Yulong Xie Univ. of Sci. and Tech. Beijing

This paper presents an optimal tracking control approach for completely unknown discrete-time nonlinear affine system. We make iterative adaptive dynamic programming (ADP) to approximately solve the Hamilton-Jacobi-Bellman equation by minimizing the finite-time performance index function. Based on input-output data, using model neural network to construct the system input-output mapping, which is used to build the augmentation system. Then the action and neural network are used to approximate the virtual control and the corresponding performance index function, respectively. It proves that the estimation errors of the neural network are uniformly ultimately bounded. At last, an example is used to demonstrate the theoretical results and the performance of the proposed approach.

17:00-17:20 SatB01-5

Iterative Learning Control for Continuous-time Systems with Locally Lipschitz Nonlinearity and Input Saturation

Jingyao Zhang Beihang Univ.
Deyuan Meng Beihang Univ.

In this paper, a data-based iterative learning control (ILC) is developed to address the output tracking problem of continuous-time locally Lipschitz nonlinear systems subject to input saturation. Under a data-based ILC update law with saturation, an extended data driven framework is established for the ILC convergence in the

presence of locally Lipschitz nonlinearity and input saturation. A relative degree condition and the input-to-state stability are given to ensure the boundedness of the state and the convergence of the output tracking error simultaneously. A simulation demonstrates the effectiveness of the results.

17:20-17:40 **SatB01-6**

On Extended State Based Kalman-Bucy Filter

Xiaocheng Zhang Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Wenchao Xue Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Haitao Fang Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Xingkang He Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.

This paper studies the state estimation problem for a class of continuous-time stochastic systems with unknown nonlinear dynamics and measurement noise. Enlightened by the extended state observer (ESO) in timely estimating both the internal unknown dynamics and the external disturbance of systems, the paper constructs the extended state based Kalman-Bucy filter (ESKBF) to achieve better filtering performance. It is shown that ESKBF can provide the upper bound of the covariance matrix of estimation error, which is critical in evaluating the filtering precision. Besides, the stability of ESKBF is rigorously proven in the presence of unknown nonlinear dynamics, while the stability of traditional Kalman-Bucy filter is hard to be guaranteed under the same condition. Moreover, the asymptotic optimality of ESKBF for time-invariant system under constant disturbance is given. Finally, numerical simulations show the effectiveness of the method.

SatB02 Room 2

IS: Data-driven technology in industry 15:40-18:00

Chair: Huiping Li Northwestern Polytechnical Univ.
CO-Chair: Dezhi Xu Jiangnan Univ.

15:40-16:00 **SatB02-1**

A Model-free Control Strategy for Battery Energy Storage with an Application to Power Accommodation

Yujin Hong Jiangnan Univ.
Dezhi Xu Jiangnan Univ.
Wenxu Yan Jiangnan Univ.
Weilin Yang Jiangnan Univ.

Modeling of battery energy storage applied in photovoltaic (PV) grid-connected system with its power accommodation via advanced controllers is a challenging task since complex features and adjustment difficulties. For the sake of it, a model-free control strategy with intelligent proportional-integral controller and tracking differentiator has been put forward. The design approach of the proposed model-free controller has also been represented in detail and applied in power accommodation. Simulations on a battery energy storage system and comparisons with traditional PI controllers are reported. Compared with PI controller, the proposed strategy has achieved the perfect control performance.

16:00-16:20 **SatB02-2**

Power Management of Battery Energy Storage System Using Model Free Adaptive Control

Weiming Zhang Jiangnan Univ.
Dezhi Xu Jiangnan Univ.
Xuyang Lou Jiangnan Univ.
Wenxu Yan Jiangnan Univ.
Weilin Yang Jiangnan Univ.

A novel adaptive control strategy based on input/output (I/O) data is proposed in this paper to solve the problem of power management of battery energy storage system (BESS). In the proposed control strategy, a time-varying parameter named pseudo-partial derivative (PPD) parameter utilized in dynamic linearization is estimated by an adaptive observer. Besides, the input saturation problem is considered and a compensation signal is added to consummate the anti-windup control algorithm. Finally, simulation results are presented to validate the effectiveness and performance of the proposed control strategy.

16:20-16:40 **SatB02-3**

Direct Torque Control of PMSM Based on Model Free IPI Controller

Yang Liu Jiangnan Univ.
Wenxu Yan Jiangnan Univ.
Dezhi Xu Jiangnan Univ.
Weilin Yang Jiangnan Univ.
Wentao Zhang Jiangnan Univ.

In conventional PMSM DTC system, the electromagnetic torque displays the excellent dynamic performance. While, the dynamic performance of the speed is not satisfying. In this paper, the model free intelligent proportional-integral controller is designed to improve the dynamic performance of the speed. The purpose of this work is to compare the proposed controller with the classical PI controller for the dynamic performance of the speed. Simulation results show the effectiveness of the proposed controller in ameliorating the dynamic performance of the speed.

16:40-17:00 **SatB02-4**

Sliding Mode Control of a Class of Nonlinear Systems

Xinxin Liu Chongqing Univ.
Feng Hu Chongqing Univ.
Xiaojie Su Chongqing Univ.

This paper concerns the sliding mode control problems for a class of nonlinear systems, named repeated scalar nonlinear systems, with a pre-scribed performance. Firstly, observer based on event-triggered scheme is

constructed to well estimate the system states. Corresponding sliding mode dynamics is obtained. Then, sliding mode controller is designed to keep that the closed-loop system trajectories to reach the pre-specified sliding region in finite time. Finally, sufficient conditions of sliding mode dynamics and error dynamics to be stochastic stable with a pre-scribed performance are provided.

17:00-17:20 **SatB02-5**

Robust Position Tracking Control of the Linear Switched Reluctance Machine Motion System

Li Qiu Shenzhen Univ.
Lun He Shenzhen Univ.
Jianfei Pan Shenzhen Univ.

This paper addresses the position tracking control problem for a linear switched reluctance machine (LSRM) motion system based on proportion-integral-derivative (PID) parameters tuning method. The closed-loop control model of the LSRM motion system is built by MATLAB/simulink. The controller and model parameters can be obtained and modified online by dSPACE real-time simulation system platform. The stability conditions and the precise PID position controller design method for LSRM are proposed by Lyapunov stability theory. Several experiment results are presented to verify the effectiveness of proposed model for the LSRM motion position tracking control system. The maximum position error is less than 0.16mm, and the experiment results show that the LSRM motion control system has good robustness.

17:20-17:40 **SatB02-6**

Modified Adaptive Control for Multi-spacecraft Attitude Coordination Problems

Zhuo Zhang Northwestern Polytechnical Univ.
Huiping Li Northwestern Polytechnical Univ.

The distributed control of spacecraft attitude coordination problems is developed in this paper. An adaptive sliding-mode (SM) controller is designed to steer the attitude of multiple spacecraft to synchronously reach zero. Then a modified chattering-free controller is proposed to eliminate the chattering of control inputs caused by the switching function. By utilizing the Lyapunov stability theory, we can prove that the presented approach ensures the multi-spacecraft attitude converge into a limited range. Finally, numerical examples are provided to illustrate that the modified control approach can achieve high control accuracy with eliminating the chattering in the presence of external disturbances and model uncertainties.

17:40-18:00 **SatB02-7**

Iterative Identification for A Class of Closed-loop Systems Based on A Greedy Algorithm

Junyao You Jiangnan Univ.
Huan Xu Jiangnan Univ.
Yanjun Liu Jiangnan Univ.
Jing Chen Jiangnan Univ.

A compressive sampling matching pursuit (CoSaMP) iterative algorithm is proposed in this paper to identify parameters and time-delays of a class of closed-loop systems where the forward channel is a CARMA model. Due to the unknown time-delays of both the feedback controller and the controlled plant, a high dimensional identification model with a sparse pa-remoter vector is derived by using an overparameterized method. Then combining the CoSaMP algorithm with the iterative idea, the parameter vector is estimated and the unmeasurable noise items are updated in each iteration. Finally, the parameters of the feedback controller are extracted based on the model equivalence principle and time-delays are estimated according to the sparse characteristic of the parameter vector. The proposed method can simultaneously estimate the parameters and time-delays from a small number of sampled data. The simulation results illustrate that the proposed algorithm is effective.

SatB03 Room 3

IS: Intelligent learning techniques for autonomous system 15:40-18:00

Chair: Qiuzhen Yan Zhejiang Univ. of Water Resources and Electric Power
CO-Chair: Tianjiang Hu National Univ. of Defense Tech.

15:40-16:00 **SatB03-1**

Repetitive Learning Control for a Class of Nonlinear Systems

Mingxuan Sun Zhejiang Univ. of Tech.
He Li Zhejiang Univ. of Tech.
Qiang Chen Zhejiang Univ. of Tech.

This paper presents a design method of repetitive learning control for a class of nonlinear uncertain systems. The control design is carried out by the estimation of the desired control and the norm-bounding uncertainty. By the adaptive learning techniques, the desired control is taken as a parametric uncertainty with regressor one. In addition, the variation of the nonlinearity, characterized by the bounding function, can be handled to alleviate the requirement for the knowledge about the system dynamics. The upper bound of the control gain is only required in this scheme. The boundedness of variables in the closed-loop system and the asymptotical convergence of the tracking error are established. And numerical results are presented to demonstrate the effectiveness of the proposed control scheme.

16:00-16:20 **SatB03-2**

Feedback-aided PID-type Iterative Learning Control against Initial State Error

Hongbo Bi Quzhou Univ.
Mingxia Yang Quzhou Univ.
Jiaquan Chen Quzhou Univ.

This paper presents a PID-type ILC (iterative learning control) algorithms for system which undertaken performance tasks repetitively over a pre-specified finite-time interval in the presence of initial state error, and the convergence analysis shows that the tracking error converges to zero asymptotically as time goes to infinity. Furthermore, a kind of initial rectifying strategy is addressed to eliminate the effect of the fixed initial state error, and the limit trajectory is stated. At last, numerical results are addressed to demonstrate the validity of the proposed learning control algorithms.

16:20-16:40 **SatB03-3**

Convergence Performance of Discrete Power Attracting Law

Lingwei Wu Taizhou Univ.
Mingxuan Sun Zhejiang Univ. of Tech.
Guang Chen Taizhou Univ.

This paper studies the tracking control of uncertain discrete-time systems, a discrete power attracting law is presented for designing the controller. The system has a faster convergence speed obviously and no chattering phenomenon. A measure of the order $O(T^3)$ disturbance-rejection is embedded in the attracting law, so that the steady-state error magnitude of the proposed method is of the order $O(T^3)$. For characterizing the tracking performance, we derive the expressions for the range of the steady-state error and the power absolute attractive layer, power monotone decreasing region. A motor servo system is taken as an example, simulation results are given to validate the effectiveness and superiority of the presented control method.

16:40-17:00 **SatB03-4**

A Unified Iterative Learning Fault Detection and Fault-tolerant Control

Qiuzhen Yan Zhejiang Univ. of Water Resources and Electric Power
Youfang Yu Zhejiang Business College
Jianping Cai Zhejiang Univ. of Water Resources and Electric Power
Qingping Zhou Tangshan Normal Univ.

In this paper, a unified iterative learning based fault detection and fault-tolerant control scheme is proposed. A system fault detector is constructed by using contraction mapping technique, and LMI technique is applied in the design of Lyapnov-based iterative controller, responsible for solving the state tracking problem no matter whether faults occur or not. Numerical results demonstrate the effectiveness of the proposed unified fault detection and control scheme.

17:00-17:20 **SatB03-5**

A Test and Evaluation Framework for Unmanned Surface Vehicle

Weiwei Kong Navy Research Academy
Weiqiang Feng Navy Research Academy
Yi Zheng Navy Research Academy
Tianjiang Hu National Univ. of Defense Tech.

Unmanned Surface Vehicle (USV) in today's military and commercial application is growing exponentially. Benefiting from the autonomous capability, this unmanned platform can execute various tasks without human directly control. So evaluation of their autonomy and other capabilities are critical to realize the autonomous operation ability of unmanned systems. We present the quantitative indices, typical scenes and a practical framework to test and evaluate the performance of an USV. Then a test and evaluation (T&E) framework was established for data collection. By setting up a simulation environment, it can be seen that the proposed framework gives quantified results with different testing assignments.

17:20-17:40 **SatB03-6**

Improved Model Free Adaptive Control for Winding System

Hongyun Xiong Central South Univ.
Ye Liao Central South Univ.
Xiaoyan Chu Central South Univ.

The winding system is a strong coupling system with parameter variability, uncertainty, structural complexity and external interference. Aiming at the problem that the saturation of the actuator of winding system affects the control effect, a modified partial form dynamic linearization (PFDL) model-free adaptive control (MFAC) method considering the actuator saturation is proposed. The MFAC method based on adaptive observer is used to reduce the complexity of pseudo-Jacobian parameter matrix. At the same time, considering the dynamic constraint of the control quantity, an anti-saturation compensator is designed to dispose the control variable input rate and the limitation of the magnitude. The results show that the improved control algorithm can dispose the actuator' saturation problem, and can realize the fast tracking and stability control of tension and speed.

17:40-18:00 **SatB03-7**

Modified P-type ILC for High-speed Trains with Varying Trial Lengths

Qiongxia Yu Henan Polytechnic Univ.
Xuhui Bu Henan Polytechnic Univ.
Ronghu Chi Qingdao Univ. of Sci. and Tech.
Zhongsheng Hou Beijing Jiaotong Univ.

High-speed trains always operate from the same departure station to the same terminal station and hence

iterative learning control (ILC) is an appropriate approach for automatic train control. However, due to complex environment and unknown uncertainties, the train may arrive at the terminal station on time, or earlier and later than the schedule time in each operation. To address this problem, a modified proportional-type (P-type) ILC is presented where the trial length in each operation can be randomly varying. Moreover, the convergence condition in 2-norm is also derived through rigorous analysis. The effectiveness of the modified P-type ILC is further verified through simulations.

SatB04 Room 4
Data-driven fault diagnosis and health maintenance (I)
15:40-17:40

Chair: Jiusun Zeng China Jiliang Univ.
CO-Chair: Lingjie Zhang Xi'an Polytechnic Univ.

15:40-16:00 SatB04-1

Yarn-dyed Fabric Defect Detection with YOLOV2 Based on Deep Convolution Neural Networks

Hongwei Zhang Xi'an Polytechnic Univ.
Lingjie Zhang Xi'an Polytechnic Univ.
Pengfei Li Xi'an Polytechnic Univ.
De Gu Jiangnan Univ.

To reduce labor costs for manual extract image features of yarn-dyed fabric defects, a method based on YOLOV2 is proposed for yarn-dyed fabric defect automatic localization and classification. First, 276 yarn-dyed fabric defect images are collected, preprocessed and labelled. Then, YOLO9000, YOLO-VOC and Tiny YOLO are used to construct fabric defect detection models. Through comparative study, YOLO-VOC is selected to further model improvement by optimize super-parameters of deep convolutional neural network. Finally, the improved deep convolutional neural network is tested for yarn-dyed fabric defect detection on practical fabric images. The experimental results indicate the proposed method is effective and low labor cost for yarn-dyed fabric defect detection.

16:00-16:20 SatB04-2

Iterative Learning Fault Estimation Algorithm for Time-delay Systems Based on Extended Observer

Hongfeng Tao Jiangnan Univ.
Qiang Wei Jiangnan Univ.

For a class of multivariable linear, time-delay systems with actuator fault and measurement bounded disturbances in output, an iterative learning fault estimation algorithm based on extended observer is proposed. The extended observer is designed in terms of the linear matrix inequality technique such that the states and disturbances can be estimated simultaneously in every trials, then the faults and disturbances can be separated for avoiding impact to each other. Afterwards, the iterative learning fault estimation algorithm by defining estimation residual is chosen to adaptively approximate the actuator fault with initial error, then the necessary and sufficient conditions for the existence of the learning algorithm is given through λ norm theory and Bellman-Gronwall inequality, and the uniform convergence criteria of the control algorithm is also discussed. Simulation results verify the feasibility and effectiveness of this algorithm.

16:20-16:40 SatB04-3

Generalized CCA with Applications for Fault Detection and Estimation

Zhiwen Chen Central South Univ.
Steven X. Ding Univ. of Duisburg-Essen
Kai Zhang Univ. of Sci. and Tech. Beijing
Chunhua Yang Central South Univ.
Tao Peng Central South Univ.

Canonical correlation analysis (CCA) is a well-established multivariate analysis method for finding the relationship between two data sets, which has been explored for fault detection recently. In this paper, we revisit the generalized canonical correlation analysis (CCA) form and discuss its applications for fault detection and estimation. The motivation of using CCA for fault detection is to reduce process uncertainty by taking the correlation coefficients into account. Then, the fault detectability in terms of fault detection rate is increased. Finally, the generalized CCA-based fault detection method is validated on the benchmark, which is a simulation of high-speed trains traction drive control system. The achieved results show that the proposed method is able to successfully detect the faults.

16:40-17:00 SatB04-4

Finite Time State Estimation and Fault Detection for Linear Switched Systems with Unknown Inputs

Junqi Yang Henan Polytechnic Univ.
Chen Wu Henan Polytechnic Univ.
Lizhi Cui Henan Polytechnic Univ.
Yantao Chen Henan Polytechnic Univ.

In this paper, we consider using finite time switched observer to estimate the states and detect the faults for a type of linear switched system with unknown inputs. We first design the finite time switched observer by a reduced-order switched system which originates from the primary switched system, where the unknown inputs are removed with the help of state and output transformations. A cluster of finite time observers are presented for all of the reduced-order subsystems. Then, by choosing any small time parameters, we can get the finite time state estimation of the reduced-order switched system by finite time switched observers. And the finite time state estimation of the primary switched system is acquired by state equivalent transformations. Next, we put forward a fault detection method using output residual. Finally, a MATLAB simulation result is

presented to confirm the reliability of the method we put forward.

17:00-17:20 **SatB04-5**

Sequential Graphical Lasso for Fault Detection and Isolation

Yi Liu Zhejiang Univ.
Jiusun Zeng China Jiliang Univ.
Lei Xie Zhejiang Univ.
Shihua Luo Jiangxi Univ. of Finance and Economics
Hongye Su Zhejiang Univ.

This article proposes a sequential graphical Lasso based approach for monitoring of complex industrial systems. The graphical Lasso is a widely used algorithm to estimate the precision matrix (inverse covariance matrix), which encodes the conditional relationship between pairs of variables given other entities. Based on the estimated precision matrix, a graphical model can be constructed to represent the structured correlation information between process variables. The proposed approach utilizes the graphical model to localize anomalous variables. Different from the conventional graphical Lasso approach, the proposed method considers an additional fusseed lasso term and a similarity term in the objective function and the optimization problem can be solved by the alternative direction method of multiplier (ADMM). Using a moving window approach, the proposed method generates a sequence of sparse Gaussian graphs and a new monitoring statistic based on penalized likelihood ratio and matrix norm is constructed. Once a fault is detected, the problem of fault isolation becomes a graph matching problem and a fault score index is calculated for each variable. The validity of proposed method in fault detection and isolation is illustrated by a typical fault observed in the Tennessee Eastman (TE) process.

17:20-17:40 **SatB04-6**

Structured Joint Sparse Principal Component Analysis for Fault Detection and Isolation

Yi Liu Zhejiang Univ.
Jiusun Zeng China Jiliang Univ.
Lei Xie Zhejiang Univ.
Shihua Luo Jiangxi Univ. of Finance and Economics
Hongye Su Zhejiang Univ.

Principal component analysis (PCA) has been widely applied in process monitoring of modern industrial systems. PCA performs fault detection by mapping the process data into a low dimensional subspace and tracking the process behavior using T2 and SPE statistics, whilst in fault isolation, it heavily relies on contribution plot or reconstruction based approaches. However, conventional methods based on contribution plot and reconstruction suffer from insufficient fault isolation capabilities. In order to improve the fault isolation performance, this article proposes a novel fault detection and isolation approach based on the Structured Joint Sparse PCA (SJSPCA). The objective function of SJSPCA involves two regularization terms: l2,1 norm and the graph Laplacian. By imposing the l2;1 norm term, SJSPCA is able to achieve row-wise sparsity, introducing the graph Laplacian regularization term can incorporate structured variable correlation information. In fault detection, conventional T2 and SPE statistics are constructed to detect abnormal situations. Once a fault is detected, a two stage fault isolation strategy is considered and a score index is calculated for each variable. The row-sparsity property of l2,1 norm ensures that the score indices associated to normal variables approach zero and the graph Laplacian constraint helps isolation of correlated faulty variables. The validity of SJSPCA in fault detection and isolation is illustrated by a process fault observed in an industrial blast furnace iron-making process.

