FINAL PROGRAM and BOOK OF ABSTRACTS

2019 IEEE 8th Data Driven Control and Learning Systems Conference (DDCLS'19)

Dali, China

May 24 –27, 2019

Organized by

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

Beijing Jiaotong University

Locally Organized by

Yunnan Association of Automation

Sponsored by

IEEE Beijing Section

IEEE Industrial Electronics Society

Kunming University of Science and Technology

Dali University

Qingdao University

Qingdao University of Science & Technology

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Welcome Message from General Chairs

Zhongsheng Hou
General Chair of DDCLS'19

Jiande Wu
General Chair of DDCLS'19

Dear Friends and Colleagues,

On behalf of the Organizing Committee, it is our greatest pleasure to welcome you to the 2019 IEEE 8th Data Driven Control and Learning Systems Conference (DDCLS'19), which is organized by Technical Committee on Data Driven Control, Learning and Optimization (DDCLO), Chinese Association of Automation, and Beijing Jiaotong University, locally organized by Yunnan Association of Automation, and sponsored by IEEE Beijing Section, IEEE Industrial Electronics Society, Kunming University of Science and Technology, Dali University and Qingdao University, all are from China. The conference is held at Grand Bay View International Hotel, Dali, Yunnan Province, China, May 24–27, 2019.

Data driven control and learning systems, together with model-based control methods forming the complete control theory, is an emerging hot research area in the field of automation engineering and in systems & control community. It focuses on control, learning and optimization for the plants whose models are unavailable. Although the study on data driven control and learning is still in the embryonic stage, it has attracted a great amount of attention within the systems and control community, such as the special issues published in the top journals: *ACTA AUTOMATICA SINICA* (2009), *IEEE Transactions on Neural Networks* (2011), *Information Sciences* (2013), *IEEE Transactions on Industrial Informatics* (2013), *IEEE Transactions on Industrial Electronics* (2015, 2017), and *IET Control Theory & Applications* (2015, 2016). In this year, the keywords 'Data Driven Control' has been formally listed with the application code F030110 as a new research domain in the project catalog of the National Natural Science Foundation of China. Further, the data driven control and learning systems would be fundamental challenges in the coming age of the *Internet of Things*, *Cyber-Physical Systems*, *Industry 4.0*, *China Manufacturing 2025*, and *Artificial Intelligence 2.0* under the big data environment, which is already on our road ahead but beyond the traditional systems & control methods.

As an inheritance of previous seven workshops, DDCLS'19 continues to attract broad interest throughout

the world, with the submission of 310 papers. This reflects the increasing interest in our field, and meanwhile creates a difficult workload in evaluating the papers and organizing a cohesive program. We are fortunate to have an exceptional Technical Program Committee (TPC) that sorted through the evaluations and integrated the individual submissions into the final technical program described in the proceedings. We also want to thank our Organizing Committee for their invaluable assistance in arranging the diverse offerings at the conference, from registration and local arrangements to technical programs. Last but not least, we would like to express our deep appreciation to Yunnan Association of Automation, Kunming University of Science and Technology and Dali 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'19 technical program comprises 24 regular sessions, 17 invited sessions and 1 best paper award session. Besides the technical sessions, the highlights of the DDCLS'19 are the keynote addresses given by distinguished senior scholars including Prof. Marios M. Polycarpou from Cyprus, Prof. Cesare Alippi from Italy, and Prof. Guanghong Yang from China, and the distinguished lectures given by active young scholars including Prof. Wei He, Jing Na, Zhiqiang Ge, Wenchao Xu, Jing Wang, Long Cheng and Xuhui Bu all from China. We sincerely appreciate all the contributors, keynote address speakers, distinguished lecture speakers, invited session organizers, and session chairs for their tremendous efforts towards a top-quality conference.

We also want to thank the 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 Dali, Yunnan Province, China and enjoy the colorful scenery and magic foods.

Best wishes

Zhongsheng Hou
General Chair of DDCLS'19

Jiande Wu
General Chair of DDCLS'19

Message from Technical Program Chairs

Mingxuan Sun
Technical Program Chair

Huaguang Zhang
Technical Program Chair

Dear Friends and Colleagues,

On behalf of the Technical Program Committee, it is our great honor to welcome you to the 2019 IEEE 8th Data Driven Control and Learning Systems Conference (DDCLS'19) in Dali, China.

The annual event of DDCLS has proven to be one of the excellent forums for scientists, researchers, engineers, and industrial practitioners to present and discuss the latest technological advancements as well as future directions and trends in Data Driven Control, Learning and Optimization, and to set up useful links for their works. DDCLS'19 has received enthusiastic responses with a total of 310 submissions. All the submissions had been processed by the Technical Program Committee. All committee members worked professionally, responsibly, and diligently. Besides evaluations from reviewers, each member also provided his/her own assessments on the assigned papers, so as to ensure that only high-quality papers would be accepted. Their commitment and hard work have enabled us to put together a very solid proceeding for our conference. The proceeding includes 257 papers which are divided into 42 oral sessions for presentation.

Along with the parallel technical sessions, we shall have three keynote addresses to be delivered by eminent researchers. These lectures will address the state-of-the-art developments and leading-edge research topics in both theory and applications in Data Driven Control, Learning and Optimization. We are indeed honored to have Prof. Marios M. Polycarpou (University of Cyprus), Prof. Cesare Alippi (Politecnico di Milano), and Prof. Guanghong Yang (Northeastern University) as the keynote address speakers. Besides, we are very lucky to have Prof. Wei He (University of Science and Technology Beijing), Jing Na (Kunming University of Science & Technology), Zhiqiang Ge (Zhejiang University), Wenchao Xu (Academy of Mathematics and Systems Science, Chinese Academy of Sciences), Jing Wang (Beijing University of Chemical Technology), Long Cheng (Institute of Automation, Chinese Academy of Sciences) and Xuhui Bu (Henan Polytechnic 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

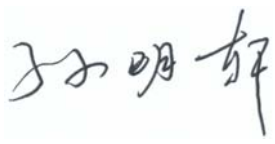
of them for their enthusiastic contributions and strong supports to DDCLS’19.

To promote the development of Data Driven Control, Learning and Optimization, we will present the “DDCLS Best Paper Award” at DDCLS’19. Based on reviewers' comments and nominations as well as the evaluations of Technical Program Committee members, 16 papers were selected for the consideration of the award by the Best Paper Award Committee. These papers were sent to distinguished experts in the relevant areas for additional evaluations in a double-blind manner. Based on their comments and recommendations, 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’19 Best Paper Award Committee. The winner of the "DDCLS Best Paper Award" will be determined by the Best Paper Award Committee after assessing the oral presentations.

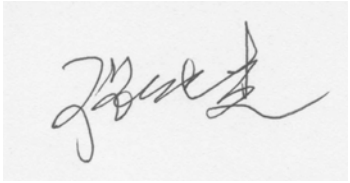
A U-disk containing the PDF files of all papers scheduled in the program and an Abstract Book will be provided at the conference to each registered participant as part of the registration material. The official conference proceedings will be published by the IEEE and included in the IEEE Xplore Database.

On behalf of the Technical Program Committee, we would like to thank all reviewers for giving time and expertise to provide comments, which are contributive to the Committee in making a fair decision on the acceptance/rejection of each paper. Thanks also go to the dedication, diligence, and commitments of the Invited Session Chairs Prof. Zengqiang Chen, Prof. Fei Qiao, Prof. Senping Tian, Prof. Qinglai Wei and Prof. Zhanshan Wang, Subject Session Chairs Prof. Zhihuan Song, Prof. Dongbin Zhao, Prof. Xin Xu and Prof. Xisheng Dai, and all the members of the Technical Program Committee. We would like to gladly acknowledge the technical sponsorship provided by the Organizing Committee of DDCLS’19 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’19 in Dali is really stimulating, rewarding, enjoyable, and memorable.



Mingxuan Sun
Technical Program Chair



Huaguang Zhang
Technical Program Chair

Keynote Address

Keynote Address 1

Fault Tolerant Control: A Lifelong Cooperative Learning Approach

Prof. Marios M. Polycarpou
University of Cyprus, Cyprus

Saturday, May 25, 2019
08:20-09:20
Qianqiusui Hall / 千秋岁

Abstract

Current developments in information and communication technologies empower new opportunities and present new challenges in monitoring and control of cyber-physical systems. The proliferation of low-cost sensing generates large amounts of heterogeneous data that need to be processed and interpreted in real time. The ubiquitous availability of data communications opens up new prospects for large-scale distributed decision and control. However, in situations where some components behave abnormally or become faulty, this may lead to serious degradation in performance or even to catastrophic system failures, especially due to cascaded effects of the interconnected subsystems. The goal of this presentation is to provide insight into various aspects of the design and analysis of fault tolerant control, to discuss a novel approach based on lifelong cooperative learning and to discuss directions for future research.

Biography

Marios M. Polycarpou is a Professor of Electrical and Computer Engineering and the Director of the KIOS Research and Innovation Center of Excellence at the University of Cyprus. He received the B.A degree in Computer Science and the B.Sc. in Electrical Engineering, both from Rice University, USA in 1987, and the M.S. and Ph.D. degrees in Electrical Engineering from the University of Southern California, in 1989 and 1992 respectively. He was the Founding Department Chair of the Electrical and Computer Engineering Dept at the University of Cyprus (2001-2008). His teaching and research interests are in intelligent systems and networks, fault diagnosis, computational intelligence, adaptive and cooperative control systems. Dr. Polycarpou has published more than 300 articles in refereed journals, edited books and refereed conference proceedings, and co-authored 7 books. He is also the holder of 6 patents. Prof. Polycarpou is the recipient of the 2016 IEEE Neural Networks Pioneer Award. He is a Fellow of IEEE and IFAC, and he received with his co-authors the 2014 Best Paper Award for the journal Building and Environment (Elsevier).

Prof Polycarpou served as the President of the IEEE Computational Intelligence Society (2012-2013), and as the Editor-in-Chief of the IEEE Transactions on Neural Networks and Learning Systems (2004-2010). He is currently the President of the European Control Association (EUCA). Prof. Polycarpou has participated in more than 60 research projects/grants, funded by several agencies and industry in Europe and the United States, including the prestigious European Research Council (ERC) Advanced Grant and the EU Teaming project.

Keynote Address 2

Neural Graph Processing

Prof. Cesare Alippi
Politecnico di Milano, Milano, Italy

Saturday, May 25, 2019
9:20-10:20
Qianqiusui Hall / 千秋岁

Abstract

Many fields, like physics, neuroscience, chemistry, and sociology, investigate phenomena by processing multivariate measurements advantageously represented as a sequence of attributed graphs. Graphs come in different forms, with variable attributes, topology, and ordering, making it difficult to perform a mathematical analysis in the graph space. Within this framework, we are interested in processing graph datastreams to solve applications e.g., detect structural changes in the graph sequence, a situation associated with time variance, faults, anomalies or events of interest as well as design sophisticated processing like those requested by predictors.

On the change detection front, theoretic results show that, under mild hypotheses, the confidence level of an event detected in the graph domain can be associated with another confidence level in an embedding space; this enables the identification of events in the graph domain by investigating embedded data. The opposite holds. However, evaluation of distances between graphs and identification of an appropriate embedding for the problem at hand are far from being trivial tasks with deep adversarial learning approaches and constant curvature manifold transformation showing to be appropriate transformations able to solve the problem. Deep autoregressive predictive models can then be designed to operate directly on graphs, hence providing the building blocks for other future sophisticated neural processing.

Biography

Cesare Alippi received the degree in electronic engineering cum laude in 1990 and PhD in 1995 from Politecnico di Milano, Italy. Currently, he is a Professor with the Politecnico di Milano, Milano, Italy and Università della Svizzera italiana, Lugano, Switzerland. He is a visiting professor at the University of Kobe, Japan, the University of Guangzhou, China and Consultant Professor at the Northwestern Polytechnic in Xi'An, China. He has been a visiting researcher at UCL (UK), MIT (USA), ESPCI (F), CASIA (RC), A*STAR (SIN).

Alippi is an IEEE Fellow, Member of the Administrative Committee of the IEEE Computational Intelligence Society, Board of Governors member of the International Neural Network Society, Board of Directors member of the European Neural Network Society, Past Vice-President education of the IEEE Computational Intelligence Society, past associate editor of the IEEE Transactions on Emerging topics in computational intelligence, the IEEE Computational Intelligence Magazine, the IEEE-Transactions on Instrumentation and Measurements, the IEEE-Transactions on Neural Networks. In 2018 he received IEEE CIS Outstanding Computational Intelligence Magazine Award, the 2016 Gabor award from the International Neural Networks Society and the IEEE Computational Intelligence Society Outstanding Transactions on Neural Networks and Learning Systems Paper Award; in 2013 the IBM Faculty award; in 2004 the IEEE Instrumentation and Measurement Society Young Engineer Award.

Current research activity addresses adaptation and learning in non-stationary environments, graph learning and Intelligence for embedded, IoT and cyber-physical systems. He holds 8 patents, has published one monograph book, 7 edited books and about 200 papers in international journals and conference proceedings.

Keynote Address 3

Data-Based Approaches to Attack Optimization and Sensor Scheduling in Cyber-Physical Systems

Prof. Guanghong Yang
Northeastern University, China

Sunday, May 26, 2019
8:20-9:20
Qianqiusui Hall / 千秋岁

Abstract

This study proposes two data-based approaches to optimal attack design and sensor scheduling for linear cyber-physical systems (CPSs) with unknown system parameters. First, the problem of designing sensor-actuator coordinated attacks is formulated as a data-based L2-gain composite optimization problem, and a new multi-objective adaptive dynamic programming method is proposed to find the optimal attack policy. Second, a data-based distributed sensor scheduling policy is developed to guarantee the H∞ performance of CPSs under a limited energy budget. With the help of Q-learning method, the optimal sensor schedule can be derived by using a distributed maximum subset extraction algorithm.

Biography

Guanghong Yang received the B.S. and M.S. degrees in Mathematics, and Ph.D. degree in control theory and control engineering with Northeastern University, China, in 1983, 1986, and 1994, respectively. He is currently a Chair Professor and the Dean with the College of Information Science and Engineering, Northeastern University. His current research interests include fault-tolerant control, fault detection and isolation, cyber physical systems, and robust control. He has published 3 monographs and over 300 papers in the international journals, and is a highly cited researcher (2014-2017) selected by Elsevier.

Dr. Yang has been a general chair of the annual Chinese Control and Decision Conference (CCDC) since 2011, and is a Deputy Editor-in-Chief for the Journal of Control and Decision, an Editor for the International Journal of Control, Automation and Systems, and an Associate Editor for the International Journal of Systems Science, the IET Control Theory and Applications and the IEEE Transactions on Fuzzy Systems.

Distinguished Lecture 1

Intelligent Control of Autonomous Flapping-Wing Robotic Aircraft

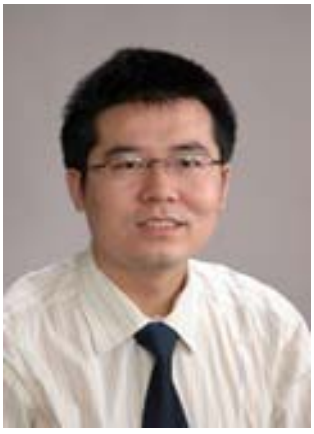
Prof. Wei He
University of Science and Technology Beijing (USTB), China.

