FINAL PROGRAM and

BOOK OF ABSTRACTS

2017 IEEE 6th Data Driven Control and Learning Systems Conference (DDCLS'17)

Chongqing, China

May 26 –27, 2017

Organized by

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

Locally Organized by

Chongqing Jiaotong University

Sponsored by

IEEE Beijing Section

IEEE Industrial Electronics Society

Beijing Jiaotong University

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Welcome Message from General Chairs

ZhongshengHou
General Chair of DDCLS'17

Pingyi Wang
General Chair of DDCLS'17

Dear Friends and Colleagues,

On behalf of the Organizing Committee, it is our greatest pleasure to welcome you to the 2017 IEEE 6th Data Driven Control and Learning Systems Conference (DDCLS'17), which is organized by Technical Committee on Data Driven Control, Learning and Optimization (DDCLO), Chinese Association of Automation, locally organized by Chongqing Jiaotong University, and sponsored by IEEE Beijing Section and IEEE Industrial Electronics Society. The conference is held at China Merchants International Convention Center, Chongqing, China, May 26 –27, 2017.

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). Further, the data driven control and learning systems would be fundamental challenges in the coming age of *Internet of Things, Cyber-Physical Systems*, *Industry 4.0*, *China Manufacturing 2025*, and *Artificial Intelligence 2.0* under the big data environment, which have already emerged on our road ahead but beyond the traditional systems & control methods.

As an inheritance of previous five workshops, DDCLS'17 continues to attract broad interest throughout the world, with acceptance of 191 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 deeply appreciation to Chongqing Jiaotong University for their great support.

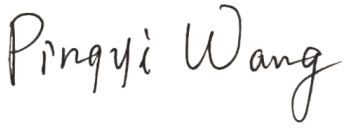
The Technical Program Committee has assembled a comprehensive technical program that covers a broad spectrum of topics in data driven control and learning systems. The DDCLS'17 technical program in May 26, 27 comprises 13 regular sessions and 11 invited sessions. Besides the technical sessions, the highlights of the DDCLS'17 are the plenary/distinguished lectures given by distinguished senior/young scholars from Italy, USA and China. We sincerely appreciate the authors, plenary/distinguished lecture 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 Chongqing and enjoy the colorful scenery and magic foods.

Best wishes

Zhongsheng Hou
General Chair of DDCLS'17



Pingyi Wang
General Chair of DDCLS'17

Message from Technical Program Chairs

Mingxuan Sun
Technical Program Chair

Huijun Gao
Technical Program Chair

Dear Friends and Colleagues,

On behalf of the Technical Program Committee, it is our great honor to welcome you to the 2017 IEEE 6th Data Driven Control and Learning Systems Conference (DDCLS’17) in Chongqing, China.

The annual event of DDCLS has proven to be one of 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’17 has received enthusiastic responses with a total of 191 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 hard works have enabled us to put together a very solid proceeding for our conference. The proceeding includes 141 papers which are divided into 24 oral sessions for presentation.

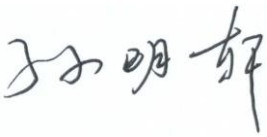
Along with the parallel technical sessions, we shall have three plenary lectures, four distinguished lectures and one panel discussion to be delivered by eminent researchers. These lectures will address the state-of-the-art developments and leading-edge research topics in both theory and applications in Data Driven Control, Learning and Optimization. We are indeed honored to have Prof. Weihua Gui (Central South University), Prof. Marco C. Campi (University of Brescia), Prof. Zhiqiang Gao (Cleveland State University) as the plenary lecturer speakers. Besides, we are very lucky to have Prof. Qinglai Wei (Institute of Automation, Chinese Academy of Sciences), Prof. Zhonghua Pang (North China University of Technology), Prof. Zhuo Wang (Beihang University) and Prof. Dezhi Xu (Jiangnan University) as distinguished lecture speakers. 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’17.

To promote the development of Data Driven Control, Learning and Optimization, we will present the “DDCLS Best Paper Award” at DDCLS’17. Based on reviewers' comments and nominations as well as the evaluations of Technical Program Committee members, 17 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 double-blind manner. Based on their comments and recommendations, five papers were shortlisted as the finalists for the award. During the conference, the oral presentations of the five finalists will be further assessed by the DDCLS’17 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 their expertise reviews, 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. Senping Tian, Prof. Jianxi Yang, Prof. Dong Shen and Prof. Qinglai Wei, Subject Session Chairs Prof. Zhihuan Song, Prof. Dongbin Zhao, Prof. Junmin Li, Prof. Xin Xu, Prof. Jianqiu Cao 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’17 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’17 in Chongqing is really stimulating, rewarding, enjoyable, and memorable.



Mingxuan Sun
Technical Program Chair

Huijun Gao
Technical Program Chair

Plenary Lectures

Plenary Lecture 1

流程工业智能优化制造

Intelligent Optimized Manufacturing in Process Industry

Prof. Weihua Gui
Central South University, China

Friday, May 26, 2017
08:50-09:50
Multi-Function Hall/多功能大厅

Abstract

流程工业主要指原材料工业，包括炼油、石化、化工、冶金、电力等行业，是国民经济中占主导地位的行业，其发展状况直接影响国家的经济基础。流程工业生产的高效化和绿色化已经成为国家重大需求。

流程工业生产具有自身与离散工业不同的显著特点，不能完全照搬离散制造业的智能制造技术，实现其跨越式发展必须解决智能化和全流程整体优化的问题，从而提出流程工业智能优化制造的自主技术模式。而知识自动化是实现原材料工业智能优化制造的核心，是面向人机物三元融合复杂开放系统的新一代网络化信息物理系统（工业认知网络）技术，可以完成以前只有人能完成的复杂分析、精确判断和创新决策等知识型工作。在以上的研究背景基础上，结合有色冶金工业智能制造及节能减排案例进行分析，对我国战略对策、研究现状及关键科学问题和主要研究内容等方面进行了讨论。

Process industry, mainly focusing on the processing and automation technology for raw materials, includes oil refining, petrochemistry, chemistry, metallurgy, electric power etc., which holds a predominant position in national economy since its development influences the economy base of a country directly and deeply. While high-efficiency and green production are momentous demands of the country's development.

Since the process industry has the its own remarkable characteristics different from the discrete industry, the intelligent manufacturing technology in the discrete industry could not be completely copied and applied to the process industry. For the leapfrog development of the process industry, the problem of intelligentization and plant-wide optimization must be addressed, which will definitely lead to the fruitful autonomous technologies for the intelligent optimized manufacturing in the process industry. Knowledge work automation, as the core of intelligent optimized manufacturing in raw material industry, is a new technology for the networked cyber-physical system (industrial cognitive network) facing Human-Cyber-Physical ternary fusion in the complex open systems, and can complete the knowledge-based tasks that are set for human before, such as complex analysis, accurate judgement and innovative decision, etc. Based on the abovementioned research background and combined with case study of energy conservation, emission reduction and intelligent manufacturing in non-ferrous metallurgical industry, the strategic countermeasures, state-of-the-art, key scientific problems and the main research areas in China, will be discussed in this talk.

Biography

Weihua Gui

桂卫华，中南大学教授，中国工程院院士。国家自然科学基金委创新群体学术带头人。

长期致力于有色冶金工业生产过程控制理论、技术和工程应用的研究，创建了以智能集成为核心的复杂有色冶金过程建模、控制与优化的理论与方法；紧密结合“产学研用”，突破了大型锌冶炼电解生产多目标综合优化控制技术、铝合金构件制备重大装备智能控制技术、铜冶炼生产全流程自动化技术以及基于机器视觉的选矿过程监控技术，形成了具有自主知识产权的有色冶金自动化关键技术，成功应用于我国铜、铝、锌等有色金属生产过程，获得显著的应用成效，打破了国外有色冶金自动化技术对我国的垄断，为我国资源独特、矿源复杂、工艺特殊的有色金属生产自动化提供了技术支撑。

获国家科技进步二等奖 3 项，省部级科技奖励 13 项；获“何梁何利基金科学与技术进步奖”、“湖南光召科技奖”、“全国优秀科技工作者”、“全国优秀教师”、“中国有色金属工业优秀科技工作者”和“中国过程控制技术贡献奖”等荣誉称号；

Weihua Gui is professor in Central South University, Academician in Chinese Academy of Engineering, the academic leader of the Innovative Group supported by National Natural Science Foundation of China.

He devoted to research of control theory, technology and engineering applications for manufacturing processes in non-ferrous metallurgical industry for a long term. By taking intelligent integration as the core, he has proposed and established theories and methods of modeling, control and optimization for the complex non-ferrous metallurgical processes. He has made great technological breakthrough in several fields, including multi-objective optimization control in large-scale zinc electrolyte process, intelligent control in the preparation of major equipment with aluminum alloy component, plant-wide automation in copper smelting process and the monitoring and control in beneficiation process based on machine vision. He gave key techniques of the non-ferrous metallurgical automation with proprietary intellectual property, and successfully applied to the production of non-ferrous metals such as copper, aluminum and zinc with remarkable effects. The achievements by him break the foreign monopoly on automation technology in the Chinese non-ferrous metallurgy, and provide technical supports for production automation of non-ferrous metals which are unique, reserved in complexity sources and made by special processed in China.

He has won the prizes of National Science and Technology Progress Award 3 times, the Province and Ministry-level Science and Technology Awards 13 times, and received other awards or honorary titles, such as the Science and Technology Award of the Ho Leung Ho Lee Foundation, Hunan Guangzhao Science and Technology Award, National Excellent Scientific and Technological Workers, National Excellent Teachers, Excellent Scientific and Technological Workers in Chinese Nonferrous Metallurgical Industry, and Contribution Award of National Process Control Technology.

Plenary Lecture 2

Virtual Reference Feedback Tuning (VRFT): a handy approach to tune industrial controllers

Prof. Marco C. Campi
University of Brescia, Italy

Friday, May 26, 2017
10:00-11:00
Multi-Function Hall/多功能大厅

Abstract

In many applications, modeling of the plant for control purposes is a complex and time-consuming task in itself. Data-based approaches offer an alternative where a set of data collected from the plant are used as a means for direct controller selection. Virtual Reference Feedback Tuning (VRFT) is a data-based model-reference tuning technique that can be implemented at low experimental and computational cost, which has shown versatility and good performance in a variety of applications. VRFT comes accompanied by a mathematical theory that sets its quality properties: when the controller class is rich enough to secure perfect model-reference matching, VRFT is shown to deliver the optimal controller, while approximate optimality is obtained for reduced order controller design by pre-filtering techniques. In this talk, we mean to provide a general and easy-to-access overview of the VRFT method.

Biography

Marco C. Campi

Marco Claudio Campi is professor of Automatic Control at the University of Brescia, Italy. He is the chair of the Technical Committee IFAC on Modeling, Identification and Signal Processing (MISP) and has been in various capacities on the Editorial Board of Automatica, Systems and Control Letters and the European Journal of Control. He is a recipient of the "Giorgio Quazza" prize, and, in 2008, received the IEEE CSS George S. Axelby outstanding paper award for the article "The Scenario Approach to Robust Control Design". He has delivered plenary and semi-plenary addresses at major conferences including SYSID, MTNS, and CDC. Currently he is a dinsinguished lecturer of the Control Systems Society. Marco Campi is a Fellow of IEEE, a member of IFAC, and a member of SIDRA.

Plenary Lecture 3

Active Disturbance Rejection Control: Data-Driven and Model Averse

Prof. Zhiqiang Gao
Cleveland State University, USA

Friday, May 26, 2017
11:00-12:00
Multi-Function Hall/多功能大厅

Abstract

Data-Driven Control (DDC) and Active Disturbance Rejection Control (ADRC) are two emerging research fields rooted in the same fundamental belief: thatthe science of automatic control cannot be built on the presumption of a detailed and accuratemathematicalmodel of the physical process. This is a ground rule established in 1954 by H.S. Tsien in his seminal book, Engineering Cybernetics, but largely not followed, unfortunately, in the ensuing developments of the modern control theory.It is shown in this talk that the intricate connection between the fields of DDC and ADRC can be explored in terms of how the critical information is selected and extracted from data. It is a question which has been recognized and contemplated by the previous generations of Chinese scholars such as H.S. Tsien, Z. Guan, and J. Han, who left us with a rich heritage of original ideas and wisdom. In particular, the need for the DDC like “continuous sensing and measuring” suggested by Tsien as the basis for the control action was taken in heart and eventually materializedsome 40 years later by Han in the form of ADRC. The ensuing dualistic paradigm of controller-rejector design, with ADRC as but one embodiment, led to the birth of a new generation of industrial control technologies and their standardization, where the longstanding problems of disturbances and controller tuning are finally resolved.It is no accident that the developments of DDC and ADRC type ideas have been intertwined throughout history, but before the meaningful cross channel dialogue can take place, before we can engage in the debate about the possibility of model-free control for example, basic concepts such as model, state, and disturbance must be reexamined and clarified, as will be attempted in this talk.

Biography

Zhiqiang Gao

Prof. Zhiqiang Gao received his Ph.D. in Electrical Engineering from the University of Notre Dame in 1990 and he has taught at Cleveland State University ever since. Faced with ever widening chasm between control theory and practice, Dr. Gao returned to the roots of controls by collaborating extensively with practicing engineers in solving real world problems, from which the foundation and authenticity of research were rebuilt. Collaborating with Prof. Jingqing Han, Dr. Gao has worked on active disturbance rejection control for nearly 20 years, nurturing it from its early, conceptual stage to a maturing and emerging industrial control technology. In doing so, he made an obscure idea clear and a new general purpose industrial controller possible, often with staggering improvements in performance and energy saving. Asking basic, rudimentary question in research and in teaching, Dr. Gao and his team find creative solutions in practice and vitality in classrooms. Dr. Gao has written extensively on the subject of ADRC and, recently, of Engineering Cybernetics, reintroducing, interpreting and preserving the original ideas of H.S. Tsien and J. Han.

Distinguished Lecturers

Distinguished Lecture 1

Local-Data-Based Self-Learning Optimal Control via Iterative Adaptive Dynamic Programming

Prof. Qinglai Wei
Institute of Automation, Chinese Academy of Sciences, China

Saturday, May 27, 2017
10:00-10:30
Multi-Function Hall/多功能大厅

Abstract

In this talk, it is concerned with a local self-learning algorithm for discrete-time nonlinear systems via iterative adaptive dynamic programming (ADP) algorithm. The present local iterative ADP algorithm permits an arbitrary positive semi-definite function to initialize the algorithm, where in each iteration, the iterative value function and iterative control law can be updated in a subset of the state space instead of the whole state space, which effectively relaxes the computational burden. A new analysis method for the convergence property is developed to prove that the iterative value functions will converge to the optimum under some mild constraints.

Biography

Qinglai Wei

Qinglai Wei is currently a Professor of The State Key Laboratory of Management and Control for Complex Systems, Institute of Automation, Chinese Academy of Sciences, Beijing, China. He has authored one book, and published over 90 international journal papers. His research interests include intelligent control, adaptive dynamic programming, data-based control, neural-network-based control, optimal control, nonlinear systems and their industrial applications. Prof. Wei is an Associate Editor of IEEE Transactions on Systems, Man, and Cybernetics: Systems since 2016, IEEE Transactions on Cognitive and Developmental Systems since 2017, Information Sciences since 2016, Neurocomputing since 2016, Optimal Control Applications and Methods since 2016, Acta Automatica Sinica since 2015, and has been holding the same position for IEEE Transactions on Neural Networks and Learning Systems during 2014--2015. He was Registration Chair of the 12th World Congress on Intelligent Control and Automation (WCICA2016), 2014 IEEE World Congress on Computational Intelligence (WCCI2014), the 2013 International Conference on Brain Inspired Cognitive Systems (BICS 2013), and the Eighth International Symposium on Neural Networks (ISNN 2011). He was the Publication Chair of 5th International Conference on Information Science and Technology (ICIST2015) and the Ninth International Symposium on Neural Networks (ISNN 2012). He was the Finance Chair of the 4th International Conference on Intelligent Control and Information Processing (ICICIP 2013) and the Publicity Chair of the 2012 International Conference on Brain Inspired Cognitive Systems (BICS 2012). He was guest editors for several international journals. He was a recipient of Shuang-Chuang Talents in Jiangsu Province, China, in 2014, Asia Pacific Neural Networks Society (APNNS) young researcher awards in 2016. He was a recipient of the Outstanding Paper Award of Acta Automatica Sinica in 2011 and Zhang Siying Outstanding Paper Award of Chinese Control and Decision Conference (CCDC) in 2015.

Distinguished Lecture 2

Data-Driven Control of Networked Nonlinear Systems with Communication Constraints

Prof. Zhonghua Pang
North China University of Technology, China

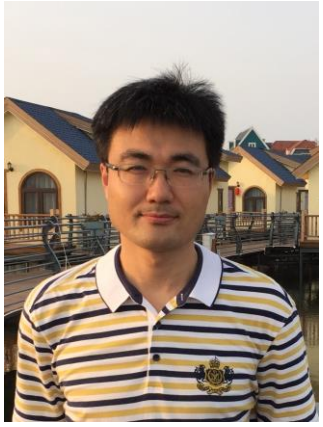
Saturday, May 27, 2017
10:30-11:00
Multi-Function Hall/多功能大厅

Abstract

In recent years, the application of communication networks in the modern industry automation is becoming more and more ubiquitous, due to their distinct advantages such as long-distance data exchange, low installation and maintenance cost, high flexibility and reliability, as well as increasing mobility. However, most of the available results on networked control systems (NCSs) are focused on linear systems. Furthermore, their effectiveness is critically dependent on the accuracy of the system model. Thus the above two facts severely hinder their further applications in practical engineering.

In practice, control of networked systems is a very complex and challenging task. This is not only because there exist communication constraints such as random network-induced delay, packet disorder and packet dropout in NCSs, but also system complexities such as nonlinearity, uncertainty and time-varying dynamics commonly exist in modern industrial processes. Fortunately, it becomes very easy to obtain large amounts of input and output data of controlled plants nowadays. Thus, a data-driven control approach is a natural choice when precise plant models are unavailable. In this talk, two data-driven networked control schemes will be introduced including their design methods and experimental examples. In addition, several networked control implementation techniques and a networked control system laboratory will also be reported.

Biography



Zhonghua Pang

Zhonghua Pang received the B.Eng. degree in automation and the M.Eng. degree in control theory and control engineering from Qingdao University of Science and Technology, China, in 2002 and 2005, respectively, and the Ph.D. degree in control theory and control engineering from the Institute of Automation, Chinese Academy of Sciences, China, in 2011. He was a Postdoctoral Fellow with the Department of Automation, Tsinghua University, China, from 2011 to 2014. Currently he is an Associate Professor with the School of Electrical and Control Engineering, North China University of Technology, China, and a visiting research fellow in University of South Wales, UK. His research interests include networked control systems, security of cyber-physical systems, and advanced control of industrial systems.

Distinguished Lecture 3

Data-Based Characteristics Analysis of Linear Discrete Time-Delay Systems

Prof. Zhuo Wang
Beihang University, China

Saturday, May 27, 2017
11:00-11:30
Multi-Function Hall/多功能大厅

Abstract

In this talk, I will introduce a series of data-based methods to analyze the characteristics of linear discrete time-delay systems which have unknown parameter matrices. These characteristics include the state stability, bounded-input bounded-state (BIBS) stability, bounded-input bounded-output (BIBO) stability, state controllability, state observability and output controllability. These data-based methods first transform the system dynamic model into an augmented state space model, and then use the measured historical and current data to construct the system matrix, state controllability matrix, state observability matrix and output controllability matrix of this augmented model, in order to analyze the corresponding characteristics. The advantages of our methods are three folds. First, they can directly verify the system properties according to measured data without the need to know system parameters. Second, their calculation precision is higher than traditional approaches, which need to identify the unknown parameter matrices. Third, our methods have lower computational complexities when constructing the controllability and observability matrices.