SatB05 Room 5
Iterative learning control (II) 15:40-17:40

Chair: Youqing Wang Beijing Univ. of Chemical Tech.
CO-Chair: JinRong Wang Guizhou Univ.

15:40-16:00 **SatB05-1**

Iterative Learning Control for Linear Conformable Fractional Differential Equations

Xiaowen Wang Guizhou Univ.
JinRong Wang Guizhou Univ.
Shengda Liu Guizhou Univ.

This paper deals with iterative learning control for a linear conformable fractional differential equation. A conformable D-type learning updating law is proposed to derive the convergence results for such type equations varying with the initial state is (not) coincident with the desired initial state. Finally, two numerical examples are given to illustrate the results.

16:00-16:20 **SatB05-2**

Iterative Learning Control for Linear Continuous-time Systems with Vector Relative Degree under Varying Trail Length

Yunshan Wei Guangzhou Univ.
Chaolun Wang Sun Yat-sen Univ.

This note considers the problem of iterative learning control (ILC) for a class of linear continuous-time multiple-input multiple-output (MIMO) systems with vector relative degree, where the trail length of control input is different from that of system state and output for a specific iteration. An iteration-average operator is included in the proposed ILC law to address the varying trail lengths. The proposed ILC algorithm allows that the control input length is iteration-varying during the ILC process, and can achieve desired trajectory tracking at control time interval. A numerical example is carried out to illustrate the effectiveness of the proposed ILC scheme.

16:20-16:40 **SatB05-3**

Iterative Learning Based Fault Estimation for Stochastic Nonlinear Systems

Jiantao Shi Nanjing Research Inst. of Electronic Tech. CETC
Yuhao Yang Nanjing Research Inst. of Electronic Tech. CETC
Jun Sun Nanjing Research Inst. of Electronic Tech. CETC
Ning Wang Nanjing Research Inst. of Electronic Tech. CETC

In this paper, the fault estimation issue is investigated for a type of nonlinear stochastic repetitive systems using the iterative learning (IL) approach. Different from the existing works, a type of systems with initial state errors, stochastic disturbance and measurement noise are considered. In order to estimate the fault, a novel nonlinear iterative learning observer (NILO) is designed by using previous input signals and output estimation errors. A necessary and sufficient condition is obtained to guarantee the uniform ultimate boundedness of fault estimation errors in terms of λ-norm with the given IL strategy. Finally, the given approach is verified by a simulation example.

16:40-17:00 **SatB05-4**

Optimal Time Allocation of Point-to-pint Iterative Learning Control with Specified Output Tracking

Xingding Zhao Beijing Univ. of Chemical Tech.
Youqing Wang Shandong Univ. of Sci. and Tech. Beijing Univ. of Chemical Tech.

This paper studies the optimal time allocation of point-to-point (P2P) iterative learning control (ILC) when tracking selected elements or linear combinations of elements in the outputs. The optimization framework of the problem is a two-stage design algorithm, which is addressed by integrating norm-optimal ILC and the gradient method. To test the performance of the proposed algorithm, we report the results of our simulation test using a gantry robot.

17:00-17:20 **SatB05-5**

Control Performance Assessment for ILC-Controlled Batch Processes Based on MPC Benchmark

Juan Wang Beijing Univ. of Chemical Tech.
Youqing Wang Shandong Univ. of Sci. and Tech. Beijing Univ. of Chemical Tech.

In this article, direct at the batch process controlled by iterative learning control (ILC), it proposes a more reasonable benchmark for the control performance assessment (CPA): the model predictive control (MPC) benchmark. First, ILC-controlled batch process is converted to a 2-D Fornasini-Marchesini (FM) model. On this basis, the cost function is constructed and the optimal learning law can be found. Then the 2D MPC performance tradeoff surface for assessment is obtained. Finally, a set of simulation experiments prove the effectiveness and feasibility of the proposed method.

17:20-17:40 **SatB05-6**

Research of Two Phase Flow Signal Denoising Based on Fractional Wavelet Transform

Chunling Fan Qingdao Univ. of Sci. & Tech.
Dengpan Chen Qingdao Univ. of Sci. & Tech.
Lichao Fan Qingdao Univ. of Sci. & Tech.

The wavelet transform(WT) is only limited to the time-frequency analysis of the signal, and denoising method based on WT will ignore the details of the signal, which can result in the loss of useful components in the signal. Although the fractional Fourier transform (FRFT) breaks through the limitation of the time-frequency domain, that is it can analyze the signal in the fractional domain, it cannot represent the local characteristics of the signal. In this paper, we propose a method of fractional wavelet transform(FRWT), which not only retains the advantages of multi-resolution analysis of wavelet analysis, but also retains the function of FRFT signal in the fractional order domain, in addition, the method can make up for the defects of FRFT which cannot characterize the local information of the signal. We apply this method to the denoising of two-phase flow signals and find that achieve a better performance.

17:40-18:00 **SatB05-7**

Exponential Stability for Event-driven Impulsive Control Systems

Zidong Ai Qingdao Univ. of Sci. & Tech.

In this work, we conduct stability analysis for a class of multi-module impulsive control systems via an event-driven scheme. By designing some event-driven conditions and a proper event-driven impulsive control law, we establish some sufficient stability criteria for the considered systems. The proposed event-driven control scheme is advantageous to reduce the utilization of communication and computation resources. Further, we study the impulsive synchronization problem for two continuous-time dynamical systems with different initial values. Finally, an example of Chua's circuit with simulations results are provided to illustrate the validity of the method.

SatB06 **Room 6**

IS: Intelligent optimization and control of urban road traffic 15:40-18:00

Chair: Li Wang North China Univ. of Tech.
CO-Chair: Zhonghe He North China Univ. of Tech.

15:40-16:00 **SatB06-1**

Design of Regional Logistics System Based on Unmanned Aerial Vehicle

Haoyuan Ni North China Univ. of Tech.
Xiaohui Deng China Highway Eng. Consultants Corp.

Bo Gong North China Univ. of Tech.
Pangwei Wang North China Univ. of Tech.

With the development of electronic commerce, a large number of labors are demanded to complete the express delivery, because of the complexity of labor management, the increasing amount of labors will result in increasing complication of the express distribution process. In addition, the express also has great limitations in mountainous areas, disaster areas and other special areas of harsh conditions. To solve the problem, this paper presents an intelligent regional logistics transportation system based on unmanned aerial vehicle (UAV). Firstly, this paper designs the application (APP) for mobile phone to send coordinate information and delivery route to the UAV. Then the GPS and visual identification location module of UVA help implement the delivery for the residential area. This system can help achieve a safer, cheaper, less delayed, more orderly and unmanned regional logistics system in residential neighborhoods or other similar areas. Finally, the problem of "last kilometer logistics" will be solved to some extent by this method.

16:00-16:20 **SatB06-2**

A Study of Bidirectional Green Wave Control Based on Random Optimal Graphical Method

Jiaqing Yan North China Univ. of Tech.
Peng Shao North China Univ. of Tech.
Qi Chen North China Univ. of Tech.
Ming Zhang North China Univ. of Tech.
Zhanying Li North China Univ. of Tech.
Li Wang North China Univ. of Tech.

With the increasing number of urban vehicles, traffic congestion is becoming more and more serious. Bidirectional green-wave coordinated control is one of the main ways to alleviate the city traffic congestion and improve the efficiency of city traffic. In this paper, a bidirectional green-wave control method based on random optimal graphic method is proposed. According to the different capacity of the road in both directions, the formula of bandwidth proration coefficient is established, and the green-wave bandwidth is allocated reasonably. The target formula of bidirectional green-wave and the target formula of the bidirectional additional bandwidth of the key intersection are used to find the suitable bidirectional green-wave band. The effectiveness of the method is evaluated using on an arterial road simulated by the VISSIM simulation software, and compared with the traditional graphic method. The simulation results show that the capacity of the optimized arterial road is improved effectively compared with the traditional graphic method.

16:20-16:40 **SatB06-3**

The Study of Traffic Flow Information Completion Based on GAN Algorithm

Min Li North China Univ. of Tech.
Li Wang North China Univ. of Tech.
Jiaqing Yan North China Univ. of Tech.
Haibo Zhang North China Univ. of Tech.
Lili Zhang North China Univ. of Tech.
Lingyu Zhang North China Univ. of Tech.

In urban road traffic, detectors often cause incomplete data and missing data as a result of inadequate coverage or equipment damage and other reasons. Therefore, the data needs to be repaired to ensure data support for the traffic management service. This paper regards traffic flow data from section geomagnetic detectors as the object, processing graphically section flow information. And the missing data of network is predicted and complemented by the idea of generating network analysis images. This paper analyzes the influence of missing area size and loss at random of data on the accuracy of complete information. The results prove the feasibility and applicability of this method.

16:40-17:00 **SatB06-4**

A Bidirectional Green Wave Band Method under Asymmetric Phase Sequence Mode Based on Mobile Navigation Data

Jiyuan Tan North China Univ. of Tech.
Ming Zhang North China Univ. of Tech.
Honghai Li Research Institute of Highway Ministry of Transport Beijing
Weiwei Guo North China Univ. of Tech.
Li Wang North China Univ. of Tech.

With the continuous development of the city, traffic congestion is a serious problem. In order to reduce average delay and average numbers of stop, this paper proposed a bidirectional green wave band method under asymmetric phase sequence mode based on free-flow speed. The main idea to the method is to design a bidirectional wave band for arterial roads. First the different speed between each two intersections is considered, three speed calculation methods are proposed in this paper. Then intersections with asymmetric phase sequence is also mentioned, this method adjust the relative offset by set a random number which range of zero to the public cycle length. Finally choose the maximum of all green wave bandwidth by graphical. In order to test the effectiveness of the arterial signal coordination method proposed by this paper, a simulation model is considered, where its performance index are the average delay and average numbers of stop. The result shows that this method can improve the traffic capacity by increasing bandwidth and reducing delay.

17:00-17:20 **SatB06-5**

Empirical Analysis of Arterial Fundamental Diagram and Optimization by Floating Car Data

Zhonghe He North China Univ. of Tech.
Ming Chen North China Univ. of Tech.
Haibo Zhang North China Univ. of Tech.

Li Wang North China Univ. of Tech.

The fundamental diagram (FD) reflects the operational status of road network traffic and it is a model describing the relationship between traffic density (traffic volume and occupancy rate) at steady state. In this paper, an empirical study is carried out on the model of Nanhuan Road in Changping District. The basic data of flow rate, occupancy rate and driving speed are obtained from the data of geomagnetic detector and floating car, and then the current road status is analyzed. According to the existing data, the traffic flow of the arterial is simulated. Based on the geographical features of the arterial and the traffic flow data, the green wave band control scheme is calculated and the data after the coordinated control is extracted. In the study of arterial coordination control, the influence of the coordination control parameters on FD shape and its influence on the capacity are analyzed.

17:20-17:40 **SatB06-6**

An Improved Stop and Go Model Considering Exhaust Emissions for Connected Vehicles

Pangwei Wang North China Univ. of Tech.
Yue Ma North China Univ. of Tech.
Hongbin Yu North China Univ. of Tech.
Li Wang North China Univ. of Tech.
Wei Zhang China Academy of Transportation Sci.

Increasing vehicle ownership causes more and more serious urban traffic jam, meanwhile it also brings about much more idle time and exhaust emissions. The Stop and Go model is used to reduce stop time when vehicles drive at low speed status. With the development of connected vehicles, in this paper, an improved Stop and Go model is established considering low speed status of the leading vehicle and the following vehicle at the same time. Firstly, by combining the advantage of connected vehicles, the improved Stop and Go model chooses the minimum emissions as the control target. According to the emissions evaluation principle of Comprehensive Modal Emissions Model (CMEM), the objective function is established; secondly, in accordance with the actual traffic conditions and the operating conditions of the sample vehicle, the constraints are established; finally, the improved Stop and Go model is simulated based on Octave software. To prove the feasibility, we use CMEM to calculate the emissions of the following vehicle in the Stop and Go model and the linear Car-Following model. The results of exhaust emissions under two different models has been analyzed. Comparing with the linear Car-Following model, the HC emissions are reduced by 28%, CO emissions are reduced by 16%, and NO x emissions are reduced by 30%. Therefore, the improved Stop and Go model can effectively reduce the emissions of vehicle exhaust.

17:40-18:00 **SatB06-7**

The Methods of Extracting Spatiotemporal Characteristics of Travel Based on Mobile Phone data

Jiyuan Tan North China Univ. of Tech.
Luxi Dong North China Univ. of Tech.
Jian Gao Research Institute of Highway Ministry of Transport Beijing
Weiwei Guo North China Univ. of Tech.
Zhengxi Li North China Univ. of Tech.

With the rapid development of urbanization in China, the problem of traffic congestion is mainly due to the rapid increase in traffic demand. Compared with a variety of travel behaviors and origin-destination spatiotemporal distribution, which is helpful for us to explore the cause of traffic congestion. Traditionally, travel surveys are time consuming and huge economic investment. The accuracy of the results were existed large errors. In recent years, data acquisition techniques and storage capabilities are developed rapidly, more and more human travel related data have been collected. These "Big Data" is brought both opportunities and challenges for extracting valid travel information. In this paper, the different trajectories of travel mode are match with traffic analysis zones through using geography information system. And then stay points are identified by clustering spatiotemporal characteristics of trajectories. Moreover, the OD matrix is established by different stay regions. The indices of travel and OD desire lines are chosen to analyze travel behaviors. Meanwhile, the OD volume distribution in rush hours are used to explain traffic demand in different urban area. The findings could be helped government make the appropriate decision of urban traffic system and made residents the better daily travel planning, which has significant reference value.

SatB07 Room 7
Data-driven modeling, optimization and scheduling (II)

15:40-18:00

Chair: Li Jia Shanghai Univ.
CO-Chair: Yuanjing Feng Zhejiang Univ. of Tech.

15:40-16:00 **SatB07-1**

Behavior Modeling for Autonomous Agents Based on Modified Evolving Behavior Trees

Qi Zhang National Univ. of Defense Tech.
Kai Xu National Univ. of Defense Tech.
Peng Jiao National Univ. of Defense Tech.
Quanjun Yin National Univ. of Defense Tech.

In modern training, entertainment and education applications, behavior trees (BTs) have been the fantastic alternative to FSMs to model and control autonomous agents. However, manually creating BTs for various task scenarios is expensive. Recently the genetic programming method has been devised to learn BTs automatically but produced limited success. One of the main reasons is the scalability problem stemming from random space search. This paper proposes a modified evolving behavior trees approach to model

agent behavior as a BT. The main features lay on the model free method through dynamic frequent subtree mining to adjust select probability of crossover point then reduce random search in evolution. Preliminary experiments, carried out on the Mario AI benchmark, show that the proposed method outperforms standard evolving behavior tree by achieving better final behavior performance with less learning episodes. Besides, some useful behavior subtrees can be mined to facilitate knowledge engineering.

16:00-16:20 **SatB07-2**

Multi-objective Optimization for Thermal Power Plant Operation Based on Improved Working Condition

Lingzhi Ye Shanghai Univ.
Li Jia Shanghai Univ.

A multi-objective optimization based on improved K-means algorithm for thermal power plant operation is proposed in this paper. First, an improved K-means algorithm that aims at updating the method of selecting the clustering number and initial clustering center is applied to divide unit load and coal quality condition. Furthermore, a multi-objective optimization method is developed to realize the balance between the economic indicator and the environmental indicator, thus the corresponding optimal operation parameters of the two performance indicators for each condition can be obtained, which can effectively guide the power station operation. Lastly, taking the historical operation data of a 300MW unit as the experimental object, the simulation results show that the proposed multi-objective optimization based on improved K-means algorithm in this paper is effective and reasonable for the power station operation.

16:20-16:40 **SatB07-3**

Big Data Mining Method of Thermal Power Based on Spark and Optimization Guidance

Mingcheng Song Shanghai Univ.
Li Jia Shanghai Univ.

With the increasing degree of information technology in the electric-power industry, the amount of big data in thermal power has increased geometrically. To address the problem of the computational bottlenecks in traditional data mining deal with big data of thermal power, big data mining of thermal power method based on Spark is presented in this paper. According to the characteristics of the actual operation of the unit, the proposed method determines the steady-state conditions of big data of thermal power and divides the working conditions based on external constraints. In addition, data mining method based on distributed computing is used to mine big data of thermal power to get the strong association rules, thus the best value of the parameters under each working condition can be got. Lastly, the historical knowledge base is established, which can guide the operation of the unit by the proposed method. This method is applied to a 300 MW unit in a power plant in Anhui Province, and mines the operation data of the unit for 10 days in a month. The results of simulation show that the proposed method can effectively mine big data of thermal power and has the advantage of computational efficiency compared with traditional data mining for big data.

16:40-17:00 **SatB07-4**

Evolutionary Game Dynamics Driven by Heterogeneous Self-learning Rules

Lei Zhou Peking Univ.
Bin Wu Beijing Univ. of Posts and Telecom.
Vítor V. Vasconcelos Princeton University.
Long Wang Peking Univ.

How to achieve full cooperation among large numbers of individuals is essential for both artificial and biological systems. Learning rules (or updating rules), which specify how individuals change their behavior over time, are vital to probe this problem. Here, we incorporate individual heterogeneity into the self-evaluation process and propose the heterogeneous self-learning dynamics. When the selection intensity is weak, we analytically derive that the final outcomes of the heterogeneous dynamics can be obtained by combining the outcomes of all the corresponding homogeneous dynamics in well-mixed populations. Meanwhile, a simple condition is found which tells whether one behavior will be more abundant than the other in the long run. All of our analytical results are verified by simulations. Our work thus reveals some interesting characteristics of heterogeneous self-learning dynamics.

17:00-17:20 **SatB07-5**

A Data-driven Voxel-wise White Matter Fiber Clustering Model Based on Priori Anatomical Data

Zhewen Cao Zhejiang Univ. of Tech.
Er Jin Zhejiang Univ. of Tech.
Siqi Zhou Zhejiang Univ. of Tech.
Ye Wu Zhejiang Univ. of Tech.
Yongqiang Li Zhejiang Univ. of Tech.
Yuanjing Feng Zhejiang Univ. of Tech.

Whole-brain fiber imaging allows nondestructive detection of human brain structural connections. The clinical application of this method is often classified as a series of fiber bundle structures of certain significance (function, structure, shape, etc.). Due to the lack of edge structure information of fiber bundles and the high variability of complex white matter structures in individual samples, fiber clustering based on anatomical information is still an open problem. In this paper, a new fiber clustering technique is proposed, which combines spatial features of whole-brain fibers and prior anatomical information as fiber similarity matching and feature extraction. In this work, we focus on the coverage of highly consistent fiber bundles in white matter structures to match anatomic features. The

method is based on multiple tests of simulated data and in vivol data. The experimental results show that this method not only improves the highly consistent coverage of fiber bundles and anatomical prior knowledge, but also simplifies the fiber data space to improve the fiber clustering similarity measured population consistency. Finally, we also discuss the application of this method in clinical research.

17:20-17:40 **SatB07-6**

Soft-sensing Development Using Adaptive PSO Optimization Based Multi-Kernel ELM with Error Feedback

Qiang Du Beijing Univ. of Chemical Tech.
Mingqing Zhang Beijing Univ. of Chemical Tech.
Qunxiong Zhu Beijing Univ. of Chemical Tech.
Yanlin He Beijing Univ. of Chemical Tech.

Some process variables are very hard to be measured directly in actual industrial processes, a soft senor model using adaptive PSO optimization based multi-kernel ELM with error feedback is proposed in this paper. Firstly, multi-kernel ELM is constructed by adding gaussian and polynomial kernel function to ameliorate the overfitting problem in traditional ELM. Secondly, we propose an adaptive PSO (APSO) for ameliorating the low efficiency problem in the later period of PSO method by adding mutation operator. When given parameter reaches a threshold, the mutation operator adaptively adjusts the position of the particle. Also, the proportion of the two kernel functions and the kernel parameters in training process are obtained by APSO. In each iteration, the training error is back propagated to the hidden layer as the co-outputs of hidden layer for further improving the accuracy and stability of the model. Finally, a simulation experiment on the purified terephthalic acid (PTA) solvent system is made to verify the modeling accuracy and optimization performances. The evaluation result demonstrates that the proposed method can provide higher accuracy and a more reliable soft senor model comparing with other method.