Saturday, May 25, 2019
10:50-11:30
Qianqiusui Hall / 千秋岁

Abstract

The bionic flapping-wing robotic aircraft is inspired by the flying ways of birds, which is regarded as a rigid-flexible coupling system. Our research focuses on the control system design of the aircraft, which makes the aircraft have great advantages such as high flexibility, low energy consumption and so on. However, flexible wings might produce the unexpected vibration and deformation under the influence of air flow. The vibration will degrade the flight performance, even shorten the lifespan of the aircraft. Therefore, designing an effective control method for suppressing vibrations of flexible wings is significant in practice. We have made several flapping-wing robotic aircrafts for experiments. The control system is designed for vibration control and autonomous flying of the flapping-wing robotic aircrafts.

Biography



Wei He received his PhD from Department of Electrical & Computer Engineering, the National University of Singapore (NUS), Singapore, in 2011, his M.Eng. and B.Eng. degrees both from School of Automation Science and Engineering, South China University of Technology (SCUT), Guangzhou, China, in 2008 and 2006 respectively. He is currently working as the Full Professor at School of Automation and Electric Engineering, University of Science and Technology Beijing (USTB), China. He is a receipt of The National Natural Science Fund for Excellent Young Scholars of China in 2015. He has been awarded a Newton Advanced Fellowship from the Royal Society, UK in 2017. He is a recipient of the IEEE SMC Society Andrew P. Sage Best Transactions Paper Award in 2017. He is serving as the Associate Editor of IEEE Transactions on Neural Networks and Learning Systems, IEEE Transactions on Control Systems Technology, IEEE Transactions on Systems, Man, and Cybernetics: Systems, IEEE/CAA Journal of Automatica Sinica, and Neurocomputing. He is the member of the IFAC TC on Distributed Parameter Systems, IFAC TC on Computational Intelligence in Control and IEEE CSS TC on Distributed Parameter Systems. His current research interests include robotics, distributed parameter systems and intelligent control systems.

Distinguished Lecture 2

Adaptive Parameter Estimation and Control via Parameter Error: A New Framework

Prof. Jing Na
Kunming University of Science & Technology, China

Saturday, May 25, 2019
11:30-12:10
Qianqiusui Hall / 千秋岁

Abstract

Adaptive parameter estimation and adaptive control have been well developed for uncertain systems to improve modeling and control performance. However, the well-known parameter estimation and adaptive control methods have been mainly designed based on the gradient algorithms (with appropriate modifications) with prediction error or control error. Hence, the parameter estimation convergence and the online verification of the required persistent excitation (PE) condition are generally difficultwith this framework. In this talk, we will introduce a novel robust, fast adaptive parameter estimation framework, where the estimation error between the unknown parameters and their estimates are explicitly obtained and then use to drive online adaptation algorithms. This new adaptation even allows to achieve finite-time parameter estimation, and can be easily incorporated into adaptive control designs to achieve tracking and parameter estimation simultaneously. We will introduce an intuitive and numerically feasible approach to online verify the PE condition. Finally, several practical application of this new adaptation to in-car parameters, adaptive control design and approximate dynamic programming for robotics, vehicles, wave energy converters (WECs) and other realistic systems will be presented.

Biography

Jing Na is currently a Professor with the Faculty of Electrical & Mechanical Engineering at Kunming University of Science & Technology, and also a Marie Curie Fellow with the University of Bristol, UK. He received the B.S. and Ph.D. degrees from the School of Automation, Beijing Institute of Technology, China, in 2004 and 2010, respectively. From January 2011 to December 2012, he was a Monaco/ITER Postdoctoral Fellow with the ITER Organization, France. Since 2010, he has been with the Kunming University of Science & Technology, where he was promoted to be a full Professor in 2013. He has hold also visiting positions with the University Politecnica de Catalunya, Spain (6 months in 2008), and with the University of Bristol, UK (12 months in 2009). Dr Na is currently an Associate Editor of the Neuro computing, and the International Journal of Modeling, Identification and Control. He has served as an international program committee Chair of ICMIC 2017, and IPC member of many international conferences (e.g., IEEE CASE, IEEE CIS&RAM, IFAC ICONS, etc).He has organized/co-organized several special issues on Complexity, Discrete Dynamics in Nature and Society, and invited session in several prestigious conferences (e.g. IEEE CDC, UKACC, CCC).

His current research interests include parameter estimation, adaptive optimal control, and nonlinear control with application to vehicle systems, servo mechanisms and energy conversion plants (e.g. engine, wave energy convertors, etc.). He has published more than 100peer reviewed journal and conference papers. Dr Na has been awarded the Best Application Paper Award of the 3rd IFAC International Conference on Intelligent Control and Automation Science (IFAC ICONS 2013), and the 2017 Hsue-shen Tsien Paper Award.

Distinguished Lecture 3

Big data analytics in the process industry: distributed modeling and applications

Prof. Zhiqiang Ge
Zhejiang University, China

Sunday, May 26, 2019
9:20-10:00
Qianqiusui Hall / 千秋岁

Abstract

Industrial big data has received much attention from both academia and industry in recent years. In this talk, distributed parallel computing frameworks are introduced for big data modeling in the process industry, based on which various applications can be carried out, such as process monitoring, fault diagnosis, key performance indices prediction and diagnosis, etc. After introduction of the research background of this talk, distributed parallel data-driven models are demonstrated for big data analytics under different application scenarios, with evaluation experiments in real industrial processes. To conclude this talk, several promising issues are highlighted for future work.

Biography

Zhiqiang Ge received the B.Eng. and Ph.D. degrees from the Department of Control Science and Engineering, Zhejiang University in 2004 and 2009, respectively. He was an Alexander von Humboldt research fellow with University of Duisburg-Essen during Nov. 2014 to Jan. 2017, and also a JSPS invitation Fellow with Kyoto University during Jun. 2018 to Aug. 2018. He is currently a Full Professor with the College of Control Science and Engineering, Zhejiang University. His research interests include industrial big data, process monitoring, quality prediction, machine learning, and Bayesian methods.

Distinguished Lecture 4

Data Driven and Optimization for Extended State Observer based Control and Filter

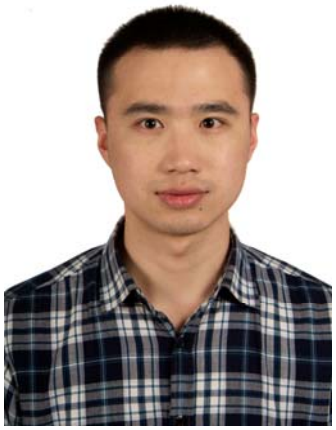
Prof. Wenchao Xue
Chinese Academy of Sciences, China

Sunday, May 26, 2019
10:20-11:00
Qianqiusui Hall / 千秋岁

Abstract

Extended state observer (ESO) has been widely used to deal with various control and filtering problems of uncertain systems. In the frame of ESO, the "total disturbance" in systems can be timely estimated from the input-data and output-data of systems. This talk will discuss the data-driven mechanism of ESO to extract the hidden information of uncertainties. The existing design methods and theoretical analysis of ESO based control will be reviewed. Next, I will focus on the optimization problem of estimating both states and uncertain dynamics, especially for the stochastic systems. The available methods and theory of extended state based Kalman filter and distributed Kalman filters will be demonstrated.

Biography



Wenchao Xue received the B.S. degree in applied mathematics from Nankai University in 2007, and the Ph.D. degree in control theory from the Academy of Mathematics and Systems Science (AMSS), Chinese Academy of Sciences (CAS) in 2012. He is now an Associate Professor of Academy of AMSS, CAS. His research interests include active disturbance rejection control, nonlinear uncertain system control and nonlinear uncertain systems filtering. Dr. Xue emphasizes on the control theory research to solve the real world problems. Several control algorithms proposed by Dr. Xue and his cooperators have been successfully implemented in existing spacecraft products. He has published more than 45 papers reviewed by peers including 20 journal papers.

Dr. Xue is an associate editor of the IFAC Journal of Control Engineering Practice. He served as associate editor for 2013-2019 American Control Conference, an associate editor for the 2015-2018 Chinese Control Conference. He also served as the chair of symposiums on disturbance rejection control for several international conferences. Currently, he is the vice secretary-general of TCCT, Chinese Association of Automation. He received the Outstanding Paper Award of 16th International Conference on Control, Automation and Systems and the Best Paper Award of IEEE 7th Data Driven Control and Learning Systems Conference.

Distinguished Lecture 5

Statistical Process Monitoring and Fault Diagnosis for Chemical Process

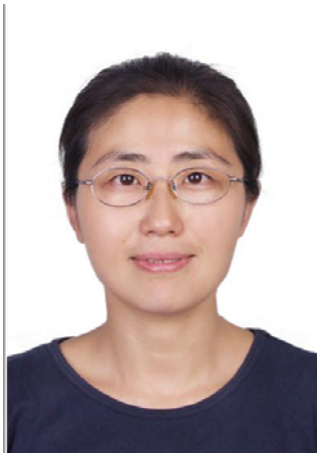
Prof. Jing Wang
Beijing University of Chemical Technology, China

Sunday, May 26, 2019
11:00-11:40
Qianqiusui Hall / 千秋岁

Abstract

Fault detection and diagnosis are extremely necessary in complex industrial systems. Data-driven monitoring technologies have been widely used to extract useful information from a large number of highly correlated process variables and historical data. Currently, the data-driven method is focus on Multivariate Statistical Process Monitoring (MSPM). The main characteristic of MSPM is to extract feature information from process data through dimensionality reduction algorithm, and to establish statistics for process monitoring. The fault detection based on data regression or classification and the fault diagnosis based on Bayesian inference are discussed here. These methods can exploit the underlying geometrical structure that contains both global and local information between the process variables and quality variables. So they can make the fault detection and diagnosis more accurate, more consistent, and faster.

Biography



Jing Wang received PhD degree in Control Science and Engineering from Northeastern University, Shenyang, China, in 1999. Currently, she is a professor in the college of information science and technology at Beijing University of Chemical Technology. Her research interests include chemical and industrial process modeling, optimization and control, iterative learning control in batch process, nonlinear model-based microscopic quality control of polymer, and process monitoring and fault diagnosis for complex industrial process. She serves as vice-chair of Beijing Association of Automation, China; a member of Technical Committee on Data-driven Control, Learning and Optimization, CAA and Technical Committee on Fault Detection, Supervision and Safety for Technical Processes, CAA.

Distinguished Lecture 6

On stochastic consensus of linear multi-agent systems with noises

Prof. Long Cheng
Chinese Academy of Sciences, China

Monday, May 27, 2019
8:20-9:00
Qianqiusui Hall / 千秋岁

Abstract

This talk introduces some recent results regarding the stochastic consensus of double-integrator multi-agent systems in noisy environments. Depending on whether the multi-agent system has a leader or not, the mean square consensus algorithm has been proposed and the corresponding necessary and sufficient conditions for ensuring the mean square consensus have been presented as well. Meanwhile, the results regarding the double-integrator multi-agent systems have been extended to the general linear multi-agent system. Finally, the rate of reaching consensus has been analyzed under some mild conditions.

Biography

Long Cheng, PhD, Professor with Institute of Automation, Chinese Academy of Sciences, Adjunct Professor with University of Chinese Academy of Sciences. He received his Bachelor degree at Nankai University, 2004, Tianjin China and received his PhD degree at Institute of Automation, Chinese Academy of Sciences, 2009, Beijing China. Dr. Cheng has published more than 50 journal papers. He is the Associate Editor of IEEE Transactions on Cybernetics, International Journal of Systems Science, Neuro computing, Acta Automatica Sinica. Dr. Cheng is the recipient of Aharon Katzir Young Investigator Award bestowed by International Neural Network Society; Young Researcher Award bestowed by Asia Pacific Neural Network Society; IEEE Transactions on Neural Networks Outstanding Paper Award bestowed by IEEE Computational Intelligence Society. Dr. Cheng's research interests include the intelligent control and optimization of robotic systems and the coordination control of multi-agent systems.

Distinguished Lecture 7

Data-driven Cooperation Control Approach for Networked Multi-agent Systems

Prof. Xuhui Bu
Henan Polytechnic University, China

Monday, May 27, 2019
9:00-9:40
Qianqiusui Hall / 千秋岁

Abstract

In recent years, with the rapid development of network technology and sensor technology, networked control systems and networked multi-agent systems based on communication connection have become hot topics in the area of control science. Most of the existing control methods for networked systems and networked multi-agent systems rely on model information for design and analysis. If the model of network system is difficult to establish, these methods will not be applicable. In this talk, several data-driven networked system control and cooperation control methods are introduced, including robust data-driven control under communication constraints, distributed data-driven cooperation control for multi-agent systems and distributed data-driven iterative learning cooperation control for multi-agent systems. The related research results give a novel cooperation control method which does not depend on the model information of the networked system. Meanwhile, this talk also gives a research framework of the robust data-driven control theory under incomplete information.

Biography

Xuhui Bu received the B.S. degree and M.S. degrees in automation control from Henan Polytechnic University, Jiaozuo, China, in 2004 and 2007, respectively, and the Ph.D. degree in control theory and application from Beijing Jiaotong University, Beijing, China, in 2011. He is currently an Professor with Henan Polytechnic University. He has authored over 50 peer-reviewed journal papers and over 20 papers in prestigious conference proceedings. He has received the Second class of Science and Technology Awards from Henan province in 2015, 2017 and 2018, respectively. He has also received the Best Paper Award from 5th Data Driven Control and Learning Systems Conference in 2016 and the Outstanding Paper Award from International Journal of Control, Automation, and Systems in 2015.

2019 IEEE 8th Data Driven Control and Learning Systems Conference (DDCLS'19)

Technical Programmes
and
Book of Abstracts

Saturday, 25 May, 2019

SatA01 **Room 1**
Iterative learning control (I) **13:30-15:30**
Chair: Chiang-Ju Chien Huafan Univ.
CO-Chair: Jinrong Wang Guizhou Univ.

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

Iterative Learning Control for Nonlinear Stieltjes Differential Equations

Yu Chen Guizhou Univ.
Jinrong Wang Guizhou Univ.
Xiaokai Cao Guizhou Univ.

The article study the ILC for nonlinear Stieltjes differential equations. We establish sufficient conditions and prove Stieltjes D-type and Stieltjes PD-type learning algorithms convergence results for such equation. The theoretical results are demonstrated using the numerical examples in the end.

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

批次过程时变动态模型的 2 维递推最小二乘辨识算法

师 佳 厦门大学.

针对批次过程分时段切换以及非稳态运行造成的本质时变动态特性，本文以递推最小二乘辨识算法为基础，在充分考虑批次过程重复运行机制的基础上，提出了一种能够同时利用批次过程时间和批次维度历史过程信息来进行辨识的 2 维递推最小二乘辨识算法。该算法最主要的优点是能够通过选择和设计沿时间和批次维度的遗忘因子来调节和平衡在线辨识算法对过程 2 维历史信息的依赖程度，从而保证在线辨识算法同时具有时间维度辨识的鲁棒稳定性和对时变 参数的快速跟踪性。通过对不同遗忘因子下辨识过程的数值仿真展示了算法的实用性、有效性和灵活性。

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

A Networked Iterative Learning Control Approach with Input Packet Dropout Adjustment Factor

Yamiao Zhang Xi'an Jiaotong Univ.
Jian Liu Xidian Univ.
Xiaoe Ruan Xi'an Jiaotong Univ.