Biography

Zhuo Wang

Zhuo Wang received the B.E. degree in automation from Beihang University, Beijing, China, in 2006; and the Ph.D. degree in electrical and computer engineering from University of Illinois at Chicago, Chicago, Illinois, USA, in 2013.

Zhuo Wang was a Postdoctoral Fellow with the Department of Electrical and Computer Engineering, University of Alberta, from 2013 to 2014. He worked as a Research Assistant Professor with the Fok Ying Tung Graduate School, Hong Kong University of Science and Technology, from 2014 to 2015. He was selected for the ``Thousand Talents Program for Distinguished Young Scholars'' by the Organization Department of the CPC Central Committee.

Zhuo Wang is currently a Professor and a Ph.D. Instructor with the School of Instrumentation Science and Optoelectronics Engineering, Beihang University. Prof. Wang is a Member of the Adaptive Dynamic Programming and Reinforcement Learning Technical Committee of IEEE Computational Intelligence Society, a Member of the Data Driven Control, Learning & Optimization Professional Committee of CAA, and is a Member of the Fault Diagnosis & Safety for Technical Processes Professional Committee of CAA. He is an Associate Editor of IEEE Transactions on Systems, Man, and Cybernetics: Systems, an Associate Editor of Control Theory & Applications, and is an Associate Editor of Pattern Recognition and Artificial Intelligence.

Distinguished Lecture 4

Improvement and Application of Model-Free Adaptive Control

Prof. Dezhi Xu
Jiangnan University, China

Saturday, May 27, 2017
11:30-12:00
Multi-Function Hall/多功能大厅

Abstract

Model-free adaptive control has received wide attention due to its low-complexity and convenience for engineering application. This report includes two parts: 1）the technique of dynamic linearization is used to improve the general model-free adaptive control, and the proposed method is applied to the process control system and micro grid system. 2）Considering the amplitude and rate saturations for actuators which widely exist in a lot of actual systems, we design the dynamic anti-windup module to eliminate the negative impact of saturation, simulation results and applications all demonstrate the effectiveness of the proposed approach.

Biography

Dezhi Xu

Dezhi Xu is an IEEE member and a member of the Technical Committee on Energy Internet of Chinese Association of Automation. He joined Jiangnan University as an associate professor and master tutor. He has published more than 40 academic papers in domestic and international journals or conferences, including 37 academic papers indexed by SCI or EI. He has 3 authorizations for patent of invention. He took charge of 5 research projects, such as youth project supported by National Natural Science Foundation of China, and he mainly took part in 4 major projects of National Natural Science Foundation of China. Now he is the reviewer for many international journals, such as several IEEE transactions and IET. His research results as important components received the 1st class award of science & technology progress for China General Chamber of Commerce in 2016. His research interests are on data-driven control, fault diagnosis and fault-tolerant control, technologies of new energy and power grid.

Program at a Glance

Friday, May 26, 2017, Chongqing China Merchants International Convention Center						
8:30-8:50	Opening ceremony, Venue: Multi-Function Hall, Chair: Prof. Xiongxiong He					
8:50-9:50	Plenary Lecture 1: Intelligent Optimized Manufacturing in Process Industry, *Prof. Weihua Gui*, Venue: Multi-Function Hall, Chair: Prof. Zhongsheng Hou					
9:50-10:00	Tea Break					
10:00-11:00	Plenary Lecture 2: Virtual Reference Feedback Tuning (VRFT): a handy approach to tune industrial controllers, *Prof. Marco C. Campi*, Venue: Multi-Function Hall, Chair: Prof. Chiang-Ju Chien					
11:00-12:00	Plenary Lecture 3: Active Disturbance Rejection Control: Data-Driven and Model Averse, *Prof. Zhiqiang Gao*, Venue: Multi-Function Hall, Chair: Prof. Prof. Huaguang Zhang					
12:00-14:00	Lunch					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
13:40-15:40	FrA01	FrA02	FrA03	FrA04	FrA05	FrA06
	Data driven control (I)	Data-driven modeling, optimization, scheduling, decision, and simulation (I)	Statistical learning, machine learning, data mining and practical applications	IS: Complex process control based on data-driven learning systems	IS: Data-driven fault diagnosis and process monitoring for complicated industrial systems (I)	IS: Adaptive Iterative Learning Control for Dynamical Systems
15:40-15:50	Tea Break					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
15:50-18:10	FrB01	FrB02	FrB03	FrB04	FrB05	FrB06
	Best Paper Award Finalist	Model-free adaptive control	ADRC technology and applications	Data-driven fault diagnosis, health maintenance and performance evaluation	Big data techniques and applications	IS: Networked traffic optimization and control
18:10-20:00	Dinner					
Saturday, May 27, 2017, Chongqing China Merchants International Convention Center						
8:30-9:50	Panel Discussion: Data Driven Control and Learning Systems, *Prof. Chenghong Wang*, *Prof. Huangguang Zhang*, Prof. *Zhiqiang Gao*, *Prof. Zhongsheng Hou*, Venue: Multi-Function Hall, Chair: Prof. Danwei Wang					
9:50-10:00	Tea Break					
10:00-10:30	Distinguished Lecture 1: Local-Data-Based Self-Learning Optimal Control via Iterative Adaptive Dynamic Programming, *Prof. Qinglai Wei*, Venue: Multi-Function Hall, Chair: Prof. Mingxuan Sun					
10:30-11:00	Distinguished Lecture 2: Data-Driven Control of Networked Nonlinear Systems with Communication Constraints, *Prof. Zhonghua Pang*, Venue: Multi-Function Hall, Chair: Prof. Zhihuan Song					
11:00-11:30	Distinguished Lecture 3: Data-Based Characteristics Analysis of Linear Discrete Time-Delay Systems, *Prof. Zhuo Wang*, Venue: Multi-Function Hall, Chair: Prof. Dongbin Zhao					
11:30-12:00	Distinguished Lecture 4: Improvement and Application of Model-Free Adaptive Control, *Prof. Dezhi Xu*, Venue: Multi-Function Hall, Chair: Prof. Zengqiang Chen					
12:00-14:00	Lunch					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
13:40-16:00	SaA01	SaA02	SaA03	SaA04	SaA05	SaA06
	Iterative learning control (I)	Iterative learning control (II)	IS: Advances in iterative learning control theory and its applications	IS: Security maintenance and fault-tolerant control for complex systems	IS: Optimization and control for complex system	IS: Modeling, solving, optimization and control for nonlinear systems and multi-agents systems
16:00-16:10	Tea Break					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
16:10-18:10	SaB01	SaB02	SaB03	SaB04	SaB05	SaB06
	Data driven control (II)	Data-driven modeling, optimization, scheduling, decision, and simulation (II)	Reinforcement learning	IS: Data-driven fault diagnosis and process monitoring for complicated industrial systems (II)	IS: Data-based learning and network control	IS: Data-based modeling, control, and intelligent monitoring in complex processes
18:15-20:00	Closing Ceremony and Banquet, Chair: Prof. Xiongxiong He					

2017 IEEE 6th Data Driven Control and Learning Systems Conference (DDCLS'17)

Technical Programmes
and
Book of Abstracts

Friday, 26 May, 2017

FrA01 **Room 1**
Data-driven control (I) **13:40-15:40**

Chair: Aihua Zhang Bohai Univ.
CO-Chair: Na Dong Tianjin Univ.

13:40-14:00 **FrA01-1**

A Novel Hybrid Method for Analog Circuit Fault Classification

Aihua Zhang Bohai Univ.
Kailun Huang Bohai Univ.
Rui Wang Bohai Univ.
Zhiqiang Zhang Bohai Univ.

Due to the growth prospect of analog circuit fault diagnosis, this paper tends to introduce a novel arithmetic model based on least squares support vector machine (LSSVM) and the semi-supervised learning (SSL) scheme which is adept at cost-saving. In the proposed method, there are two steps. Firstly, the fact that large deviation may emerge as a result of the empirical risk inspires the idea of an improved transductive least square support vector machine (T-LSSVM) which aims at obtaining the best hyperplane that equipped with the maximum margin to the support vectors no matter whether the samples are labeled or unlabeled. Secondly, to overcome the drawback of typical T-LSSVM, i.e., sensitivity to local minima, a laplcian-transductive least squares support vector machine (Lap-T-LSSVM) is proposed which can perform the fault diagnosis via a laplcian. The experiment adopts band-pass filter circuit as diagnosis object and the simulation part of this paper statistically verifies that the proposed method is superior to previous SVM in accuracy.

14:00-14:20 **FrA01-2**

Study on Multiclass Text Classification Algorithm Based on 1-a-r and Multiconlitron

Yuping Qin Bohai Univ.
Fengfeng Qiu Bohai Univ.
Qiangkui Leng Bohai Univ.
Aihua Zhang Bohai Univ.

Aim to multiclass text categorization problem, a classification algorithm based on multiconlitron and 1-a-r method is proposed in this paper. 1-a-r method is used to convert a multiclass categorization problem to several binary problems. Multiconlitron is constructed for each binary problem in input space. For the sample to be classified, the multiconlitrons are used to decide its class. The classification experiments are done on Reuters 21578, and the experimental results show, compare with 1-a-r SVMs, the proposed algorithm has better classification performance.

14:20-14:40 **FrA01-3**

Modified Function Projective Synchronization of Fractional-order Hyperchaotic Systems Based on Active Sliding Mode Control

Yuan Gao Guangxi Univ. of Science and Tech.
Hangfang Hu Guangxi Univ. of Science and Tech.
Ling Yu Guangxi Univ. of Science and Tech.
Haiying Yuan Guangxi Univ. of Science and Tech.
Xisheng Dai Guangxi Univ. of Science and Tech.

Considering the time-varying scaling function matrix and system disturbances, a new sliding mode control strategy is put forward to realize modified function projective synchronization (MFPS) of two different fractional-order hyperchaotic systems, meanwhile improve the control robustness of synchronization system. From the MFPS error equations, combining a proper fractional-order exponential reaching raw, an active controller for MFPS is derived out via sliding mode control technology. By mean of the stability theorem, the asymptotic stability of synchronization error system is proved. The simulation results of the MFPS between fractional-order hyperchaotic Lorenz system and Chen system demonstrate the validity of the presented method.

14:40-15:00 **FrA01-4**

A Data-Driven Controllability Measure for Linear Discrete-Time Systems

Haisha Niu Northeastern Univ.
Haoyuan Gao Northeastern Univ.
Zhanshan Wang Northeastern Univ.

A data-based approach is developed to analyze the controllability of linear discrete-time systems in this paper, in which the parameter matrices are unknown. The proposed method only applies the measured state and output data to verify the system property, instead of the process data of the system mathematical model. The direct analysis method can be used and the unknown parameter matrices are not necessary to gain. The data-based methods can avoid identification errors and have lower computational complexity than the traditional model-based analysis methods. Controllability measurement set forth above not only shows if the system is controllable or not, but also reveals the level of controllability of the system.

15:00-15:20 **FrA01-5**

Energy Saving Method of Refrigeration System Based on Model-Free Control Algorithm

Xueshuo Han Tianjin Univ.
Na Dong Tianjin Univ.
Jianfang Chang Tianjin Univ.

This article designs a dual-loop energy-saving control scheme for the refrigeration system. In order to cope with the actual refrigeration system with characteristics of large time-delay well, the model-free adaptive control method with input rate constraint of time delay is designed to reduce the impact of large time delay on the whole control process. Simulation study of typical system with large time delay is carried out and the energy saving control scheme designed by the presented novel model-free control algorithm is simulated. The simulation curves show that the newly

proposed control algorithm has better dynamic characteristics and faster response speed, and thus, the effectiveness of this novel control method is fully revealed.

FrA02 Room 2
Data-driven modeling, optimization, scheduling, decision, and simulation (I) 13:40-15:40

Chair: Jun Zhao Dalian Univ. of Tech.
CO-Chair: Huijin Fan Huazhong Univ. of Science and Tech.

13:40-14:00 **FrA02-1**

A Bootstrap Based Virtual Sample Generation Method for Improving the Accuracy of Modeling Complex Chemical Processes Using Small Datasets

Qunxiong Zhu Beijing Univ. of Chemical Tech.
Hongfei Gong Beijing Univ. of Chemical Tech.
Yuan Xu Beijing Univ. of Chemical Tech.
Yan-Lin He Beijing Univ. of Chemical Tech.

Though in the era of big data, it remains a challenge to be tackled that the forecasting model with high accuracy and robustness needs to be built using small size samples. One effective tool of addressing this problem is the virtual sample generation (VSG), which can generate a mass of new virtual samples on the basis of small sample sets. The bootstrap method is adopted to feasibly resample the virtual samples in this paper. The effectiveness of the proposed bootstrap virtual sample generation (BVSG) is evaluated over one real case. The experimental results show the proposed approach achieves greater performance with the aid of virtual samples.

14:00-14:20 **FrA02-2**

An Adaptive Gradient Greedy Algorithm for Compressed Sensing

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

Greedy algorithm is powerful and practical and has been used frequently in compressed sensing because it leads to relatively small calculation and easy to be realized. GraDeS (Gradient Descent with Sparsification) is one of the greedy algorithms, reconstructs signal by gradient iteration with hard threshold, however the sparsity of original signal is necessary in GraDes which means it is only applicable to signals with known sparsity, which is normally unreal in practice. This paper proposes an adaptive gradient greedy algorithm (AGraDeS) in which sparsity of signal is no more required. Experimental results show that the algorithm reconstructs signal faster and precisely in most cases compared to some traditional algorithms, especially when the signal is big and with bad sparsity, this algorithm still can obtain a better result.

14:20-14:40 **FrA02-3**

A Graphical Method of Internal Model Control Stability Analysis for MIMO Systems

Yaxu Niu Beijing Univ. of Chemical Tech.
Beiyan Jiang Beijing Univ. of Chemical Tech.
Qibing Jin Beijing Univ. of Chemical Tech.

In this paper, we address a graphical method for a two-input two-output (TITO) system to compute all feasible stable region. It is the first time that the stability region of the internal model controller parameters is given in the parameter space for multivariable system. The internal model controller can be designed by effective open-loop transfer function (EOTF). After that, the parameter space is divided into stable and unstable regions. Finally, the example is presented to demonstrate the validity of the proposed method.

14:40-15:00 **FrA02-4**

Energy Analysis and Management Method of Complex Chemical Processes Based on Index Decomposition Analysis

Zhiqiang Geng Beijing Univ. of Chemical Tech.
Huachao Gao Beijing Univ. of Chemical Tech.
Qunxiong Zhu Beijing Univ. of Chemical Tech.
Yongming Han Beijing Univ. of Chemical Tech.

Energy and management of complex chemical processes play a crucial role in the sustainable development procedure. In order to analyze the effect of the technology, management level, and production structure having on energy efficiency, we put forward an energy analysis and management method based on index decomposition analysis (IDA). The proposed method can reflect the impact of energy usage by integrating the level of energy activity, energy hierarchy and energy intensity effectively. Meanwhile, energy efficiency improvement, energy consumption reduction and energy-savings can be visually discovered by the proposed method. Finally, the proposed method is applied for energy management and conservation practices of the ethylene production process. The demonstration analysis of ethylene production has verified the practicality of the proposed method. Moreover, we can propose corresponding improvement for the ethylene production.

15:00-15:20 **FrA02-5**

Space Direction Neighborhood Preserving Embedding-Based Monitoring and Scheduling Guidance for Blast Furnace Gas System

Hongqi Zhang Dalian Univ. of Tech.
Linqing Wang Dalian Univ. of Tech.
Jun Zhao Dalian Univ. of Tech.
Wei Wang Dalian Univ. of Tech.

Blast furnace gas (BFG) system of steel enterprise generally accompanies with multi-dimension and nonlinear features. It's a hard assignment for energy

scheduling operators to make real-time scheduling decision when monitoring such system. In this study, a novel dimensionality reduction method named Space Direction Neighborhood Preserving Embedding (SDNPE) is proposed for the BFG system monitoring and scheduling units determination. To maintain the system dynamic characteristic in the low dimension space, such method constructs a neighborhood graph that searches for nearest neighbors with respect to both the neighbors in spatial scales and fluctuation tendency of the gas flow data. Then, for the BFG system monitoring and scheduling units determination, Hotelling's T2 chart and score chart are constructed upon the SDNPE model. Experiments with real-time data of an iron enterprise in China demonstrated the effectiveness of the proposed method.

FrA03 Room 3
Statistical learning, machine learning, data mining and practical applications 13:40-15:40

Chair: Xiaoli Li Beijing Univ. of Tech.
CO-Chair: Jinhai Liu Northeastern Univ.

13:40-14:00 **FrA03-1**

A Forecasting Method of Air Conditioning Energy Consumption Based on Extreme Learning Machine Algorithm

Xu Yang Univ. of Science and Tech. Beijing
Jingjing Gao Univ. of Science and Tech. Beijing
Lei Zhang Univ. of Science and Tech. Beijing
Xiaoli Li Beijing Univ. of Tech.
Liu Gu Univ. of Science and Tech. Beijing
Jiarui Cui Univ. of Science and Tech. Beijing
Chaonan Tong Univ. of Science and Tech. Beijing

This paper deals with the issue on air conditioning energy consumption and system monitoring of different data in building. Various environmental parameters are changed real-timely inside the building, and the conventional air conditioning energy consumption forecasting with the load simulation software cannot adapt to those variations. Therefore, the air conditioning energy consumption forecasting model is established based on Extreme Learning Machine Algorithm, within the interior environmental parameters of the building, those parameters are obtained through the building monitoring system which consist of environmental parameter, number of people, region area and energy consumption. The performance and effectiveness of the proposed forecasting model of air conditioning energy consumption is demonstrated through a case study of a building from practical engineering.

14:00-14:20 **FrA03-2**

An Adaptive Multi-Kernel RBF Model Using State Matching

Pinlong Cai Quanzhou Institute of Equipment Manufacturing
Hao Chen Quanzhou Institute of Equipment Manufacturing
Jingxin Zhang Quanzhou Institute of Equipment Manufacturing

Radial basis function neural network has a strong capability of non-linear mapping for system identification. Especially, using the orthogonal least square method can generate a parsimonious structure to avoid "overfitting" problem effectively. Nonetheless, it is difficult to deal with dynamic systems by static models, which exist mainly in manufacture and life. Aimed at the non-stationary time series presented by dynamic system, it is necessary to study on-line model with alterable or composite structure. This paper proposes a multi-kernel RBF neural network with some novel methods. The kernels are trained by transformations of sample set instead of just by the sample set like regular algorithms. And the on-line weight distribution of all kernels relies on state matching method to trace the changes in the system. Finally, in some numerical experiments, we validate the better performance of proposed model by comparing it to the other models.

14:20-14:40 **FrA03-3**

The Design of Attitude Heading Reference System Based on MEMS Sensing Technology

Pengge Huang Henan Univ.
Haojie Lv Henan Univ.

In view of the high cost and large volume of the traditional attitude heading reference system applied in the fields of spacecraft, robot and vehicle, a new method based on low cost MEMS sensor for AHRS is proposed. In this algorithm, the quaternion and three gyro drift are chosen as state vector to establish the state equation. At the same time, the components of acceleration of gravity and magnetic field intensity in the body fixed reference frame as the observation vector to establish the observation equation. In this algorithm, the earth's magnetic field is compensated by a special method. In order to evaluate the proposed quaternion-based extended Kalman filter algorithm, a micro quadrotor is developed. The results show that the proposed method can obtain accurate attitude information and can suppress the white noise.

14:40-15:00 **FrA03-4**

A SISO Neuro-Fuzzy Wiener Model Identification by Correlation Analysis Method

Qi Xiong Shanghai Univ.
Li Jia Shanghai Univ.
Yong Chen Petrochina Changqing Oilfield Company Oil Production Plant No.9

A novel identification algorithm is presented in this paper for neuro-fuzzy based single-input-single-output (SISO) Wiener model with colored noises. The independent identical distribution (iid) Gaussian random signals are adopted to identify the Wiener system,

leading to the separation of linear part from nonlinear counterpart in the identification problem. Therefore, the correlation analysis method can be employed for identification of linear part. Moreover, the least square method based parameter identification algorithms which can avoid the impact of colored noise is proposed to identify static nonlinear part. Lastly, an example is used to verify the effectiveness of the proposed method.