17:40-18:00 **SatB07-7**

Craft Parameters Optimization of Melt-Transportation in Polyester Fiber Production Based on Improved RVEA

Houyue Xu Donghua Univ.
Kuangrong Hao Donghua Univ.
Lei Chen Donghua Univ.
Xin Cai Donghua Univ.
Lihong Ren Donghua Univ.
Yongsheng Ding Donghua Univ.

Melt-transportation is an important process in polyester fiber production containing multiple production processes and complicate structure, its craft parameters are set general -objective optimization is proved to be an efficient method for such problems. And we built a five-objective optimization model based on five performance indicators of melt-transportation process to optimize the craft parameters. Due to the increase of the objectives' dimensions, algorithms based on non-dominated relationship cannot select individuals with good convergence and diversity for the population. Therefore, we improve the angle penalized functions of RVEA, where we adjust the penalized functions according to the diversity of the current population. The experiment results show that the improved RVEA performs competitively compared with the more challenging SDTLZ1 -SDTLZ4 test suite based on DTLZ series, and the result of melt-transportation optimization is of guiding value for polyester fiber production.

SatB08 Room 8
IS: Data-driven modeling and optimization
15:40-18:20

Chair: Aihua Zhang Bohai Univ.
CO-Chair: Liang Liu Bohai Univ.

15:40-16:00 **SatB08-1**

A Research Method of the Non-Fragile Controller Base LMI

Hui Fang Bohai Univ.
Quancheng Cheng Liaoning Mechatronics College
Chengyuan Sun Bohai Univ.

For the satellite system with two solar panels, a non-fragile controller design method based on linear matrix inequality (LMI) is presented in this paper. The controller design method based on observer is adopted, and the design of the observer and controller contains a linear fractional uncertainty disturbance, i.e. non-fragile control problem. The existence condition of the controller based on the observer is given in the form of linear matrix inequality, by using the effective matrix inequality transform technique and the Lyapunov function method. In the case of uncertainty perturbation, the design of the controller can guarantee the stability of the system. Finally, the effectiveness of the proposed method is verified by Matlab software.

16:00-16:20 **SatB08-2**

State Feedback Control of Upper-triangular Stochastic Time-delay Systems

Liang Liu Bohai Univ.
Jing Wang Bohai Univ.

This paper deals with the state feedback stabilization problem for a class of upper-triangular stochastic time-delay systems. By adopting a series of coordinate transformation, the original system is firstly transformed into an equivalent one with a designed parameter. On the basis of homogeneous domination approach and stochastic time-delay system stability theory, by suitable choosing a Lyapunov-Krasoviskii functional (LKF) and the designed parameter, the state feed Neural networks, fuzzy systems controlback controller is constructed and guaranteed that the closed-loop system is globally

asymptotically stable in probability (GASiP). The efficiency of the proposed controller is verified by a simulation example.

16:20-16:40 **SatB08-3**

Based on Improved Semi-supervise Clustering Method Training Classifier for Analog Circuit Fault Classification

Aihua Zhang Bohai Univ.
Kailun Huang Bohai Univ.
Gang Luo Jinzhou Normal College
Zhiqiang Zhang Bohai Univ.

In recent years, semi-supervised clustering as an important research subject has significance in dealing with lack of training sample sets. However, formerly semi-supervised clustering usually cannot attend satisfactory consequence in precision and training time at the same time. Aimed to the problem of clustering method assist training classifier to label the samples, produce the time optimization algorithm. Based on prior knowledge, mining the acquired unlabeled sample sets deeply of their potential data structure and combine semi-supervised fuzzy C-means(SS-FCM) arithmetic with similarity coefficient to sort out the samples for training time improvement. On the basis of little influence on classification result accuracy, gain the fuzzy similarity matrix from Euclidean distance and assess the maximum dependable sample point with its neighborhood for their similarity degree, will avoid searching the maximum dependable sample point one by one and optimize holistic clustering time costing from reduce the iterations of classifier to some extent. Through artificial circuit simulation experiment, using improvement SS-FCM assist SVM classifier and single SVM and SS-FCM assist SVM classifier to make a comparison, verify the algorithm from classify precision and arithmetic speed and the result of experiment can prove the validity of the improvement.

16:40-17:00 **SatB08-4**

A Novel Data Driven Performance Monitoring Method via Attitude Information for a Satellite

Zhiqiang Zhang Bohai Univ.
B.Xing Huo Bohai Univ.
Aihua Zhang Bohai Univ.
Chengcong Lv Bohai Univ.

Focusing on various uncertainties during a satellite is on-orbit operation, a novel data driven performance monitoring method is proposed. And this performance monitoring for a satellite is done via its attitude information. The whole attitude information is divided into multiple processions, and all of these multiple processions information (MPI) will be approached the real attitude information. This method breaks away the bind of a theoretical model. This method combines the multiple processions auto regression principal component analysis (MPAR-PCA) monitoring method based on affine propagation (AP) clustering, and the optimization procedure is deal with a MPI based particle swarm optimization algorithm (MPIPSO). Numerical simulations are proved the effectiveness of the proposed approach.

17:00-17:20 **SatB08-5**

FitCF: Collaborative Filtering Recommendation Algorithm Based on Nonlinear Fitting Weight Distribution

Yonglin Wu Bohai Univ.
Xing Xing Harbin Institute of Tech.
Bohai Univ.
Qian Chai Bohai Univ.
Zhichun Jia Bohai Univ.

The traditional collaborative filtering algorithm compute user similarity based on user rating information. Different user has different rating numbers, so it is limited to provide the same recommendation strategy based on user rating information for all users. In this paper, we propose a collaborative filtering recommendation algorithm FitCF, where the user similarity is calculated basing on user's rating and user multi-attribute. We evaluate the proposed recommendation method on the Movielens datasets. The experimental results show that our method improves the quality of recommendation method.

17:20-17:40 **SatB08-6**

A Novel Feature Weighted Twin-hypersphere Support Vector Machine for Pattern Recognition

Qing Ai Northeastern Univ.
Univ. of Sci. and Tech. Liaoning
Anna Wang Northeastern Univ.

Twin-hypersphere support vector machine (THSVM) is a binary classification method that uses two hyperspheres to depict two classes, which makes the THSVM be more reasonable for many engineering problems. The two hyperspheres can be constructed by solving two smaller-scale quadratic programming problems (QPPs), which makes the THSVM be more efficient. However THSVM treats equally all features of one sample, in real life, the importance of different features of one sample for classification is always different. For the disadvantage, we introduce feature weights into THSVM to avoid classification results being dominated by trivial relevant features, reformulate the mathematical model of THSVM, propose a novel feature weighted twin-hypersphere support vector machine (FWTHSVM) and apply information gain to evaluate the weight of each feature of one sample. The experimental results show, compared with THSVM, FWTHSVM not only ensures training time, but also has better generalization performance.

SatB09 **Room 9**

Neural networks, fuzzy systems control methods in data driven manner **15:40-17:40**

Chair: Guoshan Zhang Tianjin Univ.

CO-Chair: Kuangrong Hao Donghua Univ.

15:40-16:00 **SatB09-1**

Identification of a Class of Multi-signal Based Neuro-fuzzy Wiener Systems

Yangyang Li Shanghai Univ.
Li Jia Shanghai Univ.
Feng Li Shanghai Univ.
Qi Xiong Shanghai Univ.
Sheng Gao Shanghai Power Equipment Research Inst. Co. Ltd.

A novel multi-signal based identification approach is presented for the neuro-fuzzy Wiener model with process noise. A combined multi-signal composed of two random signals of different amplitude is adopted to solve the identification problem of the nonlinear block separated from the linear part. Then the least square method is employed to identify the nonlinearity of the Wiener model. Next, the linear parameters of the Wiener model are obtained by using the recursive least square method based on auxiliary model. Finally, an example is used to verify the effectiveness of the proposed method.

16:00-16:20 **SatB09-2**

Subordinate based Cluster Center Identification in Density Peak Clustering

Jian Hou Bohai Univ.
Aihua Zhang Bohai Univ.
Chengcong Lv Bohai Univ.
Xu E Bohai Univ.

Recently, a clustering algorithm is proposed by treating local density peaks as cluster centers. This algorithm proposes to describe the data to be clustered with local density and the distance of one data to the nearest data of larger local density. This description highlights the uniqueness of cluster centers and is utilized to determine cluster centers. With the assumption that one data and the nearest data of larger local density are in the same cluster, the non-center data are assigned labels efficiently. By studying the clustering process of this algorithm in depth, we find that the local density is not very effective in highlighting the uniqueness of cluster centers. As a result, this algorithm is dependent on the parameters in local density calculation. We discuss this problem and find that it is the role of density peaks, but not the absolute local density, that highlights the uniqueness of cluster centers. Based on this observation, we introduce the concept of subordinate and use the amount of subordinates to replace the local density in cluster center identification. Together with a new density kernel, this new criterion is shown to be effective in experiments and comparisons.

16:20-16:40 **SatB09-3**

A Parallel Feature Expansion Classification Model with Feature-based Attention Mechanism

Yingchao Yu Donghua Univ.
Kuangrong Hao Donghua Univ.
Xuesong Tang Donghua Univ.
Tong Wang Donghua Univ.
Xiaoyan Liu Donghua Univ.
Yongsheng Ding Donghua Univ.

Because of the close relationship between artificial neural network and neuroscience, some visual mechanisms are often used to improve the performance of convolutional neural networks (CNNs). Inspired by parallel processing of human brain visual information and information fusion in common brain regions, this paper designs a parallel feature expansion model (PFEM). The model can extract two features based on a parallel CNN structure, and performs two quadratic term transformations for feature expansion at the end of the feature extractors, then all the features are input to the fully connected layers and classifier after fusion. We further add feature-based attention to PFEM to correct the activation values of CNN feature maps. Experimental results on CIFAR-10 dataset show that PFEM with feature-based attention can improve the classification accuracy of the CNN.

16:40-17:00 **SatB09-4**

Data-based Adaptive Output Feedback Tracking Control for a Class of Nonlinear Systems

Ling Ren Tianjin Univ.
Guoshan Zhang Tianjin Univ.

In this paper, an output feedback tracking control scheme is proposed for a class of continuous-time nonlinear systems without specific model. A radial basis function neural network (RBFNN) observer is designed to online estimate the unmeasured inner state variables only using the input and output data. Based on the designed RBFNN observer, a sliding mode controller is derived to guarantee that the system states follow the desired trajectories. Simulation results on an example show the effectiveness and tracking performance of the proposed scheme.

17:00-17:20 **SatB09-5**

Subject Features and Hash Codes for Multi-label Image Retrieval

Changzhen Xiong North China Univ. of Tech.
Yanmei Shan North China Univ. of Tech.

In order to solve the problem that existing hashing methods cannot describe multi-label images accurately, this paper proposes a multi-label image retrieval method based on hashing codes and main part detection of an image. This method adds a fully connected layer after the region proposal network (RPN) in Faster-RCNN to learn the binary hash codes of the detected region proposals. Through the network, the region proposals in the query image and their class probabilities, spatial positions and hash codes can be obtained. Then, the main instance of query and its hash codes are extracted

according to the class probability and the spatial relations of the proposals. Finally, the images with the same class label of the query are retrieved from the database and ranked by the Hamming distance of hash codes. The top N images with the highest score are returned as the final results. Experimental verification is carried out on 2000 query images selected randomly from VCO2007 dataset, the results show that the NDCG (normalized discounted cumulative gain) is 0.8967 and the ACG (average cumulative gain) is 0.7970 when the top 1000 images selected in retrieval result. Compared with IAH (Instance aware hashing) method, they respectively increased by 1.02 and 3.04 percent. The proposed method has a good retrieval effect on the multi-label query images.

17:20-17:40 **SatB09-6**

Adaptive Neural Network Control for Vehicle Active Suspension Systems with Unknown Dead-Zones

Yanqi Zhang Liaoning Univ. of Tech.
Lei Liu Liaoning Univ. of Tech.
Yanjun Liu Liaoning Univ. of Tech.

This paper presents the development of an adaptive neural network (NN) control method for non-linear quarter-vehicle model which has the characteristics of road disturbance, parameter uncertainties and unknown dead-zones. Considering the dead-zone slopes as a model uncertainty, an adaptive NN control scheme is developed depend on backstepping technique. In this paper, uncertain non-linear functions in suspension systems are estimated by NNs. Then again, the minimal learning parameters can ensure that the computation and complexity of system are exceedingly reduced. The stability and the signals boundedness of vehicle suspension system are proved. Finally, a given simulation example shows the feasibility of the designed approach.

Sunday, 27 May, 2018

SunA01 **Room 1**
Data driven control (II) **13:30-15:30**
Chair: Qiang Chen Zhejiang Univ. of Tech.
CO-Chair: Lingling Fan Beijing Information Sci. & Tech. Univ.

13:30-13:50 **SunA01-1**

Data-driven Analysis Methods for Controllability and Observability of a Class of Discrete LTI Systems with Delays

Binquan Zhou Beihang Univ.
Zhuo Wang Beihang Univ.
Yueyang Zhai Beihang Univ.
Heng Yuan Beihang Univ.

We propose a couple of data-driven analysis methods for the state controllability and state observability of a class of discrete linear time-invariant (LTI) systems with delays, which have unknown parameter matrices. To analyze the state controllability and the state observability, these data-driven methods first transform the system model into an augmented state-space model, and then use the state/output data that were previously measured, to directly build the controllability/observability matrices of this augmented model. Our methods have two main advantages over the traditional model-based characteristics analysis approaches. First, the unknown parameter matrices are not necessary to be identified for verifying the state controllability/observability of the system, but these characteristics can be directly verified according to the measured data, thus our methods have less workload. Second, their computational complexity is lower for the construction of the state controllability/observability matrices.

13:50-14:10 **SunA01-2**

A Step-climbing Strategy of Hexapod Robot with Eccentric Wheel Legs

Chao Zhang Beijing Univ. of Tech.
Xiaoli Li Beijing Univ. of Tech.
Xiaoqing Zhu Beijing Univ. of Tech.
Yang Li Communication Univ. of China

In this paper, a design of simple and highly hexapod robot is described and a method of step-climbing is proposed. The robot structure is inspired by cockroach and it has six eccentric wheeled legs contacting with six motors through hips made by fiberglass. Its discretized gaits differs from wheeled and tracked robots who are good at flat terrain or sloping area which makes it obstacle navigation such as stairs or ditches more convenient. Gait comes from learning of six foot insects (i.e. locomotion of cockroach) including the well-known tripod gait and the way of climbing in the outdoor environment. The process of step-climbing is described in detail and we designed an open-loop control of the gait for eccentric wheel type legs without any terrain sensing or actively controlled adaptation. In our experiment the eccentric robot performed well like the cockroaches do achieving stable and robust locomotion traveling.

14:10-14:30 **SunA01-3**

Filtering Identification for Multivariate Hammerstein Systems with Coloured Noise Using Measurement Data

Linwei Li Beijing Institute of Tech.
Xuemei Ren Beijing Institute of Tech.
Yongfeng Lv Beijing Institute of Tech.

In this paper, based on the measurement data, the identification of the multivariate Hammerstein controlled autoregressive moving average system is investigated. To facilitate the parameter identification, the considered system is transferred to a regression identification model in which the bilinear parameter and linear parameter are included in the identification model. To solve the bilinear parameter estimation problem, with the

help of the hierarchical identification principle, two new identification models are constructed in which the each model is linear to parameter vector. For each identification model, a novel filtering identification algorithm is put forward to interactively estimate the parameters of the each model based on hierarchical identification principle. Filtering technique is used to improve the estimation accuracy of the presented algorithm, and the hierarchical identification idea is exploited to decrease the calculation burden of the proposed method. The conditions of convergence are introduced by using the martingale convergence theorem. Contrast examples indicate that the proposed method has a better identification performance than several existing estimation approaches.

14:30-14:50 **SunA01-4**

A Novel Data-Driven Filtering Algorithm for a Class of Discrete-time Nonlinear Systems

Lingling Fan Beijing Information Sci. & Tech. Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Rongmin Cao Beijing Information Sci. & Tech. Univ.
Honghai Ji North China Univ. of Tech.

Data-driven filtering technique has immense potential and gained significant attention lately. This paper investigates a novel data-driven filtering algorithm based on a new dynamic linearization technique in the framework of Kalman Filter for a class of discrete-time nonlinear systems. Compared with the conventional nonlinear filtering algorithms, such as Extended Kalman Filter (EKF) or Unscented Kalman Filter (UKF), the proposed data-driven filtering (DDF) method can not only be applied for nonlinear systems without precise mathematical model or linearization approximation, but also be designed by merely utilizing the I/O measurement data of the plant. The theoretical analysis shows that the proposed approach guarantees uniform ultimate boundedness of the filtering errors. The comparison numerical simulation results verify the effectiveness of the proposed approach.

14:50-15:10 **SunA01-5**

A Novel System Decomposition Method Based on Pearson Correlation and Graph Theory

Jing Jin Nanjing Tech. Univ.
Shu Zhang Nanjing Tech. Univ.
Lijuan Li Nanjing Tech. Univ.
Tao Zou Shenyang Institute of Automation, Chinese Academy of Sci.

With the increasing attention of networked control, system decomposition and distributed models show significant importance in the implementation of model-based control strategy. In the traditional system decomposition methods based on graph theory, the weight on each edge of the graph is set by state space equation to reflect the mutual influence of variables in the system. But in the actual industrial process, the acquisition of state space equation is more difficult. In this paper, a system decomposition method based on Pearson correlation coefficient and graph theory is proposed to avoid the use of state space equations. At first, a directed graph is established to represent the actual process of the industrial system and the weights on corresponding edges in the directed graph are set by the Pearson correlation coefficients between two nodes connected by these edges. Then the directed graph is decomposed into several initial subgraphs and the subgraphs will be fused according to a certain rule. Here, a fusion index is defined to select the optimal fusion results in each fusion process. After each fusion process, the termination condition is required to determine whether to continue the next round of fusion process. When the fusion process ends, the subsets obtained at this time are the results of the system decomposition. When the system decomposition is finished, the online subsystems modeling will be carried out by RPLS algorithm. Finally, the proposed algorithm is applied in the Tennessee Eastman process to verify the validity.

15:10-15:30 **SunA01-6**

A Novel Harmonic Detection Algorithm for Electric Vehicle with Charging Piles

Yonglong Peng North China Electric Power Univ.
Jianghao Huang North China Electric Power Univ.
Yabin Li North China Electric Power Univ.
Peizhe Liu NanJing Lin Yang Electric Power Tech. Co. Ltd.
Jiuhui Cao North China Electric Power Univ.

With the rapid development of electric vehicle, the problems of power quality on charging station have attracted much attention. Due to some traits of the charging station, the harmonic current changes gradually with time. What's more, the traditional harmonic detection method based on ip-iq algorithm is influenced by the low-pass filter, resulting in the detecting and starting speed are relatively slow, which cannot satisfy the requests of charging station harmonic suppression. On the basis of analyzing the charging generator model based on the six-pulse rectifier, the charging station model of the charging generator based on the six-pulse rectification is established. A novel harmonic current detection algorithm based on adaptive filter of variable step size LMS / LMF algorithm is proposed and its theory is analyzed in detail. Simulation and experiment results show that the improved harmonic detection algorithm has variously improved in terms of the tracking speed and starting speed, which achieves desired effects.

SunA02 **Room 2**
Model-free adaptive control II **13:30-15:30**
Chair: Shangtai Jin Beijing Jiaotong Univ.

CO-Chair: Rongmin Cao Beijing Information Sci. and Tech. Univ.

13:30-13:50 **SunA02-1**

Model Free Adaptive Predictive Perimeter Control for an Urban Traffic Network

Chunye Xu Beijing Jiaotong Univ.
Shangtai Jin Beijing Jiaotong Univ.
Ye Ren Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Danwei Wang Nanyang Technological Univ.