This paper proposes an iterative learning control approach with input packet dropout adjustment factor for a class of discrete-time network control systems with random packet dropout. In the scheme, the missing system output signal is replaced by the corresponding desired output signal. In addition, the linear combination of the control signal and the actual system control input signal at the previous iteration is used to drive the controlled system if the control signal generated by iterative learning controller is successfully transmitted, otherwise the actual system input at the previous iteration is directly used to drive the controlled system. It is strictly proved that under certain conditions the actual system output is convergent to the desired system output in the sense of expectation. Finally, an example is given to demonstrate the validity of findings.

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

Direct Learning Control of Trajectories Subject to Second-Order Internal Model for a Class of Nonlinear Systems

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

In this paper, we focus on the direct learning control method for a class of continuous-time nonlinear systems with parametric uncertainties. First, the definitions of direct learning control are introduced. Second-order internal model is used to define the structure of non-repeatable reference trajectories. Then, a direct learning control algorithm is proposed to achieve control objective without iterations. By means of historical control data, direct learning control technique operates in a direct way. In order to achieve a satisfactory tracking performance, the second-order internal model is applied and embedded into the direct learning control law. Finally, the efficacy of the proposed direct learning control algorithm is demonstrated by a single-link robotic manipulator with desired trajectory matching second-order internal model.

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

Iterative Learning Control for Automatic Train Operation with Discrete Gears

Hua Chen Tsinghua Univ.
Zhihua Xiong Tsinghua Univ.
Yindong Ji Tsinghua Univ.

In the traditional iterative learning control (ILC) for automatic train operation (ATO), control inputs are usually continuous signals. In this paper, a practical ILC is presented to carry out the train operation by discrete traction or braking force. The train motion dynamic model is described by linear time-varying perturbation model along with the reference trajectories, which can be identified by the historical data. The ILC based on the perturbation model can be easily used to the case with the continuous control signals because the updating law of the ILC can be derived theoretically. Then the proposed ILC method is extended to the case with discrete gears by transforming the ILC with discrete control signals into a well-defined mixed integer programming (MIP) problem. The proposed method has been illustrated on the simulation case. Simulation results show that the method can not only track the reference trajectories to a fine accuracy but also restrict the gear shift frequency of the operation process, which is helpful to improve the ride comfort index of the whole train operation.

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

Further Results on the Design of Iterative Learning Controller for Learning Performance and Memory Capacity

Chiang-Ju Chien Huafan Univ.
Wei-Chen Huafan Univ.
Ying-Chung Wang Huafan Univ.

In this paper, an iterative learning controller using sampled-data implementation is re-considered for the issue of learning performance and memory capacity. First of all, the improvement of learning performance is achieved by a combination of feedback and feedforward design. Compared with our previous work, a further result is presented to apply the learning control task for a more general class of nonlinear systems. The detailed technical analysis for convergence and robustness is also shown. Secondly, the real implementation of the iterative learning controller using digital integrated circuit chip is re-studied. A design strategy of how to reduce the memory capacity but remain the original learning control algorithm in circuit implementation is proposed. In order to demonstrate the correctness and feasibility of theoretical result and circuit design, the proposed iterative learning controller is realized by an FPGA chip and applied to a repetitive position tracking control of DC motor. From the given experimental results, we show that the effectiveness of performance improvement and reduction of memory capacity are both achieved.

SatA02 Room 2
Data driven control (I) 13:30-15:30

Chair: Xiaoli Li Beijing Univ. of Tech.
CO-Chair: Zhanshan Wang Northeastern Univ.

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

A Data Driven Fractional-order Terminal Sliding Mode Control Method

Mingdong Hou North China Electric Power Univ.
Shandong Labor Vocational and Technical College.
Yinsong Wang North China Electric Power Univ.

For a class of discrete-time nonlinear systems with disturbances, a data-driven discrete-time fractional-order terminal sliding mode control (DD-DFOTSMC) method is proposed in this paper. The algorithm is based on the compact form dynamic linearization (CFDL) technique, and the controller is designed based on the discrete terminal sliding mode technology and the Grünwald-Letnikov fractional-order definition. The parameter of the CFDL data model is called pseudo-partial derivative (PPD) and is estimated using merely I/O measurement data of the system. Theoretical analysis proves the stability of the proposed algorithm, and simulation studies demonstrate that the proposed method has higher precision and faster response speed. Finally, the effectiveness of the proposed method is validated through a continuous stirred tank reactor (CSTR) process.

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

Simplified Strategy of Three-level Indirect Matrix Converter Based on Space Vector

Xinghe Ma Henan Polytechnic Univ.
Yaguang Ma Henan Polytechnic Univ.
Junying Zhao Henan Polytechnic Univ.
Dan Xu Henan Polytechnic Univ.

According to the disadvantages of traditional three-level space vector control strategy with the complexity of the selection of switching vector order and the large computational complexity of the algorithm, a simplified space vector control strategy applied to the three-level indirect matrix converter is proposed. On the device, this method adopts a control strategy with no zero vector in the rectification stage to ensure that the input voltage power factor reaches a maximum, the inverter stage uses space vector control strategy of the simplified sector reconstruction to rotate the reference voltage into the first sector. Then reference voltage correction and level-down processing are performed. Compared with the traditional control strategy, this control strategy not only reduces the computational complexity of the algorithm but also eliminates the need to store a large amount of data in advance, and also reduces the harmonic distortion ratio. The simplified space vector control strategy is verified on simulation and an experimental prototype platform is built. The correctness and feasibility of the control strategy are verified on experimental methods.

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

Output Tracking for A class of Nonlinear Non-minimum Phase systems and its Applications

Ma Chao Nanjing Univ. of Sci. & Tech
Wang Jian Nanjing Univ. of Sci. & Tech
Sun Ruisheng Nanjing Univ. of Sci. & Tech
Tao Gang Nanjing Univ. of Sci. & Tech

In this paper, a new output synthetic method is proposed for a class of nonlinear non-minimum phase systems based on output redefinition. The thought of pole assignment is applied to the determination of new output, so that the influence on output tracking performance which is caused by nonlinear internal dynamics can be weakened. Feedback linearization and non-causal stable inverse are employed to constitute the controller. A general formula of the determination of new output is derived. The method is applied to the acceleration tracking of high-speed tail-controlled missile. The simulation results demonstrate that the controller has consistent performance in the whole working area and the ability to track complex signals.

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

Data-based Analysis on Traction Energy for Urban Rail Transit Using Clustering and Classification Methods

Jiao Zhao Beijing Jiaotong Univ.
Tao Tang Beijing Jiaotong Univ.
Jing Xun Beijing Jiaotong Univ.
Shan Jiang Beijing Mass Transit Railway Operation Corporation Limited
Ming Gao CRRC Tangshan Co.
Baifeng Ren CRRC Tangshan Co.

The energy consumption of urban rail transit is increasing gradually in recent years. Accurate data analysis of traction energy is in urgent demand for improving energy-efficiency, thus it becomes an essential research subject for the metro system. According to the characteristics of the subway, this paper analyzes the traction energy consumption data based on the clustering and classification methods. The energy data collected by the energy consumption metering device is a line from Beijing Subway. The energy data feature vectors are obtained after simply pre-processing the raw data. Cluster algorithms are applied to divide the feature vectors into several sets with the same characteristics. The energy patterns is generated by decision tree algorithm. Finally, the outliers of traction energy under the same energy pattern are selected based on local outlier factor (LOF). The analysis results show that the traction energy data can be divided into four patterns and the outliers are detected under finer clusters than before, which can help the metro companies manage the energy data delicately.

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

H ∞ Control for Singular Markovian Jump Delay Systems With Mode-dependent Derivative-term Coefficient

Yufeng Tian Northeastern Univ.
Zhanshan Wang Northeastern Univ.

This paper focuses on the H1 control problem of singular Markovian jump delay systems with mode-dependent derivative-term coefficient through an extended decomposition system. By computing a proper Lyapunov functional, a generally stochastic stability condition of singular Markovian jump systems is achieved. On this basis, a delay-dependent stabilization condition of considered system is derived in terms of tractable linear matrix inequalities (LMIs), and the H1 controller gains are directly designed. Two numerical examples are introduced to illustrate the effectiveness of the proposed results.

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

Prediction of PM2.5 Concentration Based on PSO-LSSVR

Jihan Li Beijing Univ. of Tech.
Xiaoli Li Beijing Univ. of Tech.
Linkun Wang Instrumentation Technology & Economy Institute
Yang Li Communication University of China
Kang Wang Beijing Univ. of Tech

To accurately predict the concentration of PM2.5 in the atmosphere, this paper establishes LSSVR prediction model based on historical data of atmospheric PM2.5 concentration. The parameters of LSSVR model are optimized by particle swarm optimization algorithm (PSO). According to PM2.5 concentration data per hour and meteorological conditions from June to August 2017 in Beijing, other PM2.5 concentration prediction models are established, which include ANN prediction model and ε-SVR prediction model. By comparing the prediction errors of these three prediction models, the calculated mean absolute error of the ANN prediction model was 25.24%, the mean absolute percent error of ε-SVR is 10.39%, and the mean absolute percent error of PSO-LSSVR model is 4.95%. The simulation results show that the PSO-LSSVR model is better than ANN model and ε-SVR model, and the PSO-LSSVR model has less computational time and reduces the complexity of the algorithm. Therefore, the proposed PSO-LSSVR algorithm is effective and reliable by predicting PM2.5 concentration.

SatA03 Room 3

Neural networks, fuzzy systems control in data driven manner (I) 13:30-15:30

Chair: Chun Wu Zhejiang Univ. of Tech.
CO-Chair: Zhe Li Hunan Univ.

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

Integrated Position and Speed Control for PMSM Servo System Based on Extended State Observer

Chun Wu Zhejiang Univ. of Tech.
Zijun Fu Zhejiang Univ. of Tech.
Qiang Chen Zhejiang Univ. of Tech.
Dan Zhou Zhejiang Univ. of Tech.

The permanent magnet synchronous motor (PMSM) servo systems are widely adopted in many applications, where demand fast responses, high precision and strong ability of anti-disturbance, etc. First, this paper briefly introduce the design of sliding mode control (SMC), active disturbance rejection control (ADRC) for integrated position and speed controller for PMSM servo systems. Then the SMC basd on an extended state observer (ESO) for PMSM servo system is proposed. At last, the dynamic-state, steady-state and anti-disturbance performances are compared through experimental results. And the experimental results demonstrate the SMC with ESO (SMC-ESO) can achieve faster dynamic response, smaller chattering problem and anti-disturbance performances in comparison with conventional SMC. Although the overall performances of ADRC and SMC-ESO are similar, the SMC-ESO uses less parameters than ADRC and is convenient to be realized in real embedded system.

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

An Attitude Compensation Method based on Neural Network Using Data from MEMS MARG Sensors

Xiaolong Xu Shandong Univ.
Yujie Sun Shandong Univ.
Xincheng Tian Shandong Univ.

Aiming at the attitude estimation errors existed in the attitude measurement system using the magnetic, angular rate and gravity (MARG) sensors, a novel attitude compensation algorithm based on the neural network using data from sensor networks is proposed in this paper. It provides a more accurate measurement with simple implementation. A simple Kalman filter (KF) is designed to achieve prior attitude estimation. A back-propagation neural network is designed to compensate the attitude errors for the KF. The neural network is trained by the data from MARG sensor networks and errors of attitude estimation algorithm. Taking the data from triaxial MARG sensors as inputs, the trained network could predict the estimated attitude errors in Euler-angles form. Moreover, to validate the effectiveness of the proposed algorithm, two different experiments are accomplished. In the first experiment, the designed neural network is utilized to compensate the attitude estimation errors of a micro quadrotor helicopter using the publicly available datasets. In the second experiment, the KF is combined with the neural network to estimate the attitude of a self-designed single axis platform. Results show that the estimated attitude is closer to actual attitude after compensation which indicates that it is effective to utilize the neural network to compensate for estimation errors in attitude detection field even the attitude estimation algorithm is a simple Kalman filter.

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

IRL Method for Time-continuous Two-player Nonzero Sum Game of Unknown System With Constrained-input

He Ren Northeastern Univ.
Huaguang Zhang Northeastern Univ.
Yinlei Wen Northeastern Univ.
Yunfei Mu Northeastern Univ.

This paper addresses an off-policy method for solving the optimal control problem of the two-player nonzero sum (NZS) game when the inputs are constrained. Benefit from integral reinforcement learning (IRL) technology, proposed method can achieve the optimal solutions when the system dynamics can hardly obtained in practical applications. The equivalent convergence proof of the proposed method is also figured out. Actor-critic framework is constructed by utilizing the neural networks (NNs), in detailed the actor NNs are employed to approach the optimal control meanwhile the critic NNs are employed to approach the value functions. At last, a simulation is supplied to show the accuracy and effectiveness of the method we proposed.

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

Proportional Derivative Observer Design for Nonlinear Singular Systems

Yunfei Mu Northeastern Univ.
Zilong Tan Liaoning Science and Technology Museum
Huaguang Zhang Northeastern Univ.
Juan Zhang Northeastern Univ.

This paper focuses on proportional derivative observer design for a class of Takagi-Sugeno fuzzy singular systems. According to the available knowledge on premise variables, first, observer design with known premise variables is considered, and explicit parametrization of the desired observer is also given. Moreover, observer design with unknown premise variables is further investigated. Some new conditions, which guarantee the error system to be robust stability, are derived. All the stability criterions are presented in linear matrix inequalities framework, which can be conveniently verified via Matlab. Finally, two illustrative examples are simulated to illustrate the correctness of the present schemes.

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

An Improved Iterative Dynamic Programming Control Strategy Based on Neuro-fuzzy Model for Batch Processes

Liyan Ma Shanghai Univ.
Li Jia Shanghai Univ.
Liuming Zhou Shanghai Univ.

An improved iterative dynamic programming (IDP) control strategy is proposed in this paper. It uses a Neuro-fuzzy model (NFM) to predict output values of batch processes, which avoids the disadvantage that traditional IDP relies on mathematical models. Moreover, to match the real plant better, a model parameter adaptive adjustment method is introduced. Next, a model predictive control (MPC) strategy with decreasing prediction horizon is introduced to time-axis to adjust the control law obtained from IDP during one batch. Lastly, the method is applied to a typical batch process. The simulation results show the effectiveness of the proposed method.

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

Identification of Wiener Model with Output Colored Noise Based on Separable Signal Sources

Yu Han Shanghai Univ.
Li Jia Shanghai Univ.
Feng Li Jiangsu Univ. of Tech.

Most of research works discuss the identification problem of Wiener model parameters without considering the colored noise of the actual industry process and lacking the physical basis. In order to solve

the problem, a Wiener model identification algorithm based on separable signal sources is proposed in this paper to identify the Wiener nonlinear subsystem with output noise interference. The separable signals are used to separate the dynamic linear subsystem from static nonlinear subsystem. Then, the correlation analysis approach is adopted by using a set of Gaussian signals to identify the parameters of dynamic linear subsystem. Further, the parameter identification algorithm based on recursive generalized extended least square method is proposed to estimate the parameter of the dynamic nonlinear subsystem and the noise subsystem by using a set of binary signals as the input signals.