15:00-15:20 **FrA03-5**

A Novel Adaboost Based Algorithm for Processing Defect Big Data

Yinlei Wen Northeastern Univ.
Huaguang Zhang Northeastern Univ.
Jinhai Liu Northeastern Univ.
Fangming Li Northeastern Univ.

In the practice applications of defect detecting, large amounts of data need to be analyzed. In this paper, a new analysis method is developed based on adaboost algorithm. By using neural networks with a fixed structure, a series of models are built which may be not accurate. Error rates of the models are computed to gain and adjust the weights of every model. A higher accurate model is built by the models and weights. Compared with traditional neural network method, this adaboost based method does not need to adjust the node numbers of neural networks. In addition, it remains accuracy and reduces complexity. Finally, an example is given to demonstrate the effectiveness and advantages of the methods.

FrA04 Room 4

IS: Complex process control based on data-driven learning systems **13:40-15:40**

Chair: Dazi Li Beijing Univ. of Chemical Tech.
CO-Chair: Dong Shen Beijing Univ. of Chemical Tech.

13:40-14:00 **FrA04-1**

Sampled-data Iterative Learning Control for Nonlinear Systems with Iteration Varying Lengths

Lan-Jing Wang Beijing Univ. of Chemical Tech.
Dong Shen Beijing Univ. of Chemical Tech.
Xuefang Li South Kensington Campus
Chiang-Ju Chien Huafan Univ.
Ying-Chung Wang Huafan Univ.

This note addresses the problem of sampled-data iterative learning control (SDILC) for continuous-time nonlinear systems with randomly iteration varying lengths. To deal with the iteration varying trial lengths, a P-type ILC scheme with a modified tracking error is proposed. Sufficient conditions are derived to ensure the convergence of the nonlinear system at each sampling instant. An illustrative example is carried out to verify the effectiveness of the proposed ILC algorithm.

14:00-14:20 **FrA04-2**

A Hybrid Fault Diagnosis Method based on Fuzzy Signed Directed Graph and Neighborhood Rough Set

Xin Ma Beijing Univ. of Chemical Tech.
Dazi Li Beijing Univ. of Chemical Tech.

This study presents a data-driven method for fault detection and diagnosis. Aiming at the problem of low diagnosis accuracy and not easy to obtain faulty data, the neighborhood rough set and signed directed graph are combined together to improve the diagnosis efficiency without prior knowledge. The node status in signed directed graph is described as a continuous fuzzy membership degree. The diagnosis rules are reducted from the neighborhood rough set decision table, which is established from the fuzzy signed directed graph model. The diagnosis rules base could be updated under the help of fuzzy compatible pathway deduced from signed directed graph. The efficiency of the hybrid method is demonstrated through a case study on the Tennessee Eastman benchmark problem. The fault is detected when a change occurs in the signals from the sensors and is classified into one of the fault classes. Case study shows that the method can effectively simplify the needed fault variables and improve the diagnosis efficiency.

14:20-14:40 **FrA04-3**

Model-free Output Feedback Control of Molecular Weight Distribution

Haiyan Wu Beijing Univ. of Chemical Tech.
Yu Chen Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.

The feedback control of molecular weight distribution (MWD) of polymerization is considered in this paper. Based on the neural network modeling, the control of MWD can be realized by the output feedback control (OFC) with 2-3 moments as the control object. But the control system, designed from the neural network model, has a low reliability and accuracy owing to the modeling errors and unmodeled dynamics. A practical modularized control schemes are proposed by adding the model-free control (MFC) into the existing OFC schemes for enjoying the extra performance improvement from MFC. The new control method is tested on styrene polymerization reacted in CSTR, and simulation results proved the effectiveness of the method. Furthermore, the proposed control method has an enhanced reliability and precision compared with OFC method.

14:40-15:00 **FrA04-4**

A Constrained Multi-Objective Particle Swarm Optimization Approach for the Polystyrene Grade Transition

Qing Guo Beijing Univ. of Chemical Tech.
Qilei Wu Beijing Univ. of Chemical Tech.
Juan Chen Beijing Univ. of Chemical Tech.

The grade transition operation of the polymerization process needs to simultaneously satisfy the requirements of safe operation, short transition time, low operating cost, and so on, and therefore it is a multi-objective optimization problem (MOP) with constraints. Usually, a linear weighted sum method is used to transform a multi-objective optimization problem into a single objective problem. In this work, based on the study of the grade transition operation of a continuous styrene polymerization process, we constructed two objective functions focusing on the product quality and the raw material consumption respectively. The constrained multi-objective particle swarm optimization (CMOPSO) approach using control vector parameterization is proposed to solve this multi-objective optimization problem. The process can meet the target quality specification at the end of grade transition operation by adding endpoint constraints on the quality index of the polystyrene. The simulation results confirm that the optimization method can reduce fluctuations of variables, shorten the transition time, reduce the raw materials consumption, and provide multiple grade transition strategies.

15:00-15:20 **FrA04-5**

Sliding Mode Control Based on LTR Observer for pH Neutralization Process

Chen Juan Beijing Univ. of Chemical Tech.
Dingtao Chao Beijing Univ. of Chemical Tech.
Qing Guo Beijing Univ. of Chemical Tech.

A sliding mode control (SMC) method based on loop transfer recovery (LTR) observer is proposed for the equivalent first-order model of pH neutralization process in this paper. The non-singular linear transformations is also used to make delay-free transform for the time-delay process. At the same time, two observers are designed by using LTR method: one is used to observe the system states and the other is used to estimate the variable of the sliding mode surface switch function which is difficult to obtain. And then, integrator is used to weaken the chattering. The pH process is controlled by sliding mode controller eventually. The simulation results show that the proposed method can solve the problems of nonlinear controlled object, time-delay, and parameter uncertainty exists in the pH process effectively and the system have a strong robustness.

FrA05 **Room 5**
IS: Data-driven fault diagnosis and process monitoring for complicated industrial systems (I) **13:40-15:40**

Chair: Jing Wang Beijing Univ. of Chemical Tech.
CO-Chair: Jian Feng Northeastern Univ.

13:40-14:00 **FrA05-1**

An Improved Kernel Exponential Discriminant Analysis for Fault Identification of Batch Process

Ruixuan Wang Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.
Jinglin Zhou Beijing Univ. of Chemical Tech.
Haiyan Wu Beijing Univ. of Chemical Tech.

An improved batch process fault identification approach about kernel exponential discriminant analysis (KEDA) is proposed, in which a kind of performance index based on difference degree are given to identify fault classification. This method combines the advantage of the kernel technology and the exponential discriminant analysis technique. The proposed KEDA method shows powerful ability in dealing with nonlinear, small sample size data and has a noticeable improvement in classification performance. During the real application to fault identification, the normal data model and fault data models for known faults are established according to the historical data first. Then online measurement data are fed into these models to identify the current operation status, i.e., is the system in normal or fault condition, what type of fault occurs, or does new fault appear? Finally, the proposed method is applied to a typical penicillin fermentation process and the simulation results show the effectiveness of the proposed KEDA algorithm and good performance in fault classification.

14:00-14:20 **FrA05-2**

Hidden Semi-Markov Model Based Monitoring Algorithm for Multimode Processes

Zhijiang Lou Beijing Univ. of Chemical Tech.
Youqing Wang Shandong Univ. of Science and Tech.

Several studies have adopted hidden Markov model (HMM) to monitor multimode processes. The drawback of HMM is that its inherent duration probability density is exponential and hence it is inappropriate for the modeling of multimode processes. To address this problem, hidden semi-Markov model (HSMM), which introduces the mode duration probability into HMM, is combined with principal component analysis (PCA) in this paper, named as HSMM-PCA. With the restriction of mode duration probability, HSMM-PCA can successfully identify the operation mode affiliation and build the precise PCA model for each mode. As a result, HSMM-PCA is more sensitive to abnormal conditions and has better fault detection ability for multimode processes.

14:20-14:40 **FrA05-3**

Convolution Neural Network for Classification of Magnetic Flux Leakage Response Segments

Fangming Li Northeastern Univ.
Jian Feng Northeastern Univ.
Senxiang Lu Northeastern Univ.
Jinhai Liu Northeastern Univ.
Yu Yao Northeastern Univ.

Magnetic flux leakage (MFL) inspection is one of the most commonly used nondestructive testing (NDE) technologies. This paper proposes a novel method for classifying the MFL response segments based on

convolution neural network (CNN). In order to skip the procedure of saving the normalized MFL segment and save some computing time, a normalization layer is added to the proposed model. Moreover, the rectified linear units (ReLUs) is employed as the activation functions in the convolution layers to allow the proposed model to easily obtain sparse representations. The performance of the proposed model is tested by the real MFL data collected from the experimental pipelines. The results demonstrate that the presented method can achieve a satisfactory accuracy of MFL response segment classification and can be applied to practical application.

14:40-15:00 **FrA05-4**

Emergency Fault Diagnosis for Wind Turbine Nacelle

Yu Pang Beijing Jiaotong Univ.
Limin Jia Beijing Jiaotong Univ.
Zhan Liu Beijing Jiaotong Univ.
Qianyun Gao Beijing Nego Automation Tech.

Many sets of wind turbines of the wind farm in Shan Xi province run above the rated wind speed, especially in the condition of wind speed 17m/s or above, wind turbine nacelle occurs vibration in the vertical direction of transmission chain which is characterized emergency, intermittent, accidental, and distinctive. Moreover, vibration cycle is not obvious and vibration strength is large. Severe vibration does harm to wind turbine that then will be able to lead wind turbine halt. According to this phenomenon, a method of emergency fault diagnosis for wind turbine nacelle based on empirical mode decomposition (EMD) is presented in this paper to discriminate a variety of factors carefully that have led to excessive vibration. In particular, the results are shown in this paper that strong tower shadow effect will be likely to cause excessive vibration of wind turbine nacelle, and then giving rise to shut down. In the meantime, curve theory analysis of the blade's aerodynamic characteristics is deduced in this paper. It demonstrates that the proposed method EMD works well in the face of fault diagnosis for wind turbine nacelle and better overall performance.

15:00-15:20 **FrA05-5**

Quality-Relevant Fault Monitoring Based on Locally Linear Embedding Enhanced Partial Least Squares Statistical Models

Jinglin Zhou Beijing Univ. of Chemical Tech.
Wei Gao Beijing Univ. of Chemical Tech.
Shunli Zhang Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.
Haijiang Zhu Beijing Univ. of Chemical Tech.

In recent years, the multivariate statistical process monitoring method that represented by the partial least squares method is widely used in quality control and fault diagnosis. However, the existing partial least squares method has certain shortcomings in application. In order to enhance the nonlinear processing ability of the system, a locally linear embedding enhanced partial least squares (LLEEPLS) model is proposed to enhance the local retention ability. By integrating the advantages of partial least squares and local linear embedding, the model not only has the capability of PLS to extract the maximum correlation information between process variables and quality variables, but also enhance the local retention ability of PLS to keep the local structural information of the data samples. The simulation of S-curve three-dimensional data shows that the model that based on LLEEPLS can keep the local and global features of the original data better. And the simulation of TEP simulation platform verifies the performance of the quality-related fault diagnosis is better than the existing PLS model.

FrA06 Room 6

IS: Adaptive iterative learning control for dynamical systems 13:40-15:40

Chair: Xiao-Dong Li Sun Yat-Sen Univ.
CO-Chair: Chiang-Ju Chien Huafan Univ.

13:40-14:00 **FrA06-1**

A Novel Rotor Position Detection Method Using Morphological Filter Algorithm for Brushless DC Motor

Yin Zhang Guangxi Univ. of Science and Tech.
Xiao-hua Zhou Guangxi Univ. of Science and Tech.
Yu-wei Zhang Guangxi Univ. of Science and Tech.
Xi-sheng Dai Guangxi Univ. of Science and Tech.

In this paper, by analyzing the relationship between rotor position and phase back electromotive forces (PB-EMFs) of brushless DC motor (BLDCM), a novel rotor position detection method based on morphological filter algorithm (MFA) for BLDCM is proposed. MFA is applied to identify the signal turning points (STPs) of the input stator PB-EMFs, which provides technical support for the current commutations of PWM control system. In addition, accurate current commutation point detection of BLDCM promises rotor field to keep perpendicularity with armature magnetic field, to achieve accurate detection of rotor position and position sensorless control of BLDCM. Results of simulation studies proved that, the proposed detection method can realize the position sensorless control for BLDCM by obtaining the STPs of PB-EMFs in BLDCM, which greatly improves the static and dynamic performance of speed regulation system of BLDCM, and obtaining a outstanding control effect.

14:00-14:20 **FrA06-2**

An Adaptive Iterative Learning Control for Discrete-Time Nonlinear Systems with Iteration-Varying Uncertainties

Chiang-Ju Chien Huafan Univ.
Ying-Chung Wang Huafan Univ.
Meng-Joo Er Nanyang Technological Univ.
Ronghu Chi Qingdao Univ. of Science and Tech.
Dong Shen Beijing Univ. of Chemical Tech.

In this paper, we present a new adaptive iterative learning controller for a class of discrete-time nonlinear systems with iteration-varying uncertainties including initial tracking error, system parameters and external disturbance. The learning objective is to control the nonlinear system to track an iteration-varying desired trajectory after suitable numbers of learning iterations. The main challenge for the iterative learning control design is that all the system parameters are iteration-varying. After separating the system parameters into a pure time-varying component and an iteration-varying component, the system dynamics are divided into an iteration-independent nominal part and an iteration-dependent uncertain part. An adaptive iterative learning controller is then designed to control the nominal dynamics and an iteration-varying boundary layer with dead-zone like auxiliary error is proposed to compensate for the iteration-varying uncertainties. The control parameters and the width of boundary layer are updated from trial to trial in order to guarantee the stability and convergence of the learning system. In addition to ensure the boundedness of control signals for each iteration and each time instant, we also prove that the norm of output error will asymptotically converge to a residual set whose size depends on the width of boundary layer as iteration number goes to infinity.

14:20-14:40 **FrA06-3**

PID-type Iterative Learning Control for 2-D Roesser Model

Tengfei Xiao Sun Yat-Sen Univ.
Xiao-Dong Li Sun Yat-Sen Univ.

In many practical industrial applications, the states, inputs and outputs of the systems show 2-dimensional (2-D) property and operate in a repetitive mode. A PID-type iterative learning control (ILC) is designed in this paper for 2-D system which can be described as a Roesser model and operates in a repetitive mode. The convergence conditions of the control algorithm are derived. In order to demonstrate the effectiveness of the proposed control method, simulations on a numeric example are performed.

14:40-15:00 **FrA06-4**

Four-Wheel-Steering Vehicle Control via Sliding Mode Strategy

Haying Yuan Guangxi Univ of Science and Tech.
Yuan Gao Guangxi Univ of Science and Tech.
Xisheng Dai Guangxi Univ of Science and Tech.

It proposes a sliding mode strategy integrated of rear angle and yaw moment to control the four-wheel-steering vehicle. The vehicle center of gravity slip angle and yaw rate are control variables. The one of input of sliding mode controller is the front steering angle which is supplied by sensor, while others are estimation values of disturbance bound besides the error of slip angle and yaw rate. Furthermore, the disturbance bound estimator, sliding mode controller of rear wheel angle and yaw moment are designed based on the dynamic model and ideal steering model of vehicle. The result of simulation shows the sliding mode control strategy presents good performance and robustness with the different driving conditions. Despite the change of vehicle parameters, the vehicle maneuverability and stability could be assured by stable tracking the yaw rate and zero degree of side slip angle.

15:00-15:20 **FrA06-5**

Distributed Coverage Control of Networked Heterogeneous Robots

Xiaoxia Han Southwest Jiaotong Univ.
Lei Ma Southwest Jiaotong Univ.
Kun Feng Southwest Jiaotong Univ.

This paper main focuses on the distributed coverage control of networked heterogeneous mobile robots. The heterogeneous robots are driven to their centroid of multiplicatively-weighted Voronoi regions under action of the control law, the target position is modified in real-time based on density distribution of the environment. Two types driving mechanisms are considered in this paper, different control methods are used to drive different robots to their target positions. Simulative and experimental results are given to verify the effectiveness of the improved coverage algorithm.

15:20-15:40 **FrA06-6**

Spike-Based Learning Rules for Face Recognition

Chunlin Du Sichuan Univ.
Ying Nan Sichuan Univ.
Rui Yan Sichuan Univ.

This paper proposes a biologically plausible network architecture with spiking neurons for face recognition. This network consists of three parts: feature extraction, encoding and classification. Firstly, HMAX model with four layers (C1-S1-C2-S2) is used to extract face features. The proposed feature extraction method can keep selectivity invariance and scale invariance. The next important part is to encode features to suitable spike trains for spiking neural networks. In the last part, the improved Tempotron learning rule is chosen to train the spiking neural networks with reduced computational and increased fault tolerance. In order to demonstrate the performance of spiking neural networks, we test four databases in the experiment: Yale, Extend Yale B, ORL, and FERET.

FrB01 Room 1
Best Paper Award Finalist 15:50-18:10

15:50-16:15 **FrB01-1**

Distributed Cooperative Learning over Networks via Wavelet Approximation

Jin Xie Xidian Univ.

Weisheng Chen Xidian Univ.
Hao Dai Xidian Univ.

This paper investigates the problem of the distributed cooperative learning over networks via wavelet approximation. On the basis of wavelet approximation (WA) theory, the novel distributed cooperative learning (DCL) method, called DCL-WA, is proposed in this paper. The wavelet series is used to approximate the function of network nodes. For the networked systems, DCL method is used to train the optimal weight coefficient matrix of wavelet series, so as to get the best approximation function of network nodes. An illustrative example will be presented to show the efficiency of the proposed strategy.

16:15-16:40 **FrB01-2**

Fault Detection for Uncertain Sampled-data Systems via Deterministic Learning

Tianrui Chen Guangdong Univ. of Tech.
Cong Wang Guangdong Univ. of Tech.

In this paper, an approach for rapid fault detection for a class of nonlinear sampled-data systems is proposed. First, a learning estimator is constructed to capture the unknown system dynamics effects in sampled-data systems. The key issue in the learning process is that partial neural weights will converge into their optimal values based on the deterministic learning theory. Then a knowledge bank can be established, which stores the knowledge of various system dynamics effects, such as the Euler approximation modeling error, effect of the unstructured modeling uncertainty and different fault dynamics. Second, by utilizing knowledge bank, a set of estimators are constructed. The learned knowledge can quickly be recalled to compensate the unknown system dynamics effect. As a result, the occurrence of a fault can be rapidly detected. Finally, a rigorous analysis for characterizing the detection capability of the proposed scheme is given. Simulation study is included to demonstrate the effectiveness of the approach.

16:40-17:05 **FrB01-3**

Discrete-Time Zero-Sum Games for Nonlinear Systems via Adaptive Dynamic Programming

Qinglai Wei Institute of Automation, Chinese Academy of Sciences
Ruizhuo Song Univ. of Science and Tech. Beijing
Yancai Xu Institute of Automation, Chinese Academy of Sciences
Derong Liu Univ. of Science and Tech. Beijing
Qiao Lin Institute of Automation, Chinese Academy of Sciences

In this paper, a novel discrete-time iterative zero-sum adaptive dynamic programming (ADP) algorithm is developed for solving the optimal control problems of nonlinear systems. Two iteration processes, which are lower and upper iterations, are employed to solve the lower and upper value functions, respectively. Arbitrary positive semi-definite functions are acceptable to initialize the upper and lower iterations of the iterative zero-sum ADP algorithm. It is proven that the upper and lower value functions converge to the optimal performance index function if the optimal performance index function exists, where the existence criterion of the optimal performance index function is unnecessary. Simulation examples are given to illustrate the effective performance of the present method.