Most exiting macroscopic fundamental diagram (MFD) based perimeter control methods are regarded a model-based feedback control methods, whose performance is hard to improve in practice due to the fact that traffic flow model is complex and has uncertainties. In this paper, a model free adaptive predictive perimeter control strategy is proposed for an urban traffic network. The control performance is improved by virtue of the prediction data model derived by dynamic linearization technique. The effectiveness of the proposed perimeter control algorithm is verified by comparing with the traditional PID controller in the simulation section.

13:50-14:10 **SunA02-2**

MIMO Model Free Adaptive Control of Two Degree of Freedom Manipulator

Ziqiang Zen Beijing Information Sci. and Tech. Univ.
Rongmin Cao Beijing Information Sci. and Tech. Univ.
Zhongsheng Hou Beijing Jiaotong Univ.

Aimed at plane nonlinear two-degree-of-freedom (2-dof) manipulator, which is a nonlinear multi-input and multioutput (MIMO) system, its joint angles are controlled by model-free adaptive control (MFAC) theory to realize trajectory tracking. The nonlinear system model is replaced by the compact form dynamic linearization time-varying model, and the pseudo-Jacobian matrix of the system is estimated on the basis of the input and output data of the manipulator model. The simulation results show that the compact form dynamic linearized model-free adaptive control (CFDL-MFAC) algorithm can effectively ensure the tracking performance of the system output, and the error remains within a certain range.

14:10-14:30 **SunA02-3**

Modeling and Control of Parafoil Systems Based on CFD

Wannan Wu Nankai Univ.
Qinglin Sun Nankai Univ.
Mingwei Sun Nankai Univ.
Zengqiang Chen Nankai Univ.

Accurate calculation of canopy aerodynamic parameters is a great significance issue in the modeling of a parafoil airdrop system. Based on the computational fluid dynamics, this paper calculates the aerodynamic parameters of the parafoil systems, and then the output data is used to estimate the deflection and incision factors. The estimated lift and drag coefficients instead of the traditional parameters based on lifting-line theory are incorporated into the six degrees of freedom dynamic model of a parafoil system. The active disturbance rejection control strategy is applied to control the systems. The effectiveness of the proposed method can be demonstrated by the simulation results. The work in this paper may be a reference for the parafoil system design.

14:30-14:50 **SunA02-4**

Discrete Control of Micro Quadrotor Aircraft via Sampling Feedback

Fakui Wang Xidian Univ.
Weisheng Chen Xidian Univ.
Hao Dai Xidian Univ.
Jing Li Xidian Univ.
Jinping Jia Xidian Univ.

This paper studies a discrete control algorithm of through sampling feedback. On the digital computer control platform, a sampled-data controller is designed to control a quadrotor UAV system based on backstepping control method and the proposed continuous controller. The results show that, compared with theoretically continuous time control scheme, our discrete controller can realize the purpose of stable flight. Finally, a simulation example is given to show the effectiveness of the proposed control scheme.

14:50-15:10 **SunA02-5**

Tracking Control Strategy of PMSLM with a Novel Observer-based Compensator and a RBFNN-based Controller

Zhentian Liu Naval Univ. of Engineering
Guangsen Wang Naval Univ. of Engineering
Zhiwei Wang Naval Univ. of Engineering

This paper is devoted to a high-precision tracking control strategy of permanent magnet synchronous linear motor (PMSLM). Firstly, the field-oriented control model of the PMSLM is established to calculate the electromagnetic thrust. To reconstruct the system states and reject the lump disturbance, a novel observer-based compensator is proposed, taking the basic ideas of the frequency-domain disturbance observer and the time-domain one (the extended state observer in active disturbance rejection control, ADRC). A radial-basis-function neural network (RBFNN) controller with accurate approximation capability is utilized to tracking the desired motion trajectory. Contrasted to the RBFNN's parameters self-evolved, a simple and unique parameters tuning method is derived to guarantee the compensator performance. All the proposed algorithms are implemented in a rapid control prototype (RCP) real-time simulation platform and the simulation and experiment results validate the rightness of theoretical

analysis and the feasibility of the proposed methods.

15:10-15:30 **SunA02-6**

Stability Criterion for Networked Control Systems (NCS) Based On T-S Model Time-varying Delays

Tao Liu Qilu Univ. of Tech.

This paper deals with the stability of a class of NCS with t-s fuzzy systems and time-varying delays. A new standard is more conservative than the current result by using a new lyapunov-krasovskii function method and an interactive convex method. The validity and superiority of this method are verified by an example.

SunA03 Room 3
ADRC technology and applications II 13:30-15:30

Chair: Zengqiang Chen Nankai Univ.
CO-Chair: Wenchao Xue Chinese Academy of Sci. Univ. of Chinese Academy of Sci.

13:30-13:50 **SunA03-1**

Modeling and Analysis of the Novel Stator Excitation Brushless Motor Based on Active Disturbance Rejection Control

Kelei Wang Nankai Univ.
Zengqiang Chen Nankai Univ.
Mingwei Sun Nankai Univ.
Qinglin Sun Nankai Univ.

A novel stator excitation brushless motor having no windings and magnets in the rotor was proposed in this paper. The stator of the motor contains two sets of windings which named three-phase power windings and excitation windings, respectively. In the grasp of the working principles of the stator excitation brushless motor, the mathematical model in the rotor rotating coordinate system is deduced and the characteristics of the model with strongly coupling and strongly nonlinear are verified by simulation. A speed regulating system based on the first-order linear active disturbance rejection control is designed. The linear extended state observer can estimate and compensate the general disturbances, making the flux and torque components decoupled. The simulation results show that the linear active disturbance rejection control not only has better dynamic and static characteristics than traditional PI algorithm, but also has stronger robustness to the load mutation and parameter variations of the motor.

13:50-14:10 **SunA03-2**

Unknown Input and Measurement Noise Estimations for Switched Nonlinear Systems

Fanglai Zhu Tongji Univ.
Jiancheng Zhang Tongji Univ.
Fengning Wang Tongji Univ.
Shenghui Guo Suzhou Univ. of Sci.and Tech.

The problem of unknown input and measurement noise estimations for a class of switched Lipschitz nonlinear systems is investigated in this paper. An augmented state is used to construct a new descriptor system to deal with the measurement noise in output vector, and then the descriptor system does not contain measurement noise in form. The main results are for the constructed descriptor system, a new Lyapunov-type precondition is developed in detail to present a sliding mode observer, which can estimate both the original system states and unknown inputs simultaneously. And the sliding model term is introduced to deal with the system nonlinearity and the unknown input. Finally, a simulation example of an electric circuit system is considered to show the effectiveness of the proposed methods.

14:10-14:30 **SunA03-3**

On Disturbance Rejection of Piezo-actuated Nanopositioner

Wei Wei Beijing Tech. and Business Univ.
Pengfei Xia Beijing Tech. and Business Univ.
Min Zuo Beijing Tech. and Business Univ.

This paper concentrates on the active disturbance rejection control of a nanopositioner driven by a piezoelectric actuator. Hysteresis reduces the accuracy or even breaks the stability of a nanopositioner. For the purpose of improving the closed-loop performance of a nanopositioning stage, active disturbance rejection control (ADRC) is utilized. Fourth order extended state observer is designed to get system output, first and second derivative of system output, and the total disturbance. System performance can be guaranteed by compensating total disturbance via control law. Based on an identified model of a nanopositioning stage, simulations have been performed. Numerical results have been presented to confirm the ability of ADRC in high-precision positioning.

14:30-14:50 **SunA03-4**

A Data-driven Process Monitoring Approach with Disturbance Decoupling

Hao Luo Harbin Institute of Tech.
Kuan Li Harbin Institute of Tech.
Mingyi Huo Harbin Institute of Tech.
Shen Yin Harbin Institute of Tech.
Okyay Kaynak Bogazici Univ.

This paper presents the study on the data-driven process monitoring system design for the dynamic processes with deterministic disturbance. The basic idea of the proposed methods are to identify the stable kernel representation (SKR) of the dynamic process by projecting the process data into different subspaces. With the help of the projection, the kernel subspace, which delivers the residual decoupled from the disturbance, can be further determined. Based on the identified data-driven SKRs, process monitoring systems are developed. The performance and

effectiveness of the proposed schemes are verified and demonstrated through the numerical study on randomly generated systems.

14:50-15:10 **SunA03-5**

The Position Tracking Control System of Induction Motors Based on Stator-flux-oriented Vector Control

KeYu Zhuang Qingdao Univ. of Sci. and Tech.

Asynchronous motor is a common motor in electric vehicle. In this paper, the position tracking control system based on stator flux oriented vector control (SFOVC) combining advantages of rotor flux oriented vector control and direct torque control is studied. A continuous closed-loop controller is adopted to correct the calculated position angle of stator flux and the torque ripple is small. This method is less affected by the parametric variation of rotor, with accurate stator flux observation and high position tracking accuracy. Simulation results demonstrate the effectiveness of this new control strategy.

15:10-15:30 **SunA03-6**

Sliding Mode Control of the Penicillin Fermentation System Based on Nonlinear Disturbance Observer

Tengfei Zhang Jiangnan Univ.
Xing Fang Jiangnan Univ.
Fei Liu Jiangnan Univ.

A feed-forward compensation strategy for the disturbance is proposed for the control problem of the bacteria in the fermentation process of the penicillin. Firstly, the nonlinear disturbance observer is designed to estimate the lumped disturbance of the system. Then, a sliding mode control law is designed for the system. The design of the control law guarantees the closed loop system is asymptotically stable and achieve the purpose of tracking control for the bacteria's concentration in the system. The simulation results show that this method can enhance the anti-disturbance capability and improve the control performance of the system.

SunA04 **Room 4**
Iterative learning control (III) **13:30-15:30**

Chair: Xiaodong Li Sun Yat-sen Univ.
CO-Chair: Xisheng Dai Guangxi University of Sci. and Tech

13:30-13:50 **SunA04-1**

ILC for a Kind of Linear Switched Systems Specified by Random Time-iteration Driven Switching Signals

Xuan Yang Xi'an Polytechnic Univ.
Xiaoe Ruan Xian Jiaotong Univ.

The note considers an iterative learning control scheme for a kind of switched repetitive systems. The manipulated systems are specified by arbitrary switching signals with respective to both time variable and iteration index. By employing Lebesgue-p norm, the learning performance is analyzed and a sufficient condition of convergence is derived. Results show that the concerned control law works well for tracking problem of the switched systems when the switching rules are expanded to time-iteration domain. Simulation is included to verify the validity of the approach.

13:50-14:10 **SunA04-2**

Iterative Learning Identification for Discrete Parabolic Distributed Parameter Systems

Lanlan Liu Guangxi University of Sci. and Tech
Xisheng Dai Guangxi University of Sci. and Tech
Xingyu Zhou Guangxi University of Sci. and Tech
Shali Yu Guangzhou college of South China Univ. of Tech

This paper presents an iterative learning identification scheme for discrete parabolic distributed parameter systems with unknown curve surface parameters. The method achieves identification through iterative learning control concepts, a Ptype learning identification controller is employed to estimate the spatial-temporal varying curve surface iteratively. Then, the sufficient convergence conditions for identification error in the sense of L2 norm has been presented through rigorous analysis. In the end, numerical simulations are shown to illustrate the effectiveness of the proposed learning identification algorithm.

14:10-14:30 **SunA04-3**

Sliding Mode Control of the RTAC System

Zhongtian Chen Zhejiang Univ. of Tech.
Xiangqing Wu Zhejiang Sci-Tech. Univ.
Xianhua Ou Zhejiang Univ. of Tech.
Xiongxiong He Zhejiang Univ. of Tech.

A sliding mode control (SMC) method is proposed for the rotational/translational actuator (RTAC) system，which is proposed without linearizing or approximating the dynamics. Different from the existing control methods, external disturbances arc taken into consideration in this paper. In particular, after some model transformations, the dynamic model of the RTAC is transformed into a cascade form. Then, based on the backstepping technique, a virtual control variable is proposed for the first subsystem and a corresponding deviation-based subsystem is introduced. On the basis of the deviation*based subsystem, a sliding mode controller is proposed straightforwardly. Simulation results including a comparative study are given to examine the control performance of the proposed scheme.

14:30-14:50 **SunA04-4**

Robust Repetitive Learning Control of Lower Limb Exoskeleton with Hybrid Electro-hydraulic System

Yong Yang Xihua Univ.
Deqing Huang Southwest Jiaotong Univ.
Xiucheng Dong Xihua Univ.

In this paper, robust repetitive learning control for lower limb exoskeleton, CASWELL-II, is addressed. A hybrid electro-hydraulic system which consist of unidirectional servo valve and magnetic valve is presented to driven the exoskeleton leg. First, a full state space model of CASWELL-II is worked out by combining both the rigid body and hybrid electro-hydraulic actuators dynamics. Second, a robust repetitive learning controller is presented to perform the periodic tracking task of the hybrid electro-hydraulic actuators via backstepping design, and the stability of the closed-loop system is proved by Lyapunov method. Finally, the controller is realized and tested on CASWELL-II by experiment.

14:50-15:10 **SunA04-5**

Networked Iterative Learning Control for Nonlinear Switched Discrete-time Systems with Random Measurement Packet Losses

Angji Lin Sun Yat-sen Univ.
Shuting Sun Sun Yat-sen Univ.
Xiaodong Li Sun Yat-sen Univ.

For nonlinear switched discrete-time systems with random measurement packet losses modeled by a Bernoulli-type stochastic sequence, this paper presents a P-type networked Iterative Learning Control (ILC) algorithm with an attenuating forgetting factor. In this ILC scheme, the random measurement packet losses are replaced by the desired output data. Under a given switching rule, the convergence of ILC tracking error in mathematical expectation in each of subsystems is proved by mathematical induction, and the convergent condition of the proposed networked P-type ILC algorithm is given. An illustrative simulation is used to verify the effectiveness of the proposed ILC algorithm.

15:10-15:30 **SunA04-6**

Time-varying Lag Synchronization of Complex Dynamical Networks with Unknown Channel Time-delay

Wenjie Zhao Xidian Univ.
Junmin Li Xidian Univ.

In this paper, time-varying lag synchronization is proposed. Lag time is not fixed but time-varying because the channel delay is usually time varying. Moreover, this channel delay is unknown in this paper. Controllers are designed to achieve the lag synchronization of two complex dynamical networks with unknown time-varying channel delay. Based on the Lyapunov function and barbalat lemma, a sufficient condition is derived. Numerical example is given to demonstrate the effectiveness of the proposed theoretical results.

SunA05 Room 5

IS: Iterative learning identification and control

13:30-15:30

Chair: Deqing Huang Southwest Jiaotong Univ.
CO-Chair: Qiao Zhu Southwest Jiaotong Univ.

13:30-13:48 **SunA05-1**

Iterative Learning Based Model Identification and State of Charge Estimation of Lithium-ion Battery

Qiao Zhu Southwest Jiaotong Univ.
Meng'en Xu Southwest Jiaotong Univ.
Meng'qian Zheng Southwest Jiaotong Univ.

This work focuses on the accurate identification of Lithium-ion battery's nonlinear parameters by using an iterative learning method. First, the 2nd-order RC model is introduced. Then, when the battery repeatedly implements a discharging trial from SOC 100% to 0%, an iterative learning based recursive least square (IL-RLS) algorithm is presented to accurately identify the nonlinear parameters of the regression model. The essential idea of IL-RLS algorithm is to improve the current parameter estimations by learning the estimation errors of the previous trails. Notably, the IL-RLS algorithm needs to be implemented offline for the long-time repetitive trials, which is the price worth paying to accurately identify the nonlinear parameters. After that, the parameters are identified as the functions of SOC by using the IL-RLS, which are verified by comparing with the result of the classic identification method for current pulses. Finally, by using the classic extended Kalman filter (EKF) as well as the parameters identified by the IL-RLS to estimate the SOC, three dynamic operation conditions are given to show the efficiency of the IL-RLS, where all the SOC estimation errors are less than 2%.

13:48-14:06 **SunA05-2**

High-precision Tracking of Piezoelectric Actuator Using Dual-Loop Iterative Learning Control

Yupei Jian Southwest Jiaotong Univ.
Xin Kang Southwest Jiaotong Univ.
Wanqiu Yang Southwest Jiaotong Univ.
Da Min Southwest Jiaotong Univ.
Deqing Huang Southwest Jiaotong Univ.

Rate-dependent hysteretic nonlinearity, which is an inherent characteristic of piezoelectric actuators (PEAs), causes a significant challenge in precise motion control of piezoelectric nanopositioning stages. In this paper, by assuming that the model of PEA takes a Hammerstein structure, two dual-loop iterative learning control (ILC) schemes are designed to deal with both input hysteresis and dynamics of system synchronously. As a comparison, two extra tests using single loop ILC are performed to manifest the efficacy of the proposed algorithm. Simulation results show that the dual-loop ILC schemes are superior to the single loop ILC schemes in terms of convergence speed and control accuracy.

14:06-14:24 **SunA05-3**

A State of Charge Estimation Approach Based on Fractional Order Adaptive Extended Kalman Filter for Lithium-ion Batteries

Meng'en Xu Southwest Jiaotong Univ.
Qiao Zhu Southwest Jiaotong Univ.
Meng'qian Zheng Southwest Jiaotong Univ.

This paper is focused on the state of charge (SOC) estimation of a lithium-ion battery in electric vehicles (EVs) based on a fractional order adaptive extended Kalman filter (FOAEKF). First, a fractional order second-order RC model is employed for the state estimation by utilizing the physical behavior of the battery. Second, the parameters in the fractional order second-order RC model are identified by genetic algorithm (GA), including the fractional orders and the corresponding resistance and capacitance values. The calculation precisions of the fractional order model (FOM) and integral order model (IOM) are validated and compared under typical discharge test. Then, AEKF algorithm, as multi-parameter closed-loop feedback algorithm, is used to achieve better robustness. Finally, two dynamic operation conditions are given to show the efficiency of the fractional order adaptive extended Kalman filter (FOAEKF) by comparing with the classic extended Kalman filter (EKF) and adaptive extended Kalman filter (AEKF).

14:24-14:42 **SunA05-4**

Data-driven Adaptive Optimal Tracking Control for Completely Unknown Systems

Dawei Hou Kunming Univ of Sci. and Tech.
Jing Na Kunming Univ of Sci. and Tech.
Guanbin Gao Kunming Univ of Sci. and Tech.
Guang Li Queen Mary Univ. of London

In this paper, an online data-driven based solution is developed for linear quadratic tracking (LQT) problem of linear systems with completely unknown dynamics. By applying the vectorization operator and Kronecker product, an adaptive identifier is first built to identify the unknown system dynamics, where a new adaptive law with guaranteed convergence is proposed. By using system augmentation method and introducing a discounted factor in the cost function, a compact form of LQT formulation is proposed, where the feedforward and feedback control actions can be obtained simultaneously. Finally, a new policy iteration is introduced to solve the derived augmented algebraic Riccati equation (ARE). Simulation results are presented to demonstrate the effectiveness of the proposed algorithm.

14:42-15:00 **SunA05-5**

Dynamic State Estimation Using Event-trigger Master-slave Nonlinear Filter for WAMS Applications

Qing Yuan Beijing Institute of Tech.
Fengdi Zhang Beijing Aerospace Automatic Control Inst.
Hengheng Gong Beijing Institute of Tech.
Luyu Li Beijing Inst. of Radio Measurement
Sen Li Beijing Institute of Tech.
Xiaozhong Liao Beijing Institute of Tech.
Zhen Li Beijing Institute of Tech.
Zhuoyue Song Beijing Institute of Tech.
Xiangdong Liu Beijing Institute of Tech.

The real-time state estimation becomes greatly important with the wide application of phasor measurement unit (PMU) in distributed generation (DG) for wide-area measurement systems (WAMS). In view of estimation, particle filter (PF) is capable of providing the best performance but at the cost of heavy computation burden. Besides, the growing grid size sustainably boosts the amount of data communication from PMU, causing the congestion. An event-trigger master-slave nonlinear filter (ETMSNF) is proposed to guarantee the estimation accuracy and get the communication bandwidth relieved. The local slave filter at the generator node carries out the local estimation and event-trigger strategy using unscented transformation, which is identical tothe center slave. The master filter at the center is designed using Monte Carlo method to improve the center's estimation accuracy by the cooperation with the center slave. Such master-slave filtering structure can fully utilize the computation capability both at the center and node. Simulation on the standard IEEE 39-bus system verify the performance of ET-MSNF.