SatA04 **Room 4**
Data-driven modeling, optimization and scheduling (I) **13:30-15:30**
Chair: Guanbin Gao Kunming Univ. of Sci. and Tech.
CO-Chair: Zhao Jun Dalian Univ. of Tech.

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

A Fast Real-time Algorithm for Outlier Elimination Based on Polynomial Modeling

Zhangming He National Univ. of Defense Tech.
China Academy of Space Tech.
Tao Ren National Univ. of Defense Tech.
Chen Zhu National Univ. of Defense Tech.
Juhui Wei National Univ. of Defense Tech.
Guosheng Li National Univ. of Defense Tech.

Data recorded by the recording system often appear outliers. In order to correctly reflect and predict the falling process of aircraft debris, it is necessary to deal with the outliers. In this paper, MATLAB/MATHEMATICA symbolic math toolbox is used to solve the inverse matrix of the design matrix, which eases the reasoning by our brain, because the formula is very complicated. Based on the result above, the polynomial fitting and recursive formula are deduced for filtering and prediction, and finally the theoretical result are successfully applied for outlier detection and reconstruction of the aircraft target debris trajectory. The results show that this method seems quite feasible and can eliminate the outliers effectively.

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

Self-Balance Control of Electric Unicycle Based on Active Disturbance Rejection Control

Guangchao Liang Zhejiang Univ.
Taiyuan Univ. of Sci. and Tech.
Lingjian Ye Ningbo Institute of Tech.
Zhejiang Univ.
Minfeng Zhu Zhejiang Univ.

For self-balance control of electric unicycle (EU), the conventional PID control often leads to poor dynamic performance. In this paper, an active disturbance rejection control (ADRC) based control design approach is proposed to improve the control performance. Firstly, the dynamic model of unicycle is explored, which builds up the fundamental relation between the input and output, namely motor output torque and the attitude pitch angle. Since the physical model is nonlinear and highly sensitive to external conditions such as the system load, a sophisticated control strategy is required for practical usage. To this end, a three-level cascaded control system is designed, which is composed of the current loop, the motor speed loop, and the attitude loop, respectively. The former two loops are for speed regulation of the unicycle, while the third loop controls the attitude based on the ADRC to deal with various uncertainties. The control performance is verified through simulation studies along with comparisons with the conventional PID control. Results show that the ADRC-based control system achieved better self-balance for attitude control, where the attitude adjustment period is shortened and the overshot of the attitude is also reduced.

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

Disturbance Observer-Based Inverse Optimal Tracking Control of the Unmanned Aerial Helicopter

Haoxiang Ma Nanjing Univ. of Aeronautics and Astronautics
Mou Chen Nanjing Univ. of Aeronautics and Astronautics
Qingxian Wu Nanjing Univ. of Aeronautics and Astronautics

The attitude and altitude tracking control problem of an unmanned aerial helicopter (UAH) with unknown external disturbances is solved by employing an optimal control method in this paper. An inverse optimal control approach is adopted which avoids solving the associated Hamilton-Jacobi-Bellman (HJB) equation. A disturbance observer-based control (DOBC) method is utilized to deal with the unknown disturbances. To ensure the convergence of all tracking errors, a particular control Lyapunov function is selected via inverse optimal method. The performance of this developed control method is illustrated by simulation results.

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

Design of a Measurement System for Industrial Robots' Calibration based on Cable Encoders

Yuan Li Kunming Univ. of Sci. and Tech.
Guanbin Gao Kunming Univ. of Sci. and Tech.
Jing Na Kunming Univ. of Sci. and Tech.
Hongwei Zhang Kunming Univ. of Sci. and Tech.

To acquire the non-complete end information of industrial robots, a novel measurement system based on single-station cable actuated position encoder was designed. Firstly, the overall technical scheme of the

measurement system was developed. Then the components of the system were selected based on the design principle, and the mechanical structure of the measurement system was designed. Based on C#, the upper computer software for acquiring the data of the encoder was developed. Based on Visual C, we developed the communication software which acquires the joint angles of industrial robots. With the joint angles, the coordinates of the industrial robot's end were calculated through the kinematic model based on MDH method. The experimental results show that the system can complete the measurement work in the non-complete end information calibration system of industrial robots.

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

Current Efficiency Prediction of Aluminum Reduction Production Based on TCGWO-KELM

Chenhua Xu Guangxi Univ.
Jinzhi Zhang Guangxi Univ.
Qingbao Huang Guangxi Univ.
Mingkun Huang Guangxi Univ.
Chun Xie Guangxi Univ.
Xin Yu Guangxi Univ.

Because the method of the current efficiency has not been properly determined in the process of aluminum reduction so far, it is difficult to obtain real-time effective current efficiency data to guide aluminum reduction production. In this paper, a current efficiency prediction model based on kernel extreme learning machine (KELM) is established, which is improved by the tent chaotic grey wolf optimization algorithm. Firstly, aluminum reduction process is analyzed and obtained the parameters affecting the current efficiency of the aluminum production. In order to avoid the adverse effect of data redundancy on the prediction model, the principal component analysis method is used to reduce the dimension of the data. Secondly, the model of current efficiency based on KELM is established. In order to improve the training precision and increase the robustness of the algorithm, the improved grey wolf optimization algorithm is proposed to optimize the key parameters of the model. Finally, the current efficiency prediction model was trained and tested using the on-site production data. The results demonstrate the effectiveness of the prediction model and can provide decision-making reference for aluminum reduction production.

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

A Modified Data-Driven Regression Model for Power Flow Analysis

Chun Qin Dalian Univ. of Tech.
Linqing Wang Dalian Univ. of Tech.
Zhongyang Han Dalian Univ. of Tech.
Jun Zhao Dalian Univ. of Tech.
Wei Wang Dalian Univ. of Tech.

As one of the most important procedure in system recognition, Power Flow (PF) analysis is the pivotal basis of achieving optimal operation and production. Due to the difficulty of obtaining system parameters, low calculation accuracy and high computation costs, model-driven approaches, such as DC Power Flow (DCPF), cannot provide satisfied results for real application. While with the massive accumulated data from industrial enterprise, data-driven linearization approaches of PF become an effective alternative. In this paper, we propose a modified data-driven regression model that reveals the mapping rules between the known and unknown variables in power system. Then, the update mode of this model is further derived, which facilitates PF calculations with different variations of bus types. A regression model of network loss is also built so as to reflect the efficiency of the system as well as enhance comprehensiveness of the proposed data-driven PF analysis. The experimental results of 8 standard test systems demonstrate that the proposed model has a significant improvement on both computational accuracy and computation speed comparing with model-driven approaches and the inverse regression model of PF.

SatA05 Room5

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

Chair: Xu Yang Beijing Univ. of Sci. & Tech.
CO-Chair: Le Zhou Zhejiang University of Sci & Tech.

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

EEG-based Emotion Recognition using Temporal Convolutional Network

Liuqing Yang Beijing Univ. of Sci. & Tech.
Jiwei Liu Beijing Univ. of Sci. & Tech.

Emotion recognition based on physiological signal can be used in many applications such as, intelligent human computer interface design, emotional disorder diagnoses. For traditional approaches, the prior knowledge is required to design and extract a range of features from physiological signal. The generalization ability of traditional methods is poor because of the lack of high-level features. Using deep-learning methodologies to analyze physiological signal, i.e. EEG, becomes increasingly attractive for recognizing emotions. In this paper, we design a sequence model based on deep-learning that uses Temporal Convolutional Network (TCN) to extract high-level features in consideration of the time dependence of physiological signals for EEG emotion recognition. Specifically, we extract the differential entropy feature in seconds and construct a time series with fixed-length time window data as the input to TCN, and then using soft max to classify. Furthermore, in order to get reliable results, we divide the samples according to the trials, avoiding the testing set samples and training set samples from the same trial. Specifically, we first divide

the samples according to the trials as the testing set and the training set, and then segment the trials in the testing set and training set with fixed time window length to obtain more samples respectively. To evaluate the performance of the proposed model, we conduct the emotion classification experiments on DEAP database. The experimental results show the effectiveness of our proposed model for EEG emotion recognition.

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

A General Inversion Method Based on Magnetic Flux Leakage Inspection

Yifu Ren Northeastern Univ.
Jinhai Liu Northeastern Univ.
Xue Yu Northeastern Univ.
Hegui Zhu Northeastern Univ.

Aiming at the problem that the transfer accuracy of profile inversion model in different pipeline fields is not high enough in magnetic flux leakage (MFL) inspection, this paper presents a general inversion method. Firstly, the defect features of different pipelines are transferred by transfer component analysis (TCA), to reduce the difference of data probability distribution between them. Then, the post-transfer defect features are used to perform defect inversion with random forest (RF) algorithm. The real data are required from the domestic in-service oil pipelines in experiments. The experimental results show that the proposed method can effectively develop inversion accuracy by applying the inversion model into other pipeline fields.

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

Energy Consumption Optimization for Public Buildings by Using Data-driven Heuristic Dynamic Programming Algorithm

Mingrui Shi Beijing Univ. of Sci. & Tech.
Xu Yang Beijing Univ. of Sci. & Tech.
Xudong Liu Beijing Univ. of Sci. & Tech.
Jiarui Cui Beijing Univ. of Sci. & Tech.
Jian Huang Beijing Univ. of Sci. & Tech.
Chaonan Tong Beijing Univ. of Sci. & Tech.

This paper proposes an optimization method on energy consumption for public buildings based on the data-driven heuristic dynamic programming algorithm. To this end, a large amount of building data is first collected from a well-established monitoring system, including electricity, environmental information and human behaviors. According to this, the model network of HDP structure is then proposed by using BP neural network, furthermore, the optimal weights of action network and critic network are solved during the iteration process of HDP. At last, the performance and the effectiveness of HDP optimization are demonstrated through a case study of a building energy consumption monitoring system from practical engineering viewpoint.

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

Data-Driven Predictive Model Based on Locally Weighted Bayesian Gaussian Regression

Weiming Shao Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Zhihuan Song Zhejiang Univ.
Le Zhou Zhejiang University of Sci. & Tech.

In this paper, a data-driven modeling approach referred to as the 'locally weighted Bayesian Gaussian regression (LWBGR)' is proposed to develop soft sensor for nonlinear industrial process. The LWBGR handles nonlinearities by constructing localized models and accommodates process uncertainties by adopting the probabilistic way. An important feature of the LWBGR is that each localized model is a fully Bayesian Gaussian regression model where the mean and covariance are treated as random variables rather than deterministic parameters. By doing so the LWBGR can achieve enhanced capabilities in dealing with overfitting and numerical issues, which leads to higher predictive accuracy and more stable solution. The performance of the LWBGR is evaluated using a real-world industrial process, and the results demonstrate the advantages of the LWBGR over the deterministic and other probabilistic locally weighted models.

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

Eddy Current Scanning Image Denoising Method Based on Principal Component Analysis and Manifold Learning

Jun Bao Kunming Univ. of Sci. & Tech.
Bo Ye Kunming Univ. of Sci. & Tech.
Weiquan Deng Kunming Univ. of Sci. & Tech.
Jiande Wu Kunming Univ. of Sci. & Tech.
Xiaodong Wang Kunming Univ. of Sci. & Tech.

Due to the complicated industrial environment and the poor surface conditions of detected materials, scanning images inevitably contain various noise in actual eddy current imaging detection, which seriously affects the detection result. Aiming at the above problem, we propose an eddy current scanning image denoising method based on principal component analysis (PCA) and locally linear embedding (LLE) in this paper. First, the method uses PCA to preliminarily remove noise from the scanning image. Then, the method uses the reconstruction algorithm of LLE to reconstruct the PCA-processed image by its neighborhoods, which further denoise the eddy current scanning image and optimize their details and edges while retaining their local geometric constructions. The experimental results have shown that, compared with other methods, the proposed method not only removes noise more effectively but also retains the details of the scanning image.

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

Head Pose Estimation with Siamese Convolutional Neural Network

Fuxun Gao Shanghai Univ. of Sci. & Tech.
Chaoli Wang Shanghai Univ. of Sci. & Tech.

In order to get rid of the dependence on key points and improve the accuracy of pose estimation, in this paper, we propose a method of estimating the 3D head pose using a convolutional neural network with Siamese structure. Firstly, the rank labels of head pose which used to train the Siamese network can be automatically generated from the continuous head pose labels. The Siamese network can rank the head pose deflect levels and this step is equivalent to coarse classification. Secondly, after Siamese network is trained, the continuous raw pose labels were used to fine-tuning a branch of Siamese network and let the network regress the continuous pose ground truth. For avoiding duplicate computation caused by Siamese network, we add a ensemble layer to the network. In addition, high intensity brightness adjustment and Gaussian blur are imposed on images to distort images in data augmentation, so our method will achieve perfect performances in low quality images. Experiments show that our method has higher accuracy than the state-of-the-art methods of estimating head pose from RGB images, stronger robustness than the method of head pose estimation with key points, and wider application range than the method of head pose estimation with depth data.

SatA06 Room 6
Applications of Data-driven Methods to Industrial Processes 13:30-15:30

Chair: Kaixiang Peng Beijing Univ. of Sci. & Tech.
CO-Chair: Yongming Han Beijing Univ. of Chemical Tech.

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

A Novel Multivariable Nonlinear Time Series Prediction Method for APSO-Elman Network

Ke Ren Beijing Univ. of Chemical Tech.
Yongjian Wang Beijing Univ. of Chemical Tech.
Bo Yang Beijing Univ. of Chemical Tech.
Hongguang Li Beijing Univ. of Chemical Tech.

Elman neural network is a local dynamic neural network with good approximation fitting ability, which is suitable for the prediction of complex nonlinear time series models. When multi-variable, multi-step nonlinear industrial process prediction is involved. However, the traditional Elman neural network learning parameters are too slow, difficult to find an optimal parameter. To overcome the weakness of the traditional Elman neural network, this paper proposed a new adaptive particle swarm optimization Elman (APSO-Elman) neural network, which can achieve better results for nonlinear, multi-step, multivariate time series prediction. Find the optimal weight parameters for the neural network. Firstly, the data mining method is applied to select the appropriate correlation variables, then the APSO-Elman algorithm is used to find the optimal neural network weight parameters. To verify the effectiveness of the method, the non-isothermal continuous tank stirred reactor discharge concentration is used to predict. Compared with the traditional Elman neural network and PSO-Elman network, the results show that the method can accelerate the learning rate of parameters and find the optimal parameters, thus improving the accuracy of discharge concentration prediction.

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

PA-OMT: A Performance Assessment and Online Monitoring Toolbox for Process Monitoring and Fault Detection

Tianjing Qi Beijing Univ. of Sci. & Tech.
Ruohui Chu Beijing Univ. of Sci. & Tech.
Kai Zhang Beijing Univ. of Sci. & Tech.
Kaixiang Peng Beijing Univ. of Sci. & Tech.
Peng Tang Beijing Univ. of Sci. & Tech.

Process monitoring and fault detection (PM-FD) methods have been widely used in practice to ensure the safe operation of the process. It has been found that although lots of PM-FD methods were proposed, there is few work focusing on developing a versatile performance assessment software to determine the optimal method for on-line monitoring. This paper is devoted to develop a MATLAB-based performance assessment and on-line monitoring toolbox (PA-OMT) for process monitoring. The software has a friendly graphical user interface (GUI), and is packaged into a separate version. It can be installed in different versions of Windows system and used without MATLAB. The purpose of the toolbox is to integrate performance assessment and on-line monitoring, and to provide a general platform for the application of PM-FD methods. Nine important basic algorithms are collected inside the toolbox, and external algorithms can also be uploaded through the interface. The platform is applied to the Tennessee Eastman (TE) process, which proves the effectiveness, versatility and practicability of the toolbox.