17:05-17:30 **FrB01-4**

Switching Autoregressive Dynamic Latent Variable Model for Fault Detection in Multimode Processes

Jiaqi Zheng Zhejiang Univ.
Le Zhou Zhejiang Univ. of Science & Tech.
Zhiqiang Ge Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

The characteristics of dynamic, uncertainty and time variant are very common in the industrial processes and should be paid enough attentions for process control and monitoring purpose. As a high-order Bayesian network model, autoregressive dynamic latent variable (AR-DLV) is able to effectively extract both auto-correlations and cross-correlations in data for a dynamic process. However, the operating conditions will be frequently changed in a real production line, which indicates that the measurements cannot be described using a single steady-state model. In this paper, a set of switching AR-DLV models are proposed in the probabilistic Framework, which extends the original single model to its multimode form. Based on it, a hierarchical fault detection method is developed for fault detection in multimode dynamic processes. Finally, the proposed method is demonstrated by a simulated case study.

17:30-17:55 **FrB01-5**

Active Vibration Control of Piezoelectricity Cantilever Beam Using an Adaptive Feedforward Control Method

Jun-Zhou Yue Southwest Jiaotong Univ.
Qiao Zhu Southwest Jiaotong Univ.

This work is focused on the active vibration control of piezoelectric cantilever beam, where an adaptive feeedforward controller (AFC) is utilized to reject the vibration with unknown multiple frequencies. First, the experiment setup and its mathematical model are introduced. Due to that the channel between the disturbance and the vibration output is unknown in practice, a concept of equivalent input disturbance (EID) is employed to put an equivalent disturbance into the input channel. In this situation, the vibration control can be achieved by setting the control input be the identified EID. Then, for the disturbance with known frequencies, the AFC is introduced to perfectly reject the disturbance but is sensitive to the frequencies. In order to accurately identify the unknown frequencies of disturbance in

presence of the random disturbances and un-modeled nonlinear dynamics, the time-frequency- analysis method is employed to precisely identify the unknown frequencies of the disturbance. Finally, two cases are given to illustrate the efficiency of the AFC algorithm by experiment.

FrB02 Room 2

Model-free adaptive control 15:50-18:10

Chair: Haoping Wang Nanjing Univ. of Science and Tech.

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

15:50-16:10 FrB02-1

Model Free Control Based Nonlinear Integral-Backstepping Control for Blood Glucose Regulation

Qi Wu Nanjing Univ. of Science and Tech.
Haoping Wang Nanjing Univ. of Science and Tech.
Yang Tian Nanjing Univ. of Science and Tech.

In this paper, a Model Free Control based Nonlinear Integral Backstepping Control (MFC-NIB) strategy is developed and applied to blood glucose regulation systems, which is a typical biological system with parameter variations, uncertainties and external disturbances. Firstly, an Intelligent Proportional controller (iP), which is based on model-free theory and whose algebraic estimation technique is replaced by a Time-Delay Estimation (TDE) method is developed. Secondly, to improve the control convergence, the MFC-NIB is studied based on the proposed iP. Finally, to demonstrate the performance and effectiveness of the proposed method MFC-NIB, the simulations with comparisons with iP have been implemented on the referred glycemia regulation systems.

16:10-16:30 FrB02-2

The Model-Free Adaptive Control for Complex Connected Systems in the H-type Motion Platform

Jingshen Qi Beijing Information Science and Tech. Univ.
Rongmin Cao Beijing Information Science and Tech. Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Huixing Zhou China Agricultural Univ.

The key of controlling the H-type motion platform is to realize the synchronous feed of two linear motors. There are many disadvantages of traditional master slave serial synchronous control method. In view of this, this paper designs a new controller which is decentralized estimation and centralized control type Model-Free Adaptive Control. Effectively make up the shortcomings of the master-slave series control mode, and improve the positioning accuracy of the system.

16:30-16:50 FrB02-3

Model-Free Adaptive MIMO Control Algorithm in the Application of the Polishing Robot

Binbin Gao Beijing Information Science and Tech. Univ.
Rongmin Cao Beijing Information Science and Tech. Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Huixing Zhou China Agricultural Univ.

In this paper, we introduce the Compact Form Dynamic Linearization based Model-Free Adaptive Control (CFDL-MFAC) algorithm in the MIMO (Multiple Input Multiple Output) control system. Firstly, we give the content and principle of the compact model-free control algorithm, and then analyze the stability error of the control method. The control system model of the sanding robot is given, and the structure is discussed. Finally, the model - free control algorithm of tight form is applied to the control system and simulation is made. The results show that the compact model-free control algorithm has a good control effect and adaptive control characteristic for the controlled object with coupled time-varying polishing robot. This method also provides a new way to solve the problem of MIMO control system.

16:50-17:10 FrB02-4

Adaptive Backstepping Control Algorithm for a Rotorcraft Disturbed by Different Wind

Lei Zhang Jilin Univ.
Chunyang Fu Jilin Univ.
Xiaojun Guo Jilin Univ.
Yue Bai Jilin Univ.
Yantao Tian Jilin Univ.

In order to keep the attitude stability of the rotorcraft under external wind disturbance, the mathematical model of the rotorcraft under wind disturbance is established. Integral terms are added into the conventional backstepping method to resist the continuing wind disturbance which has a low amplitude. Adaptive control approach is used to compensate for the model error of rotorcraft and the sudden gust. The disadvantage of the conventional backstepping method in resisting the wind disturbance is improved. The simulation results show that the controllers designed by this method have better disturbance rejection performance and tracking performance.

17:10-17:30 FrB02-5

A Novel Data-Driven Predictive Control for Networked Control Systems with Random Packet Dropouts

Shuo Zhen Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Chenkun Yin Beijing Jiaotong Univ.

This paper is concerned with a novel date-driven predictive control method for networked control systems (NCSs), where the network links from sensors

to controllers and from controllers to actuators are subject to random packet dropouts. In order to make full use of the I/O data of the controlled system to improve system performance, an improved model-free adaptive predictive control (iMFAPC) method is proposed by modifying the criterion function. Then, a networked control scheme is developed based on iMFAPC, whose basic principle is to compensate the lost packets by the corresponding predictive values. Finally, the effectiveness of the proposed control scheme for the packet dropout problem in the networked control system is validated through both simulations and experiments.

17:30-17:50 **FrB02-6**

Freeway and Side Road Balancing Control Scheme using MFAILC

Jing Mei Beijing Jiaotong Univ.
Ye Ren Beijing Jiaotong Univ.
Shangtai Jin Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.

In order to alleviate the congestion between the side road and the freeway, a novel balancing control scheme is proposed based on model free adaptive iterative learning control (MFAILC) in this paper. Controller realization possesses the model free attribute to merely utilize the measured input and output (I/O) data of the collective plant of side road and freeway. The control performance is enhanced by utilizing the repetitive information collected from the controlled system. In the last section, the proposed MFAILC based balancing control method is furtherly implement to the numerical simulation platform to show the effectiveness.

FrB03 Room 3
ADRC technology and applications 15:50-18:10

Chair: Zengqiang Chen Nankai Univ.
CO-Chair: Xiangyang Li South China Univ. of Tech.

15:50-16:10 **FrB03-1**

Active Disturbance Rejection Generalized Predictive Control and Application on Large Time-delay System

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

An improved control algorithm called active disturbance rejection generalized predictive control which combines advantages of active disturbance rejection control and generalized predictive control is proposed for time-delay systems in this paper to improve the limitations of active disturbance rejection control (ADRC) in plants with large time-delay and the defects of generalized predictive control method such as huge computation and strong dependence on mathematical model. The method proposed in this paper can deduce the general solution to the Diophantine equations off-line without the parameters identification of the system by the existence of the extended state observer. Hence, the online computation burden of this improved method is reduced and the application is enlarged. Simulation results shows that this proposed design turns out to be a new solution for the large time-delay systems owing to the ability of generalized predictive control algorithm.

16:10-16:30 **FrB03-2**

Quantitative Relationship in Terms of Time-Delay Tolerance of Two Kinds of Extended State Observers

Minnan Piao Nankai Univ.
Kai Zhu Beijing Aerospace Technology Institute
Mingwei Sun Nankai Univ.
Zenghui Wang Univ. of South Africa
Zengqiang Chen Nankai Univ.

Active Disturbance Rejection Control (ADRC), an innovative control method, has been applied successfully in dealing with internal uncertainties and external disturbances. However, ADRC for time-delay plants is still a challenge due to the restriction on the bandwidth of the extended state observer (ESO). When designing the ESO for time-delay plants, both full-order and reduced-order extended state observers can be utilized and the selection of the proper order and the bandwidth of the ESO is necessary. Therefore we seek to compare the two kinds of observers in terms of the time-delay tolerance of the closed-loop stability and find an appropriate bandwidth to ensure the robustness to the time-delay uncertainty. First, the quantitative bandwidth relationship between the two kinds of observers is established with the equivalent effective bandwidth, and then the time-delay tolerance of the closed-loop stability are calculated for the first- and second-order plants to conduct the comparison, whilst the effects of the bandwidth and other parameters on the time-delay tolerance is analyzed. Furthermore, simulation results for a second-order plant are provided to verify the meaning of this investigation.

16:30-16:50 **FrB03-3**

Attitude Control for Multi-Rotor Aircraft with Output Constraints

Chunyang Fu Jilin Univ.
Lei Zhang Jilin Univ.
Xiaojun Guo Jilin Univ.
Yantao Tian Jilin Univ.

In this study, the authors present attitude control design for multi-rotor aircraft subjects to output constraints and various disturbances. To prevent output constraints violation, a Barrier Lyapunov Function (BLF) is introduced and the controller is designed based on backstepping algorithm. To enhance the robustness of the system, a linear extended state observer (LESO) from linear active disturbance rejection control (LADRC) is employed to estimate the disturbances and compensate the impact. It is proved that the proposed control algorithm guarantees the tracking error

converging to zero asymptotic. Finally, simulation experiments validate the effectiveness and superiority of our control approach.

16:50-17:10 **FrB03-4**

Improved Auto Disturbance Rejection Control Strategy for Space -Vector-Modulated Matrix Converter

Xinghe Ma Henan Polytechnic Univ.
Shaohui Zhang Henan Polytechnic Univ.
Junying Zhao Henan Polytechnic Univ.

The control strategies of disturbance for the space-vector-modulated matrix converter (SVM-MC) are developed. In this paper, an improved auto disturbance rejection control (ADRC) strategy is proposed to solve the problem that the performance of the output side of the MC is easily affected by the disturbance of the input side. According to the basic principle of the traditional ADRC, the non-linear feedback function is reconstructed, and the improved strategy is designed to solve the controller's dynamic buffeting. The experimental results show that the SVM-MC based on improved ADRC has good output performance in both steady-state conditions and dynamic disturbance conditions, and the output waveforms harmonic distortion is low.

17:10-17:30 **FrB03-5**

Robust ADRC for Nonlinear Time-Varying System with Uncertainties

Xiangyang Li South China Univ. of Tech.
Wei Ai South China Univ. of Tech.
Zhiqiang Gao Cleveland State Univ.
Senping Tian South China Univ. of Tech.

Active disturbance rejection control (ADRC) exemplifies the spirit of the data-driven control (DDC) design strategy and shows much promise in obtaining consistent applications in industrial control systems with uncertainties, without the premise that the detailed mathematical model of the controlled system is given. Instead, it is shown that the information needed for the control system to work at high level of effectiveness can be extracted from the input-output data by the use of the extended state observer (ESO). On the other hand, it is shown in this paper that the robustness of ADRC depends on the effectiveness of ESO. Furthermore, taking advantage of the rich body of knowledge in the existing field of robust control, the estimation error in ESO is analysed and, for the purpose of improved robustness, a unique nonlinear component is added to the conventional ADRC law. The modified ADRC which is a kind of robust ADRC law is validated in simulation for a nonlinear time-varying system with parametric and functional uncertainties. It is shown that the proposed robust ADRC law provides more effective tracking performance than the conventional ADRC when the bandwidth of ESO is not wide enough.

17:30-17:50 **FrB03-6**

Interactive ADRC Design for Flight Attitude Control

Shunjian Ma Nankai Univ.
Mingwei Sun Nankai Univ.
Zengqiang Chen Nankai Univ.

Flight vehicle attitude control is of great importance. In this paper, a flight controller based on active disturbance rejection control (ADRC) is proposed. Then stability margin tester is utilized to tune the parameters of the controller to meet the specified stability margins, which will serve as a practical tuning method in practice. Moreover, the CAD software based on MATLAB GUI is designed to integrate the tuning and simulation process. Then the simulations are implemented to demonstrate the effectiveness of this controller and tuning method.

FrB04 Room 4

Data-driven fault diagnosis, health maintenance and performance evaluation 15:50-18:10

Chair: Zehui Mao Nanjing Univ. of Aeronautics and Astronautics
CO-Chair: Xuhui Bu Henan Polytechnic Univ.

15:50-16:10 **FrB04-1**

Incipient Fault Detection and Variable Isolation based on Subspace Decomposition and Distribution Dissimilarity Analysis

Chunhui Zhao Zhejiang Univ.
Xuanhong Chen Zhejiang Univ.
Limin Lu Zhejiang Univ.
Shumei Zhang Zhejiang Univ.
Youxian Sun Zhejiang Univ.

The conventional multivariate statistical process control (MSPC) methods may not be sensitive to detection of incipient changes since they in general quantify the distance between the new sample and the modeling samples without checking the changes of data distribution. In the present work, a dissimilarity analysis and quality-relevant subspace decomposition based process monitoring method is developed to detect incipient abnormal behaviors that can not be readily picked up by the conventional MSPC. First, the data is divided into quality-relevant subspace and the other subspace. Then dissimilarity analysis is performed to quantitatively evaluate the distribution difference between the normal condition and fault status for both subspaces. It can evaluate the incipient abnormal behaviors from the quality-relevant perspective to reveal the influences of incipient abnormality on quality. The paper demonstrates that the new method is more sensitive to detection and isolation of incipient abnormal behaviors that are responsible for distortion of the underlying covariance structure. Besides, it can tell whether the incipient fault can influence the quality index or not. Its feasibility and performance are illustrated with industrial process data.

16:10-16:30 **FrB04-2**

Multiple-Fault Diagnosis of Analog Circuit with Tolerance

Haidi Dong Xi'an Research Institution of Hi-Tech.
Te Ma Xi'an Research Institution of Hi-Tech.
Bing He Xi'an Research Institution of Hi-Tech.
Jianfei Zheng Xi'an Research Institution of Hi-Tech.
Gang Liu Xi'an Research Institution of Hi-Tech.

A novel method, consisting of fault detection, rough set generation, element isolation and parameter estimation is presented for multiple-fault diagnosis on analog circuit with tolerance. Firstly, a linear-programming concept is developed to transform fault detection of circuit with limited accessible terminals for measurement to check existence of a feasible solution under tolerance constraints. Secondly, fault characteristic equation is deduced to generate a fault rough set. It is proved that the node voltages of nominal circuit can be used in fault characteristic equation with tolerance. Lastly, fault detection of circuit with revised deviation restriction for suspected fault elements is proceeded to locate faulty elements and estimate their parameters. The diagnosis accuracy and parameter identification precision of the method are verified by simulation results.

16:30-16:50 **FrB04-3**

Fault Detection and Reconstruction for Single Area Load Frequency Control System

Xiaochen Wang Henan Polytechnic Univ.
Yantao Chen Henan Polytechnic Univ.
Junqi Yang Henan Polytechnic Univ.
Chen Wu Henan Polytechnic Univ.

In order to improve the reliability of single area load frequency system, the problem of fault diagnosis of single area load frequency control system based on observer is studied. In this paper, the issues of fault detection and reconstruction for single area load frequency control systems with uncertainty and disturbance by designing adaptive sliding mode observer are considered. By constructing a single area load frequency control system model, the dynamic equations of the load frequency control system are given. Then, a robust adaptive sliding mode observer is designed, and fault diagnosis is carried out for the system. Next, based on super-twisting algorithm the derivative of system output is can be obtained, and the purpose of reconstruction for actuator faults is realized. Subsequently, the proposed methods of both fault detection and reconstruction are applied to a single area load frequency control system, and the simulation results verify the feasibility and effectiveness of them.

16:50-17:10 **FrB04-4**

A Profust-Reliability-Based Health Monitoring Technique of Spacecraft

Boneng Tan Beijing Institute of Spacecraft System Engineering
Haiyan Yu Beijing Institute of Spacecraft System Engineering
Jinfeng Zhou Beijing Institute of Spacecraft System Engineering
Danni Nian Beijing Institute of Spacecraft System Engineering
Zhiyao Zhao Beihang Univ.

The system health management technology uses observation data, system models, and relative intelligent algorithms to monitor system anomaly, evaluate system degradation, predict residual life, and further determine the corresponding maintenance and operation strategy. Recently, the in-orbit management work of spacecraft in China focuses on fault detection and diagnosis, whereas the spacecraft's health management technology stays in the Framework study status. For the spacecraft's health monitoring, the theory and algorithm are important to support practical engineering. Therefore, this paper introduces the profust-reliability-based health monitoring method into the in-orbit management work of spacecraft. This method analyzes telemetry parameters of spacecraft, and calculates the profust reliability of telemetry parameters, component, and system, respectively. Then, the health level of the spacecraft is classified according to the calculated profust reliability value. This method provides a new thought to the in-orbit management work of spacecraft. The simulation result shows that this method can effectively evaluate the health status of spacecraft system.

17:10-17:30 **FrB04-5**

Weighted Least Squares State Estimation of Power System Based on Real-Time Weight Adjustment Method

Haoyuan Gao Northeastern Univ.
Ruiyun Wang China Railway Fifth Survey And Design Institute Group Co. LTD.
Yanmei Zhao Northeastern Univ.
Zhanshan Wang Northeastern Univ.

The large error data in the measurement data will greatly affect the estimation accuracy of the weighted least squares state estimator. The traditional method of selecting the weights can not effectively suppress the bad data, and the existing bad data recognition algorithms may not effectively recognize multiple bad data at the same time, although which well recognize single bad data. This paper presents a real-time weight adjustment method to reduce the impact of large error data on the estimation accuracy. The algorithm is divided into two stages. In the first stage, the state estimator that applies inverse of the variance as the weight is used to obtain the estimated values of the measured data. The second stage uses the actual measurement data and the estimated values of the obtained measurement data to calculate the new weights. And through these new weights, one would

obtain the operating state of the power system, i.e., the estimation values of state variable. This method makes full use of high precision data to reduce the influence of large error data and improve the accuracy of state estimator.

17:30-17:50 **FrB04-6**

A New Fault Diagnosis Method Based on Component-Wise Expectation-Maximization Algorithm and K-Means Algorithm

Bowen Hou National Univ. of Defense Tech.
Zhangming He National Univ. of Defense Tech.
Beijing Institute of Control Engineering
Jiongqi Wang National Univ. of Defense Tech.
Bowen Sun National Univ. of Defense Tech.
Kun Zhang National Univ. of Defense Tech.

In this paper, a fault diagnosis method is proposed based on component-wise expectation maximization algorithm and k-means algorithm, and it is applied for diagnosing the fault of the satellite attitude determination control system. First, Gaussian mixture model and the its traditional parameter estimation algorithm are reviewed. The component-wise expectation-maximization algorithm is used to estimate the parameters of Gaussian mixture model, which can lower the computational complexity of parameter estimation. Moreover, fault diagnosis, both detection and isolation, is carried out based on Gaussian mixture model, component-wise expectation maximization algorithm and k-means algorithm. Finally, both traditional method and our proposed method are applied for fault diagnosis on the satellite attitude determination control system. The simulation result shows that the new proposed method can, significantly, lower the computational complexity, while the traditional and the new methods have nearly the same performance.