15:00-15:15 **SunA05-6**

A Modified Q-filter Model-Inverse Based ILC and Its Application on PMLSM

Jun Cao Harbin Institute of Tech.
Yang Liu Harbin Institute of Tech.
Li Li Harbin Institute of Tech.
Xiuyan Peng Harbin Institute of Tech.

Iterative learning control (ILC) is essential for the achievement of high servo performance for linear motors. This paper investigates a modified Q-filter model-inversion based ILC. Compared to existing model-inversion based ILC algorithms, two distinct features make the modified algorithm appealing: 1) the tradeoff that must be made by the traditional Q-filter model-inversion based ILC between robustness and converged error is removed. 2) The robustness to uncertainties is enhanced without the deterioration of asymptotic. The effectiveness and superiority of the proposed Q-filter are illustrated by both theoretical analysis and experimental results.

15:15-15:30 **SunA05-7**

Adaptive Iterative Learning Control Mechanism for Nonlinear Systems Subject to High-order Internal Model

Wei Zhou Jiangsu Vocational Inst. of Commerce
Miao Yu Zhejiang Univ.

This technical note addresses an adaptive iterative learning control (AILC) problem for nonlinear dynamical systems with partially unknown iteration-varying parameter. Referring to the scheme of state-space, an

AILC effort is presented for randomly varying reference tracking together with initial shift problem in iteration domain. Furthermore, the AILC technique is extended to systems with several parameters in discussion. A simulation example confirms the validity of the proposed method.

SunA06 Room 6
Data-driven fault diagnosis and health maintenance (II)
13:30-15:30

Chair: Jian Feng Northeastern Univ.
CO-Chair: Xiaogang Deng China Univ. of Petroleum.

13:30-13:50 SunA06-1

Multi-layer Monitoring for Parallel Batch Processes with Input Trajectory Adjustment

Feifan Shen Ningbo Institute of Tech., Zhejiang Univ.
Lingjian Ye Ningbo Institute of Tech., Zhejiang Univ.
Xiushui Ma Ningbo Institute of Tech., Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

This paper develops a multi-layer fault detection method for parallel batch process monitoring. Besides, an input trajectory adjustment strategy related to monitoring stage is implemented to improve the economic performance. Firstly, a global MPCA monitoring model is constructed with input-relevant variables for all parallel batches. Then, several individual BWPLS monitoring models are established to deal with the model uncertainty of local parallel batches. When no abnormal condition is detected by both monitoring layers, a new input trajectory with better economic performance for the current batch is calculated with input-relevant constraints defined by the global monitoring layer as well as a surrogate model. As a result, these layers are related to each other, which provide a reliable and effective monitoring and adjustment framework for parallel batches. A fed-batch reactor is introduced for performance evaluation and the result proves the effectiveness of the proposed method.

13:50-14:10 SunA06-2

Improved Kernel Fisher Discriminant Analysis for Nonlinear Process Fault Pattern Recognition

Xiaogang Deng China Univ. of Petroleum
Baowei Sun China Univ. of Petroleum
Lei Wang China Univ. of Petroleum

Kernel Fisher discriminant analysis (KFDA) has emerged as a well-known nonlinear fault pattern recognition method. However, traditional KFDA method does not consider the utilization of the high order statistical information of process variables, and ignores the mining of the local data structure characteristic. To achieve better fault pattern recognition performance, this paper proposes an improved KFDA method, called statistics local KFDA (SLKFDA). In the proposed method, two technologies, including statistics pattern analysis (SPA) and local structure analysis (LSA), are combined to enhance the basic KFDA method. Firstly, SPA is applied to extract the original process variables' statistics with different orders. Then the KFDA optimization objective is modified by considering the local structure preserving. Lastly, a fault classifier is developed to recognize fault pattern. Simulations on one benchmark process demonstrate that the proposed SLKFDA method has a superior fault pattern recognition performance.

14:10-14:30 SunA06-3

A KNN-SVR Data Mending Method for Insufficient Data of Magnetic Flux Leakage Detection

Xinbo Zhang Northeastern Univ.
Jian Feng Northeastern Univ.
Zhiqiang Yao China Academy of Safety Sci. and Tech.
Jinhai Liu Northeastern Univ.
Huaguang Zhang Northeastern Univ.

In magnetic flux leakage (MFL) detection, transient fault appears unavoidably on individual sensor when collecting magnetic flux leakage signals, which makes MFL data insufficient. Data mending for insufficient data concerns the accuracy of the defects inversion. A precise data mending method based on K Nearest Neighbor- Support Vector Regression (KNN-SVR) is introduced. Which effectively reduces the training cost of SVR and greatly improves the accuracy of the algorithm. The method is tested by experiment data obtained. The results demonstrate that the proposed method can improve the accuracy rate of data mending of insufficient data and the time cost is acceptable.

14:30-14:50 SunA06-4

Accuracy Analysis of Polynomial Model and Auto Regressive Model for Data-driven Fault Detection

Bowen Sun National Univ. of Defense Tech.
Zhangming He National Univ. of Defense Tech.
China Academy of Space Tech.
Shuqing Xu National Univ. of Defense Tech.
Haiyin Zhou National Univ. of Defense Tech.
China Academy of Space Tech.
Jiongqi Wang National Univ. of Defense Tech.

The key of data-driven fault detection method lies in the full and effective understanding of the detected data, and the fitting for the detected data is an effective means to realize the parameterization of the data model. In this paper, the polynomial model and the autoregressive model are used to estimate and predict the non-stationary data and the stationary data respectively, so as to achieve the data-driven fault detection. The estimation accuracy of the parameter model is analyzed. The relationship between the prediction accuracy and the prediction duration, the polynomial fitting window,

the fitting order are given theoretically. Finally, numerical simulation results are given, which can provide some support for data-driven fault detection to some extent.

14:50-15:10 **SunA06-5**

A Data-driven System-level Health State Prognostics Method for Large-scale Spacecraft Systems

Runfeng Chen China Academy of Space Tech.
Hong Yang China Academy of Space Tech.

Large-scale spacecraft, such as space station, highlights the systems' reliability and safety. Using prognostics to predict the trend of the system health state evolution can help find out the potential dangers and prevent the unexpected failure from happening. With the adoption of data-driven ideology, a system-level health state prognostics method is proposed to predict the trend information. First, the characteristics of the large-scale spacecraft and the system-level health definition are analyzed. Then the details of the solution method are described. The novelty of this method is to use the network science knowledge to extract the system-level features. The adopted predicting method is briefly introduced. Finally, a real case study with on-orbit telemetry data is presented, and relevant conclusions are drawn for reference.

15:10-15:30 **SunA06-6**

Fault Diagnosis Method Based on Improved Deep Boltzmann Machines

Dan Liu Xi'an Jiaotong Univ.
Qin Wang Xi'an Jiaotong Univ.
Jiaojiao Tao Xi'an Jiaotong Univ.
Guang Li Xi'an Jiaotong Univ.
Jie Wu Xi'an Jiaotong Univ.

With the increasing complexity of mechanical equipment, the traditional signal-based fault diagnosis methods cannot meet the current needs of fast, accurate and intelligent fault diagnosis due to its low efficiency and over-reliance on experience and subjective judgment of diagnosticians. Deep learning has powerful feature extraction and pattern recognition ability, and once the model is established, it can perform rapid pattern recognition. Based on this, a fault diagnosis method based on deep Boltzmann machines is proposed in this paper. Firstly, to solve the problem that DBMs can only deal with binary data, the Gaussian units are used to replace the binary visible units of the deep Boltzmann machines to construct the improved deep Boltzmann machines model, enabled the deep Boltzmann machines to process real-valued data. After the model is constructed, it is applied to process vibration signals for fault diagnosis. We present result on the CWRU bearing datasets， which shows that the improved DBMs learn generative models well and are good at fault recognition tasks.

SunA07 Room 7

Applications of data-driven methods to complex processes (III) 13:30-15:30

Chair: Shan Liu Zhejiang Univ.
CO-Chair: Shuang Cong Univ. of Sci. and Tech. of China.

13:30-13:50 **SunA07-1**

Quantum Noise Protection via Weak Measurement for Quantum Mixed States

Sajede Harraz Univ. of Sci. and Tech. of China.
Shuang Cong Univ. of Sci. and Tech. of China.
Feng Shuang Inst. of Intelligent Machines, Chinese Academy of Sci.

Due to the interaction with the environment, a quantum state is often affected by the different types of noises which becomes one of the biggest problems for practical quantum computation. We study the possibility of protecting the mixed state of a quantum system that goes through noise by weak measurements and control operations. The aim is to find the optimal measurement strength and control operations and make the input and output states as close as possible. We show that our scheme can effectively protect arbitrary mixed states against typical types of noise sources: amplitude damping, phase damping and amplitude-phase damping. The optimal measurement and control operators are deduced in different bases of the Bloch sphere to find the best control scheme for each type of noise. The effectiveness of our control scheme is demonstrated by simulation results.

13:50-14:10 **SunA07-2**

Velocity Decomposition Based Planning Algorithm for Grasping Moving Object

Xinyu Ye Zhejiang Univ.
Shan Liu Zhejiang Univ.

An online planning method is proposed for an industrial manipulator to grasp a moving object whose motion is not long-term predictable. Due to the limited time when the moving object stays within the limited workspace of the fixed manipulator, the manipulator has to grasp the object before it leaves the workspace. The planning algorithm brings the end effector of the manipulator to the vicinity of the object quickly and makes it match the pose of the object at first, then grasps the object. In term of the states of the object and the end effector, the velocity of the end effector is decomposed to three directions. The accelerations of each direction are planned to make sure that the end effector can achieve stably tracking of the moving object in a short time. According to these accelerations, the velocity of the end effector and the joints velocities are obtained through pseudo inverse of the Jacobian matrix of the manipulator. Several simulation examples show that the proposed method can finish the grasping tasks faster than conventional methods.

14:10-14:30 **SunA07-3**

The Equivalence Induced by Unifying Fitness Mappings in Frequency-dependent Moran Process

Feng Huang Peking Univ.
Xiaojie Chen Univ. of Electronic Sci. and Tech. of China
Long Wang Peking Univ.

As one of the most prevalent microscopic mechanisms, frequency-dependent Moran process is widely adopted to model the traits' evolution of agents in a well-mixed population, where an individual is chosen for reproduction proportional to its fitness. Using a pair of specific fitness mappings, it has been demonstrated that the Moran process leads to identical evolutionary outcomes under weak selection. But does the equivalent relation hold for any two fitness functions? In this paper, by introducing a general mapping that fitness is an arbitrary non-negative function of payoff and selection intensity, we unify the fitness mappings. And accordingly we investigate whether the unifying fitness mappings can lead to equivalent evolutionary outcomes in frequency-dependent Moran process. By calculating fixation probabilities and fixation times under weak selection, we find that the effect of different fitness mappings on these two quantities just embody in a constant factor under mild conditions. In particular, this constant factor can be absorbed into the selection intensity by proper rescaling or make the payoff matrix change a scale. Thus, in spite of the scaling factor, any two fitness functions are equivalent under weak selection for frequency-dependent Moran process.

14:30-14:50 **SunA07-4**

Research and Application of a Line Fault Location System in Chongqing

Jiabin Liu State Grid Chongqing Yongchuan Power Supply Co.
Xin Mao State Grid Chongqing Yongchuan Power Supply Co.
Liang Huang State Grid Chongqing Yongchuan Power Supply Co.
Zongcheng Li State Grid Chongqing Yongchuan Power Supply Co.
Min Fan Chongqing Univ.
Huan Chen Chongqing Univ.
Libo Fan Chongqing Univ.

Chongqing is located in southwest China, where the landform mainly consists of hills and mountains and there are broad sloping areas. In order to rapidly locate and isolate faults and facilitate inspection, a line fault location system suitable for Chongqing's mountainous terrain was designed in this paper where the structure of the line fault location system was proposed, and the key technologies related to the core components of the system such as fault indicators and signal generators were described in details. This system uses fault indicators designed based on the signal injection method to realize fault line selection and fault section location for single-phase ground faults in the 10kV neutral ungrounded system. In this way, the misjudgments on load fluctuations and on-off inrushes by the fault indicator can be avoided effectively. The experimental results and practical application show that this line fault location system is applicable to the mountainous terrain in Chongqing, and it takes less time to find out and handle faults, thereby enhancing distribution automation.

14:50-15:10 **SunA07-5**

Balanced Levitation Control of PEMS High Speed Maglev Train Considering System Model Non-symmetry

Zhiqiang Wang National Univ. of Defence Tech.
Cuicui Huang National Univ. of Defence Tech.
Xiaolong Li National Univ. of Defence Tech.
Zhiqiang Long National Univ. of Defence Tech.

PEMS (permanent magnetic and Electro-Magnetic Suspension) high speed maglev train is proposed on the basic of normal EMS (Electro-Magnetic Suspension) high speed maglev train with permanent added into the electromagnet for the purpose of reducing the levitation current. In high speed maglev train, joint structure which consists of two subsystems is the fundamental levitation unit. The advantage of this joint structure is: the two subsystems can share the burden of the load which makes the levitation current small. However it is found in practical engineering that due to the system non-symmetry, especially the difference between two levitation gap signal, the burden of load is not equally shared which external disturbances and the other subsystem is not fully taken use of. To solve this problem, a balanced control method is proposed. Simulation results have verified the effectiveness of the balanced control method.

15:10-15:30 **SunA07-6**

Effective Cancer Classification Based on Gene Expression Data Using Multidimensional Mutual Information and ELM

Qunxiong Zhu Beijing Univ. of Chemical Tech.
Yuan Fan Beijing Univ. of Chemical Tech.
Yanlin He Beijing Univ. of Chemical Tech.
Yuan Xu Beijing Univ. of Chemical Tech.

In the microarray data research field, it is quite challenging to make classification due to small sample size and the high dimension of data. Moreover, the feature selection is crucial. In this paper, we propose multidimensional mutual information (MMI) feature selection method to select the most informative features for classification. After feature selection using the proposed MMI, Extreme Learning Machine (ELM) is used as an efficient classifier. So as to evaluate the performance of the proposed methodology, a typical dataset called Leukemia is selected to carry out a case

study. Simulation results demonstrate the effectiveness of our proposed method.

SunA08 Room8
IS: parameter identification, learning, and control for nonlinear systems 13:30-15:30

Chair: Min Fu Ocean Univ. of China
CO-Chair: Ronghu Chi Qingdao Univ. of Sci. & Tech.

13:30-13:50 SunA08-1

Data-driven Adaptive Iterative Learning Control Based on a Local Dynamic Linearization

Shuhua Zhang Qingdao Univ. of Sci. & Tech.
Yu Hui Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.

Linearization technique is inevitable for the controller design and analysis of the nonlinear systems. However, the traditional linearization methods require model information, which is difficult to obtain for the complex nonlinear system. In this article, a new local dynamic linearzation method is proposed using the differential mean-value theorem, which is data-driven and can be estimated by using the I/O data only. Then a new adaptive iterative learning control is proposed by using the optimal technology, where the controller design and analysis is data-driven without using any model information. The simulation verifies the monotonic convergence and practicability of this method.

13:50-14:10 SunA08-2

Moving Object Real-time Detection and Tracking Method Based on Improved Gaussian Mixture Model

Shanliang Zhu Qingdao Univ. of Sci. & Tech.
Xin Gao Qingdao Univ. of Sci. & Tech.
Haoyu Wang Qingdao Univ. of Sci. & Tech.
Guangwei Xu Qingdao Univ. of Sci. & Tech.
Qiuling Xie Qingdao Univ. of Sci. & Tech.
Shuguo Yang Qingdao Univ. of Sci. & Tech.

In order to improve the reliability of moving objects detection and tracking, this paper presents a method for moving object real-time detection and tracking based on Vibe and Gaussian mixture model (GMM). This method uses the "Virtual" background model that is training by video sequence instead of the first frame image for background modeling. And the foreground object is extracted based on the pixel classification. Finally, according to the morphological method, the clearer moving targets are conducted to realize the real-time detection and tracking. The experimental results show that, in comparison with the current mainstream background subtraction techniques, our approach effectively works on a wide range of complex scenarios, faster detection speed, and more reliable detection results.

14:10-14:30 SunA08-3

On the Design and Analysis of a Learning Control Algorithm for Point-to-point Tracking Tasks

Na Lin Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.
Ruikun Zhang Qingdao Univ. of Sci. & Tech.

A simple iterative learning control approach is proposed to track specific target points in this work. For a general linear system, a P-type point-to-point ILC and a PD-type point-to-point ILC laws are designed, respectively. The two control laws only use the tracking error at the specified point to update the input signal at the corresponding specified point. The input signal between two consecutive specified points remains the same as the input signal at the previous specified point. The proposed method has the advantages of simple structure and easy application. The convergence analysis and simulation results further confirmed the availability of the method.

14:30-14:50 SunA08-4

A Simplified Control Scheme for Nonlinear Feedback System Based on Operator Theory

Congcong Jia Qingdao Univ. of Sci. & Tech.
Ni Bu Qingdao Univ. of Sci. & Tech.

In this paper, the operator-based right coprime factorization method is applied to deal with the stability issue of nonlinear feedback system, wherein the inverse of the right factor obtained from the isomorphism-based factorization method is discussed and is proved to be stable, thus the Bezout identity is satisfied with the designed controllers. Meanwhile, the nonlinear feedback system is stable.

14:50-15:10 SunA08-5

Feature Extraction and Classification of Hyperspectral Image Based on 3D- convolution Neural Network

Xuefeng Liu Qingdao Univ. of Sci. & Tech.
Qiaoqiao Sun Qingdao Univ. of Sci. & Tech.
Yue Meng Qingdao Univ. of Sci. & Tech.
Congcong Wang Qingdao Univ. of Sci. & Tech.
Min Fu Ocean Univ. of China

Deep learning has huge potential for hyperspectral image (HSI) classification. In order to fully exploit the information in HSI and improve the classification accuracy, a new classification method based on 3D-convolutional neural network (3D-CNN) is proposed. In the meantime, virtual samples are introduced to solve the problem of insufficient samples of HSI. The experimental results show that the proposed method has a good application prospect in HSI classification.

15:10-15:30 SunA08-6

Least Squares Based Iterative Parameter Estimation Algorithm for CARAR Systems

Lijuan Wan Qingdao Univ. of Sci. & Tech.
Chunping Chen Qingdao Univ. of Sci. & Tech.
Yan Ji Qingdao Univ. of Sci. & Tech.

This paper investigates the identification problems of a controlled autoregressive system with autoregressive noise (CARAR system for short) from input and output data. By applying the iterative method and the hierarchical identification principle, a least squares identification algorithm is presented. The basic idea is to replace the unknown noise terms in the information vector with their estimated residuals. The simulation test results show the effectiveness of this algorithm.

SunA09 Room 9
IS: Data-driven technologies and application in complex systems 13:30-15:30

Chair: Jing Wang Beijing Univ. of Chemical Tech.
CO-Chair: Congzhi Huang North China Electric Power Univ.

13:30-13:50 SunA09-1

On-line Active Fault Detection Based on Set-membership Ellipsoid and Moving Window

Junde Wang Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.
Jinglin Zhou Beijing Univ. of Chemical Tech.

On-line active fault detection (AFD) and its optimization problems are proposed based on the set-membership ellipsoid technique in order to solve the problem of on-line fault detection. The design of auxiliary input signal should satisfy two conditions: the signal amplitude is small enough without obvious impact on the system, and it simultaneously separates the system output in the normal and fault operation. Here we describe the output set as an ellipsoid under the framework of set-membership. The system model of moving window is established based on the parity space, and the equivalent optimization design of auxiliary input signal is solved based on this model. The proposed method can significantly reduce the complexity of the optimization calculation and conveniently obtain the auxiliary input signal on-line. The system fault is detected more intuitively by comparing the degree of separation between the output ellipsoid of the actual system and that of the identification normal (or fault) model. The simulation results on a general example verify the effectiveness of the proposed method.

13:50-14:10 SunA09-2

Comparison of the Least Absolute Deviation Algorithms and Its Application in CPA

Han Zhang Beijing Univ. of Chemical Tech.
Jinglin Zhou Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.