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

An Improved Extreme Learning Machine Based on Auto-Encoder for Production Predictive Modeling of Industrial Processes

Zhiqiang Geng Beijing Univ. of Chemical Tech.
Qingchao Meng Beijing Univ. of Chemical Tech.
Yongming Han Beijing Univ. of Chemical Tech.
Qin Wei Beijing Univ. of Chemical Tech.
Zhi Ouyang Beijing Univ. of Chemical Tech.

Industrial process data has the characteristics of complexity, variability and noisy, which brings challenges to data driven production predictive modeling for industrial processes basing on the

traditional extreme learning machine (ELM). Therefore, this paper proposes an improved ELM based on auto-encoder (AE) (AE-ELM). The AE can extract the main features with lower-dimension by eliminating the linear correlation among the original complex data. Then, the main features are used as the inputs of the ELM. For the purpose of verifying the effectiveness of the proposed method, the AE-ELM model has been experimented on the production prediction of the pure terephthalic acid (PTA). The experimental results prove that the AE-ELM is less sensitive to the structure of the traditional ELM and principal components extraction based robust ELM (PCE-RELM). Moreover, the modeling accuracy can be improved by 2.4%, which has certain guiding significance for process modeling and production prediction.

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

Dynamic compensation for Supply Disruption Management

Shanshan Li Southeast Univ.
Yong He Southeast Univ.

This paper investigates a dynamic flexible compensation strategy to deal with supply disruptions. The manufacturer sources from a single supplier, and production could be completely interrupted by a supply disruption. Market demand is deterministic, but sensitive to the length of disruption duration and the level of compensation. By formulating a state-space framework to capture the demand dynamics during disruption, we present a deterministic optimal control approach that optimizes the dynamic flexible compensation strategy for supply disruption. Via Pontryagin's Maximum Principle, four types of optimal dynamic compensation strategies are proposed under the consideration of costs, disruption duration, and customer sensitivity. The results provide analytical guidance on how to dynamically adapt the price of compensation during the whole disruption period.

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

Process Monitoring Using a Sequence to Sequence Model

Haibin Wu National Taiwan Univ.
Cheng-Hung Chou National Tsing Hua Univ.
Yuan Yao National Tsing Hua Univ.
David Shan Hill Wong National Tsing Hua Univ.
Yi Liu Zhejiang Univ. of Tech.

Industrial process monitoring systems aim to mine valuable patterns from a large volume of process data for detecting abnormalities in an efficient and effective manner. To deal with nonlinearity and sequentiality of process data, various nonlinear and dynamic models have been adopted in previous research, which usually take both manipulated and measured variables into consideration to maximize the utilization of the available information. However, from the viewpoint of process engineers, changes only in manipulated variables should not be considered as faults. Instead, these are routine control actions to reject disturbances. As long as the process can be regulated, it is unnecessary to raise alarms. In this work, a sequence to sequence neural network model with gated recurrent units (GRUs) is proposed for efficient process monitoring, while superfluous alarms are suppressed. The feasibility of the proposed method is illustrated by the case study on the benchmark Tennessee Eastman (TE) process.

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

Adaptive Reinforcement Learning Tracking Control for Second-Order Multi-Agent Systems

Weiwei Bai Guangdong Univ. of Tech.
Liang Cao Guangdong Univ. of Tech.
Guowei Dong Guangdong Univ. of Tech.
Hongyi Li Guangdong Univ. of Tech.

In this paper, the adaptive reinforcement learning tracking control problem is studied for second-order pure-feedback multi-agent systems (MASs). The pure-feedback MASs are transformed into strict-feedback form by using the mean value theorem. The reinforcement learning approach is applied to handle the unknown functions and system control performance index. Moreover, the error terms are introduced to the controller, which can improve the robust of the control scheme. The theoretical analysis indicates that all the signals and tracking errors in close-loop system are semi-global uniformly ultimately bounded (SGUUB), and the numerical simulation are conducted to verify the superiority of this scheme.

SatB01 Room 1

Best Paper Award Finalist **15:50-17:30**

Chair: Zhihuan Song Zhejiang Univ.
Zengqiang Chen Nankai Univ.

15:50-16:10 **SatB01-1**

A Data-driven State Observation Method for Atomic Spin-exchange Relaxation-free Comagnetometer

Zhuo Wang Beihang Univ.
Jiong Huang Beihang Univ.
Wei Quan Beihang Univ.
Lihong Duan Beihang Univ.
Weijia Zhang Beihang Univ.
Yang Fu Beihang Univ.

The atomic dual-axis spin-exchange relaxation-free (SERF) comagnetometer system is investigated in this paper. We first establish a state-space model of the atomic SERF comagnetometer system according to its linearized Bloch equations, by selecting the transverse polarizations of electron spin and nuclear spin as the state variables. However, the transverse nuclear spin polarizations cannot be directly measured, which means some of the system states cannot be directly observed. To solve this problem, we propose a data-driven state

observation (DDSO) method to estimate the nuclear spin polarizations in real time. Simulation results based on practical system parameters illustrate the feasibility of the DDSO method.

16:10-16:30 **SatB01-2**

Lα-regularization-based Sparse Semi-supervised Learning for Data with Complex Distributions

Qi Zhang Univ. of International Business & Economics.
Tianguang Chu Peking Univ.

We consider in this paper two kinds of complex data, i.e., multimodal and mixmodal data, and aim to develop data-driven learning models to exploit the intrinsic characteristics of the data. An lα-regularization-based sparse semi-supervised graph embedding (SSGE) model for feature extraction upon multimodal and mix modal data is presented by incorporating the hierarchical locality with non-convex sparsity, facilitating better interpretation of the projections. Semi-supervised projection learning and lα-regularization-based sparse subspace learning are implemented successively, with feasible solving algorithms presented. Experiments for face recognition verifies the feasibility and effectiveness of the proposed SSGE model in both multimodal and mixmodal situations.

16:30-16:50 **SatB01-3**

Iterative Learning Control of Methane Steam Reforming Reaction in Operating Solid Oxide Fuel Cell

Xin Kang Southwest Jiaotong Univ.
Yong Chen Southwest Jiaotong Univ.
Liyuan Fan The Univ. of Melbourne
Deqing Huang Southwest Jiaotong Univ.

As one kind of new power plants, solid oxide fuel cell (SOFC) possesses distinctive advantages, such as the high efficiency in energy conversion, the tiny effect towards environmental pollution, and the abundant fuel sources, etc. Nevertheless, the drastic chemical reactions inside and the high operating temperature (up to 1000_C) lead to a series of problems in structural analysis, controller design as well as safety concern of SOFC. In this paper, a novel iterative learning control (ILC) scheme are proposed for the precise management of the efficiency of methane conversion in SOFC, where the reaction temperature is selected as the control input for the single-input scenario. The learning convergence condition of ILC, the learning rate as well as the robustness are derived through rigorous analysis. The simple structure and model-free nature of ILC makes it applicable although the methane steam reforming (MSR) process is with complicated dynamics and severe potential uncertainties. The effectiveness of the proposed ILC schemes is confirmed via numerical simulations.

16:50-17:10 **SatB01-4**

Adaptive Fuzzy Control for a Constrained Robot in the Presence of Input Nonlinearity

Linghuan Kong Univ. of Sci. & Tech. Beijing
Wei He Univ. of Sci. & Tech. Beijing

An adaptive fuzzy finite-time control policy is developed for an uncertain n-link robot with input saturation and time-varying output constraints. Compared with previous works, the introduced finite-time stability criterion is used for the tracking control of the robot. Furthermore, cot-type Barrier Lyapunov functions (BLFs) are introduced for guaranteeing output constraints, which can be considered as a substitution of other BLFs. A fuzzy approximation-based adaptive finite-time control scheme is constructed for stabilizing the robotic system. With Lyapunov theory, it has been proved that all the error signals are semi-global practical finite-time stable (SGPFS). At last, the effectiveness of the proposed scheme is verified by simulation results.

17:10-17:30 **SatB01-5**

Recursive Correlative Statistical Analysis Method for Incipient Fault Detection

Hao Zhang Beijing Univ. of Chemical Tech.
Youqing Wang Shandong Univ. of Science and Tech.

In this paper, a new data-driven process monitoring method called recursive correlative statistical analysis (RCSA) is proposed. This process combines correlative statistical analysis method with sliding window technique to detect incipient faults. Compared with the existing fault detection method based on principal component analysis (PCA) algorithm, the RCSA method fully utilizes the information of process variables and quality variables in the detection process. The method of using sliding window to solve incipient faults inevitably increases the computation because a large number of repeated window calculations is needed. Therefore, a recursive method with less complexity is proposed in this paper; the amount of calculation is reduced to a certain extent. Finally, a numerical example shows the effectiveness of the proposed method in detecting small faults.

SatB02 Room 2

Data-driven fault diagnosis and health maintenance (I)

15:50-18:10

Chair: Jianming Zhang Zhejiang Univ.
CO-Chair: Zhouxiao Xiao Huazhong Univ. of Sci. & Tech.

15:50-16:10 **SatB02-1**

False Data Injection Attack Design in Multi-sensor Systems Based on KL Divergence Theory

Dan Ye Northeastern Univ.
Jiyan Wang Northeastern Univ.

In this paper, a security issue for Cyber-Physical Systems (CPSs) is considered. We analyse a multi-sensor system equipped with a remote state estimation and a set of detectors. From the perspective of a malicious attacker, one intends to modify the innovation sequence by injecting a Gaussian noise and further destroys the system performance. The state estimation error covariance recursion are derived to quantify the effect of an attack. Furthermore, we study the worst-case false data injection (FDI) attack scenario, where the maximal attack probability is limited by the threshold of Kullback-Leibler divergence detector. Finally, a numerical example is shown to demonstrate the effectiveness of the worst-case FDI attack.

16:10-16:30 **SatB02-2**

Thermal Power Plant Process Monitoring using Mutual Information and Distributed Statistical Model

Delun Chen China Jiliang Univ.
Jiusun Zeng China Jiliang Univ.
Xiaoyu Liang China Jiliang Univ.

In this paper, a distributed modeling method is proposed to monitor a practical thermal power plant, which consists of a large number of process variables as well as huge number of data records. In order to simplify the monitoring task, the process variables are decomposed into several sub-blocks by investigating the mutual information matrix estimated from data. Based on the data samples in each sub-block, a set of monitoring models are constructed using principal component analysis (PCA). The monitoring statistics are then integrated using Bayesian method. Whenever a fault is observed, the sub-blocks that are affected by the fault are analyzed and faulty variables are isolated using contribution plot. Finally, the fault root causes are diagnosed using causality analysis. Through the analysis of process data from a practical power plant, the feasibility and efficiency of the proposed method is verified.

16:30-16:50 **SatB02-3**

An Improved BP Neural Network Fault Detection Based on Time Series Modeling

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

Combined with data-driven and artificial intelligence, in this paper, we propose a two-layer fault detection mode based on time series modeling and BP neural network. The method is used to realize the autonomy and intelligence of system fault detection. Firstly, we introduce the non-stable characteristics of the system measurement data to construct a non-stationary time series model. Secondly, we use the parameter characteristics of the time series model to determine the node number of input layer, and the neural network parameters will be adaptively determined. Thus, the training data can be used to test the network structure, and then the fault detection can be realized. The simulation data shows that the method is effective and can improve the fault detection performance.

16:50-17:10 **SatB02-4**

Fault detection and diagnosis based on Adam-ICA

Xinxin Shen Zhejiang Univ.
Jianming Zhang Zhejiang Univ.

The traditional FastICA method uses the Newton iteration method which often leads to local minimum solution, so that the suitable independent components are not obtained. To solve this problem, a modified ICA algorithm based on adaptive gradient algorithm (Adam) called Adam-ICA is proposed for the purpose of multivariate statistical processes monitoring (MSPM). The basic idea of this algorithm is to extract the main independent components from the original data by adaptive low order moment estimation for fault diagnosis and analysis. The proposed monitoring method is applied to fault detection and diagnosis of the vehicle dataset. The results show that the Adam-ICA method is more efficient.

17:10-17:30 **SatB02-5**

Fault Detection for the Suspension System of Maglev Train Based on FWHT and SVDD

Ping Wang National Univ. of Defense Tech.
Zhiqiang Long National Univ. of Defense Tech.
Fengshan Dou National Univ. of Defense Tech.
Mingda Zhai National Univ. of Defense Tech.

In order to achieve fault detection of the suspension system, a fault detection method based on support vector data description is proposed. In the proposed method, the moving time window is used to extract the healthy samples, and the fast Walsh-Hadamard transform and the median filter are used to extract features and filter. Then support vector data description is used to establish the threshold of the health model, finally the health model is used to fault detection for the suspension system. The experiment results show the correctness and effectiveness of the method which can be applied for fault detection.

17:30-17:50 **SatB02-6**

Remaining Useful Life Prediction of Lithium-ion Battery Based on Unscented Kalman Filter and Back propagation Neural Network

Zhouxiao Xiao Huazhong Univ. of Sci. & Tech.
Huajing Fang Huazhong Univ. of Sci. & Tech.
Zheng Li Huazhong Univ. of Sci. & Tech.
Yang Chang Huazhong Univ. of Sci. & Tech.

Lithium-ion batteries are the key components of many electronic devices and complex systems. In order to decrease the threat of battery failure, as well as to improve the dependability and safety of the system, it is essential to effectively model the batteries performance degradation indicators and accurately predict the remaining useful life (RUL) of the batteries. In this paper, the unscented Kalman filter (UKF) algorithm is fused with back propagation (BP) neural network to increase the prediction accuracy of RUL of lithium-ion batteries. The BP neural network predicts the residual of UKF by auto-regressive form. The UKF utilizes the predicted residual to update the degradation model parameters iteratively. The simulation indicates that the proposed method achieves much better prediction accuracy and is more adaptable to the degradation characteristics of different prediction starting points of different battery individuals.

17:50-18:10 **SatB02-7**

Visual Detection System of Automotive Parts Attitude Based on Deep Learning

Jiaxu Zhang Xi'an Univ. of Tech.
Shaolin Hu Xi'an Univ. of Tech.
Univ. of Petrochemical Tech.
Haoqiang Shi Xi'an Univ. of Tech.

In the automobile assembly process, pose detection technology is the key technology in the assembly system, which plays an important role in the assembly work and will directly affect the assembly results. In order to improve the detection intelligence and accuracy, the deep learning vision technology is applied to the attitude measurement of automotive parts assembly, and a method of extracting key points by deep learning is proposed. Different from the traditional methods, the deep convolutional network has strong robustness and versatility. Therefore, this paper proposes a joint detection method for double convolutional networks. First, the deep convolutional network is used to predict the key points of the part. Then, the recursive convolutional neural network is used to optimize the prediction result. Finally, the key point coordinates are substituted into the PnP algorithm to check whether the part pose conforms to the standard. The simulation results show that the method can accurately realize the target attitude detection.