17:50-18:10 **FrB04-7**

Discrete Wavelet Transform Based Data Trend Prediction for Marine Diesel Engine

Yifei Pan Nanjing Univ. of Aeronautics and Astronautics
Zehui Mao Nanjing Univ. of Aeronautics and Astronautics
Quan Xiao Nanjing Univ. of Aeronautics and Astronautics
Xiao He Institute of System Engineering China State Shipbuilding Corporation
Yu Zhang Institute of System Engineering China State Shipbuilding Corporation

In this paper, a multi-model data trend prediction method is proposed for marine diesel engine to prognosis of fault. According to the data characteristics, the discrete wavelet transform is used to process the data, which can eliminate the noise of the high-frequency and retain the low-frequency signal. The auto-regression, the gray model, the BP neural network and the radial-based neural network methods are employed to trend prediction and the result are compared. In terms of convergence speed, the autoregressive model has better performance of the fault prognosis. In terms of fitting error, the neural network model has better accuracy.

FrB05 Room 5
Big data techniques and applications 15:50-18:10

Chair: Shen Yin Harbin Institute of Tech.
CO-Chair: Min Fan Chongqing Univ.

15:50-16:10 **FrB05-1**

Research on Combined State Estimation of Current Reckoning Method and Innovation Graph Approach Point at Identification Subjects

Na Zhang State Grid Shanxi Electric Power Research Institute
Suquan Zhou Harbin Institute of Tech.
Xiaoqian Li State Grid Shanxi Electric Power Research Institute
Jingjin Cao State Grid Shanxi Electric Power Research Institute
Wei Wang State Grid Shanxi Electric Power Research Institute

The innovation graph method and current reckoning method are combined to realize complementary advantages and comprehensive identification in this paper. For different identification objects, using different main identification method, the bad measurement is mainly based on current reckoning method, and the topology change identification is mainly done by the innovation graph method. This way is aimed at using the current reckoning method and innovation graph method each recognition advantages, to achieve mutual integration, complement identification purpose.

16:10-16:30 **FrB05-2**

Design and Application of Smart Power Utilization System in Pilot Districts of Chongqing

Bo Zhang China Electric Power Research Institute,
Meng Zhou China Electric Power Research Institute,
Min Fan Chongqing Univ.
Zhihong Liu State Grid Power Company of Chongqing
Qi Han Chongqing Univ.

This paper proposes an overall design for a smart power utilization system, and presents a realizable method based on practices in pilot districts in Chongqing. This design can effectively achieve data transmission and communication among many subsystems, while information management and monitoring & controlling of smart power utilization districts in the subsystems are divided into different security zones. This system has two outstanding characteristics. One is that monitoring and accurate fault location for user's meters and power distribution equipment are realized through regional power distribution automation. The other is that electric vehicle charge pile management can make full use of peak and valley load shifting and realize efficient coordinate regulation by distribution load. This smart power utilization system has been successfully put into

use in Jiaxinqinyuan and Fubaoquan districts in Chongqing.

16:30-16:50 **FrB05-3**

Analysis of Control Technology on Electromagnetic Noise of Permanent Magnet Synchronous Motor

Wei Wang Bohai Univ.
Houhua Shen Bohai Univ.
Shen Yin Harbin Institute of Tech.

For disc type permanent magnet motor with different ratio of axial length to diameter, their sound field distribution are different, and structure parameters also have effects on electromagnetic noise. This paper discusses the relationship between structure parameters (such as ratio of axial length to diameter, effective pole arc coefficient, length of magnetization direction, width of stator slot, length of air-gap) and electromagnetic noise, and put forward how to choose noise measuring point and suppress noise for disc type motors with different shapes.

16:50-17:10 **FrB05-4**

Speed Sensorless Vector Control of Semi-Submerged Ship Dynamic Positioning Based on LSSUKF

Wenlong Yao Qingdao Univ. of Science & Tech.
Guotao Zhuang Qingdao Univ. of Science & Tech.
Yuan Liu Qingdao Ocean Shipping Mariners College
Ailing Chen Qingdao Ocean Shipping Mariners College

In this paper, a robust UKF algorithm based on Least-Square is proposed for the semi-submerged ship dynamic positioning speed sensorless control system, which lacks the ability to adapt itself to system state anomalies. The algorithm uses the Least-Square method to compute the suboptimal fading factor, it adjusts the filter estimation gain adaptively, and it realizes the strong tracking to the real state of the system. The algorithm is applied to the semi-submerged ship dynamic position sensorless control system and compared with the standard UKF. The results show that when the state of the dynamic positioning system is abnormal, the improved UKF algorithm based on the Least-Square for positioning control system has better control quality and response characteristics. The disturbance rejection ability and robustness of the system are improved, and its estimation ability to disturbance is enhanced obviously, which improves the positioning accuracy of the semi-submerged ship dynamic positioning system.

17:10-17:30 **FrB05-5**

Development of Protection Device for Anti-Override Trip Based on Optical Fiber Locking Control

Wei Wang State Grid Shanxi Electric Power Research Institute
Lin Yan State Grid Taiyuan Power Supply Co.
Muqin Tian Taiyuan Univ. of Tech.
Hua Yu State Grid Shanxi Electric Power Research Institute
Shaoping Guan State Grid Shanxi Electric Power Research Institute

In order to solve the problem of override trip in high-voltage power supply system of coal mine, a new scheme for preventing override trip was proposed based on optical fiber locking control. Referring to a typical mine power supply system, the short circuit protection principle of high-voltage grid based on optical fiber locking was analyzed. The hardware circuit, as well as the control procedures of protection devices was developed, and the performance experiments were carried on. It has been shown by experiments that the scheme can figure out the coordination between switchgears in high-voltage power grid of coal mine, and can solve the selective problem of over-current protection. In addition, the override trip fault can be prevented effectively. Therefore, with the scheme proposed in this paper, the reliability and safety of the mine power supply system can be improved.

17:30-17:50 **FrB05-6**

Incorrect Operation Accident's Analysis in Overvoltage and Differential Protection of Main Transformer Clearance

Wei Wang State Grid Shanxi Electric Power Research Institute
Yu Han State Grid Shanxi Electric Power Research Institute
Hua Yu State Grid Shanxi Electric Power Research Institute
Na Zhang State Grid Shanxi Electric Power Research Institute
Lin Yan State Grid Taiyuan Power Supply Co.

Modern power grid has already become one of the pillar industry of the national economy. The safety and steady operation of power grid is closely related to the development of all walks of life and national economy and the fundamental interests of people. So it is significant to ensure the safety of grid in production and operation, and the electric power supply. In this essay, connecting with a practical situation which caused by dead ground, main transformer gap breakdown, CT neutral line broken, wrong actions of differential protection and clearance overvoltage, some improvement measures and advice will be put out by comprehensive reviewing and detailed analyzing the reason and process of the accident to avoid the occurrence of such things.

FrB06 Room 6

IS: Networked traffic optimization and control

15:50-18:10

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

15:50-16:10 **FrB06-1**

Analysis of multi intersection state controllability under the constraint of saturation equilibrium

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

In view of the existing regional traffic state classification method can not completely reflect the controllable state of city road network problems, puts forward a constraint based on saturation equilibrium of multi intersection state controllability analysis model. First, the equilibrium of saturation control method to control the multi intersection; secondly, the equilibrium of saturation constraints, introducing demand rate and cumulative rate of definition of multi intersection controllability. Finally, the simulation is carried out using the actual data of the road network, the results show that the proposed algorithm can more accurately reflect the control of city road network.

16:10-16:30 **FrB06-2**

The Characteristics Research of Commuting Travel Mode Split and Origin Destination (OD) Distribution in Shenzhen, China

Jiyuan Tan North China Univ. of Tech.
Yibin Huang North China Univ. of Tech.
Zhengxi Li North China Univ. of Tech.
Li Wang North China Univ. of Tech.
Weiwei Guo North China Univ. of Tech.
Honghai Li Research Institute of Highway Ministry of Transport Beijing

With the rapid development of urbanization in China, the government usually face the problem of traffic congestion, mainly due to the rapid increase in traffic demand. Group disparity between commuting mode choice and origin destination space distribution has enabled us to explore the cause of these differences and basic causes of traffic congestion. In recent years, commuting mode and behavior based spatial analysis have sprung up. However, it is difficult to study the relationship between commuting mode choice and origin destination space distribution since the commuting characteristics data are invisible in a specific space. In this paper, the classical origin destination (OD) theory is usually employed to calculate data when studying commuting mode choice and we take Shenzhen as an example to study the daily travel mode of residents. Meanwhile, the traffic volume distribution of taxis, buses and subways in rush hours, which was analyzed as the basis for commuting travel split. Moreover, the OD data of taxi, bus and subway trips were used to explain the distribution of job-housing and traffic demand in different urban area. The results will be useful for optimizing the structure of the Shenzhzhen municipal traffic system in the final, which has important reference value.

16:30-16:50 **FrB06-3**

Integrated modeling and control of urban road traffic networks

Zhonghe He North China Univ. of Tech.
Lingyu Zhang North China Univ. of Tech.
Haibo Zhang North China Univ. of Tech.
Xiaoming Liu North China Univ. of Tech.

Urban freeway is the aorta of urban traffic, but in recent years, traffic congestion has become prominent increasingly, which seriously affects the urban traffic efficiency. Based on the analysis of the traffic flow characteristic of urban freeway and streets system, the macroscopic traffic flow model integrated urban freeway with streets system is established, by using store-and-forward model to describe the evolution law of states for the two systems. Then on this basis, the green ratio adaptive control method based on linear quadratic optimal control is put forward. Finally, the VISSIM traffic simulation software is used to simulate and compare with the fixed-time signal control. The simulation results show the feasibility and effectiveness of the method.

16:50-17:10 **FrB06-4**

A Multi-Mode Cooperative Adaptive Cruise Switching Control Model for Connected Vehicles Considering Abnormal Communication

Pangwei Wang North China Univ. of Tech.
Chuan Jiang North China Univ. of Tech.
Xiaohui Deng China Highway Engineering Consulting Group Co.
Wang Li North China Univ. of Tech.
Hui Deng North China Univ. of Tech.
Zhonghe He North China Univ. of Tech.

With the development of vehicle-to-vehicle (V2V)/vehicle-to-inFrastructure (V2I) communication systems, the spacing between two vehicles is shortened effectively and the traffic efficiency is improved. Meanwhile, abnormal wireless communication caused by time-delay, packet-dropout and failure brings the new traffic security problem. In this paper, we take connected vehicle platoons as the research object. Firstly, a traditional cooperative adaptive cruise control (CACC) system is established based on distributed controller; secondly, according to the influence of abnormal wireless communication, we present a multi-mode switching control model to improve the CACC controller; thirdly, according to the conditions of string stability, the ranges of controller parameters and constant time headway (CTH) are obtained; finally, the feasibility of the controller is simulated based on Matlab/Simulink. The test results show that the multi-mode CACC controller can not only avoid the influence of abnormal communication on intelligent connected vehicle platoon, but also ensure the string stability under the smaller driving spacing in the meantime.

17:10-17:30 **FrB06-5**

LQR-based Perimeter Control Approach for Urban Road Traffic Networks

Haibo Zhang North China Univ. of Tech.
Lingyu Zhang North China Univ. of Tech.
Zhonghe He North China Univ. of Tech.
Min Li North China Univ. of Tech.

Continuous increase of traffic demands, often more than the network capacity, is the primary reason for traffic congestion. Recently, the existence of macroscopic fundamental diagram in urban road network has been validated by many research works, and then activated the researches for the perimeter control of the network to realize objective of reducing network congestion. In this paper, the centralized state-feedback control design approach for the perimeter control of the network, with the objective of the network balance, is developed, which can realize the balance of network flows and moreover guarantee the maximum network capacity in saturated state of the network. A state-space model of the network perimeter control, with the number of vehicles in links as state variables and perimeter flows as control inputs, is first proposed. Furthermore, LQR approach is applied for the design of perimeter input. Also, the distributed signal control approach of the network under the proposed perimeter control law is proposed, realizing the integration of the perimeter and signal control of the network.

17:30-17:50 **FrB06-6**

Real-time queue length perception with green wave band point optimization based on floating vehicle

Li Wang North China Univ. of Tech.
Ke Pan North China Univ. of Tech.
Xingyu Wang North China Univ. of Tech.

With the development of satellite positioning technology and network communication technology, the floating vehicle data has the advantages of large amount of data, high precision and wide coverage. In order to improve the green wave control effect ,combines the floating vehicle trajectory data with distributed wave theory, makes the real-time prediction of queue length of current cycle and the time of complete disappearance, and analyzes the green-start coordination, green-middle coordination and green-end coordination in the advantages and disadvantages, designs an optimal control strategy with dynamic green point floating vehicle queue length based on real-time sensing green , improves the efficiency of green band, through simulation experiments to prove the effectiveness of the proposed method.

17:50-18:10 **FrB06-7**

Evaluation System for Automatic Fare Gate Capacity Based on Delphi and Improved FAHP

Huijuan Zhou North China Univ. of Tech.
Meijie Jia North China Univ. of Tech.
Yanwei Feng Hisense TransTech Co.
Yu Liu North China Univ. of Tech.

The index of gate capacity evaluation in urban rail traffic involves many factors. From the aspect of supply-demand relationship, the evaluation system for gate capacity of urban rail traffic is constructed, which integrating Delphi method and improved Fuzzy Analytical Hierarchy Process (FAHP). Four first-level indices and thirteen second-level indices are selected. Fuxingmen station on Subway Line 1 is taken as an example to computer indices that affect the gate capacity. These three indices of gates number, passenger's familiarity and gate failure rate are emphasized. The example results prove the evaluation system conform to reality and have strong operability and availability.

Saturday, 27 May, 2017

SaA01 **Room 1**
Iterative learning control (I) **13:40-16:00**

Chair: Xiaoe Ruan Xi'an Jiaotong Univ.
CO-Chair: Mingxuan Sun Zhejiang Univ. of Tech.

13:40-14:00 **SaA01-1**

Convergence Characteristic of PI-type Iterative Learning Control for Linear Time-Invariant Systems

Xiaoe Ruan Xi'an Jiaotong Univ.
Yan Liu Xi'an Jiaotong Univ.
Yaoyu Li University of Texas at Dallas

The paper exploits the convergence characteristics of the first- and second-order PI-type iterative learning control (ILC) schemes for linear time-invariant (LTI) systems with direct-through terms. The aim is to investigate the effects of the integration embedments into the conventional P-type ILC rule. In the exploitation, the tracking errors are assessed in the form of the Lebesgue-p norm and the convergences are derived in virtue of the generalized Young inequality of convolution integral. The derivations convey that the convergence monotonicities are guaranteed for the first-order PI-type ILC. At the same time, the convergence is ensured for the case when the second-order PI-type ILC is implemented on the systems. Numerical simulations testify the validity and effectiveness.

14:00-14:20 **SaA01-2**

An ILC Method of Formation Control for Multi-Agent System with One-Step Random Time-Delay

Jialu Zhang Shanghai Univ.
Yong Fang Shanghai Univ.
Yuzhou Wu Shanghai Univ.

In this paper, we consider iterative learning control (ILC) for discrete-time multi-agent system formation with one-step random time-delay. Random delays during transmission seriously affect the convergence performance of multi-agent formation. Based on one-step random time-delay model, the transition matrix of system is derived, which contains the impact factors of random delays. A learning control scheme and the convergence of system tracking errors is guaranteed. Simulation results show that convergence rate is reduced with the probabilities of time-delay higher.

14:20-14:40 **SaA01-3**

Iterative Learning Identification Using Quantized Observations

Xuhui Bu Henan Polytechnic Univ
Jian Liu Henan Polytechnic Univ.
Zhongsheng Hou Beijing Jiaotong Univ

This paper develops a novel iterative learning parameter identification algorithm for a class of single parameter systems with multi-threshold quantized observations. The identification algorithm is constructed along the iteration axis and it can incorporate the parameter identification ability and the learning ability to deal with unknown time-varying parameters. Based on the recursive form of the estimation error along the iteration axis, it is proved that the convergence of parameter estimation can be guaranteed over the whole finite time interval. A numerical example is given to demonstrate the effectiveness of the algorithms.

14:40-15:00 **SaA01-4**

High-Order PD^\alpha-Type Iterative Learning Control and its Lebesgue-p norm Convergence

Lei Li Xi'an Jiaotong Univ.

This paper investigates a high-order PD^{alpha} type iterative learning control strategy for a class of fractional-order linear time-invariant systems with Caputo derivative $0<alpha<1$. On the basis of fractional integration by parts and generalized Young inequality, sufficient convergence condition of this learning control law is established in the sense of Lebesgue-p norm. It is shown that the convergence condition is not only dependent of the fractional-order derivative learning gains, along with the system order, but also dependent of the proportional learning gains and all the matrices associated with the system. Finally, a numerical example is given to demonstrate the validity of the results.

15:00-15:20 **SaA01-5**

Path-Tracking of Mobile Robot Using Feedback-Aided P-Type Iterative Learning Control against Initial State Error

Yang Zhao Shandong Univ.
Fengyu Zhou Shandong Univ.
Da Wang Shandong Normal Univ.
Yan Li Shandong Univ.

In this paper, we present an iterative learning control (ILC) frameworks for robust path-tracking problem of nonholonomic mobile robots in the presence of initial shifts. The major difficulties are caused by simultaneous existence of state disturbances and biased initial state in the mobile robot kinematic system. To design ILC strategy for such problem, a new ILC scheme is proposed as a combination of an initial rectifying term and a feedback-aided P-type learning algorithm. Sufficient conditions of convergence of this approach are given and the global convergence is proved. Simulation results also verify the effectiveness of the proposed scheme.

15:20-15:40 **SaA01-6**

Switching-Function Dynamics Based Design of Sliding Mode Repetitive Controllers

Mingxuan Sun Zhejiang Univ. of Tech.
Wenwei Zhou Zhejiang Univ. of Tech.
Qiang Chen Zhejiang Univ. of Tech.

This paper addresses the problem of repetitive control for systems where the reference input is a periodic signal, with known period. The sliding mode repetitive controller based on switching-function dynamics is designed to eliminate the disturbances with the same period. In exponential reaching law, the sign function is replaced with power item to decrease chattering and a measure of disturbance-rejection is embedded in to solve the system uncertainties. In order to characterize the performance of closed system, monotone decreasing area boundary and absolute convergence layer boundary of switching-variate are defined and the bounds are derived in details.

15:40-16:00 **SaA01-7**

Finite-Time Adaptive Robust Control

Mingxuan Sun Zhejiang Univ. of Tech.
Jianyong Chen Zhejiang Univ. of Tech.
Wenzhou Vocational College of Science and Tech.
He Li Zhejiang Univ. of Tech.

This paper presents a finite-time control strategy for uncertain systems with unknown time-invariant parameters. The finite-time adaptive robust controller is designed via Lyapunov approach, where projection-type integral and incremental adaptation laws are applied in estimation of the time-invariant parametric uncertainties, respectively. The terminal attractor is suggested in the adaptive robust controller, and with the proposed control schemes, the finite time convergence can be realized. The bounded error convergence result is obtained in the presence of disturbances. Otherwise, the zero-error convergence can be achieved. The numerical results demonstrate the effectiveness of the proposed control schemes.

SaA02 Room 2
Iterative learning control (II) 13:40-16:00

Chair: Senping Tian South China Univ. of Tech.
CO-Chair: Junmin Li Xidian Univ.

13:40-14:00 **SaA02-1**

Iterative Learning Control for a Class of Singular Distributed Parameter Systems

Xingyu Zhou Guangxi Univ. of Science and Tech.
Xisheng Dai Guangxi Univ. of Science and Tech.
Guilin Univ. of Electronic Tech.
Senping Tian South China Univ. of Tech.
Sange Mei Guangxi Univ. of Science and Tech.