The least mean square (LMS) algorithm has been widely used in system identification, but it cannot deal with non-Gaussian noise well. For systems with non-Gaussian interference, in this paper we propose to utilize the least absolute deviation (LAD) algorithm instead of the LMS algorithm for parameter identification. Three algorithms are introduced to solve the LAD criterion. We experimentally prove that the LAD algorithm outperforms the LMS for processing non-Gaussian noise. However, LAD is not calculated as fast as least squares, which needs further improvement in the future.

14:10-14:30 SunA09-3

An Improved Medical Image Denoising Algorithm Based on One - dimensional Heat Transfer Equation

YanZhu Zhang Shen yang Li gong Univ.
MingHai Zhang Shen yang Li gong Univ.
Qi Yang Shen yang Li gong Univ.
Tianhao Wang Tongji Univ.

Denoising is a critical step for medical image processing. When applied to medical image processing, the traditional denoising algorithm has the disadvantages of being vague. This paper presents an improved image denoising method to combine the fractional differential mask operator and one-dimensional heat transfer equation. Due to the amplitude-frequency characteristic of fractional differential operation, this algorithm can preserve more image texture information and overcome the staircase effect in the region where the gray level of image smoothing does not change much. The algorithm has strong ability of to remove noise, preserve for the edge features and texture details of the image. The experimental results show that the medical images processed by the algorithm preserve more pathological information than that of the common method of denoising partial differential images. The improved algorithm provides reliable evidence for the subsequent medical diagnosis.

14:30-14:50 SunA09-4

Feature Extraction Method of Fluidized Bed Agglomeration Based on ReliefF and PCA

Zhe Wang Beijing Univ. of Chemical Tech.
Haiyan Wu Beijing Univ. of Chemical Tech.
Weiguo Lin Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.

Agglomeration of polymer in fluidized bed reactors (FBRs) can seriously hinder the industry production. In order to monitor agglomerations, the acoustic method was introduced, and the ReliefF based principal component analysis (PCA) was proposed to extract the feature of acoustic signals. Firstly, the time-domain and frequency-domain features of acoustic signals generated by reactant particles impinging on the wall of the FBR were analyzed and a high-dimensional feature vector was found which can distinguish normal and abnormal signals. The PCA method was used for removing the correlation between the feature matrix of training data, and the cumulative weight metrics based

on ReliefF was designed for the selection of feature. Then a low-dimensional feature vector was selected for fault modeling. The proposed method was applied to a polyethylene pilot plant, experimental results show that the method can effectively improve the detection accuracy of agglomeration fault, and improve the reliability of acoustic method.

14:50-15:10 **SunA09-5**

Wind Turbine Unit Power Prediction Based on Wavelet Neural Network Optimized by Brain Storm Optimization Algorithm

Qiang Guo State Grid Shanxi Electric Power Research Inst.
Zhiwei Xue State Grid Shanxi Electric Power Co.
Longying Zhang State Grid Shanxi Electric Power Research Inst.
Xiaohui Lu State Grid Shanxi Electric Power Co.
Yue Yin North China Electric Power Univ.
Congzhi Huang North China Electric Power Univ.

The construction of the wind power curve is of great significance to the wind turbines. Based on the accurate model of wind power curve developed, it can be employed for the wind power prediction and fault diagnosis. Normally, the wind turbine manufacturer provides the standard wind power curve, which is measured at standard conditions. However, the actual situation of the wind turbine is different from the standard state and is constantly changing. The wind power curve needs to be modified. The wind power curve essentially establishes a functional relationship between wind speed and active power. The neural networks have the ability to approximate function. In this paper, based on the actual data from a wind farm in Shanxi Province, the wavelet neural network is used to model the wind power curve, and the initial parameters are determined by using the brain storm optimization algorithm. The probability of the non-convergence in the learning process of the wavelet neural network is greatly reduced. Extensive experimental results are presented to validate the effectiveness of the proposed approach.

15:10-15:30 **SunA09-6**

Organic Compound Identification Based on Terahertz Spectrum

Junxiu Liu Beijing Univ. of Chemical Tech.
Bin Du Beijing Univ. of Chemical Tech.
Zhengchao Shen Beijing Univ. of Chemical Tech.
Haijiang Zhu Beijing Univ. of Chemical Tech.

This paper brings an organic compound identification method based on terahertz time-domain spectrum. Firstly, the absorption coefficient spectrums of the substance samples are estimated depending on the time-domain signal and the features are extracted from these spectrums in the range of 0.2-2.5THz. Secondly, the classifier model of the extracted features is established using the support vector machine (SVM) for the training samples. Finally, the identified rate is calculated in terms of the trained model for the test samples. In the experiments, we compared the performance of the feature extraction using principal component analysis (PCA), linear discriminant analysis (LDA) and frequency-amplitude parameters respectively. The experimental results show that the support vector machine combined with principal component analysis performs more classification performance.

SunB01 Room1
Iterative learning control (IV) 15:40-17:40

Chair: Xiaoe Ruan Xi'an Jiaotong Univ.
CO-Chair: Ruikun Zhang Qingdao Univ. of Sci. and Tech.

15:40-16:00 **SunB01-1**

Network-based Iterative Learning Control Approaches with Communication Delay Adjustment Factors for LTI Systems

Jian Liu Xidian Univ.
Xiaoe Ruan Xian Jiaotong Univ.

The paper develops two novel network-based iterative learning control approaches with communication delay adjustment factors for SISO LTI systems. Suppose that communication delay is subject to 0-1 Bernoulli distribution. In the two approaches, the actual system input is the synchronous system input at the previous iteration if the system input at the current iteration is delayed, otherwise the actual system input is a linear combination of the synchronous system inputs at the current and previous iterations, where the coefficients are dependent upon the input communication delay probability. For the output signals used by the ILC unit, we give two strategies. One is the same as that for the actual system input; the other one is that the actually utilized output is the synchronous desired output if the system output is delayed, otherwise the actually utilized output is a linear combination of the synchronous system output at the current iteration and the synchronous desired output, where the coefficients are dependent upon the output communication delay probability. It is shown that under certain conditions the expectation of the system output is convergent to the desired output. Finally, we use an example to illustrate the effectiveness of the developed NILC approaches.

16:00-16:20 **SunB01-2**

Reliable Control of Nonlinear System with Input Saturation by Adaptive Iterative Learning Control

Ruikun Zhang Qingdao Univ. of Sci. and Tech.
Ronghu Chi Qingdao Univ. of Sci. and Tech.

In this paper, reliable control strategy is studied for nonlinear system with input saturation by adaptive iterative learning control. The system dynamic function is described by a class of nonlinearly parameterized functions with input saturation and actuator faults. In order to address nonlinearity of system, input saturation

and the actuator fault term, we design an adaptive iterative learning reliable controller (AILRC) which is a feedback P-type ILC controller. Based on the constructed composite energy function (CEF) and some necessary assumptions, the convergence analysis is given which shows that the system tracking error converges to zero when the iteration number tends to infinity. Finally, simulation is given to illustrate the correctness of the proposed AILRC.

16:20-16:40 **SunB01-3**

Saturated D-type ILC for Multicopter Trajectory Tracking Based on Additive State Decomposition

Chenxu Ke Beihang Univ.
Jinrui Ren Beihang Univ.
Quan Quan Beihang Univ.

In this paper, a saturated D-type iterative learning control (ILC) method is proposed for multicopter trajectory tracking based on the additive state decomposition (ASD) method. By using the ASD method, the multicopter nonlinear horizontal channel with input saturation is divided into a linear primary system and a nonlinear secondary system. The ILC method for linear systems can be used directly in the linear primary system to track desired trajectories. A state feedback is applied to stabilize the nonlinear secondary system. Then, the above two controllers are combined to achieve the control goal. Simulation results demonstrate the feasibility of the proposed method for the multicopter trajectory tracking problem with input saturation and other nonlinearities.

16:40-17:00 **SunB01-4**

Spatial Iterative Learning Control for Pitch of Wind Turbine

Yan Liu Xi'an Jiaotong Univ.
Xiaoe Ruan Xi'an Jiaotong Univ.

This paper investigates a PD-type spatial iterative learning control (SILC) method for the wind turbine pitch control system in order to maintain the stationary output power constant with the wind speed increase in region 3. The pitch control system is considered as the repetitive operation system, then the temporal domain linear time-invariant pitch control system transforms to a spatial domain linear spatial-variant pitch control system, the PD-type SILC algorithmic generates the upgraded pitch angle control inputs by compensating for the initial input with proportional and derivative actions based on the tracking error between the desired output rotor speed and the measured rotor speed in real time. By adopting the Lebesgue-p norm and the generalized Young inequality of convolution integral, the convergence of the PD-type SILC for pitch control system is derived. Finally, some numerical simulations are presented to verify the effectiveness and validity of the SILC in wind turbine pitch control system.

17:00-17:20 **SunB01-5**

Computationally Inexpensive Robust Data Driven Optimal Point-to-point Tracking ILC for City Subway Trains Subject to Iteration-dependent Disturbances

Genfeng Liu Beijing Jiaotong Univ
Zhongsheng Hou Beijing Jiaotong Univ

This paper presents a robust data driven optimal point-to-point ILC for subway trains with multiple-point tracking and subject to iteration-dependent disturbances by only utilizing input output data of the train system. Firstly, the tracking task requires that the control input is updated according to the prespecified measured multiple-point tracking error values rather than the complete output trajectory, which can reduce computational cost. Secondly, without model information of the train system, a robust data driven control law is designed. Then, rigorous analysis is developed which demonstrates that the train tracking error is monotonic uniformly ultimately bounded convergence and the ultimate bound which only depends on the disturbances boundedness. Finally, a simulation is conducted for train system to verify the effectiveness of theoretical studies.

17:20-17:40 **SunB01-6**

Vehicle Detection and Classification Using Convolutional Neural Networks

Minglan Sheng Chongqing Jiaotong Univ.
Chunfang Liu Chongqing Jiaotong Univ.
Qi Zhang Chongqing Jiaotong Univ.
Lu Lou Chongqing Jiaotong Univ.
Yu Zheng Chongqing Vocational College of Transportation

The vehicle detection and classification are important tasks in intelligent transportation system. The traditional methods of vehicle detection and classification often cause the coarse-grained results due to suffering from the limited viewpoints. Inspired by the latest achievements of Deep Learning successfully applied on images classification in recent years, this paper presents a method based on convolutional neural network, which consists of two steps: vehicle area detection and vehicle brand classification. Several typical network models have been applied in training and classification experiments for the detailed contrast analysis, such as RCNN (Regions with Convolutional Neural Network features), Faster RCNN, AlexNet, Vggnet, GoogLenet and Resnet. The proposed method can identify the vehicle models, brands and other information accurately and in real time, with the original data dataset, the algorithm can obtain the results with average accuracy about 89% in the classification of seven kinds of vehicle models.

SunB02 **Room 2**
Statistical learning and machine learning in automation field (II) **15:40-17:40**

Chair: Li Ning Shanghai Jiao Tong Univ.
CO-Chair: Shangtai Jin Beijing Jiaotong Univ.

15:40-16:00 **SunB02-1**

An EMD-RF Based Short-term Wind Power Forecasting Method

Weizhou Shen Shanghai Jiao Tong Univ.
Na Jiang Shanghai Jiao Tong Univ.
Ning Li Shanghai Jiao Tong Univ.

Wind power forecasting of wind field has been a common problem recently. Due to the randomness and volatility of wind power, predicting wind power accurately is a challenge for dispatchers who need to establish dispatching strategies. This paper presents a wind power forecasting method based on empirical mode decomposition (EMD) and random forest (RF). This method applies EMD to decompose wind power sequence into several intrinsic mode functions (IMF) and a residual component, then RF is used to train each component. Finally, the predicting results of each component are summed together to obtain the wind power forecasting values. The proposed method is tested on actual data from a wind farm in America. The result shows that compared with the traditional forecasting model, the EMD-RF method reduces the forecasting error and track the change of wind power more accurately.

16:00-16:20 **SunB02-2**

Ensemble of Extreme Learning Machines for Regression

Atmane Khellal Beijing Institute of Tech.
Hongbin Ma Beijing Institute of Tech.
Qing Fei Beijing Institute of Tech.

Regression, as a particular task of machine learning, performs a vital part in data-driven modeling, by finding the connections between the system state variables without any explicit knowledge about the system, using a collection of input-output data. To enhance the prediction performance and maximize the training speed, we propose a fully learnable ensemble of Extreme Learning Machines (ELMs) for regression. The developed approach learns the combination of different individual models, using the ELM algorithm, which is applied to minimize both the prediction error and the norm of the network parameters, which leads to higher generalization performance under Bartlett's theory. Moreover, the average based ELM ensemble may be viewed as a particular case of our model. Extensive experiments on many standard regression benchmark datasets have been carried out, and comparison with different models has been performed. The experimental findings confirm that the proposed ensemble can reach competitive results in term of the generalization performance, and the training speed. Furthermore, the influence of different hyperparameters on the performance, in term of the prediction error and the training speed, of the developed model has been investigated to provide a meaningful guideline to practical applications.

16:20-16:40 **SunB02-3**

Driver Behavior Analysis for Advanced Driver Assistance System

Hua Chen Jilin Univ.
Fengkai Zhao Jilin Univ.
Kai Huang Jilin Univ.
Yantao Tian Jilin Univ.

In order to improve the comfort and acceptance of the advanced driver assistance system, many researchers have spent a lot of effort to study the driver's driving characteristics in the specific conditions. Unlike previous works, two new basic driving conditions are defined in this paper. In order to analyze the driver behavior, we select the vehicle trajectory data provided by NGSIM. The Spearman correlation coefficients is used to statistically analyze the major factors affecting driver behavior based on screened NGSIM data. Further, this paper discusses the characteristics of driver reaction delay. The work of this paper will benefit the follow-up research on advanced driver assistance system development.

16:40-17:00 **SunB02-4**

A New Measure of Dynamic Similarity for Nonlinear Systems Based on Gap Metric and Deterministic Learning Theory

Danfeng Chen Foshan Univ.
Cong Wang South China Univ. of Tech.
Wenbo Zhu Foshan Univ.

For nonlinear dynamical systems, structural stability is a fundamental concept. It provides a qualitative tool for analyzing the equivalent relation between a nonlinear dynamical system and its perturbed system. Currently, most researches about structural stability, including some applications in practical systems, are mainly limited to qualitative analysis. In this paper, our focus is on the quantitative property of structural stability. A new measure will be proposed from the perspective of structural stability and gap metric under the Deterministic Learning theory, which provides more incentives for further applications in pattern recognition, classification as well as fault detection. Simulation studies are included to further demonstrate the effectiveness of this measure.

17:00-17:20 **SunB02-5**

Direction of Arrival Estimation Based on Generalized Reference Curve Model

Lizhi Cui Henan Polytechnic Univ.
Xuhui Bu Henan Polytechnic Univ.
Junqi Yang Henan Polytechnic Univ.
Yi Yang Henan Polytechnic Univ.
Weina He Pingdingshan Univ.

Currently, the widely used methods for direction of arrival (DOA) estimation were constructed based on the subspace, such as Multiple Signal Classification (MUSIC) and Estimating Signal Parameter via Rotational Invariance Techniques (ESPRIT), which required that the number of sources is known beforehand. In this paper, a new model based on the Generalized Reference Curve Model (GRCM) for the DOA estimation was proposed, which do not need to know the sources number in advance. And the comparison of the performance between the proposed model and the MUSIC model was given to demonstrate the effectiveness of our method. The algorithm of Multi-target Intermittent Particle Swarm Optimization (MIPSO) was adopted to solve the model proposed in this paper, and the performance of the MIPSO was analyzed through a simulation. The result shown that:(1) the GRCM was an effective model to solve the DOA estimation without prior knowledge of the sources number; (2) the MIPSO was an efficient algorithm to solve the DOA estimation with much shorter operation time and high precision.

17:20-17:40 **SunB02-6**

Short-term Traffic Flow Prediction Based on XGBoost

Xuchen Dong Beijing Jiaotong Univ.
Ting Lei Beijing Jiaotong Univ.
Shangtai Jin Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.

Fast and accurate short-term traffic flow prediction is an important precondition for traffic analysis and control. Due to the fact that the short-term traffic flow has nonlinear characteristic and changes randomly, concurrent computation is difficult for traditional machine learning algorithms. In this paper, a traffic flow prediction model combining wavelets decomposition and reconstruction with the extreme gradient boosting (XGBoost) algorithm is proposed to predict the short-term traffic flow. First, in the training part, wavelet de-noising algorithm is utilized to obtain the high and low frequency information of target traffic flow. Secondly, the high frequency information of traffic flow is processed by threshold method. After that, the high and low frequency information is reconstituted as the training label. Finally, the de-noised target flow is sent to the XGBoost algorithm for training to predict traffic flow. In this way, the trend of the traffic flow in each sample period is retained, and the influence of the short-term high frequency noise is reduced. The proposed traffic flow prediction method is tested base on the traffic flow detector data collected in Beijing, and the proposed method is compared with support vector machine (SVM) algorithm. The result shows that the prediction accuracy of the proposed algorithm is much higher than SVM, which is of great importance in the field of traffic flow prediction.

SunB03 Room 3

Applications of data-driven methods to complex processes (II) 15:40-17:40

Chair: Yujie Sun State Nuclear Electric Power Planning Design & Research Inst. Co.
CO-Chair: Zhendong Zhang Henan Polytechnic Univ.

15:40-16:00 **SunB03-1**

VISSIM Parameter Calibration Based on Traffic Characteristics Distribution at Signalized Intersections

Ning Li State Nuclear Electric Power Planning Design & Research Inst. Co.
Yujie Sun State Nuclear Electric Power Planning Design & Research Inst. Co.

In order to increase the accuracy of traffic simulation and better reproduce the real traffic condition at signalized intersections, this paper proposed a parameter calibration method based on the traffic distribution rules at signalized intersections. First, after qualitatively analyzing the traffic condition at signalized intersections based on dynamic traffic features, this paper selected the key parameters that need to be calibrated. Then, regarding the selected key parameters, this paper first designed and implemented the collecting method. Then filtered and analyzed the data, and acquired the distribution pattern of each key parameter at signalized intersection. Finally, in order to validate the calibration process based on vehicle types through simulation, this paper chose travel time and number of stops as validation parameters. The results showed that there had been a great increase in the accuracy after calibration. The maximum inaccuracy among all evaluation parameters was 14.6%, which indicated that the calibration process based on traffic characteristics distribution at signalized intersections was effective.

16:00-16:20 **SunB03-2**

Application of Improved Genetic Algorithm to Unmanned Surface Vehicle Path Planning

Yang Long Wuhan Univ. of Tech. Hubei Minzu Univ.
Yixin Su Wuhan Univ. of Tech.
Huajun Zhang Wuhan Univ. of Tech.
Ming Li Wuhan Univ. of Tech.

Lake patrol is an important part of lake water environment management and the path planning is the key problem to lake patrol. In order to solve this kind of path planning problem, an improved genetic algorithm is proposed. A new initial population method is proposed to create the better quality of the initial population, and the adaptive crossover probability and mutation probability are designed. In this paper, the grid method is used to construct the working environment of the lake patrol unmanned surface vehicle (USV). Compared with the traditional genetic algorithm, the improved genetic algorithm can obtain the shorter and a safer

non-collision path in different lake environments. The simulation results demonstrate that the path planning of the lake patrol USV with the improved genetic algorithm is reasonable and effective.

16:20-16:40 **SunB03-3**

On Closed-loop Control of Matrix Converter with Double Voltage Control

Xinghe Ma Henan Polytechnic Univ.
Zhendong Zhang Henan Polytechnic Univ.
Dan Xu Henan Polytechnic Univ.
Kunchao Wang Henan Polytechnic Univ.

A novel closed-loop control strategy is designed and researched for a matrix converter with dual voltage synthesis control. The closed-loop control strategy is based on the dual-voltage control of the matrix converter duty cycle calculation characteristics, the deviation between the ideal input voltage duty cycle and the equivalent input voltage duty cycle is calculated, and the calculated deviation is added as the negative feedback variable of the closed loop system to the next duty cycle calculation period. In order to achieve the purpose of closed-loop control. The closed-loop control strategy proposed in this paper is used to solve the problem that the output side voltage performance of the matrix converter is affected by the input side voltage distortion and the performance of the internal components of the matrix converter is not ideal. To ensure that the actual output voltage of the matrix converter to better meet the desired voltage, improved its disturbance after the output voltage quality reduction, improve the output performance. The experimental results show that the output voltage of the matrix converter with this new closed - loop control method is closer to the desired voltage, the output current waveform is smoother and the output voltage quality is more ideal.