SatB03 Room 3
Technology of complex big-data systems and applications 15:50-18:10

Chair: Xiongxiong He Zhejiang Univ. of Tech.
Zhejiang Univ.
CO-Chair: Li Deng Shanghai Univ.

15:50-16:10 **SatB03-1**

A New Quality Control Method for Cotton Spinning

Jingfeng Shao Xi'an Polytechnic Univ.
Chuangtao Ma Xi'an Polytechnic Univ.

To solve the cotton yarn quality characteristic value fluctuation, we proposed a quality control method based on data-driven in the cotton spinning, and analyzed the uncertainty factors that affects quality characteristic values. For this method, we firstly studied the reasons and regularities of the spinning quality fluctuation in the spinning process, and made the knowledge association among yarn attributes be expressed. Second, through human-man-system engineering theory, all uncertainty factors were partitioned into six categories. Then, a multi-process hierarchy quality control model oriented to the cotton spinning was built and a new multi-objective evolutionary algorithm was proposed. As verified by the experiment and simulation, the results have shown that the quality control can achieve a full range analysis of quality control uncertainty for cotton spinning, which are from the reason and regularity of quality fluctuation to generation mechanism, mutual relations, and behavior identification of the uncertainty factors.

16:10-16:30 **SatB03-2**

Improve Spark-based Application Performance Using Bayesian Hyperparameter Optimization

Kexue Li Shanghai Univ.
Li Deng Shanghai Univ.
Yakang Lu Shanghai Univ.
Jinda Wu Shanghai Univ.

Metagenomics sequences assembly has an insurmountable obstacle in computational and memory resources limitations. SpaRC, a scalable sequence clustering application using Apache Spark, provides a scalable solution for clustering billions of reads from the next-generation sequencing (NGS) technologies. However, optimizing parameters to achieve better accuracy at this scale becomes very challenging and expensive. Here we explored Bayesian hyperparameter optimization to alleviate this problems by tuning the parameters to achieve near optimal cluster accuracy, without expensive parameter exploration. We report cluster performance on both short reads (Illumina) and long reads (PacBio) sequencing platforms. Results indicates that the methods offers great improvement in clustering performance. We hope insights we gained in this experiment can be generally applied to similar genomics applications based on Spark.

16:30-16:50 **SatB03-3**

Compressed Sensing System with Simultaneous Optimization of Sensing Matrix and Sparsifying Dictionary Applied in Gastrointestinal Images for Remote Diagnosis

Qianru Jiang Zhejiang Univ.
Sheng Li Zhejiang Univ.
Fengling Hu Zhejiang Univ. of Tech.
Liping Chang Zhejiang Univ.
Huang Bai Hangzhou Normal Univ.

Zhongtian Chen Zhejiang Univ.
Chang Li Zhejiang Univ.
Xiongxiong He Zhejiang Univ.

This paper copes with the compressed sensing (CS) technique which can be applied in remote diagnose on gastrointestinal disease. The images from gastrointestinal endoscopes can be compressed by a designed sensing matrix so that the transmission rate can be improved. Then the estimate images can be recovered in the designed sensing matrix and trained dictionary by using proper recovery algorithms. The algorithms are designed for optimizing sensing matrix and sparsifying dictionary alternatively, which will bring accurate recovery performance. The simulations demonstrate the superiority in the application of remote diagnose by adopting CS technique.

16:50-17:10 **SatB03-4**

Link Prediction in Drug-drug Interaction Network with Syncretic Naive Bayes Method

Runfang Wang Nankai Univ.
Qiangchen Chen Nankai Univ.
Zhongxin Liu Nankai Univ.

As is known to all, the pharmacological effects of drugs may change, and even generate unpredictable consequences when several drugs are taken simultaneously. However, the connection information of complex network with drug as the node is incomplete and inaccurate, and link prediction can be used as a favorable auxiliary tool to solve such problems. In this paper, a Syncretic Naïve Bayes (SNB) method is developed by utilizing the Local Naïve Bayes (LNB) method and node degree to quantify the influence of common neighbors and node pairs themselves, respectively, Subsequently, the proposed method is extended with the idea of Common Neighbors (CN), Adamic-Adar (AA)and Resource Allocation(RA) method. Experimental results on drug-drug interaction network demonstrate the effectiveness and applicability of the proposed method, especially when the observed network is very sparse.

17:10-17:30 **SatB03-5**

Automatic Classification based on Features Fusion for Upper Gastrointestinal WCE Images

Min Yu Zhejiang Univ. of Tech.
Sheng Li Zhejiang Univ. of Tech.
Fengling Hu Zhejiang Univ.
Liping Chang Zhejiang Univ. of Tech.
Ni Zhang Zhejiang Univ. of Tech.
Qianru Jiang Zhejiang Univ. of Tech.
Dongwei He Zhejiang Univ. of Tech.
Xiongxiong He Zhejiang Univ. of Tech.

Wireless Capsule Endoscopy (WCE) is an important clinical application which suffers a time-consuming review procedure. A WCE images automatic classification algorithm which fuses color and texture features is proposed to alleviate the burdensome task. A pre-process that aims to label *shadow* and *highlight* is implemented via a new automatic tuning algorithm based on superpixel-level. Hue-Saturation (HS) histograms and a new texture feature named colour scale invariant local ternary pattern (CSILTP) are extracted as local descriptors. A strategy of feature fusion that utilizes discrimination power analysis (DPA) is applied to reduce the dimension of features. The random forest (RF) classifier is then used to discriminate WCE images. The experiment results indicate a better performance of proposed method compared with some existing approaches.

17:30-17:50 **SatB03-6**

Intestinal Polyps Recognition Based on Annular Spatial Pyramid Matching with Locality-Constrained Linear Coding for Gastroscopy Diagnosis

Dongwei He Zhejiang Univ. of Tech.
Fengling Hu Zhejiang Univ.
Sheng Li Zhejiang Univ. of Tech.
Xiongxiong He Zhejiang Univ. of Tech.
Liping Chang Zhejiang Univ. of Tech.
Ni Zhang Zhejiang Univ. of Tech.
Qianru Jiang Zhejiang Univ. of Tech.
Zhongchao Wang Zhejiang Univ. of Tech.

A novel automatic polyp recognition scheme called Annular Spatial Pyramid Matching (ASPM) with Locality Constrained Linear Coding (LLC) is proposed by considering the annular structure of the intestinal images at multilevel. Firstly, detailed texture features extracted from the samples including normal and polyp images are calculated and then LLC method is employed on these features to obtain a sparse representation. Secondly, a strategy of annular region segmentation based on Spatial Pyramid Matching is proposed to improve the effectiveness of processing for intestinal images. Then, the final representation for each image is obtained by max-pooling the codes of features. Finally, SVM classifier is developed to carry out polyp images classification tasks. The experimental results indicate that the proposed algorithm outperforms the analysed state-of-the-art methods on the polyps recognition.

17:50-18:10 **SatB03-7**

Brain-Computer Interface System of Steady-State Visual Evoked Potentials Based on Fractional Domain Features

Qi Yang Beijing Information Sci. & Tech. Univ.
YingNian Wu Beijing Information Sci. & Tech. Univ.
RongMin Cao Beijing Information Sci. & Tech. Univ.

In this paper, a Brain-Computer Interface (BCI) based on Steady-State Visual Evoked Potential (SSVEP) is designed. In order to improve the accuracy of model classification with small sample size fractional Fourier

transform is used to replace the Fourier transform in the Mel-Frequency Cepstral Coefficients. The improved features are used to train the Hidden Markov Models. Improved accuracy by 3% in offline tests. In the actual experiment, the recognition accuracy of the volunteers reached 90%. The information transform rate (ITR) reaches 42bits/min.

SatB04 **Room 4**
IS：Uncertainty rejection and data driven **15:50-17:50**
Chair: Wenchao Xue Chinese Academy of Sci.
CO-Chair: Wei Ai South China Univ. of Tech.

15:50-16:10 **SatB04-1**

Dynamic Linearization based Adaptive Nonlinear Active Disturbance Rejection Control
Yu Hui Qingdao Univ. of Sci. and Tech.
Ronghu Chi Qingdao Univ. of Sci. and Tech.

This work deals with the control issue in disturbed discrete-time nonlinear nonaffine system. A novel adaptive nonlinear active disturbance rejection control based on dynamic linearization technique is designed. Through dynamic linearization technique, the nonlinear nonaffine system is translated into a linear parametric data model with a nonlinear uncertainty. The estimations of unknown parameter and the nonlinear uncertainty are proposed by using an adaptive law and an extended state observer, respectively. By considering parameter adaptation, the dynamics of reference trajectory, the uncertainty compensation, and nonlinear error feedback simultaneously, an adaptive nonlinear error feedback control law is proposed. The final simulations verify the practicability and the validity of the proposed control scheme.

16:10-16:30 **SatB04-2**

Attitude Control of Hypersonic Vehicle Based on Optimized ADRC
Minnan Piao Nankai Univ.
Mingwei Sun Nankai Univ.
Jian Huang Beijing Automatic Control and Equipment Institute
Zenghui Wang South Africa Univ.
Zengqiang Chen Nankai Univ.

In this paper, two types of practical angle of attack control schemes are proposed for hypersonic vehicle which is subject to large unmodeled, parametric uncertainties and external disturbances. In the first scheme, the pitch angle control method based on the second-order linear active disturbance rejection control is directly applied to the angle of attack control through simple command transformation. Inner-loop pitch angular rate feedback is performed first to enhance the damping in the second scheme, and then first-order linear active disturbance rejection control is designed for the overdamped plant. Both schemes provide simple and robust solutions to the angle of attack control. To achieve desired stability and performance robustness, nonsmooth $H\infty$ synthesis technique is utilized to optimize the controller within the designed flight envelope. Nonlinear simulations are performed to validate the advantages of the proposed methods.

16:30-16:50 **SatB04-3**

Differentiator-Based Disturbance Observer
Xiangyang Li South China Univ. of Tech.
Zhiqiang Gao Cleveland State Univ.
Wei Ai South China Univ. of Tech.
Senping Tian South China Univ. of Tech.

The analysis of nonlinear disturbance observer (NDO) is first given in detail and an equivalent differentiator structure is used to explain the NDO. The design procedure of NDO is given according to this equivalent structure. Then the structure and principle of the generalized differentiator-based disturbance observer (DBDO) is given and compared with NDO in their structure and algorithm. As one of DBDO, tracking differentiator (TD) based disturbance observer is applied to compare NDO in simulations. Simulations for disturbance estimation show that both NDO and TD based disturbance observer have very effective disturbance estimation performance but the later has less design restriction

16:50-17:10 **SatB04-4**

Research and Application of Active Disturbance Rejection Based Iterative Learning Control for the Brushless DC Motor
Wei Ai South China Univ. of Tech.
Haonan Wang South China Univ. of Tech.
XiangYang Li South China Univ. of Tech.

Though the BLDC motor exhibits high potential for applications in motion control systems with high precision, the nonlinear characteristics of the motor give a big challenge in its application. To compensate the uncertainty and nonlinearity in the motor cycle, especially the torque ripple during commutation, a new algorithm, active disturbance rejection based iterative learning control (ADR-based ILC) is presented to achieve better dynamic characteristics and realize commutation torque ripple reduction. Regarding the motor rotation cycle as the iteration cycle, and the angle position as the space domain, this algorithm is based on a linear iterative extended state observer (LIESO) in the rotation iterative domain, which can estimate explicitly the uncertainty of the BLDC system according to the tracking error during the rotation cycle process. Based on the uncertainty compensation strategy, simulation results show that ADR-based ILC scheme ensures good dynamic performance, robustness, adaptability and demonstrate prominent torque ripple reduction ability.

17:10-17:30 **SatB04-5**

Piezoelectric Vibration Control for an All-clamped Plate by an Active Disturbance Rejection Control with Nonlinear Extended State Observer

Chaowei Zhu Yangzhou Univ.
Shengquan Li Yangzhou Univ.
Juan Li Yangzhou Univ.
Qibo Mao Nanchang HangKong Univ.

Considering the nonlinearity, strong coupling and model uncertainty in the all-clamped plate, an active disturbance rejection control (ADRC) method with nonlinear extended state observer (NESO) is proposed. First, a semi-physical platform is set up in MATLAB/Simulink real-time environment based on piezoelectric actuator, accelerometer and NI-PCIE system, and then build a mathematical model for this platform. Second, it introduces the nonlinear extended state observer to estimate the internal and external disturbances such as modeling errors, high-order harmonics and external excitation, and then compensates them to eliminate their influence on the system in real time. Finally, the vibration active control experiment is performed on the platform to test and verify the proposed method. The results show that the proposed control method has an excellent ability to suppress disturbance.

17:30-17:50 **SatB04-6**

On Extended State Observer Based Control for A class of Nonaffine Systems with Unknown Saturation

Xiaojing Song Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Sen Chen Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.
Wenchao Xue Chinese Academy of Sci.
Univ. of Chinese Academy of Sci.

This paper studies the control problem for a class of nonaffine uncertain systems with unknown saturation. The system model is built to describe many physical plants satisfying generalized saturation model of control input. The inflection point of the saturation model, which is critical for conventional controller design, is assumed to be unknown in this paper. The extended state observer is constructed to not only online estimate the "total disturbance" but also identify the inflection point. The simulation results on the typical aircraft flight control module show the effectiveness of the proposed controller.

SatB05 Room 5
Data-driven fault diagnosis and health management 15:40-18:10

Chair: Ying Zheng Huazhong Univ. of Sci. & Tech.
CO-Chair: Yong Zhang Wuhan Univ. of Sci. & Tech.

15:50-16:10 **SatB05-1**

Aluminum Electrolysis Multi-fault Diagnosis Using Wavelet Packet Decomposition and Directed Acyclic Graph Support Vector Machine

Kaibo Zhou Huazhong Univ. of Sci. & Tech.
Xudong Chen Huazhong Univ. of Sci. & Tech.
Gaofeng Xu Huazhong Univ. of Sci. & Tech.
Yaobao Ge Huazhong Univ. of Sci. & Tech.
Zhixin Zhang Huazhong Univ. of Sci. & Tech.

The operation condition of aluminum electrolytic cells is critical to the stability of the aluminum electrolysis process. Under the tough working environment, there will be many abnormal states in the cells, detrimental to aluminum quality, aluminum electrolysis efficiency and electrolytic cells life. Therefore, it's of great significance to develop an effective process monitoring and multi-fault diagnosis method. The diagnosis accuracy and the speed of traditional multi-classification methods are limited. To solve these problems, a fault detection and multi-fault diagnosis framework based on wavelet packet decomposition (WPD) and directed acyclic graph support vector machine (DAG-SVM) is proposed. First, features are extracted from aluminum electrolytic cell voltage signals. Then, DAG-SVM is used to detect and diagnose abnormal states. The result shows that the proposed method can detect and diagnose three abnormal states, anode effect state, voltage instability and liquid aluminum fluctuation with a high precision. The accuracy can reach about 86.8%.

16:10-16:30 **SatB05-2**

Anode effect prediction based on Light Gradient Boosting Machine

Xiaoran Chen Huazhong Univ. of Sci. & Tech.
Kaibo Zhou Huazhong Univ. of Sci. & Tech.
Hao Pan Huazhong Univ. of Sci. & Tech.
Xudong Chen Huazhong Univ. of Sci. & Tech.