This paper addresses iterative learning control problem for singular distributed parameter systems with parabolic type. Owing to singular value decomposition theory, the singular distributed parameter systems are transformed into its dynamic decomposition standard form. Then, in virtue of the Bellman-Gronwall inequality and contraction mapping approach, the learning convergence of L2 norm of output errors has been guaranteed through rigorous analysis. Sufficient convergent conditions are provided under two cases. In the end, numerical simulations are presented to validate the effectiveness of P-type ILC scheme.

14:00-14:20 **SaA02-2**

Fuzzy Adaptive Iterative Learning Control for Consensus of Multi-Agent Systems with Imprecise Communication Topology Structure

Jiaxi Chen Xidian Univ.
Junmin Li Xidian Univ.
Jinsha Li Xidian Univ.

This paper investigates the adaptive consensus problem of first-order linearly parameterized multi-agent systems (MASs) with imprecise communication topology structure. T-S fuzzy models are presented to describe leader-followers MASs with imprecise communication topology structure, and a fuzzy distributed adaptive iterative learning control protocol is proposed. With the dynamic of leader unknown to any of the agent, the proposed protocol guarantees that the follower agents can track the leader uniformly on [0,T] for consensus problem. A sufficient condition of the consensus for the closed-loop multi-agent system (MAS) is given based on Lypapunov stability theory. Finally, a simulation example is given to illustrate the effectiveness of the proposed method in this study.

14:20-14:40 **SaA02-3**

Analysis of Iterative Learning Control of an Oscillating System with pure Delay

Chengbin Liang Guizhou Univ.
JinRong Wang Guizhou Univ.
Wei Wei Guizhou Minzu Univ.

By using delayed matrix sine and cosine of polynomial degrees methods, we design learning updating laws for an oscillating system with pure delay to track the reference accurately. Several convergence results of open-loop, closed-loop and open-closed-loop P-type and D-type convergence results are obtained. We give two numerical examples in final section.

14:40-15:00 **SaA02-4**

Fuzzy Neural Network Based Adaptive Iterative Learning Control Scheme for Velocity Tracking of Wheeled Mobile Robots

Xiaochun Lu Hohai Univ.
Jiangsu Key Laboratory of Power Transmission & Distribution Equipment Tech.
Juntao Fei Hohai Univ.
Jiao Huang Hohai Univ.

The velocity tracking problem of wheeled mobile robots (WMRs) which work with repeatable trajectories and different initial errors is discussed in the paper. Three mathematical models of WMR, namely, kinematic model, dynamic model and DC motor driven model, are deduced

and the stratagem of fuzzy neural network based adaptive iterative learning control (FNN-AILC), which includes the components of fuzzy neural network, approximation errors and feedback, is presented. The proposed scheme can deal with MIMO system, which is distinguished from previous research work. The simulation is presented and the result verify the effectiveness of the controller.

15:00-15:20 **SaA02-5**

Iterative Learning Control for Switched Singular Systems

Panpan Gu South China Univ. of Tech.
Senping Tian South China Univ. of Tech.

This paper deals with the problem of iterative learning control for a class of switched singular systems. And the considered switched systems with arbitrary switching rules are operated during a finite time interval repetitively. Based on the singular value decomposition method, the switched singular systems are transformed into the switched differential-algebraic systems. According to the characteristics of the switched differential-algebraic systems, an iterative learning control algorithm, which is composed of D-type and P-type learning algorithms, is proposed. Using the contraction mapping principle, it is shown that the algorithm can guarantee the state tracking error converges uniformly to zero as the iteration increases. A numerical example is given to illustrate the effectiveness of the proposed algorithm.

15:20-15:40 **SaA02-6**

Feedback-aided Iterative Learning Control for a Class of Discrete Systems

Hongbo Bi Quzhou Univ.
Hailun Wang Quzhou Univ.
Mingxia Yang Quzhou Univ.

This paper presents the problem of iterative learning control for tracking the given trajectory in pre-specified finite time interval. A feedback-aided PD-type learning control algorithm is proposed, and the convergence analysis result indicates that the output trajectory achieves completely convergence with the respect time, as the iteration number goes to infinity. Furthermore, the result is generalized to the PID-type (even PMID-type) learning control methods, and the relevant results are obtained. Finally, the numerical results are presented to demonstrate the effectiveness of the proposed learning algorithms.

15:40-16:00 **SaA02-7**

High-Order Iterative Learning Control for Nonlinear Systems

Guojun Li Zhejiang Police College

Iterative learning control demands initial state in each iteration is the same, which is equal to desired state. But this condition is unattainable in practice. This paper addresses the problem of some fixed initial state in iterative learning control based on high-order nonlinear system. It presents a new control algorithm. In the process of tracking, this algorithm can rectify the initial errors through a step-by-step rectifying controller. The controller rectifies the x_{n} at first, then x_{n−1} after finishing the rectifying action of x_{n}, and so on. All of these rectifying action are finished in a small interval. Furthermore, the algorithm has shown effective in the improvement of tracking performance through simulation.

SaA03 Room 3

IS: Advances in iterative learning control theory and its applications 13:40-16:00

Chair: Deqing Huang Southwest Jiaotong Univ.
CO-Chair: Bing Chu Univ. of Southampton

13:40-14:00 **SaA03-1**

A Novel Repetitive Iterative Learning Control for Linear Discrete-Time Systems with Time-Iteration-Varying Reference

Qiao Zhu Southwest Jiaotong Univ.

The purpose of this work is to improve the tracking performance of the iterative learning control (ILC) by designing a new learning law that has the ability to update the input along both the time and iterative axes. First, the reference is generated by a high-order internal model (HOIM) along the iterative axis and can be approximated by an HOIM along the time axis. Then, the HOIM-based repetitive control (RC) and ILC design methods are introduced, which can update the input along the time and iterative axes, respectively. Inspired by the design methods of the HOIM-based RC and ILC, a new ILC scheme, named as repetitive iterative learning control (RILC), is constructed by incorporating both the HOIMs of the reference along the time and iterative axes. Due to the additional use of the time-varying information of the reference, it is verified that the RILC is superior to the ILC. Finally, a microscale robotic deposition system is given to illustrate the advantage of the proposed RILC scheme.

14:00-14:20 **SaA03-2**

Boundary Tracking Control for MIMO PDE-ODE Cascade Systems via Learning Control Approach

Xuefang Li South Kensington Campus
Deqing Huang Southwest Jiaotong Univ.
Dong Shen Beijing Univ. of Chemical Tech.
Jian-Xin Xu National Univ. of Singapore

This work addresses the boundary tracking control of a class of MIMO PDE-ODE cascade systems via learning control approach. Due to the temporal-, spatial- and iteration-varying properties, one of the key steps before the controller design is to reduce the variation of the systems. Therefore, frequency domain analysis

techniques are adopted in this work, which can be used to remove the time domain impact and then facilitate the learning controller design. The convergence analysis is derived rigorously based on contraction mapping methodology. Moreover, the effect of input and measurement disturbances to the ILC performance is also discussed. In the end, a numerical example is illustrated to present to effectiveness of the proposed controller.

14:20-14:40 **SaA03-3**

Iterative Learning Control for a Timoshenko Beam with Input Backlash

Tingting Meng Univ. of Electronic Science and Tech.
Wei He Univ. of Science and Tech. Beijing
Deqing Huang Southwest Jiaotong Univ.
Lung-Jieh Yang Tamkang Univ.
Changyin Sun Southeast Univ.

In this paper, vibration control is addressed for a Timoshenko beam system with input backlash and external disturbances. By integrating iterative learning control into adaptive control, two dual-loop adaptive iterative learning control schemes are proposed in the presence of the input backlash. Two observers are designed to estimate two bounded terms, which are divided from the backlash inputs. Based on the defined composite energy function, all the signals are proved to be bounded in each iteration. Along the iteration axis, (I) the input backlash is tackled; (II) the transverse displacements and the angle displacements are suppressed to zero; and (III) the spatiotemporally varying disturbance and the time-varying disturbance are rejected. Simulations are provided to manifest the effectiveness of the proposed control laws.

14:40-15:00 **SaA03-4**

Adaptive Control of a Flexible Riser System

Fang Guo South China Univ. of Tech.
Yu Liu Univ. of Nebraska-Lincoln.
South China Univ. of Tech.
Zhijia Zhao South China Univ. of Tech.

An adaptive boundary controller is developed in this article for minimizing the vibration displacement of a flexible riser. The dynamics of riser system is represented by partial-ordinary differential equations. Through combining boundary control, adaptive technique with backstepping technique, an adaptive boundary controller is given for realizing vibration restraint for the riser system, where an adaptive law is developed for coping with parametric uncertainties and a signum function is introduced for mitigating the boundary disturbance. With the designed adaptive boundary controller, the spillover instability can be successfully avoided. Finally, simulations are displayed to explain that the given controller is valid to realize vibration restraint of a flexible riser.

15:00-15:20 **SaA03-5**

Sampled-Data Repetitive Learning Control of Electro-Hydraulic Actuator for Lower Limb Rehabilitation Exoskeleton

Yong Yang Southwest Jiaotong Univ.
Lei Ma Southwest Jiaotong Univ.
Deqing Huang Southwest Jiaotong Univ.
Yongkui Sun Southwest Jiaotong Univ.
Yang Shu China Academy of Engineering Physics

In this paper, sampled-data repetitive learning control design of electro-hydraulic actuator used in lower limb exoskeleton for rehabilitation is addressed. The controller is proposed entirely in the discrete-time domain. First, the discrete-time model of the electro-hydraulic actuator is derived by direct discretization using Euler approximation, where the equivalent mass and force acted on the electro-hydraulic actuator are assumed to vary periodically by considering the repetitive motion of exoskeleton legs. Second, a repetitive learning controller is developed to learn the unknown periodic parameters by utilizing the backstepping technique. The tracking convergence of the closed-loop system and the boundedness of all the involved signals are obtained via rigorous analysis. Finally, the control performance of the proposed controller is verified by simulation.

15:20-15:40 **SaA03-6**

Point-to-Point ILC with Accelerated Convergence

Bing Chu Univ. of Southampton
David H Owens Zhengzhou Univ.
Univ. of Sheffield
Chris T Freeman Univ. of Southampton.
Yanhong Liu Zhengzhou Univ.

This paper proposes a novel point-to-point iterative learning control (ILC) algorithm for high performance trajectory tracking applications. Based on a successive project formulation of the point-to-point ILC design problem, two point-to-point ILC design algorithms can be derived: one algorithm recovers the norm optimal point to point ILC algorithm with a desirable physical property of converging to the minimum norm (energy) solution, and the other one (interestingly) has accelerated convergence speed which could lead to significant reduction in system configuration time/cost. Numerical results are provided to demonstrate the proposed algorithms' effectiveness.

15:40-16:00 **SaA03-7**

A Discrete-Time Direct Learning Control Scheme for Magnitude-Varying Trajectories Tracking

Wei Zhou Jiangsu Vocational Institute of Commerce
Miao Yu Zhejiang Univ.
Baobin Liu Jiangsu Vocational Institute of Commerce

In this paper, a direct learning control scheme is proposed for a class of discrete-time systems tracking magnitude-varying reference trajectories. The reference trajectories vary in magnitude with known ratios. A direct learning control algorithm is designed for systems with adequate pre-stored control information profiles, and especially for systems working nonrepetitively in practice. By using pre-stored control input data, the new learning control input can be developed directly. The simulation results of permanent magnet linear motor show that the proposed direct learning control approach achieves perfect tracking.

SaA04 Room 4
IS: Security maintenance and fault-tolerant control for complex systems 13:40-16:00

Chair: Darong Huang Chongqing Jiaotong Univ.
CO-Chair: Ying Zheng Huazhong Univ. of Science and Tech.

13:40-14:00 SaA04-1

A Universal Modeling Approach for Wind Turbine Condition Monitoring based on SCADA Data

Yan Ren Northeastern Univ.
Fuming Qu Northeastern Univ.
Jinhai Liu Northeastern Univ.
Jian Feng Northeastern Univ.
Xiaodong Li China Gas Turbine Establishment

In this paper, a universal approach to building wind turbines prediction models has been proposed. BPNN is used to establish the forecasting model from the perspective of large data analysis based on the SCADA data. First, the power quality of wind turbines will affect the power supply to the grid, thus the power can represent the performance of the WTs. So the active power is selected as the output of the model. Other condition parameters are clustered according to k-means and the silhouette coefficient is used as the basis of clustering. Second, correlation within the class is calculated and unrelated quantities in each class are maintained to reduce the dimensionality of the data. Then the remaining condition parameters associated with the output power are retained. Thus the large condition parameters can be represented by several representative parameters as input to the prediction model. Finally, according to the relative error probability distribution to monitor WTs' condition. This method can be widely used in any wind farm, effectively remove the redundant parameters, thus more intuitively and quickly used for condition monitoring.

14:00-14:20 SaA04-2

Fault Diagnosis of Discrete Event Systems with Time Sequence Constraint

Meng Liao Huazhong Univ. of Science and Tech.
Cui Lu China Ship Development and Design Center
Hong Zhang Huazhong Univ. of Science and Tech.
Sheng- jie Wei China Ship Development and Design Center
Ying Zheng Huazhong Univ. of Science and Tech.

Automata model based method is widely applied for fault diagnosis of discrete event systems. In practical systems, the occurrences of system events often have fixed order, and the faults may be recoverable. The traditional automata model cannot handle these problems. In this paper, an automata model containing the information of time sequence is built, which will help to describe the system accurately and simplify the structure of the model. Based on this model, a diagnosis method is proposed to diagnose the faults, which searches for the observable events sequence of the system to obtain diagnosis results. An example indicates that the proposed method can reduce the number of diagnose paths and save diagnosis time compared with the traditional method.

14:20-14:40 SaA04-3

Moving Object Recognition Based on SVM and Binary Decision Tree

Yingjie Fu Northeastern Univ.
Dazhong Ma Northeastern Univ.
Huaguang Zhang Northeastern Univ.
Li Zheng Beijing Huahang Radio Measurement & Research Inst.

This paper designs an algorithm for moving object recognition based on support vector machine (SVM) in order to identify and classify the moving objects accurately. In view of the advantages of support vector machine in small sample, nonlinear and high dimensional pattern recognition, a classifier based on support vector machine (SVM) is constructed. Feature vector classified samples composed of shape features is used to train and classify support vector machines, and the support vector machine and binary decision tree are combined to form multi class classifier. The object feature vector is used as the input of SVM, and we will use the classifier to classify the detected moving objects. The experimental results show that the proposed algorithm can identify and classify different objects in video images accurately.

14:40-15:00 SaA04-4

Research on Compositional Structure Simulation and Interactive Design of Tujia Brocade

Gang Zhao Central China Normal Univ.
Yawen Chen Central China Normal Univ.
Bingbing Di Central China Normal Univ.
Shuai Lu Central China Normal Univ.
Yali Yu Central China Normal Univ.
Hui Zan Central China Normal Univ.

The Tujia nationality's brocade (short as Tujia brocade or Xilankapu) is one of the Tujia traditional handicrafts; it has been widely used in Tujia people's daily life,

especially for the people reside in the YouShui River Basin. Tujia brocade not only has many varieties, manifestations and performance styles, but also very rich design patterns, these exhibits aesthetic sentiment and national consciousness. It is important effect on the deep excavation of Tujia brocade culture and virtual design by analyzing the compositional structure and structural parameters of Tujia brocade, the paper deconstructs and analysis the structures of Tujia brocade, discusses the hierarchical composition and structure parameter in the analysis of a large number of traditional classic patterns. It develops Tujia brocade structure simulation and interactive design system based on Unity 3D technology, which simulates innovative patterns and presents them visually by changing the compositional structure parameters values, these vector diagrams of Tujia brocade could be directly used in the intelligent machine production.

15:00-15:20 **SaA04-5**

A New Method of the Shortest Path Planning for Unmanned Aerial Vehicles

Darong Huang Chongqing Jiaotong Univ.
Dong Zhao Chongqing Jiaotong Univ.
Ling Zhao Chongqing Jiaotong Univ.

In this paper, the optimal route and deployment scheme are designed to ensure the shortest retention time for unmanned aerial vehicles (UAV) in risk area. Firstly, according to the known data and radar scanning range, the regional distribution map of target grope and regional distribution map of base are obtained, respectively. Secondly, based on the different scanning bandwidth of loads, target points are classified by using clustering analysis. This makes the target points fall on the scanning bandwidth of UAV as far as possible, accordingly reduce the UAV's scanning times. This problem can be regarded as a travelling salesman problem in radar scanning range. Finally, the deployment result and locally optimal route are obtained by 0-1 programming in LINGO. Furthermore, we improve the locally optimal route using particle swarm optimization and acquire the globally optimal route.

15:20-15:40 **SaA04-6**

A Short-Term Traffic Flow Forecasting Method Based on Markov Chain and Grey Verhulst Model

Darong Huang Chongqing Jiaotong Univ.
Zhenping Deng Chongqing Jiaotong Univ.
Ling Zhao Chongqing Jiaotong Univ.
Bo Mi Chongqing Jiaotong Univ.

The traffic system is a nonlinear and time-varying complex system with the human body being involved. At the same time, the highly uncertain and nonlinear of short-term traffic flow due to the complicated factors such as road construction, traffic accident, complex weather and trip distribution. et. So the short-term traffic flow prediction is more difficult than the long-term forecast. First of all, aiming at the uncertain and time-varying characteristics of the short-term traffic flow, the main single-model prediction methods and the combination forecast models are summarized and analyzed. Finally, a combined forecasting method based on Markov chain theory and grey Verhuls model with less data demand and parameter is proposed. The experimental results show that the combined model can obtain a high prediction accuracy.

15:40-16:00 **SaA04-7**

A Prognostic Approach for Systems Subject to Wiener Degradation Process with Cumulative-Type Random Shocks

Zhengxin Zhang Xi'an Research Inst. of High-Tech.
Changhua Hu Xi'an Research Inst. of High-Tech.
Xiaosheng Si Xi'an Research Inst. of High-Tech.
JianXun Zhang Xi'an Research Inst. of High-Tech.
Quan Shi Xi'an Research Inst. of High-Tech.

Condition monitoring data have been widely used as to evaluate the health state and reliability, as well as estimate the remaining useful life (RUL) for degrading systems. Among various degradation modeling and RUL estimating methods, Wiener process based models are recognized by both scholars and engineers as the one of the most effect tools, and thus becomes very popular nowadays. In this paper, a prognostic approach is developed for degrading systems whose performance evolution is captures by an integration of Wiener process and cumulative-type of random shocks depicted by a compound Poisson process. Under the concept of first hitting time, an approximate lifetime distribution in analytical form, which greatly reduces the computing time while proving an adequately accurate result, has been formulated. The parameter estimation framework based expectation maximization (EM) algorithm has been derived. Simulations and case study of the degradation of Li-ion batteries are executed to illustrate and validate the proposed method. The results demonstrate that the approach in this paper can not only handle the positive shocks but also process the negative shocks, which outperforms most of the existing models.

SaA05 Room 5

IS: Optimization and control for complex system

13:40-16:00

Chair: Zhonghua Pang North China Univ. of Tech.
CO-Chair: Cunwu Han North China Univ. of Tech.

13:40-14:00 **SaA05-1**

Optimization for the Upper Bound of the Perturbed Parameters in Singularly Perturbed System Based on Genetic Algorithm

Lei Liu North China Univ. of Tech.
Zejin Feng North China Univ. of Tech.
Cunwu Han North China Univ. of Tech.

In this paper, a class of linear singularly perturbed

system and the optimal problem of the upper bound of the perturbed parameter based on the genetic algorithm are considered. Firstly, the problem of the asymptotically stability is studied in the term of Lyapunov stability theory based on the Linear Matrix Inequality (LMI). Then, the standard problem of the upper perturbed parameter to be optimized is presented. Thirdly, the optimization algorithm for the upper bound of the perturbed parameter in the linear singularly perturbed system is gave out based on the genetic algorithm. Lastly, two numerical examples are provided to demonstrate the effectiveness and feasibility of the proposed results.