16:40-17:00 **SunB03-4**

DMPC Applied to the Temperature Regulation System of Building under Packet Dropout Communication

Qingnan Huang Guangxi Univ. of Sci. and Tech.
Liujun Xie Guangxi Univ. of Sci. and Tech.

A solution to the interference of control signals and signal loss in the process of signal transmission in the process of decentralized model predictive control (DMPC) is introduced in this paper. Judging whether the data packet is lost at each time sampling signal，Then the approximate value of the lost signal at this time is calculated in an alternative way. The results show that: this method is feasible.

17:00-17:20 **SunB03-5**

Optimization Parameters of PID Controller for Powered Ankle-foot Prosthesis Based on CMA Evolution Strategy

Kaiyang Yin Wuhan Univ. of Tech.
Muye Pang Wuhan Univ. of Tech.
Kui Xiang Wuhan Univ. of Tech.
Chen Jing Wuhan Univ. of Tech.

Optimization parameters of PID controller based on Covariance Matrix Adaptation Evolution Strategy (CMA-ES) is presented in this paper. It is used to solve the problem of torque control for powered ankle-foot prosthesis. Original optimization parameters method of PID controller for powered ankle-foot is time-consuming and cannot get satisfied control effect. The parameters of PID control are used as an individual of CMA-ES in this paper. Appropriate fitness function is selected to adjust the PID parameters on line. Step signal and torque approximation are used as the system input to verify the controller performance. In unit-step response, the overshoot of original PID is 15 times as much as it of CMA-ES PID, the setting time of original PID is 6 times as much as it of CMA-ES PID. In device torque response, the output of CMA-ES PID is stabilized throughout the control process. These indicates that CMA-ES PID is an effective control strategy for torque control of powered ankle-foot prosthesis.

17:20-17:40 **SunB03-6**

Robust Stability for Nonlinear Fuzzy Network Control Systems with Time Varying Delay

Yue Hu Qilu Univ. of Tech.
Hongqian Lu Qilu Univ. of Tech.
Chaoqun Guo Qilu Univ. of Tech.
Xingping Liu Qilu Univ. of Tech.
Renren Wang Qilu Univ. of Tech.
Hongwei Chen Ji Nan Building Source Cement Products Co.LTD

In this paper, there will be considered the robust stability problem in the nonlinear fuzzy network control system. In the nonlinear fuzzy network control system, the delay dependent condition is proposed by the linear matrix inequality (LMI) method. Based on an applicable free weighting matrix (FWM) method, the delay upper bound of the fuzzy network control system is obtained. Finally, there will be given a numerical example to proof the proposed method.

SunB04 Room 4
Data-driven fault diagnosis and health maintenance (III)
15:40-17:40

Chair: Mou Chen Nanjing University of Aeronautics and Astronautics
CO-Chair: Tianzhen Wang Shanghai Maritime Univ. University of Brest

15:40-16:00 **SunB04-1**

Feature Extraction of Gearbox based on Order Analysis of Instantaneous Angular Speed

Lin Liang Xi'an Jiaotong Univ.
Zhe Lei Xi'an Jiaotong Univ.
Maolin Li Xi'an Jiaotong Univ.
Xiangwei Kong Xi'an Jiaotong Univ.

As key components in a mechanical transmission chain, gearboxes work in non-stationary conditions in many cases and the effect of conventional vibration analysis is limited by low signal-noise ratio. Considering the advantage of Instantaneous Angular Speed (IAS), this paper proposes a gearbox feature extraction method based on the order analysis of IAS signals. Firstly, IAS signals of the input and output shafts are sampled synchronously by photoelectric encoders. Then the instantaneous angular speed difference (IASD) between the input shaft and output shaft is calculated to eliminate the interference of the transmission channel. Finally, the order spectrum of the gearbox can be obtained by the Fourier transform of IASD signal. Thus, gearbox's working status can be judged according to the characteristic distribution of rotational components in the order spectrum. The effectiveness of this method has been validated experimentally on a two-stage gearbox test rig.

16:00-16:20 **SunB04-2**

Continuous Multivariable Integral Sliding Mode Control of Rigid Spacecraft with Actuator Faults

Xiuyun Zhang Tianjin Univ.
Qun Zong Tianjin Univ.
Wenjing Liu Beijing Inst. of Control Engineering
Jie Wang Hebei Univ. of Tech.

This paper investigates the fault-tolerant control (FTC) for the rigid spacecraft. A continuous multivariable integral sliding mode (CMISM) FTC is developed, which is capable of ensuring the finite-time stability of the closed-loop system in the presence of actuator malfunctions and external disturbances. Firstly, a smooth second order controller is designed for the finite time convergence of nominal system. Then, the conventional discontinuous part of ISM to reject faults and disturbances is modified by a continuous multivariable twisting control, which could obtain a better dynamic response and anti-disturbance performance. A rigorous proof of the finite time stability of closed-loop system is derived by utilizing Lyapunov method. Finally, the efficiency of the proposed method is illustrated by numerical simulations.

16:20-16:40 **SunB04-3**

Anomaly Detection of Satellite Telemetry in Orbit Based on Sequence and Point Feature Combination

Ying Du 63758 Unit of PLA.
Xin Liang Xi'an Satellite Control Center.
Fei Wang 63758 Unit of PLA
Chao Sun 63758 Unit of PLA
XiaoFei Hua 63758 Unit of PLA

Aiming at the detection problems of low accuracy, high false alarm rate in the detection of satellite telemetry timing data, a satellite telemetry anomaly detection model is presented based on combination of sequence and point features. The model firstly makes steady separation in telemetry data to obtain data trends and steady residual; as the data trends contain most of telemetry sequence information, the non-stationary telemetry sequence feature is reconstructed on each separation layer by performing inverse data trends transform on these coefficients. And stable residual is mainly composed of telemetry random point, the telemetry point feature is reconstructed on the final separation layer by performing inverse steady residual transform on these coefficients. Finally, the integrated anomaly detection model, that is double autoregressive combined model, is constructed by fuse the two features. The results of anomaly detection experiment in the telemetry data of a certain type of satellite power system show that the model can adapt to the complex changes of satellite telemetry data in orbit, reduce decision interference from noise and outliers effectively, reduce the false alarm rate, improve detection precision, achieve effective detection in the anomaly threshold of satellite telemetry data on orbit.

16:40-17:00 **SunB04-4**

Fault-Tolerant Motion Planning of Redundant Manipulator with Initial Position Error

Kene Li Guangxi Univ. of Sci. and Tech.
Univ. of Rhode Island
Jin Yang Guangxi Univ. of Sci. and Tech.
Chengzhi Yuan Univ. of Rhode Island
Jianqin Xu Guangxi Univ. of Sci. and Tech.
Xisheng Dai Guangxi Univ. of Sci. and Tech.
Jiawei Luo Jiangxi Vocational College of Industry and Engineering

In the robotic manipulator operation practice, it is necessary to adjust the manipulator initial state to an accurate configuration for executing a given path tracking task. However, it is difficult to achieve a desired accurate configuration, which would lead to an unexpected initial position error of the end-effector. In this paper, based on a new neural-dynamic design method, i.e., Zhang dynamics, a fault-tolerant motion planning scheme is presented to diminish the initial position error arising in the manipulator state adjustment. Such a motion planning scheme of redundant manipulators can rapidly and smoothly diminish the initial position error during the task execution. Computer simulations performed based on a four-link manipulator model are presented to illustrate the validity and advantages of such a fault-tolerant motion planning scheme with an initial position error for redundant robot arms.

17:00-17:20 **SunB04-5**

LQR-based Optimal Tracking Fault Tolerant Control for a Helicopter with Actuator Faults

Kun Yan Nanjing Univ. of Aeronautics and Astronautics
Qingxian Wu Nanjing Univ. of Aeronautics and Astronautics

Mou Chen Nanjing Univ. of Aeronautics and Astronautics

This study develops an optimal tracking fault tolerant control (FTC) scheme for a helicopter with actuator faults, which integrates the FTC, tracking control and optimal control in one unified framework. The unknown continuous function which is composed of actuator faults is handled using the disturbance observer technology. The trajectory tracking problem is transformed into an optimal control problem and the optimal FTC law is presented to ensure the tracking errors convergence based on the linear quadratic regulator (LQR) control technology. Simulation results obtained show that the proposed optimal tracking fault tolerant controller is effective and useful.

17:20-17:40 **SunB04-6**

An Arm Isolation and Reconfiguration Fault Tolerant Control Method Based on Data-driven Methodology for Cascaded Seven-level Inverter

Jiahui Zhang Shanghai Maritime Univ.
Zhuo Liu Shanghai Maritime Univ.
Tianzhen Wang Shanghai Maritime Univ.
Univ. of Brest
M.E.H. Benbouzid Univ. of Brest
Yide Wang Shanghai Maritime Univ.

Inverts, especially multi-level inverters are widely used in many fields, such as industrial production, transportation, aviation and so on. So great significance should be attached to the diagnosis and fault tolerance of inverters to keep the stability of systems. Data-driven approaches make full use of the process data to monitor the systems, so the voltage signals are collected firstly and then preprocessed and processed by specific strategy, fault labels will be produced hereafter. When the fault labels from data-driven fault detection and diagnosis system are generated, relevant fault tolerant control method will be activated in fault tolerant control system. Some measurements are necessary to achieve the higher utilization ratio of healthy IGBTs and sinusoidal output voltage. Based on above consideration, a group isolation and reconfiguration fault tolerant control method based on data-driven methodology for cascaded seven-level inverter is proposed here to reconfigure the SPWM, in which every H-bridge is divided into two groups. The simulation of cascaded seven-level inverter is built and the result indicates that the utilization of healthy IGBTs is improved.

SunB05 Room 5
Data-driven fault diagnosis and health maintenance (IV)

15:40-17:40

Chair: Ying Yang Peking Univ.
CO-Chair: Le Zhou Zhejiang Univ. of Sci. & Tech.
Zhejiang Univ.

15:40-16:00 **SunB05-1**

A Model-data Integrated Cyber Security Risk Assessment Method for Industrial Control Systems

Yuan Peng Huazhong Univ. of Sci. and Tech.
Kaixing Huang Huazhong Univ. of Sci. and Tech.
Weixun Tu Huazhong Univ. of Sci. and Tech.
Chunjie Zhou Huazhong Univ. of Sci. and Tech.

Rapid development and application of ICT technologies in industrial control systems (ICS) has introduced serious security problem, as the cyber-attack can cause physical damage, ensuring the cyber security is extremely important. Risk assessment is a key component in security protection process, but existing methods of risk assessment generally lack the capacity of quantifcation and the adaptability to the dynamic evolution of ICS. In this paper, we discuss a model-data integrated risk assessment method. In the proposed method, Bayesian network model is applied to achieve quantitative risk assessment, and the model is optimized dynamically using an online data-driven parameter learning strategy, which can improve the accuracy of real-time dynamic assessment result. The effectiveness of proposed method is demonstrated with a case study on a simulated process control system.

16:00-16:20 **SunB05-2**

A Wind Turbine Fault Diagnosis Method with Self-updating Model based on SCADA Data Mining

Fuming Qu Northeastern Univ.
Jinhai Liu Northeastern Univ.
Yu Zhang Datang New Energy Experimental Research Inst.
Jian Feng Northeastern Univ.
Xiaowei Hong Northeastern Univ.

This paper presents a fault diagnosis method with self-updating model (FDSU) based on supervisory control and data acquisition (SCADA) data mining. First, a two-step feature selection, including a correlation clustering method and a feature selection method, is proposed to extract the key features. Then based on the features, the expert-based and the learning-based models are combined together, so that the diagnosis can be more accurate and more widely applicable. Moreover, a self-updating model mechanism is proposed, which automatically updates the existed expert-based models to the learning-based models. The SCADA data collected from a wind farm in northern China is used in experiments. The results show that FDSU is more effective in WT fault diagnosis. What's more, the efficiency of FDSU can be continuously improved with the accumulation of data.

16:20-16:40 **SunB05-3**

Detecting Incipient Faults in Quad-rotor Unmanned Aerial Vehicle Based on Detrending and Denoising Techniques

Zhangming He National Univ. of Defense Tech.

China Academy of Space Tech.
Juhui Wei National Univ. of Defense Tech.
Bowen Hou National Univ. of Defense Tech.

Incipient faults are not easy to be detected, because they tend to be buried by the trend or the measurement noise. The paper proposes an applicable method for detecting incipient fault in the quad-rotor unmanned aerial vehicle (UAV). The approach in this paper is based on a detrending and denoising technique. The detrending algorithm is implemented based on the selected design functions, which can extract the normal trend from the training data, and then predict the normal trend in the testing data. The denoising algorithm is realized based on the weighted cumulative sum method, which can reduce the variance of the noise in the prediction residual. The proposed method is applied to detect the incipient fault in an experimental quad-rotor UAV, which shows that the performance of the proposed method is better than the traditional multivariate detection statistic in detecting incipient faults.

16:40-17:00 **SunB05-4**

Structural Health Monitoring of Offshore Wind Turbine based on Online Data-driven Support Vector Machine

Ao Zhang Ocean Univ. of China
Ming Li Ocean Univ. of China
Lin Zhou Ocean Univ. of China

The structural health monitoring (SHM) of the offshore wind turbine based on data-driven is supposed to extract the numeral characteristics and classify the health condition from the data stream acquired from sensors. Traditional classification method like support vector machine (SVM) and clustering method cannot process data stream directly. In this paper, according to the features of data stream, the SHM system is designed with improved the clustering method, and the health condition is classified online by time-domain and frequency-domain SVM classifiers based on data stream. The experiments are performed with the measured data of the vibration detection of the offshore turbine structures to evaluate the system. The experiment results show that the SHM system proposed in this paper can process the online vibration detection data stream and classify the health condition.

17:00-17:20 **SunB05-5**

Recursive Autoregressive Dynamic Latent Variable Model for Fault Detection of Dynamic Process with Missing Values

Le Zhou Zhejiang Univ. of Sci. & Tech. Zhejiang Univ.
Jiaxin Yu Zhejiang Univ. of Sci. & Tech.
Jing Jie Zhejiang Univ. of Sci. & Tech.
Zhihuan Song Zhejiang Univ.

For the dynamic processes, both the auto-correlations and the cross-correlations need to be extracted. In the previous work, the autoregressive dynamic latent variable (ARDLV) model is able to achieve this goal since an AR process is used for high-order dynamic process modelling. However, the training data set usually contain the missing values, which leads to the normal ARDLV invalid. In this paper, a novel recursive ARDLV model is proposed for fault detection of the dynamic process with missing values. In the proposed model, the missing value and the model parameters are estimated alternatively in the probabilistic framework. Finally, a case study is illustrated to reveal the performance of proposed method, in which an incomplete data set is used for fault detection purpose.

17:20-17:40 **SunB05-6**

A Novel Scheme for Fault Detection Using Data-driven Gap Metric Technique

Ruijie Liu Peking Univ.
Ying Yang Peking Univ.
Zhengen Zhao Peking Univ.
Jing Zhou Peking Univ.

This paper considers the fault detection problem for uncertain linear time-invariant systems. Based on the data-driven computational method for the gap metric, a fault detection scheme is designed by monitoring the gap metric between the running process and its nominal system with the direct use of offline and online data. Moreover, an alternative iterative realization of the stable image representation is proposed, based on which the gap metric is obtained and the fault detection is conducted with less calculation efforts. In addition, owing to the physical properties behind the gap metric, reliability analysis for systems with multiplicative faults is addressed. The numerical simulation examples are presented to demonstrate the effectiveness of the fault detection scheme.

SunB06 Room 6
Data-driven modeling, optimization and scheduling (III)
15:40-17:40

Chair: Zhenlei Wang East China Univ. of Sci. and Tech.
CO-Chair: Tianhong Pan Jiangsu Univ.

15:40-16:00 **SunB06-1**

Fast Positioning of Rotating Center Based on Correction of Finite Angle Deviation of CT System

Deyu Duan Qingdao Univ. of Sci. and Tech.
Fahui Zhai Qingdao Univ. of Sci. and Tech.
Yuqin Cao Qingdao Univ. of Sci. and Tech.
Huaqiong Hou Qingdao Univ. of Sci. and Tech.
Shuguo Yang Qingdao Univ. of Sci. and Tech.

Note that it is very important to determine accurately the position of the Center of Rotation (COR) to the image reconstruction in the CT scanning system, in this paper, we establish the model of fast determining COR by using

the correction of finite angle deviation, moreover apply certain algorithms to achieve the center of rotation calibration. By simulating original signal or the original signal with noise, we obtain that the artifact of the reconstructed image is significantly less and the image quality is also raised, thus the center of rotation can be accurately determined. Compared with the known algorithms, the model in this paper has a small amount of calculation and strong resistance to random noise. Consequently, our model and algorithm are helpful for determining COR.

16:00-16:20 **SunB06-2**

Performance Analysis of Marine Guidance Systematic Error Separation Based on Linear Model

Xuanying Zhou Nation Univ. of Defense and Tech.
Zhengming Wang Nation Univ. of Defense and Tech.
Dong Li Unit 94, PLA 91550
Jiongqi Wang Nation Univ. of Defense and Tech.

As the guidance systematic errors of inertial missiles directly determine the guidance accuracy, error separation is a vital data processing problem. The key point of error separation is to find out a good parameter estimation method and to design a suitable estimation strategy according to the errors' physical characteristics. Based on the linear regression model of the guidance systematic error separation, this study gives the comparisons of four parameter estimation methods, which are Least Square Estimation (LSE), Bayesian estimation, Principal Component Analysis (PCA) and regularization method, and gives the simulations of PCA and Regularization method. Moreover, combining with the initial errors of sea-based missiles, we design two estimation strategies named the sorting strategy and the iteration strategy. The results illustrate that these two new strategies can separate more errors than the traditional overall strategy.

16:20-16:40 **SunB06-3**

A Novel Improved Grey Wolf Optimization Algorithm for Numerical Optimization and PID controller Design

Tao Zhang East China Univ. of Sci. and Tech.
Xin Wang Shanghai Jiao Tong Univ.
Zhenlei Wang East China Univ. of Sci. and Tech.

The grey wolf optimization (GWO) algorithm, one of the recently proposed bio-inspired algorithms, simulates the leadership hierarchy and hunting mechanism of grey wolves in nature. The GWO has a good performance in some optimization tasks, but its search capacity decreases with the increasing search scope and dimension. This paper proposes an improved GWO (IGWO) algorithm, in which Levy flight strategy and a sine cosine operator with adaptive step are incorporated to significantly improve the performance of the algorithm. The Levy flight strategy is used to strengthen the efficiency of global search. The adaptive sine cosine operator is introduced to improve the local search ability. Experimental results based on twenty unconstrained benchmark problems show the superiority of the proposed IGWO. Furthermore, the IGWO is utilized in PID controller design. The comparison results show that the IGWO algorithm is better than, or at least comparable to, other well-established swarm intelligence algorithms.

16:40-17:00 **SunB06-4**

The Design of an Intelligent Livestock Production Monitoring and Management System

Yu Wang Chinese Academy of Agricultural Sci.
Xi Yong Ministry of water resources
Zhaofeng Chen Jiangsu Broadcasting Cable Information Network Corp. Ltd.
Haiyuan Zheng Beijing Perfect World Software Tech. Development Corp. Ltd.
Jiayu Zhuang Chinese Academy of Agricultural Sci.
Jiajia Liu Chinese Academy of Agricultural Sci.

This article introduces a highly intelligent and widely applicable system for intelligent management and control of livestock production. This system mainly provides the functions of feed use monitoring and control, RFID e-label identification, quality traceability, animal farming environment monitoring, growth monitoring and predication, etc. This article gives detailed introduction of the animal farming environment monitoring, growth monitoring and algorithms used by the predication function in the system. This system effectively improve the production efficiency of animal farming as well as the survival rate and off-taking rate of animal products, thus shortening cycles of animal farming. This system provides a convenient platform for standardized livestock production and management. Animal farming in multiple locations and for multiple times finally generate big data of farming of various types of animals. Constant exploration of such data can help optimize animal farming practices and provide technical support for more science-based and precise animal farming.