The fault detection of the anode effect is of great significance in the process of aluminum electrolysis. Effective prediction of the anode effect can increase the output of the electrolytic cell and reduce the power consumption. In this paper, data is extracted from the real-time production process of aluminum electrolysis. In order to remove the redundancy and noise in the data and save the time cost of manual selection of features, the principal component analysis method is used to optimize other algorithms, and then compare with Light GBM. It has been proved by experiments that the Light GBM model not only improves the prediction accuracy of the anode effect to 99.9%, but also advances the fault prediction time to 40 minutes, which has high practical application value.

16:30-16:50 **SatB05-3**

Water Quality Prediction for Hanjiang with Optimized Support Vector Regression

Jing Zhang Wuhan Univ. of Sci. & Tech.
Yong Zhang Wuhan Univ. of Sci. & Tech.
Liaogehao Chen Wuhan Univ. of Sci. & Tech.
Qi Wang Wuhan Univ. of Sci. & Tech.
Min Zhao Wuhan Univ. of Sci. & Tech.

Water quality prediction is of great significance to the policies of water quality control which are made by the government. In this paper, the prediction problem of Hanjiang water quality is investigated with genetic algorithm (GA) and support vector regression (SVR). Based on the collected water quality data of Hanjiang, SVR is utilized to train the prediction model, and achieve the result of water quality prediction. In order to obtain higher prediction accuracy, particle swarm optimization algorithm (PSO), grid search (GS) and GA are chosen to optimize the parameters of SVR, respectively. Experimental results show that the prediction accuracy of GA-SVR algorithm is significantly higher than SVR, PSO-SVR and GS-SVR.

16:50-17:10 **SatB05-4**

A Variable Selection Method for Fault Isolation through Bayesian Information Criterion

Lang Liu Huazhong Univ. of Sci. & Tech.
Weidong Yang Huazhong Univ. of Sci. & Tech.
Hong Zhang Huazhong Univ. of Sci. & Tech.
Huijin Fan Huazhong Univ. of Sci. & Tech.
Bo Tao Huazhong Univ. of Sci. & Tech.

In industrial process, fault isolation technology can identify the major variables leading to faults. Contribution plots and reconstruction-based methods are common tools, but both of them have the smearing effect. To solve this problem, Bayesian theory based method have been developed. Unfortunately, they usually have a high misdiagnosis rate when handling multiple faults with small magnitudes. In this paper, a new fault isolation method based on Bayesian information criterion is proposed. Firstly, the fault isolation problem is transformed into a mixed integer nonlinear programming problem. Then, to reduce the difficulty of calculation, the original problem is simplified into a series of nested mixed integer quadratic programming problems by using forward selection strategy. Finally, these problems can be solved by branch and bound algorithm. The effectiveness of the proposed method is verified by Monte Carlo simulation.

17:10-17:30 **SatB05-5**

A Novel Health Index for Battery RUL Degradation Modeling and Prognostics

Qiuhui Ma Huazhong Univ. of Sci. & Tech.
Yan Wang Zhengzhou Univ. of Light Industry
Weidong Yang Huazhong Univ. of Sci. & Tech.
Bo Tao Huazhong Univ. of Sci. & Tech.
Ying Zheng Huazhong Univ. of Sci. & Tech.

Lithium-ion batteries are widely used in our daily life. However, with the frequent use of lithium battery, the performance of lithium battery decreases due to the change of internal physical properties. The most intuitive result is that the capacity gradually decreases with the use of the battery. Therefore, timely and effective prediction of lithium-ion battery remaining useful life (RUL) is particularly important. In this paper, two new health indexes (HI), namely, discharging time difference of equal voltage interval (DtD_EVI) and discharging temperature difference of equal time interval (DTD_EtI), are proposed to represent the degradation process of lithium battery. Pearson correlation coefficient is used to analyze the relationship between these two health indexes and capacity, and then support vector regression (SVR) is used to establish the RUL regression model. Finally, the validity of the proposed method is verified by analyzing the lithium battery dataset of NASA.

17:30-17:50 **SatB05-6**

A Check Valve Fault Diagnosis Method Based on Variational Mode Decomposition and Permutation Entropy

Zhen Pan Kunming Univ. of Sci. and Tech.
Guoyong Huang Kunming Univ. of Sci. and Tech.
Yugang Fan Kunming Univ. of Sci. and Tech.

Aiming at the problem that the vibration signal of the check valve has background noise and low fault recognition rate, a signal characteristics extraction method based on variational mode decomposition and permutation entropy was proposed. The extreme learning machine was used for fault recognition . Firstly , the check valve vibration signal was decomposed by the variational mode decomposition , and the intrinsic mode functions were obtained in different scales. Secondly, the permutation entropy of each intrinsic mode function was calculated and used to compose the multiscale feature vector. Finally, the high-dimensional feature vector was input to the extreme learning machine for check valve fault diagnosis. The comparison is made with EEMD and LCD (local characteristic-scale decomposition). The experimental results show that the method can effectively identify the fault type of the check valve.

17:50-18:10 **SatB05-7**

Comparison of 3D Object Detection Based on LiDAR Point Cloud

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Xiaolei Zhou North China Electric Power Univ.
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Dongbin Zhao Institute of Automation, Chinese Academy of Sci.
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Dianwei Qian North China Electric Power Univ.

3D object detection and scene understanding are the key technologies for autonomous driving scenarios. Due to the differences in configuration and datasets used by each 3D object detection algorithm, it is difficult to evaluate the performance of each method. In this work, we provide a comparison of the advanced 3D object detection networks based on LiDAR point cloud in recent two years and analyze each network structure in detail. For the open-sourced networks, we reproduce them on KITTI dataset benchmark with following their original algorithms. Meanwhile, in order to provide more powerful results, we also utilize nuScenes dataset to retrain the networks as mentioned above. The experimental results show that the performance of the networks with point cloud and images as input is better than that of a single input network.

SatB06 Room 6
IS: Data-driven based state estimation and ADRC
15:50-17:50

Chair: Zhonghua Pang North China Univ. of Tech.
CO-Chair: Wei Wei Beijing Tech. & Business Univ.

15:50-16:10 SatB06-1

SLAM Fusion Optimization Based on Monocular Vision and Inertial Sensor

Xuebo Jin Beijing Tech. & Business Univ.
Kaiyu Zhang Beijing Tech. & Business Univ.
Binbin Wang Beijing Tech. & Business Univ.
Tingli Su Beijing Tech. & Business Univ.
Jianglei Kong Beijing Tech. & Business Univ.
Yuting Bai Beijing Institute of Tech.

Simultaneous Localization and Mapping (SLAM) is a key technology in the field of robotics, and it is the key part and foundation for the complete autonomous control and intelligence of robots. With the continuous development of 3D computer vision algorithms, the vision-based SLAM method had become a research hotspot in recent years. However, the visual SLAM method relies too much on the feature information of the surrounding environment, cannot deal with the scene texture missing and dynamic scenes. Moreover, the visual sensor frame rate is low, which cannot handle the fast motion of the target. The Inertial Measurement Unit (IMU) measures the angular velocity and acceleration of the sensor itself, which has significant complementarity with the vision sensor, and has the potential to build a more robust SLAM system. In this paper, a fusion optimization method is proposed, in which the local optimization and global optimization methods are used in parallel. The local optimization uses the optimization of sliding window to obtain pose information. The global optimization focuses on the information of all points and gives a method to correct each of the previous key frame. This paper also proposes a relative marginalization method to ensure the global consistency of optimization and improve the precision of optimization. The experimental results show that the proposed method can obtain accurate target motion trajectory and improve the positioning accuracy of SLAM.

16:10-16:30 SatB06-2

A Robust Adaptive Control with Extended State Observer for a Piezo-actuated Nano-positioner

Pengfei Xia Beijing Tech. & Business Univ.
Wei Wei Beijing Tech. & Business Univ.
Zaiwen Liu Beijing Tech. & Business Univ.
Min Zuo Beijing Tech. & Business Univ.

Positioning control of a nano-positioner driven by a piezoelectric actuator is discussed. Robust adaptive control with extended state observer is presented for the trajectory tracking control. Radial basis function neural network (RBFNN) is utilized to estimate the unknown nonlinearities. Extended state observer (ESO) is also taken to observe the total disturbance, which includes external disturbances and hysteresis. Both the RBFNN and the ESO are utilized to reduce the dependence on model information. A nano-positioner model is established. Simulations confirm the robust adaptive control with ESO is effective in improving positioning accuracy.

16:30-16:50 SatB06-3

An Intelligent Supervision System of Environmental Pollution in Industrial Park

Li Wang Beijing Tech. & Business Univ.
Bo Han Beijing Tech. & Business Univ.
Jiping Xu Beijing Tech. & Business Univ.
Zhiyao Zhao Beijing Tech. & Business Univ.
Xiaoyi Wang Beijing Tech. & Business Univ.

In order to solve the present problem of China's industrial park which caused by environmental pollution, this paper adopts axios interface technology, Web service technology, node.js technology, developing an intelligent supervision system for environmental pollution in industrial parks. Through this system, which can achieve the function of remote real-time monitoring, forecasting and early warning, decision analysis of various environmental pollutants discharged by enterprises and emergency management of environmental pollution emergencies in industrial parks. The system can obtain real-time environmental pollutant discharge data of each enterprise through monitors

installed in industrial parks, according to the obtained data using radial basis function (RBF) neural network algorithm to predict the trend of environmental pollutants of various enterprises. Also, according to the environmental pollutants data we get for each enterprise risk analysis, then the risk analysis results for decision-making of the enterprise. What's more, we use all the results to be displayed visually.

16:50-17:10 **SatB06-4**

Attenuation of Periodic Disturbances via Customized ADRC Solution: a Case of Highly Oscillatory 3DOF Torsional Plant

Rafal Madonski Southeast Univ.
M.Ram Irez-Neria Universidad Politecnica del Valle de Mexico
Zhiqiang Gao Cleveland State Univ.
Jun Yang Southeast Univ.
Shihua Li Southeast Univ.

In this work, the problem of estimating and suppressing periodic disturbances in feedback control systems is addressed. The problem is formulated and solved here in the framework of active disturbance rejection control (ADRC). The new, custom ADRC-based solution uses a special modified version of a resonant extended state observer, a recently introduced tool dedicated to reconstructing harmonic-type uncertainties. The controller synthesis is performed in the absence of a detailed plant mathematical model, with only a rough value of disturbance frequency needed. In order to make the proposed observer-based control structure more practically appealing, it is expressed here in an alternative, error-driven form, which makes it resemble industry-proven feedback controller forms (like PID). The effectiveness of the proposed scheme is validated through laboratory experiments conducted on a 3DOF torsional plant, in which trajectory tracking task has to be realized despite the presence of periodic disturbance coming from the underactuated, unmodeled, compliant plant dynamics.

17:10-17:30 **SatB06-5**

A Novel Modified Robust Model-Free Adaptive Control Method for a Class of Nonlinear Systems with Time Delay

Shida Liu Beihang Univ.
Beijing Jiaotong Univ.
Zhongsheng Hou Qingdao Univ.
Beijing Jiaotong Univ.
Yuan Guo Beijing Jiaotong Univ.
Lei Guo Beihang Univ.

In this work, a novel robust model free adaptive control (Ro-MFAC) algorithm is proposed for a class of discrete nonlinear systems existing both large time delay and disturbance. The main feather of Ro-MFAC is that the controller is designed only based on the input and output data of the system by using a new dynamic linearization technique with a time-varying parameter termed pseudo gradient. Moreover, by combining a novel augmented pseudo gradient, the Ro-MFAC can effectively suppress the system disturbance, such that the Ro-MFAC has strong robustness. Meanwhile, by using the tracking differentiators, the Ro-MFAC controller can also deal with the time delay existing in the system. Furthermore, the numerical simulation results verify the effectiveness of proposed Ro-MFAC.

17:30-17:50 **SatB06-6**

Improved Model Free Adaptive Control Based on Compact Form Dynamic Linearization

Zhonghua Pang North China Univ. of Tech.
Wentai Song North China Univ. of Tech.
North China Univ. of Tech.
Wencheng Luo North China Univ. of Tech.
Cunwu Han North China Univ. of Tech.
Dehui Sun North China Univ. of Tech.

With the development of modern industry and information science and technology, modern industrial processes become more and more complex, which brings many challenges for model-based controller design. In this case, data-driven control is a complementary approach to model-based control. This paper proposes an improved model free adaptive control method based on compact format dynamic linearization technique for a class of nonlinear systems. Its control law consists of a time-varying proportional term, a time-varying integral term, and a time-varying derivative term. As a result, compared with the original method where there is only a time-varying integral term, it can strongly improve the dynamical performance of control systems. The effectiveness of the proposed method is demonstrated through simulation results.

Sunday, May 26, 2019

SunA01 **Room 1**
Iterative learning control (II) **13:30-15:30**

Chair: Junmin Li XiDian Univ.
CO-Chair: Qiao Zhu Southwest Jiaotong Univ.

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

Closed-Loop Iterative Learning Control for Linear Singular Systems with Fixed Initial State Errors

Shuang Ding South China Univ. of Tech.
Senping Tian South China Univ. of Tech.
Shali Yu Guangzhou College of South China Univ. of Tech.
Xiangyang Li South China Univ. of Tech.

With regard to a class of linear singular systems, the problem of iterative learning control in consideration of fixed initial state errors is investigated. By constructing the initial modified signal, a new type of closed-loop

iterative learning algorithm is applied to design the iterative learning control system. After enough iterations, complete tracking of the reference signal over the preset time interval can be realized. A simulation example is given to show the effectiveness of the approach.

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

A Simple Reference Model based PID Control for Wafer Scanner Systems

Qiao Zhu Southwest Jiaotong Univ.
Junxiong Chen Southwest Jiaotong Univ.
Fazhi Song Southwest Jiaotong Univ.
Yang Liu Southwest Jiaotong Univ.

In this work, we propose a new and simple controller design based on internal model principle (IMP) and existing PID, with the implementation on a wafer stage. PID has been well applied to solve control engineering problems owing to its flexibility to handle various control tasks, and the easiness to tune PID gains for a variety of plants. However, PID may fail to achieve satisfactory tracking performance when dealing with a complex control task that is beyond a simple step reference. IMP suggests that a good control response can only be expected when the internal model of the reference is incorporated into the control loop. For a well-tuned PID, however, it is not that straightforward to incorporate the internal model of the reference into the existing PID. In this work, focusing on a real wafer stage, we explore a new control design approach, reference-model (RM)-based PID, to achieve the internal model and meanwhile retain the well-tuned PID. The new controller design for the wafer stage is achieved through several steps. First, the body plots of the experimental setup of wafer stage are acquired and a second order approximate model is established. Second, a reference model specific in wafer stage is given and its inherent internal model is analyzed. Then, the feedback controller is constructed by concatenating the internal model and an existing PID that has been well tuned. Next, considering the low-frequency characteristic of the reference, the internal model is further modified with a simple high-pass filter such that more of high-frequency components in the tracking error could be suppressed. Finally, in experiments, more accurate tracking performance of the RM-based PID is illustrated by comparing with two classic PIDs with different bandwidths.

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

Consensus of Nonlinear Multi-agent System under Independent Topology

Dan Zhang XiDian Univ.
Junmin Li XiDian Univ.