14:00-14:20 **SaA05-2**

Multi-rate Process Fault Detection Based on Kernel Partial Least Squares

Zhi-jun Li North China Univ. of Tech.
Le-le Liang North China Univ. of Tech.
Cun-wu Han North China Univ. of Tech.
De-hui Sun North China Univ. of Tech.

In view of the process variables associated with quality variable multi-rate nonlinear systems for process monitoring, a multi-rate kernel partial least squares algorithm was proposed. The same sampling rate can be achieved in the algorithm by interpolation-filter-decimation, and then kernel partial least squares is implemented. The method made full use of the sample in a large number of incomplete data information and reduced the multi-rate sampling bias caused by data, the offline modeling and online monitoring strategy were proposed. Then case studies on TE process simulation was given to prove the effectiveness of the proposed algorithm compared to kernel partial least squares methods. The results show that the proposed method has a better performance in multi-rate nonlinear systems process monitoring.

14:20-14:40 **SaA05-3**

Data-Driven Neuro-Optimal Tracking Control of Ozone Generation Process Based on Adaptive Dynamic Programming

Zhe Dong North China Univ. of Tech.
Wenjuan Liu North China Univ. of Tech.
Yueheng Li North China Univ. of Tech.
Jie Han North China Univ. of Tech.
Mengjiao Chen North China Univ. of Tech.

Ozone is considered as one of the strongest oxidizing agent, yet it leaves no residues that are harmful to global environment. In this paper, the close loop control of ozone generator has been studied. The main concern of this issue is to achieve desired ozone concentration. Due to the ozone generation process is a complex nonlinear multivariable system, which is different to model and regulate, thus a date-driven neuro-control method is adopted to construct the dynamics of the system, and the adaptive dynamic programming algorithm(ADP) is used for controller design and optimization. According to the hardware-in-loop simulation, the ozone generation process can be effectively approximated by the neuro-network model, and the concentration and flow rate of ozone can be tracked by the ADP controller.

14:40-15:00 **SaA05-4**

Application of Fuzzy Adaptive PID Control Algorithm in Ozone Wastewater Treatment Systems

Xin Sun North China Univ. of Tech.
Zhonghua Pang North China Univ. of Tech.
Cunwu Han North China Univ. of Tech.

With the serious pollution of urban industry, sewage treatment has become an urgent problem to be solved. However, there are many problems in the traditional sewage treatment process, resulting in waste of energy, secondary pollution, and so on. In order to overcome the lack of artificial dosing in ozone water treatment system, this paper presents a fuzzy adaptive PID control algorithm for ozone water treatment systems with large time-delay and strong nonlinear characteristic. The Smith predictor is used to compensate for the large time-delay in chemical reaction and detection instrument, which can improve the response speed. The fuzzy adaptive PID controller is designed to deal with the strong nonlinearity. Simulation results are given to verify the effectiveness of the controller.

15:00-15:20 **SaA05-5**

Research on a Neural Network Model Based on Non-Associative Learning Mechanism and Its Application

Song Bi North China Univ. of Tech.
Qi Diao North China Univ. of Tech.
Xiaofeng Chai North China Univ. of Tech.
Cunwu Han North China Univ. of Tech.

Habituation is non-associative learning mechanism of biological neurons. This paper studied the simplified description of associative learning mechanism, and based on the classical M-P (McCulloch - Pitts) neuron model, put forward study neurons model with the ability of habituation learning, including habituation neurons. At the same time, in this paper, based on the simplified description of Learning neurons, the mathematical model of habituation neurons is designed, and habituation neurons are applied to deep convolution neural networks. It has been verified by experiment that habituation neurons have typical habituation learning ability, and can optimize the performance of convolution networks.

15:20-15:40 **SaA05-6**

Research and Design of Control System Based on NRF24l01 for Intellectualized Vehicle

Dunli Hu North China Univ. of Tech.
Haoran Ke North China Univ. of Tech.
Wenqing Fu North China Univ. of Tech.

Modern production requests higher ability of transportation, thus we need intelligent machine to replace human to work. The automated guided vehicle can carry heavy loads by human, people can choice which way they go and how fast they run. The chip that we select is STM32f103VET6 which can provide many functions and it is frequently-used in intelligent machine. We select L298n to control DC-motor and actuator can control direction. In the way of wireless communication, we use the NRFl24l01 to transfer instruction. To communicate with MCGS, we take RS232 to complete the mission. Then we select electromagnetic transducer of Lan Zhou to get electromagnetic signal and fit the rechargeable battery to provide power for AGV. The control mode is that upper monitor send order to AGV by NRF24l01. Then it transfers order to STM32f103 to control DC-motor.

15:40-16:00 **SaA05-7**

Data Driven Control of Underflow Slurry Concentration in Deep Cone Thickener

Ji-ning Xu North China Univ. of Tech.
Zhan-bin Zhao Beijing JCHX Mine Tech Research Institute Co.
Feng-qiang Wang North China Univ. of Tech.

Deep cone thickener control problem is a key point of Tailings paste fill (TSF). This paper presents a new method to extract inherent and practical parameters of the thickener, and determine control strategy based on thickening process data mining. Bypassing difficulty of deep cone thickener modeling, the proposed method could obtain practical control rules, also has good adaptability to different thickener structure and backfilling materials.

SaA06 Room 6

IS: Modeling, solving, optimization and control for nonlinear systems and multi-agents systems

13:40-16:00

Chair: Ruikun Zhang Qingdao Univ. of Science and Tech.
CO-Chair: Ronghu Chi Qingdao Univ. of Science and Tech.

13:40-14:00 **SaA06-1**

Consensus Tracking of Multi-Agent Systems with Time-delays Using Adaptive Iterative Learning Control

Ruikun Zhang Qingdao Univ. of Science and Tech.
Ronghu Chi Qingdao Univ. of Science and Tech.
Zhongsheng Hou Beijing Jiaotong Univ.

In this technical note, we study the consensus tracking problem of multi-agents system (MAS) with state time-delays. All the agents of the MAS are homogeneous, whose dynamic function is described by a nonlinearly parameterized functions with unknown state time-delays. Moreover, we assume in this paper that the virtual leader (regarded as the desired trajectory) can be accessible to at least one agent. Based on some necessary assumptions, a distributed adaptive iterative learning control (AILC) scheme is proposed. In order to prove the convergence of tracking error, a time-weighted Lyapunov-Krasovskii-Like composite energy function (CEF) is constructed. The result of convergence analysis shows that the proposed control scheme can guarantee all the followers track the virtual leader along the iteration domain. A numerical simulation is given to illustrate the effectiveness of the proposed adaptive iterative learning controller.

14:00-14:20 **SaA06-2**

The Existence of Response Solution for Strongly Dissipative Nonlinear Differential Equations

Xinli Zhang Qingdao Univ. of Science and Tech. Ocean Univ. of China.

We consider the nonlinear equation with dissipative term and the function F is real analytic. By the method based on Renormalizaion Group techniques and Multiscale techniques, we prove the existence of quasi-periodic solutions for the above-mentioned equation. This generalize the known results in the literature.

14:20-14:40 **SaA06-3**

Second-Order Consensus of Multi-Agent Systems with Linear Dynamics

Zunshui Cheng Qingdao Univ. of Science and Tech.
Konghe Xie Qingdao Univ. of Science and Tech.

This paper considers a second-order consensus problem for linear multi-agent systems with directed topology. In the systems, each agent can be controlled by controlling its position and velocity. To reach the consensus of the systems, the feedback gain is designed in the control input of the consensus protocol. The control input of each agent is influenced by its position and velocity. There is a directed spanning tree in the corresponding communication topology. This condition is general and weak. Some sufficient conditions are obtained to solve the consensus problem. At last, a simple case is given to verify the correctness of the results.

14:40-15:00 **SaA06-4**

Direct Torque Control Method of PMSM Based on Fractional Order PID Controller

Yaobin Yue Qingdao Univ. of Science and Tech.
Ruikun Zhang Qingdao Univ. of Science and Tech.
Bing Wu Qingdao Univ. of Science and Tech.
Wei Shao Qingdao Univ. of Science and Tech.

Permanent magnet synchronous motor (PMSM) is a strongly coupled nonlinear system. In this paper, the speed control of PMSM with the direct torque control (DTC) scheme and SVPWM is studied, using the fractional order calculus theory to design the fractional order controller. Simulation results show that the control

system has better dynamic performance and capacity of resisting disturbance than the integer order PID controller. The results provide a theoretical basis and foundation for the development and application of fractional order controller in the PMSM speed control system.

15:00-15:20 **SaA06-5**

Prediction of Shield Machine Tool Failure and the Study of Control Strategy Based on Ant Colony Optimization - The Neural Network

Guotao Zhuang Qingdao Univ. of Science and Tech.
Chunliang Zhao Qingdao Univ. of Science and Tech.
Xin Yue Qingdao Univ. of Science and Tech.
Zongjie Du Qingdao Univ. of Science and Tech.
Shulin Sui Qingdao Univ. of Science and Tech.

It is important significance for cutting down erection time and operation guidance to research of shield machine tool failure. In this paper, we establish tool failure prediction model based on ACO-BP algorithm which combines with the nonlinear mapping characteristics of neural network and mining data characteristics from the subway. We compare systematic choice of the dependent variable and the variable according to the practical problems. For the dependent variable, the authors choose to wear and life respectively according to the cutting tool failure of effect; for the variable, we apply the principal component analysis and gray correlation to choose factors under different targets combined with the actual situation. Ant colony algorithm is used to reduce the problem of low efficiency because of ant colony large-scale iterations. And then, we do fine-tuning through feedback, and select the final weights and threshold, the number of hidden layer nodes. The analysis results show that the ACO-BP prediction model is effective and accurate. Finally, the control strategy for the abnormal damage is given.

15:20-15:40 **SaA06-6**

The Project Management of Corneal Transplantation in Animal Experiments Based on BP Neural Network

Hua Dong Qingdao Univ. of Science and Tech.
Xueying Yang Qingdao Univ. of Science and Tech.

Corneal diseases are increasing year by year in the world, because of the lack of cornea donation. Thus, the management of artificial corneal transplantation becomes more and more necessary. As an important stage of medical device research projects, the animal experiments of artificial cornea should be completed before the clinical trials. In this paper, the cornea was prepared from cornea of pig eyes. Firstly, we use BP neural network to train the data of corneal transplantation of 36 New Zealand rabbits, and then to predict the weighted sum of the remaining 4 New Zealand rabbits. The predictive results were compared with the actual data, and the comparison and error analysis reveal the adaptability and accuracy of the predictive results, which can make us carry out the process monitoring of corneal transplantation, and select the optimal artificial cornea. The project management of corneal transplantation can provide the theoretical support and reference for the management of corneal transplantation, and further lay the experimental foundation for the development of corneal clinical trials.

15:40-16:00 **SaA06-7**

3D Reconstruction of Non-cooperative Target Based on Line Correspondences

Wei Shao Qingdao Univ. of Science and Tech.
Yin Ma Qingdao Univ. of Science and Tech.
Tianhao Gu Qingdao Univ. of Science and Tech.

According to the needs of the development of aerospace technology in China, this paper proposes a method of characteristic line detection and matching to reconstruct accurately and robustly the non-cooperative target. The geometric and algebraic constraints are given by its 2D images, and the linear equations about position and attitude of the aircraft relative to the non-cooperative target are deduced by lines. Then, by using the least-square method, the aircraft's motions are obtained. Lastly, the 3D target is reconstructed by utilizing aircraft's position and attitude. The extensive experiments over simulated images and parameters demonstrate the robustness, accuracy and effectiveness of our method.

SaB01 Room 1
Data-driven control (II) 16:10-18:10

Chair: Shan Liu Zhejiang Univ.
CO-Chair: Tianjiang Hu National Univ. of Defense Tech.

16:10-16:30 **SaB01-1**

Fuzzy Modeling and Control of a Class of Simple Pendulum System Based on Robust Technology

Liang Zhang Bohai Univ.
Ming Li Bohai Univ.

This paper is concerned with the problem of fuzzy modeling in the T-S fuzzy systems. In order to obtain relative simple T-S fuzzy model, combined with the traditional linearization approximation method on the fuzzy modeling. It deals the nonlinear term of unable to approximate with the same method of the uncertainties of processing, so that it could design the uncertainty T-S fuzzy system with the robust technology. Although the presented modeling method will obtain larger dimension matrix inequality, it can be decreased the number of fuzzy rules. The matrix inequality dimension and the number of fuzzy rules would be discussed in a simulation example based on the comparison of control calculation burden.

16:30-16:50 **SaB01-2**

Robustness Analysis of the Complex Network

Mingxin Liang Southwest Univ.
Fanzhen Lin Southwest Univ.
Chao Gao Southwest Univ.
Zili Zhang Southwest Univ.

The robustness is one of the primary characteristics of a real system, which impacts the function and performance of the system. Many real systems in our real world can be formulated as complex networks. It is a feasible method to estimate the robustness of real systems from the perspective of complex networks. The robustness evaluation is one of the basic and hot research topics in the field of complex networks. This paper presents a network-based simulation platform for analyzing and evaluating the robustness of a real system in terms of existing famous measurements. Furthermore, some experiments are implemented in networks with various topologies and scales under the conditions of different types of attacks. The results show that the structural topology is the major factor in the robustness of a network. And malicious attacks result in more damages than random attacks. And there is a correlation among different attack patterns based on various vertex centralities.

16:50-17:10 **SaB01-3**

Design and Implementation of a Gasoline-Electric Hybrid Propulsion System for a Micro Triple Tilt-Rotor VTOL UAV

Wang Lu National Univ. of Defense Tech.
Daibing Zhang National Univ. of Defense Tech.
Jiyang Zhang National Univ. of Defense Tech.
Tengxiang Li National Univ. of Defense Tech.
Tianjiang Hu National Univ. of Defense Tech.

Vertical take-off and landing (VTOL) aerial vehicles have been a hot topic in the aerospace field, since they possess joint advantages of the multi-rotor drone and the fixed-wing unmanned aerial vehicle (UAV). In this paper, a novel propulsion scheme is concentrated on for a micro triple tilt-rotor VTOL prototype. Furthermore, the design, implementation and analysis of a gasoline-electric hybrid propulsion system are respectively presented. Hybrid power architecture is designed with constraints on the characteristics of the power-plants and the energy and is based on three fundamental hybrid-electric configurations. The dynamic model and attitude control principle is also given for this triple tilt-rotor VTOL UAV. Dynamics performance testing is conducted by flight experiments of the developed micro triple tilt-rotor VTOL prototype.

17:10-17:30 **SaB01-4**

Visual Servo Control for Wheeled Robot Platooning Based on Homography

Yu Cao Zhejiang Univ.
Shan Liu Zhejiang Univ.

This paper presents a visual servo control approach based on homography for the leader-follower platooning system which consists of two wheeled robots. The proposed approach only requires the image taken under the ideal position with respect to the leader and correspond distance to the plane pattern attach to leader robot. A virtual robot can be generated according the homography and leader robot, thus, the platooning control is transformed into the trajectory tracking problem in this paper. Instead of common homography decomposition, the entries of homography matrix are used to design the estimator for velocity of the leader and control law to drive the follower to reach desired position in leader-follower platooning system under the satisfy-action of the nonholonomic constraints. In the end, the simulation verifies the feasibility and effectiveness of the approach.

17:30-17:50 **SaB01-5**

Study on Middle and Low Speed Maglev Track Irregularity Detection Based on Threshold Filtering Algorithm

Junyuan Tang National Univ. of Defense Tech.
Jun Wu National Univ. of Defense Tech.
Shengjun Huang National Univ. of Defense Tech.

Maglev train is a new urban transportation tool, and as a significant component of maglev transportation system, the track would directly affect the safety of train operation. An algorithm based on triple threshold filtering is put forward to conduct detection of maglev track, which can be used to screen abnormal points to judge the vertical suspected irregularity of track. In the scheme proposed herein, the threshold setting for clearance differences, current change rate, acceleration differences on suspended controller are conducted according to characteristics of low sampling rate, high data repeatability and large data volume of automobile data recorder, it can extract information of track irregularity. In order to improve the reliability of the algorithm, 20 sets of data from 5 independent bogies of multiple vehicles are clustered for analysis, and get the suspected position range of track irregularity. The data of maglev train of Changsha operating railway was tested finally.

SaB02 Room2
Data-driven modeling, optimization, scheduling, decision, and simulation (II) 16:10-18:10

Chair: Yan Li Shandong Univ.
CO-Chair: Darong Huang Chongqing Jiaotong Univ.

16:10-16:30 **SaB02-1**

Smart Distribution Network Operating Condition Recognition Based on Big Data Analysis

Min Fan Chongqing Univ.
Bo Zhang China Electric Power Research Institute
Qiang Yao Beijing Inhand Networks Co. LTD.
Jianliang Zhang Beijing Inhand Networks Co. LTD.

Darong Huang Chongqing Jiaotong Univ.
Qi Han Chongqing Univ.

In order to guarantee the power quality and the highly efficient operation of the power network, a reliable operating condition recognition system of distribution networks is necessary. For the sake of solving the problem of multi-condition recognition, an operating condition recognition system based on the workflow of decision-making tree is proposed. In the process, big data of waveforms acquired by an online recording system is transformed into characteristics through time-domain, frequency-domain and wavelet transformation, and ANN (Artificial Neural Networks) models is automatically built with the training of those characteristics of waveform data. As shown by the experimental results, this recognition system can accurately recognize operating conditions and improve the automatic operating capacity of distribution networks.

16:30-16:50 **SaB02-2**

Data Fusion for Multi-Structure and Unequal-Precision Estimation

Zhangming He National Univ. of Defense Tech.
Zhengfang Ma No. 11 School, NingXiang.
Jiongqi Wang National Univ. of Defense Tech.
Xuanyin Zhou National Univ. of Defense Tech.
Zhiwen Chen No. 11 School, NingXiang
Dayi Wang Univ. of Central South
Bowen Hou National Univ. of Defense Tech.

Data fusion for parameter estimation with multi-structure and unequal-precision is considered in this paper. Matrix tools e.g., congruent transformation, trace function and matrix differential, are used to analyze the estimation performance. Theoretical results reveal that: the single equipment estimate, the optimal fusion estimate, and the joint estimate are some special cases of the fusion estimate. Moreover, the precisions of different fusion estimation methods are compared, the relations among which are provided in the following theorems. The performance of the four estimates are validated by the simulation of trajectory calculation for the V-2 missile.

16:50-17:10 **SaB02-3**

Inferring Waiting Time Distributions of Temporal Networks Using Unicast-Based Active Sampling

Xun Li Fudan Univ.
Lang Cao Zhengzhou Univ.

Recent empirical evidence from research on temporal networks has shown the time constraints imposed on individual interactions are crucial for understanding the generic structure and dynamics of networks. A desirable but challenging task is sampling the waiting time distribution (WTD) associated with their internal interactions, a defining feature that reflects the added time dimension of temporal networks. Here, we extend the random-walk exploration techniques for static networks to adapt to this time-extended inferential problem. Specifically, we propose an active unicast protocol where random walk is assumed to occur at the moment of the α-th appearance of outgoing temporal link, with parameter α unnecessarily equal to 1. Using the ``Redistribute-to-the-Right'' imputation technique, we find that this purposely delayed transition mechanism of random walk allows correct recovery of the entire distributional shape of underlying WTDs, including a variety of empirically relevant, non-Poissonian cases. Numerical results also verify the validity of the proposed self-consistent iterative estimator for WTDs. Our scheme provides an effective and flexible route for active sampling of temporal networks and can be extended in a broad array of applications.

17:10-17:30 **SaB02-4**

Data-Driven Augmented Reality Display and Operations for UAV Ground Stations

Xiaoyue Ji National Univ. of Defense Tech.
Xiaojia Xiang National Univ. of Defense Tech.
Tianjiang Hu National Univ. of Defense Tech.