17:00-17:20 **SunB06-5**

Edge Effect Detection for Real-time Cellular Analyzer Using Functional Principal Component Analysis

Qian Guo Jiangsu Univ.
Tianhong Pan Jiangsu Univ.

To detect cytotoxicity of chemicals, many instruments have been developed. One popular tool is real time cellular analyzer (RTCA). Nevertheless, abnormal time-dependent cellular response curves (TCRCs) always occur and disturb experimental results when the wells are at the edge of E-plate. Therefore, a method is proposed to detect edge effect which is detrimental to the experimental quality. In this work, these TCRCs were considered as observations of a random variable on a functional space and Functional Principal Component Analysis (FPCA) was utilized to extract principal

components of TCRCs to find unusual curves. The average normalized cell index (NCI) of the inner wells was defined as the standard. Then all TCRCs were analyzed by FPCA to find abnormal TCRCs which would be removed automatically by computer. This approach has never been applied in RTCA system to determine edge effect. Experimental results indicate that the FPCA algorithm achieves a comparable detection rate.

17:20-17:40 **SunB06-6**

Robust H ∞ Stability for Lurie Nonlinear Stochastic Network Control Systems with Time-varying Delay

Hongqian Lu Qilu Univ. of Tech. (Shandong Academy of Sci.
Chaoqun Guo Qilu Univ. of Tech. (Shandong Academy of Sci.
Yue Hu Qilu Univ. of Tech. (Shandong Academy of Sci.
Xingping Liu Qilu Univ. of Tech. (Shandong Academy of Sci.
Hongwei Chen Ji Nan Building Source Cement Products Co.LTD

This paper researches the robust H ∞ stochastic stability criterion of lurie nonlinear stochastic network control system containing time-varying delay. Common network control systems are feedback systems and more and more network control systems possess nonlinear and stochastic character. The parameter uncertainties are concerned directly to the network control system. This note employs the improved free weighting matrix (IFWM) method to analyze the lurie nonlinear stochastic network system's robust H ∞ stochastic stability criterion. A numerical example is presented to demonstrate the suitability of the method put forward in this paper.

SunB07 Room 7
IS: Data-driven fault analysis and diagnosis

15:40-17:40

Chair: Ying Zheng Huazhong Univ. of Sci. and Tech.
CO-Chair: Xiangshun Li Wuhan Univ. of Tech.

15:40-16:00 **SunB07-1**

Fault Diagnosis Method Based on Kernel Fuzzy C-means Clustering with Gravitational Search Algorithm

Biyuan Wu Wuhan Univ. of Tech.
Xiangshun Li Wuhan Univ. of Tech.

The main drawback of the traditional fuzzy C-means clustering algorithm (FCM) is the randomness of the initial clustering center, which usually leads to the local optimal solutions and have a great influence on the clustering results. It also has to mention the FCM cannot deal with the non-linear data effectively. In this paper, gravitational search algorithm (GSA) is proposed to solve the randomness of the clustering centers. In addition, kernel fuzzy c-means clustering (KFCM) is introduced, which can improve the clustering result of the fuzzy c-means clustering for non-linear data. Finally, the proposed improved algorithm are verified with the three-tank system, and the results show that the concurrent faults can be diagnosed effectively.

16:00-16:20 **SunB07-2**

Fault Detection in the Closed-loop System Using One-class Support Vector Machine

Zhiang Li Wuhan Univ. of Tech.
Xiangshun Li Wuhan Univ. of Tech.

Feedback controller in closed loop usually makes the system more robust to external disturbances and makes faults difficult to detect. Here, an OCSVM based fault detection method is applied to detect faults in closed loops. By training data from normal samples and establishing OCSVM model, the fault detection of closed loop system is realized. This method not only overcomes the influence of non-Gauss nonlinear process data to closed-loop process, but also considers the dynamic characteristics of the data. Finally the method is verified with the three-tank system.

16:20-16:40 **SunB07-3**

Unsupervised Fault Detection Based on Laplacian Score and TEDA

Chuyue Lou Wuhan Univ. of Tech.
Xiangshun Li Wuhan Univ. of Tech.

The drawback to Typicality and Eccentricity Data Analytics (TEDA), a classic unsupervised learning algorithm, is that TEDA requires strict priori knowledge during the stage of data preprocessing. In view of the disadvantage, a method of unsupervised fault detection called Laplacian Score with TEDA (LS-TEDA) is proposed. Features are selected by LS and unsupervised fault detection is realized by using TEDA in this method. LS-TEDA has been applied with Lublin Sugar Factory and the result shows high accuracy in fault detection.

16:40-17:00 **SunB07-4**

Wavelons-constructed Autoencoder-based Deep Neural Network for Fault Detection in Chemical Processes

Miao Jin Huazhong Univ. of Sci. and Tech.
Weidong Yang Huazhong Univ. of Sci. and Tech.
Yan Wang Zhengzhou Univ. of Light Industry
Hong Zhang Huazhong Univ. of Sci. and Tech.

Considering the co-existence of the measured variables and the control variables in chemical process, a wavelons-constructed autoencoder-based deep neural network (WA-DNN) method is proposed in this paper. Firstly, an autoencoder is constructed with wavelons (neurons with wavelet activation function) to analyze the input signal. Then, the deep learning structure with ELUs is adopted to extract the deep complex features of the

fault to be fed into the softmax classifier, the binary output of which represents whether the fault occurs or not. In our algorithm, the ELUs are able to code the degree of the presence of particular phenomena in the frequency-domain features that wavelons acquire from measured signals. At the same time, neurons are capable of memorizing the numerical value of temporal and spatial information of variables. Experiment results on Tennessee Eastman Process (TEP) show that the proposed method improves the accuracy of fault diagnosis compared with the existing algorithms.

17:00-17:20 **SunB07-5**

Anode Effect prediction based on Expectation Maximization and XGBoost model

Zhixin Zhang Huazhong Univ. of Sci. and Tech.
Gaofeng Xu Huazhong Univ. of Sci. and Tech.
Hongting Wang Huazhong Univ. of Sci. and Tech.
Kaibo Zhou Huazhong Univ. of Sci. and Tech.

Anode Effect Prediction problem has been drawing great research interest of scientists, due to its significant values in reducing energy consumption and improving the efficiency of aluminum electrolysis. However, a large number of missing values contained in the collected data from the aluminum reduction cell are always neglected in the works, resulting in a decline in prediction accuracy and generalization ability. To solve this problem, a combined model of Expectation Maximization and XGBoost (EM-XGBoost) is proposed. Firstly, the original incomplete samples collected from the aluminum cells are recovered by Expectation Maximization (EM) algorithm. Afterwards, the XGBoost model trains on the recovered data, and then predicts the result for new samples. The more comprehensive metrics accuracy and F1 Score are introduced for evaluation. The results in the experiment show that the proposed model improves the accuracy to 99.7% and the F1 Score can achieve 99.8% under the premise of forecasting 30 minutes in advance. The proposed model not only has a high prediction accuracy, but also owns an excellent generalization ability.

17:20-17:40 **SunB07-6**

Generalized Reconstruction-based Contribution for Multiple Faults Diagnosis with Bayesian Decision

Wei Zhou Huazhong Univ. of Sci. and Tech.
Weidong Yang Huazhong Univ. of Sci. and Tech.
Yan Wang Zhengzhou Univ. of Light Industry
Hong Zhang Huazhong Univ. of Sci. and Tech.

In fault diagnosis of industrial process, there are usually more than one variable that are faulty. When multiple faults occur, the generalized reconstruction-based contribution can be helpful while traditional RBC may make mistakes. Due to the correlation between the variables, these faults usually propagate to other normal variables, which is called smearing effect. Thus, it is helpful to consider the pervious fault diagnosis results. In this paper, a data-driven fault diagnosis method which is based on generalized RBC and bayesian decision is presented. This method combines multi-dimensional RBC and bayesian decision. The proposed method improves the diagnosis capability of multiple and minor faults with greater noise. A numerical simulation example is given to show the effectiveness and superiority of the proposed method.

SunB08 Room 8

IS: New trends in data-based modeling, optimization and control 15:40-17:40

Chair: Ronghu Chi Qingdao Univ. of Sci. & Tech.
CO-Chair: Xinli Wang Shandong Univ.

15:40-16:00 **SunB08-1**

A Data-driven Optimal Iterative Learning Control with Data Loss Compensation

Yunkai Lv Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.
Na Lin Qingdao Univ. of Sci. & Tech.

In this work, a control scheme with compensation along the iteration axis is discussed for discrete time nonlinear systems with random data loss. The loss of output data from sensor to controller is considered, and the data missing is described through a variable satisfying the Bernoulli distribution. The lost output value is estimated by using the time-varying parameter and the output value of the last iteration to compensate the influence of data loss on the plant. A numerical simulation example verifies the validity of the algorithm.

16:00-16:20 **SunB08-2**

A K-shell Improved Method for the Importance of Complex Network Nodes

Jianmin Xing Qingdao Univ. of Sci. & Tech.
Jianqiang Chen Qingdao Univ. of Sci. & Tech.
Xiuwen Sun Qingdao Univ. of Sci. & Tech.
Xinli Zhang Qingdao Univ. of Sci. & Tech.
Ruikun Zhang Qingdao Univ. of Sci. & Tech.

In this paper, a weighted k-shell method is proposed to further improve the distinction of node importance by taking advantage of the number of iterations and edge weights when the node is deleted. The weighted k-shell decomposition method is applied to simple networks and complex networks respectively. The simulation results show that the improved method has low computational complexity, high result resolution and high accuracy.

16:20-16:40 **SunB08-3**

A Data-driven Optimal ILC Method Incorporated with Extended State Observer for Nonlinear Discrete-time Repetitive Systems

Yu Hui Qingdao Univ. of Sci. & Tech.
Shuhua Zhang Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.

In this work, a novel data-driven optimal ILC with an extended state observer for a class of nonlinear non-affine discrete-time repetitive system has been proposed. The main feature of the approach is that the controller design depends merely on the I/O data, and an ESO has been introduced for the estimation of disturbance and uncertainty. The final simulation results verify the effectiveness of the proposed method.

16:40-17:00 **SunB08-4**

An Iterative Learning Controller for Superheat Degree of VCC System

Xiaohong Yin Qingdao Univ. of Sci. & Tech.
Xinli Wang Shandong Univ.
Ximei Liu Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.
Mingming Lin Qingdao Univ. of Sci. & Tech.
Fanglin Liu Linyi Univ.

The air-conditioning system has played an indispensable role in daily life, which can provide a comfortable and healthy residential environment for people. The vapor compressor refrigeration cycle (VCC) system, one of the core cycles of HVAC system, produces a cooling effect. In this research, an iterative learning control (ILC) strategy is proposed for the VCC system. In the first place, the least-square method of system identification has been adopted to obtain a data driven model. Moreover, in order to hold superheat degree of VCC system on a safe level, an ILC controller is developed. Finally, a simulation is provided to test the validity of the proposed controller.

17:00-17:20 **SunB08-5**

Autonomous Navigation Based on Multi-sensor CIFIMM-SCKF

Chunping Chen Qingdao Univ. of Sci. & Tech.
Wenlong Yao Qingdao Univ. of Sci. & Tech.
Wei Shao Qingdao Univ. of Sci. & Tech.

A multi-sensor SCKF algorithm based on cubature information filter (CIF) is proposed for the problem of nonlinear state estimation and multi-sensor information fusion of the spacecraft. The multi-model filtering idea is adopted to realize the state filtering by embedding spherical radial volume rules in the extended information filter (EIF) framework, it not only preserves the excellent performance of the cubature Kalman filter algorithm, but also easily extends to multi-model navigation system for the state estimation. The simulation results show that the autonomous navigation method based on cubature information filtering multi-sensor SCKF can effectively avoid the problem of filter divergence due to the linearization error of the model and overcomes the unsteady filtering value of the UKF algorithm. The algorithm has higher accuracy and can be more effectively solve the problem of state estimation in the case of strong multi-sensor nonlinearity.

17:20-17:40 **SunB08-6**

Vector Control of Semi-submerged Ship Dynamic Positioning based on Model-free Adaptive Sliding Mode

Wenlong Yao Qingdao Univ. of Sci. & Tech.
Jiali Wang Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.

The model-free adaptive sliding mode vector control of propulsion motor is proposed for the semi-submerged ship dynamic positioning system for the problem of dynamic positioning propulsion motor control system with uncertain dynamics and load variations during rough sea conditions. The dynamic linear equation of dynamic positioning propulsion motor is derived. The convergence of the model and the sliding mode control method proves that the pseudo-partial derivative can be adjusted online to ensure the uniform and bounded of tracking error for the propulsion motor control system, and the performance of semi-submerged ship dynamic positioning system based on model-free adaptive sliding mode vector control and self-tuning PI vector control are compared. The simulation results show that the improved vector control has the characteristics of faster convergence speed and smaller steady-state error for the dynamic positioning propulsion motor.

SunB09 Room 9
IS: AI and its Applications on Fault Diagnosis

15:40-18:00

Chair: Darong Huang Southwest Jiaotong Univ.
CO-Chair: Na Qin Chongqing Jiaotong Univ.

15:40-16:00 **SunB09-1**

Fault Diagnosis of High-speed Train Bogie Based on Spectrogram and Multi-channel Voting

Liyuan Su Southwest Jiaotong Univ.
Lei Ma Southwest Jiaotong Univ.
Na Qin Southwest Jiaotong Univ.
Deqing Huang Southwest Jiaotong Univ.
Andrew Kemp Univ. of Leeds

Fault diagnosis of high-speed train bogie is of great importance in ensuring the safety of train operation. The multichannel vibration signals measured at different positions on the bogies characterize the dynamics of the vehicle and contain key information describing the performance of the bogie components. However, due to the complexity and uncertainty of the signals, it is hard to extract stable features that represent the characteristics of the signals. Besides, manual selection of reliable channels is indispensable in existing works. This paper presents an ensemble of methods for fault type recognition of high-speed train bogie based on spectrogram images and voting method. First, vibration

signals of bogies are transformed to spectrogram images that are then taken as the input of Random Forests (RFs). In the next, four voting methods including Plurality Voting (PV), Classification Entropy (CE), Winner Takes All (WTA), as well as a novel method we proposed using neural network (NN) is applied for combining all the channels' classification results to give a final decision on fault type. The proposed method not only avoid complicated feature extraction procedures by using a simple transform, but also make the best of multiple channels by automatic combination. Experiments conducted on the dataset based on SIMPACK simulations have verified the efficacy of the presented method in classifying key component(s) failures, with accuracy near 100%. Further, a more complex fault state in which the components of bogies only lose their effectiveness partially, instead of fully, has been tested and analyzed, where near 90% of accuracy is achieved. These results demonstrate the high robustness of the new method.

16:00-16:20 **SunB09-2**

Motor Imagery Signal Classification Using Sparse Representation with Elastic Net Constraint

Xin Deng Chongqing Univ. of Posts and Telecom.
Danni Li Chongqing Univ. of Posts and Telecom.
Jianxun Mi Chongqing Univ. of Posts and Telecom.
Fengxing Gao Chongqing Univ. of Posts and Telecom.
Qiaosong Chen Chongqing Univ. of Posts and Telecom.
Jin Wang Chongqing Univ. of Posts and Telecom.
Rui Liu Chongqing Univ. of Posts and Telecom.

In recent years, the brain-computer interface (BCI) technology based on the motor imagery has provided a new method for people to communicate with the outside world. How to effectively extract features and improve the recognition rate of EEG signals is one of the hot problems in this field. This study is based on the motor imagery ECoG signals, in which the common spatial pattern (CSP) algorithm is used for feature extraction, and then the extracted energy features are classified by the classification algorithms. In order to improve the classification accuracy of the ECoG signals, this study introduces the sparse representation-based classification (SRC) algorithm with the elastic network constraint. Then the accelerated proximal gradient (APG) algorithm and the least angle regression (LARS) algorithm are respectively applied to sparse coding for the ECoG signals. The elastic network which combines the L1 norm and the L2 norm not only avoids the over-fitting problem, but also has a higher prediction ability than the Lasso algorithm. The experimental results demonstrate that the proposed method can achieve better classification performance than other algorithms, such as the sparse representation algorithms with L1 minimization, SVM, KNN, Adaboost, and Naive Bayes.

16:20-16:40 **SunB09-3**

High-speed Train Bogie Faults Diagnosis Using Singular Spectrum Analysis

Yongkui Sun Southwest Jiaotong Univ.
Na Qin Southwest Jiaotong Univ.
Lei Ma Southwest Jiaotong Univ.

Bogies support high-speed train carriage, stabilize trains on both straight and curved track and improve ride quality by absorbing vibration and they play a vital role in the operation of high-speed trains. This paper addresses faults diagnosis of high speed train bogies using singular spectrum analysis. A modified singular difference spectrum criterion is formulated to select a dimension of subspace l, and the useful signal of an original signal is reconstructed by l-dimensional subspace. A detection statistic is sum of squared Euclidean distances between lag vector of test matrix and the l-dimensional subspace of base matrix. Experimental results testify that the proposed approach not only detects the bogie failure, but also identifies the time instant of bogie failure.

16:40-17:00 **SunB09-4**

Fault Diagnosis of Rolling Bearing Based on EMD Combined with HHT Envelope and Wavelet Spectrum Transform

Yabin Ma State Grid Anhui Electric Power Research Inst.
Chen Chen State Grid Anhui Electric Power Research Inst.
Qiqi Shu State Grid Anhui Electric Power Research Inst.
Jian Wang Nari (Beijing) Jiehong Tech. Co.Ltd.
Hongliang Liu Nari (Beijing) Jiehong Tech. Co.Ltd.
Darong Huang Chongqing Jiaotong Univ.

A novel method based on Hilbert Transform (HT) and Empirical Mode Decomposition (EMD) algorithm is proposed in this paper which separates time series into intrinsic mode functions (IMFs) with different time scales and applies the Hilbert transformation for every IMF to obtain the Hilbert spectrum. Firstly, relevant theories of the proposed method are introduced. Then, based on these theoretical introductions, the fault vibration signals of rolling bearing are dealt with accordingly algorithm. The research results demonstrate that the characteristic frequency of bearing fault can be obtained by proposed method, which is more effective compared with existing algorithm.

17:00-17:20 **SunB09-5**

Lane Detection Based on Straight Line Model and K-means Clustering

Jinyu Liu Chongqing Jiaotong Univ.
Lu Lou Chongqing Jiaotong Univ.
Darong Huang Chongqing Jiaotong Univ.
Yu Zheng Chongqing Vocational College of Transportation

Wang Xia Chongqing Jiaotong Univ.

This paper presents an effective and robust algorithm to detect the lanes in highway. It uses Hough Transform to fit the lane line of top view of the road and extracts the most representative lane line in each category after clustering all the lines, which is then followed by a post-processing step. The results show that this algorithm can effectively reduce the disturbance of vehicles and guardrails to achieve 90% correct rate.

17:20-17:40 **SunB09-7**

On Fault Diagnosis of Gear Box Based On De-trending Multifractal

Jing Ding Chongqing Jiaotong Univ.
Ling Zhao Chongqing Jiaotong Univ.
Darong Huang Chongqing Jiaotong Univ.

For the non-stationary and nonlinear complex characteristics of gearbox vibration signals under fault condition, the identification of pitting failure, gear breakage and wear fault of gear box is recognized based on de-trended wave analysis and multifractal method. Multifractal spectrum has a clear physical significance, and it can characterize the kinetic mechanism of the signal, which makes it suitable to be the fault feature parameter of stationary signal, but not suitable for non-stationary signal. De-trended fluctuation analysis can filter out the trend component in the sequence effectively, and determine the long-range correlation characteristics in detecting signal and noise which can be used to deal with non-stationary data. In this paper, the two methods are combined to be the fault diagnosis method of gearbox. First, de-trended fluctuation analysis is used to process the gearbox signal, then the multifractal parameters are extracted that can be treated as the fault features to diagnose the gearbox fault. Finally, the experimental data of the gearbox are compared and analyzed. The experimental results show that the fault diagnosis method of MF -DFA improves the classification precision of the fault diagnosis.