The commonly used 2D Display is limited in aiding operators to control unmanned aerial vehicles (UAVs) within complex environments, due to its weak immersion. In this paper, we propose a data-driven 3D augmented reality approach. Pre-known data and experience can be integrated into to constructing a 3D virtual scenario. Furthermore, the on-board sensor data are continuously updated to this scenario during the task process. Under such circumstance, the static scenario and dynamic data are fused together by using the UAV's position and orientation. Task-associated information, e.g. route points and flying status, is simultaneously imported into the scenario to augment the virtual reality and to support the operator as well. Eventually, the AR ground station prototype is designed and implemented. Experimental results of quad rotors demonstrate that the developed system is feasible and effective to strengthen immersion with the virtual reality glasses.

17:30-17:50 **SaB02-5**

Fractional Order Dynamics for Clarithromycin against Helicobacter Pylori

Yan Li Shandong Univ.
Yundong Sun Shandong Univ.
Wenchao Wang Shandong Univ.

This paper discusses a novel strategy of dynamic modeling of clarithromycin against Helicobacter pylori. A nonlinear fractional order equivalent circuit model is proposed to describe kill-time curves for different concentrations of antibiotics and different ages of bacteria. The efficiency of the time domain analysis method has been proved by plenty of tested data. All

model parameters and variables, that come from external data, are closely related to the internal characteristics of antibiotics against bacterium. It provides a group of quantified indices of bactericidal mechanism in spite of knowledge of complex micro-scale mechanisms. A number of conjectures are presented to extend possible applications of this paper.

SaB03 **Room 3**
Reinforcement learning **16:10-18:10**

Chair: Xin Xu National Univ. of Defense Tech.
CO-Chair: Qinglai Wei Institute of Automation, Chinese Academy of Sciences

16:10-16:30 **SaB03-1**

Data-Driven vs Model-Driven Imitative Learning

Hamidou Tembine New York University Abu Dhabi

One of the fundamental problems of an interconnected interactive system is the huge amounts of data that are being generated by every entity. Unfortunately, we seek information not data, and therefore, a growing bottleneck is exactly how to extract and learn useful information from data. In this paper, we study information-theoretic learning in data-driven games. We show that the imitative Boltzmann-Gibbs strategy is the maximizer of the perturbed payoff where the perturbation function is the relative entropy from the previous strategy to the current one. In particular, the imitative strategy is the best learning scheme with the respect to data-driven games with cost of moves. Based on it, we revisit the classical imitative Boltzmann-Gibbs learning in data-driven games. Due to communication complexity and noisy data measurements, the classical imitative Boltzmann-Gibbs cannot be applied directly in situations were only numerical values of player's own payoff is measured. A combined fully distributed payoff and strategy imitative learning (CODIPAS) is proposed. Connections between the rest points of the resulting game dynamics, equilibria are established.

16:30-16:50 **SaB03-2**

Constrained Robust Optimal Sliding Mode Control for Uncertain Nonlinear Systems Using ADP Approach

Qiuxia Qu Northeastern Univ.
Huaguang Zhang Northeastern Univ.
Rui Yu Northeastern Univ.
Geyang Xiao Northeastern Univ.

In this paper, a novel constrained composite sliding mode controller is studied for uncertain nonlinear systems with input saturation. Based on integral sliding mode (ISM) and approximate dynamic programming (ADP) theory, the proposed sliding mode control consists of discontinuous control used for completely compensating matched uncertainties and continuous control which results in an optimal sliding mode dynamics. Without using linearization techniques, the constrained optimal control law for nominal nonlinear systems is approximated by using an online approximate learning algorithm with actor-critic NN framework. Lyapunov techniques are used to demonstrate the uniform ultimate bounded (UUB) convergence condition for closed-loop nominal system and the weight errors.

16:50-17:10 **SaB03-3**

A Data-Driven ADP with RBF Network and LMS Learning Algorithm

Zhijian Huang Shanghai Maritime Univ.
Shanghai Jiao Tong Univ.
Yudong Li Shanghai Maritime Univ.
Wentao Chen Shanghai Maritime Univ
Qin Zhang Shanghai Maritime Univ
Qili Wu Shanghai Maritime Univ
Qinmin Tan Shanghai Maritime Univ
Zhiyuan Yang Shanghai Maritime Univ

ADP is an effective optimal method. However, the optimal effect depends on its network structure and training algorithm. This paper adopts RBF neural network to realize its critic and action networks after a detailed analysis on ADP. The LMS method is introduced as training algorithm, and a novel basis function is defined, which achieves global optimization and online control. The validity is verified by finding the optimal point through local minimums.

17:10-17:30 **SaB03-4**

A Multi-Agent Reinforcement Learning Algorithm Based on Stackelberg Game

Chi Cheng Nanjing Univ.
Zhangqing Zhu Nanjing Univ.
Bo Xin Nanjing Univ.
Chunlin Chen Nanjing Univ.

Multi-agent reinforcement learning has been paid much attention due to its wide applications in various engineering systems. In this paper, the control problems in large-scale multi-agent systems with multiple roles are formulated into a multi-player Stackelberg game, which provides a new perspective on cooperative issues. Then a Stackelberg Q-learning algorithm is proposed and knowledge transfer is applied to improve the efficiency of the learning process. Finally the proposed algorithm is applied to cognitive radio networks. Simulation results indicate that the Stackelberg Q-learning algorithm can efficiently promote the utility of the agents in the system, and significantly reduce the interference caused by the jammer.

17:30-17:50 **SaB03-5**

A Kernel-Based Extreme Learning Modeling Method for Speed Decision Making of Autonomous Land Vehicles

Xiangfei Wu National Univ. of Defense Tech.
Xin Xu National Univ. of Defense Tech.
Xiaohui Li National Univ. of Defense Tech.
Kai Li National Univ. of Defense Tech.

Bohan Jiang National Univ. of Defense Tech.

This paper presents a kernel-based extreme learning machine (KELM) modeling method for speed decision making of autonomous land vehicles (ALVs) on rural roads. The model is obtained offline via the KELM algorithm using a small number of typical samples collected by an ALV platform on rural roads from experienced drivers. Compared with other typical machine learning algorithms such as support vector regression and extreme learning machine, the KELM method has the advantages of fast training speed and higher modeling precision. Real-vehicle experiments have been carried out to test the model on an ALV platform on rural roads online. The experimental results demonstrate the effectiveness of the proposed speed decision-making model.

17:30-17:50 **SaB03-6**

Improving Reinforcement Learning Output Feedback Control for Unknown Nonlinear Pure Feedback System

Dazi Li Beijing Univ. of Chemical Tech.
Wei Wang Beijing Univ. of Chemical Tech.

Due to the nonaffine nature, tracking control of unknown nonlinear pure feedback system is difficult. Traditional control method based on backstepping has the problem of differential explosion. Reinforcement learning control strategy can avoid this problem. However, the tracking error is relatively large because of lack of system structure information. To overcome this problem, an improved reinforcement learning algorithm by a novel actor network weight correction factor is proposed. This factor can adaptively adjust the weight update rate according to the change of the reference trajectory so that the control policy will be adjusted more timely. Simulation results demonstrate that performance of the controller is improved significantly.

SaB04 Room 4

IS: Data-driven fault diagnosis and process monitoring for complicated industrial systems (II) 16:10-18:10

Chair: Jing Wang Beijing Univ. of Chemical Tech.
CO-Chair: Zhihuan Song Zhejiang Univ.

16:10-16:30 **SaB04-1**

Density Peaks Clustering Based Sub-Phase Partition and Monitoring for Batch Process

Haolan Yan Huazhong Univ. of Science and Tech.
Weidong Yang Huazhong Univ. of Science and Tech.
Hong Zhang Huazhong Univ. of Science and Tech.
Bo Tao Huazhong Univ. of Science and Tech.
Ying Zheng Huazhong Univ. of Science and Tech.

Multi-phase is one of the characteristics of the batch process. In this paper, Density Peaks Clustering (DPC) algorithm is applied to identify the different sub-phases and transition phase of batch processes. First, the three-dimensional training data is unfolded into K time-slice two-dimensional matrices. Then, the DPC algorithm is used to find out the cluster centers and divide the process into multiple sub-phases. In DPC algorithm, local density and the minimum distance between the data points are calculated to find the most suitable cluster centers. Finally, Multi PCA models are built for each sub-phase, and T^2 and SPE statistics are computed to monitor the process online. The proposed method has the following advantages: firstly, it can identify the different sub-phases including transition phases; secondly, there is no need to specify the cluster numbers and initialize cluster centers; finally, it does not require a prior knowledge, and has low computational complexity. This method is applied on penicillin fermentation simulation system. The results verify the effectiveness of the proposed method.

16:30-16:50 **SaB04-2**

An Anti-Windup IMC Structure with Feed-Forward Compensators Base on Qualitative Analysis

Zhongwei Liu Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.
Qibing Jin Beijing Univ. of Chemical Tech.
Linfeng Qi Beijing Univ. of Chemical Tech.
Beiyan Jiang Beijing Univ. of Chemical Tech.

This paper addresses a feed-forward anti-windup structure and its detailed realization method based on qualitative analysis, by adding three static compensators to the Internal model control (IMC) structure to compensate the controller output defects caused by the input saturation, which has a perfect tracking performance and interference elimination. A new anti-windup IMC structure with three feed-forward compensators which can be transformed into IMC-PID controller is provided, with a design procedure formulated as a constrained optimization problem depended on SCS algorithm. Illustrative examples are given to show the effectiveness and merits of the Anti-windup IMC-PID structure based on the qualitative analysis.

16:50-17:10 **SaB04-3**

Fault Diagnosis Based on Sparse Class Gaussian Restrict Boltzmann Machine Model

Jie Yang Zhejiang Univ.
Zhihuan Song Zhejiang Univ.
Li Jiang Zhejiang Univ.

Restrict Boltzmann Machine, a generative model that consists of one visible layer and one hidden layer, plays an important role in deep learning. It can be used as a feature extractor in an unsupervised way. In process diagnosis area, we develop the Sparse Class Gaussian Restrict Boltzmann Machine as a discriminative nonlinear feature extractor for classification in order to solve the discriminative task. Moreover, for the purpose of overcoming the overfitting and raising the training efficiency, we add a sparse constraint for the hidden

layer during the training time. Our experimental results based on TE process benchmark successfully demonstrate that this model significantly outperforms MLP classifier, and other GRBM based models, and the sparse constraint we employed has a positive effect on the classification performance.

17:10-17:30 **SaB04-4**

Performance Assessment Based on Minimum Entropy of Feedback Control Loops

Huiyuan You Beijing Univ. of Chemical Tech.
Jinglin Zhou Beijing Univ. of Chemical Tech.
Haijiang Zhu Beijing Univ. of Chemical Tech.
Dazi Li Beijing Univ. of Chemical Tech.

Performance assessment for control loop is mainly to check whether the control loop runs in a healthy and economic operation state or not, while variance is usually as an index implied in conventional performance assessment methods for feedback control loop. The former assessment methods are quite effective in assessment of linear Gaussian system. But if the disturbance follows non-Gaussian distribution such as bimodal distribution, performance assessment based on variance may not fit. In this paper, to assess non-Gaussian control loop system, entropy of feedback-invariant in linear non-Gaussian system is calculated firstly. Then, we focus on a new benchmark based on information theory and minimum entropy criterion, and the method of estimating entropy assessment index is proposed. Finally, examples are given to demonstrate the effectiveness.

17:30-17:50 **SaB04-5**

Incipient Fault Feature Extraction Method of Gearbox Based on Wavelet Package and PCA

Ding Jing Chongqing Jiaotong Univ.
Ling Zhao Chongqing Jiaotong Univ.
Chongqing Univ.
Darong Huang Chongqing Jiaotong Univ.

A fault feature extraction model based on PCA and wavelet packet is proposed to describe the characteristics of gearbox fault feature, which is expressed by low amplitude of the vibration signals, and easy to be disturbed by system and noise. Firstly, the PCA is used to reduce the correlation between the data dimension and the data. Then, the gearbox signals are decomposed by wavelet packet, and reconstructed based on the frequency bandwidth characteristics. After choosing those main frequency band which reflects the change of signal caused by the fault, and normalizing the selected frequency band, then we can obtain the fault characteristic value. Finally, the vibration signal of the gearbox is treated as an example to verify the effectiveness of the method. The comparative analysis shows that the combination of PCA and wavelet packet is more effective than the wavelet packet.

SaB05 Room 5

IS: Data-based learning and network control 16:10-18:10

Chair: Deyuan Meng Beihang Univ.
CO-Chair: Lin Zhao Qingdao Univ.

16:10-16:30 **SaB05-1**

Adaptive Bipartite Consensus Tracking Control for Coopetition Multi-Agent Systems with Input Saturation

Lin Zhao Qingdao Univ.
Jinpeng Yu Qingdao Univ.

This paper studies the adaptive bipartite consensus tracking problems for second-order coopetition multi-agent systems with input saturation. A fuzzy-based command filtered backstepping scheme is developed, which can guarantee the bipartite position tracking errors converging to the desired neighborhood and all the closed-loop signals are bounded although the nonlinear dynamics are unknown and the input saturation exists. An example is included to verify the proposed method.

16:30-16:50 **SaB05-2**

Microarray Classification with Noise via Weighted Adaptive Elastic Net

Juntao Li Henan Univ of Economics and Law
Jingxuan Wang Capital Medical Univ.
Yuhan Zheng Henan Normal Univ.
Huimin Xiao Henan Univ of Economics and Law

Adaptive elastic net has been widely studied in microarray classification due to the elegant performances in gene selection. However, the classification accuracy will be affected if noise is included. This paper proposes a weighted adaptive elastic net for binary microarray classification with noise by using the distances from the sample points to both class centers. The performance of adaptive gene selection is proved and the solution path algorithm is developed. Results on two cancer data added 4 additional samples illustrate that the weighted adaptive elastic net can achieve considerable classification accuracy and select the genes related with diseases.

16:50-17:10 **SaB05-3**

Consensus Problems on Multi-Agent Networks with Directed Dynamic Interactions

Lingyu Li China Electronics Tech Group Corp.
Weili Niu Beihang Univ.

This paper deals with cooperative control problems for multi-agent networks subject to directed dynamic interactions. The directed dynamic interactions in these networks are described by directed dynamic graphs which admit adjacency weights of edges in terms of transfer functions. A distributed dynamic protocol is proposed based on the nearest neighbor rule, and the Lyapunov-based approach is adopted to perform convergence analysis of networks. We prove that, with

adjacency weights being appropriately designed, the networks can achieve consensus if and only if the directed dynamic graph contains a spanning tree. Simulations are given to illustrate the effectiveness of the proposed consensus results for cooperative networks in the presence of directed dynamic interactions.

17:10-17:30 **SaB05-4**

Robust Iterative Learning Control with High-Order Internal Models for SISO Nonrepetitive Systems

Jingyao Zhang Beihang Univ.
Deyuan Meng Beihang Univ.
Wei Feng Beihang Univ.

In this paper, we address robust iterative learning control (ILC) problem for nonrepetitive systems subject to iteration-varying desired references generated by high-order internal models (HOIM). A modified high-order ILC algorithm is proposed by incorporating HOIM into the ILC algorithm design. We give one condition to guarantee the bounded system trajectories and tracking errors under the assumption that all system matrices, initial states, learning gain coefficients and iteration-varying reference trajectories are bounded. Furthermore, if the variations of all system matrices between two successive iterations converge to zeros and the initial state at each iteration satisfies the HOIM progressively, we give one additional condition together with the former one to guarantee the perfect zero-error tracking.

17:30-17:50 **SaB05-5**

Robust Exponential Consensus of Multi-Agent Systems with Switching Topologies and Communication Delays

Bin Zhang Beijing Univ. of Posts and Telecommunication

The robust exponential consensus problems of multi-agent systems with switching topologies and communication delays are investigated by using Lyapunov-Krasovskii functions. A neighbor-based protocol is introduced, based on which the closed-loop system is transformed into a reduced-order form. Sufficient conditions in terms of a matrix inequality are given which guarantee robust exponential consensus of the system with a desired stability degree. In addition, the result is extended to the case in the presence of actuator faults. Simulations are provided to demonstrate the effectiveness of the theoretical results.

SaB06 **Room 6**

IS: Data-based modeling, control, and intelligent monitoring in complex processes **16:10-18:10**

Chair: Ronghu Chi Qingdao Univ. of Science and Tech.

CO-Chair: Mingming Lin Qingdao Univ. of Science and Tech.

16:10-16:30 **SaB06-1**

Coal Mine Safety Warning System Based on Principal Component Method and Neural Network

Xiangzhong Meng Qingdao Univ. of Science and Tech.
Peng Lu Qingdao Univ. of Science and Tech.

This paper introduces the safety situation of coal production and the current situation of the applications of data driven approaches in coal mine safety early warning. Through the analysis of coal mine monitoring data and coal mine safety accidents, this paper presents a fault diagnosis method based on principal component method and BP neural network. The principal component method is used to extract the information of coal mine fault state from monitoring data. By establishing a BP neural network model, the extracted information is then used as fault sample input of the neural network. Research indicates, this fault diagnosis method takes the advantages principal component method and BP neural network and can effectively extract the coal mine fault state characteristics to achieve fault early warning.

16:30-16:50 **SaB06-2**

Propulsion Motor Vector Control based on ILC for Dynamic Positioning System

Wenlong Yao Qingdao Univ. of Science and Tech.
Ronghu Chi Qingdao Univ. of Science and Tech.
Yuan Liu Qingdao Ocean Shipping Mariners College
Ailing Chen Qingdao Ocean Shipping Mariners College

Speed sensorless vector control of propulsion motor for dynamic positioning system based on ILC is proposed for the problem of frequency operation of the controller which caused by the unknown external load disturbance that acting in the propulsion motor of dynamic positioning system. The periodic torque ripples are reduced by introducing the speed error compensation based on ILC into the update algorithm of the speed sensorless vector control by utilizing the previous error data and error changing trend, and the results were compared with the traditional speed sensorless PI vector control. It shows that the torque ripples of propulsion motor were minimized, the state observer accuracy and robustness performance of the dynamic positioning control system was improved.

16:50-17:10 **SaB06-3**

Data-Driven Adaptive Iterative Learning Predictive Control

Yunkai Lv Qingdao Univ. of Science and Tech.
Ronghu Chi Qingdao Univ. of Science and Tech.

A novel data driven predictive iterative learning control (DDPILC) is proposed for a class of discrete nonlinear systems in this work. The design of the controller only depends on the I/O data of the system and no explicit process model is required. More prediction information along the iteration axis is utilized in the learning control

law to improve the control performance. The availability of the proposed approaches is verified by simulation results.

17:10-17:30 **SaB06-4**

Iterative Learning State Estimation for Nonlinear Repetitive Processes

Yu Hui Qingdao Univ. of Science and Tech.
Ronghu Chi Qingdao Univ. of Science and Tech.

This paper explores the question about iterative learning observer design about a kind of nonlinear plants have repetitive operating characteristics. Different from traditional methods, the proposed iterative learning state observer is conducted and updated along the iteration direction. Furthermore, the method has been proposed has data-driven nature and derives from nonlinear systems directly, where no any model information is required except for the input and output measurements. A simulation case was employed to prove the performance of the given observer.

17:30-17:50 **SaB06-5**

Model Free Adaptive Control for Organic Rankine Cycle Processes

Mingming Lin Qingdao Univ. of Science and Tech.
Ronghu Chi Qingdao Univ. of Science and Tech.
Xiaohong Yin Qingdao Univ. of Science and Tech.
Ximei Liu Qingdao Univ. of Science and Tech.

In this paper, a data-driven model free adaptive control (MFAC) scheme, based on a novel transformation and linearization of the evaporator model, is developed for superheat at the evaporator outlet in an organic Rankine cycle (ORC) processes. The designing procedures of the proposed approach are presented. The main feature of the method is that the controller designing depends only on the measured input pump rotating speed and output superheat. Simulation results demonstrate the effectiveness of the proposed controller.