This article solves the consensus problem for second-order multi-agent systems (MASs) in continuous time with nonlinear dynamics under different position and velocity graph. Combining the graph theory, a novel distributed iterative learning control mechanism is derived, and a sufficient convergence condition is proposed under the compressing mapping framework. It is proved that the convergence can be attained with the existence of the control gain matrix by rigorous analysis. Lastly, the validity of main result is verified by a simulation.

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

Unified Optimization of Upper Stability Bound and Tracking Performance Index for Singularly Perturbed Systems

Lei Liu North China Univ. of Tech.
Yuqian Liu North China Univ. of Tech.
Cunwu Han North China Univ. of Tech.
Xiaoping Zhang North China Univ. of Tech.

In this paper, the problem of unified optimization of upper stability bound ε^* and tracking performance index J^* for singularly perturbed systems is considered. First, an optimal output tracking controller is given based on the method of minimum value principle, such that the original system achieves asymptotically stable and asymptotic tracking of the tracking system and the minimum value of quadratic performance index can be obtained. Furthermore, based on Nash game theory, an algorithm to optimize (ε^*, J^*) simultaneously which transfers multi-objective problem into a single objective problem as well we determines the objective weights. Finally, one numerical example is given to illustrate the correctness and feasibility of the proposed results.

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

Design and Manufacture of Two-wheeled Self-balancing Vehicle Based on 32-bit Single-chip Microcomputer Control

Shali Yu Guangzhou College of South China Univ. of Tech.
Senping Tian South China Univ. of Tech.

In this paper, based on the Kinetis 60 chip of Lanzhou Electronics, a two-wheeled self-balancing intelligent vehicle is designed. The built-in solid-state gyroscope is used to judge the status in vehicle body system. By using the PID algorithm, the motor can be driven to achieve two-wheel self-balancing function. Moreover, we also can get the speed control function which is up to two point five meters every second.

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

An Iterative Learning Controller for Continuous Systems with Variable Iteration Interval

Yunshan Wei Guangzhou Univ.
Kai Wan Sun Yat-sen Univ.

In iterative learning control (ILC) strategy, to achieve the perfect tracking in a fixed time interval, a common assumption is that the iteration interval in each repetitive operation should be fixed. An iterative learning controller is designed for continuous systems with variable iteration interval in this note. The control input and tracking error with variable iteration interval are modified by Bernoulli stochastic variable. The iterative learning controller is designed by using the modified control input and tracking error. The sufficient convergence condition is proposed to enable the system to maintain asymptotic tracking capability under varying iteration interval. An illustrative example is used to validate the effectiveness of the presented controller.

SunA02 **Room 2**

Data-Driven fault diagnosis and health maintenance (II)

13:30-15:30

Chair: Yandong Hou Henan Univ.
CO-Chair: Xin Huo Harbin Institute of Tech.

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

A Hybrid Prognostic Approach Based on UKF and Optimized RBF

Xiaoyang Mei Huazhong Univ. of Sci. & Tech.
Huajing Fang Huazhong Univ. of Sci. & Tech.

Prognostics and health management (PHM) is of great significance for complex systems. Making full use of the known information of systems is an urgent problem to be solved to ensure the efficient operation. So, utilizing both of the mechanism model and data generated during the operation could predicting as precisely as possible. In this paper, a hybrid approach based on unscented Kalman filter (UKF) and optimized Radial Basis Function (RBF) neural network is proposed. Firstly, UKF is utilized as model-based method to obtain the initial prognosis. Then, a neural network based on Radial Basis Function (RBF) integrated with K-means clustering algorithm (K-means-RBF) is built and trained by the deviation series which is emerged in the UKF modeling process. Finally, initial prognosis is corrected with the predicted deviation. The lithium-ion battery data set of Maryland University is employed to verify the effectiveness of this given approach. The remaining useful life (RUL) of battery is predicted. The experimental results show that the prognosis of the hybrid approach is credible. The accuracy of appended data-driven method is higher than that of single source algorithm.

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

Torquer-Based Active Vibration Control for GyroWheel System with Hooke Joint

Yuanyuan Zhang Harbin Institute of Tech.
Xin Huo Harbin Institute of Tech.
Haiyuan Liu The 14th Research Institute China Electronics Technology Group Corp.
Hui Zhao Harbin Institute of Tech.

GyroWheel is considered to be an innovative device that is designed for the attitude control system of the micro satellite. Its actuating capabilities of the control moment gyro combined with the rate sensing capabilities of the tuned rotor gyro are realized by using a spinning flex-gimbal with Hooke Joint. For a 3-DOF GyroWheel rotor with high spinning velocity, the uneven mass distribution and undesirable factors related to the characteristics of Hooke Joint, are inevitable that bring about undesired vibration which hinders the improvement of the specification performance and control accuracy. To suppress unexpected vibration of GyroWheel rotor, two methods about active vibration control based on the torquer are proposed. Some theoretical analysis and simulation illustrations based on SimMechanics are developed in this paper, which provide useful guidance for further experimental studies.

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

Lithium-ion Battery Remaining Useful Life Prediction Based on An Integrated Method

Yan Yan Huazhong Univ. of Sci. & Tech.
Huajing Fang Huazhong Univ. of Sci. & Tech.
Zheng li Huazhong Univ. of Sci. & Tech.

As the main power source in many electronic and electrical devices, lithium-ion battery plays a critical role in the safety and reliability of industrial systems. So it is of great importance to evaluate the performance degradation and predict the remaining useful life (RUL) for batteries. This paper developed a novel integrated method to realize RUL prediction by combining unscented Kalman filter (UKF), empirical mode decomposition (EMD) and relevance vector regression (RVR). First of all, UKF is used to estimate and adjust the system states and make the original error residual series. Then, the error series will be decomposed by EMD, and the decomposition result will be analyzed to produce a new error sequence which will be used by RVR to make prediction of the prognostic error residual. Finally, UKF will adopt the predicted error residual to estimate the battery parameters recursively and predict RUL. The result of the experiment on a lithium battery shows that, the proposed method has excellent performance of reliability and prediction accuracy.

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

Fault Detection of Multimodal Chemical Process Based on CLTSA

Yankun Han Henan Univ.
Ruirui Huang Henan Univ.
Yandong Hou Henan Univ.
Qianshuai Cheng Henan Univ.

For modern chemical process often has multiple operational modes and monitoring data in the process are often nonlinear and high dimensional, a new fault detection method based on improved local tangent

space alignment (LTSA) is proposed in this paper. Firstly, aiming at the characteristics of multi-modality of the chemical process, an improved LTSA algorithm is proposed in the paper, called correlation tangent space arrangement (CLTSA). In CLTSA, the variable r is constructed and used to describe the relationship between the multivariate variables and reconstruct the global coordinates of monitoring data. Then, the incremental learning mechanism is introduced in CLTSA. For newly collected data, only some elements of the transition matrix need to be updated. And the matrix similarity statistics is established to maintain the size of the transition matrix, which has improved the efficiency of the algorithm. Finally, nonlinear principal elements in monitoring data are extracted through CLTSA and statistics T 2 and SPE are used to monitor the change of the principal elements. When the monitored amount exceeds the threshold, it is determined that a fault has occurred in the chemical process. The simulation results of TE process show that the method proposed in the paper has a high fault detection rate and provides a new way for fault detection of multi-modal nonlinear chemical processes.

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

Multimode Process Monitoring Based on Modified Probabilistic Linear Discriminant Analysis

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

This paper focus on developing an effective method to monitor the industrial process with multiple operation conditions. By utilizing the technique of probabilistic linear discriminant analysis (PLDA), the between- and within-class latent variables can extract more useful information. The proposed method, the modified PLDA (MPLDA), transforms the centralized samples into a new type of between-class latent variables. The current mode operation condition can be identified by comparing a series of cosine similarities deduced by the original and the new between-class latent variables. The online monitoring procedures are built on the basis of this mode identification. Unlike the conventional T 2 and Q statistics designed for within-class latent variable, the proposed monitoring statistics take both between- and within-class latent variables into consideration. For the model training, the joint updating expectation-maximization (EM) algorithm is developed. The enhanced performance of the MPLDA based method is illustrated by the application of Tennessee Eastman (TE) process.

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

Fault Diagnosis of Check Valve Based on WVD and NMF

Jihui Luo Kunming Univ. of Sci. & Tech.
Guoyong Huang Kunming Univ. of Sci. & Tech.
Jun Ma Kunming Univ. of Sci. & Tech.

This paper proposes a check valve fault diagnosis method based on time-frequency images and Non-negative Matrix Factorization (NMF), which transforms the fault features extraction of time domain signals into fault features extraction of time-frequency images. Firstly, the vibration signals of the check valve are decomposed by Differential Empirical Mode Decomposition (DEMD), and the Intrinsic Mode Functions (IMFs) containing more feature information are selected to reconstruct the signals by correlation coefficient method. Secondly, Wigner-Ville Distribution (WVD) is used to analysis the reconstruct signals and obtain the time-frequency images, then NMF is applied to decompose the time-frequency image matrixes and get the feature matrix. Finally, the feature vectors are classified via the Support Vector Machine (SVM) which is optimized by Genetic Algorithm (GA) to complete the fault diagnosis of the high pressure diaphragm pump check valve. The method is validated using data from three operating states of the high pressure diaphragm pump check valve. The experimental result shows that the proposed method can effectively extract the fault features and identify fault types of the check valve. The average classification accuracy rate is up to 99.17%, which is higher than using the time domain and frequency domain features as input.

SunA03 — Room 3
Data driven control (II) — 13:30-15:30

Chair: Deqing Huang Southwest Jiaotong Univ.
CO-Chair: Yongpeng Weng Dalian Maritime Univ.

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

A Novel Self-tuning Control Method with Application to Nonlinear Processes

Bi Zhang Shenyang Institute of Automation, Chinese Academy of Sci. Institutes of Robotics and Intelligent Manufacturing, Chinese Academy of Sci.
Xiaowei Tan Shenyang Institute of Automation, Chinese Academy of Sci. Institutes of Robotics and Intelligent Manufacturing, Chinese Academy of Sci.
Xingang Zhao Shenyang Institute of Automation, Chinese Academy of Sci. Institutes of Robotics and Intelligent Manufacturing, Chinese Academy of Sci.

Hammerstein models have been considered as a class of well-known nonlinear systems, which have been prove to be attractive for system modeling and controller design tasks. In this brief, we introduce a new control strategy for such kind of systems. Interestingly, the system uncertainties, including the input block

description error, the linear subsystem's unstable zero property and the colored added noise issues, have all been considered. According to the modified cost function, the parameter adaptation law has been online implemented throughout the use of a robust estimator. Meanwhile, based on the parameter estimates, the control law has been designed for the compensation of the modeling mismatch which is caused by unmodeled dynamics estimation. A simple but rigorous proof has been given to illustrate that the nonlinear model based control system stability can be properly achieved based on some reasonable and practical conditions. Finally, the proposed controller has been used for a representative nonlinear system, that is, a continuous stirred tank reactor (CSTR) system. Comparison studies have been presented to show the wider applicability of the novel method than some existing ones.

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

Adaptive Parameter Estimation for MISO System Using Decomposition Principle

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

In the paper, we discuss the identification of the multiple-input and single-output (MISO) system. Based on the internal relation of the linear subsystem and nonlinear element, the estimation model of the system considered is recasted as the entirety estimation equation. For the equation, here the single parameter item and bilinear parameter item coexist. Because the bilinear item includes compound parameters, the calculative burden of the identification method will be high. Then, to cut down the amount of calculation, the matrix conversion technology is utilized to reconstruct two estimation models. In parameter estimation process, for each model, an adaptive parameter estimation scheme is submitted to interactively identify the estimated parameters by virtue of hierarchical identification idea. Via the stochastic theory and martingale theorem, the convergence of parameter estimation is provided. The numerical simulation verifies the usefulness of the presented estimator.

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

Fuzzy Sliding Mode Control for a Quadrotor UAV

Tianpeng Huang Southwest Jiaotong Univ.
Binbin Li Southwest Jiaotong Univ.
Awais Shah Southwest Jiaotong Univ.
Na Qin Southwest Jiaotong Univ.
Deqing Huang Southwest Jiaotong Univ.

In this paper, a fuzzy sliding mode control (FSMC) method is presented for the altitude and attitude tracking problem of a quadortor unmanned aerial vehicle (UAV) system. The nonlinear dynamic model of the quadrotor UAV is first established based on the Euler-Lagrange method. Then, a sliding mode controller (SMC) is designed based on the nonlinear model. Further, to address the severe chattering phenomenon associated with the pure SMC, additional fuzzy control is adopted to adjust the switching gain. Finally, the proposed controller is tested via Matlab/Simulink. The results show that the control performance of FSMC is superior to PID control and fuzzy PID control in the sense of tracking accuracy and suppression of switching chattering.

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

Finite-Duration Consensus of Multi-Agent Systems Using a Generic Attracting Law

Mingxuan Sun Zhejiang Univ. of Tech.
Xing Li Zhejiang Univ. of Tech.

This paper is concerned with the convergence rate improvement of consensus of multi-agent systems, for which we introduce a generic attracting law (GAL), involving three terms which specify a generic action for improvement of convergence performance. The conventional double power-rate attracting law is modified for forming GAL, by adding a proportional term, and the convergence rate of the system can be dramatically improved. Through the two-phase analysis, an estimate for the upper bound of the settling time function is given, by which the obtained upper bound depends upon the initial state, and is finite without regard to the value of the initial state. The GAL is adopted for the purpose of consensus of multi-agent systems. A nonlinear protocol is designed to make the system undertaken achieve finite-duration consensus, and numerical results are presented to validate its effectiveness.

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

An EEG Signal Analysis Method based on Elastic Network Combined with Filter Bank

Xue-Zhi Cai Shanghai Univ.
Jian-Guo Wang Shanghai Univ.
Yu Wang Shanghai Univ.
Yuan Yao National Tsing-Hua Univ.
Chao Xu Baoshan Iron and Steel Co. Ltd.

Brain Computer Interface (BCI) is a new way of interaction between the human brain and the outside world. The analysis of EEG (Electroencephalogram) signals is crucial in the field of brain-computer interface. In this paper, a feature selection and classification method based on encapsulated elastic network is proposed in combination with filter banks. The effectiveness of the method is demonstrated by the case of motion-imagining EEG signals in international competition data. At the same time, the method is compared with the conventional band selection method and the filtered elastic network feature selection method

to prove the superiority of the method in the classification performance of the BCI system.

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

Data-Driven Sliding Mode Control with Moving Surface for Unknown MIMO Discrete-Time Nonlinear Processes

Lichuan Liu Dalian Maritime Univ.
Jiapeng Li Dalian Maritime Univ.
Yongpeng Weng Dalian Maritime Univ.
Ning Wang Dalian Maritime Univ.
Yi Liu Dalian Maritime Univ.

A novel moving surface is proposed for data-driven sliding mode controller design to deal with the unknown multi-input multi-output discrete nonlinear processes with both uncertainties and disturbances. The key point of this study is to design a data-based moving sliding surface and the corresponding data-driven robust controller. A sliding mode surface with time-varying gain matrix is proposed at first and then transformed into an equivalent data-based form via observer strategy and non-parametric dynamic linearization technique. By further deploying the data-driven strategy, an efficient adaptive law is developed to update the aforementioned gain matrix: As the adaptive law is developed based on the strategy of improving the control performance, a fast tracking with little overshoot and small chattering is obtained. Lastly, the efficacy of the proposed approach is testified by both simulation and theoretical analysis.

SunA04 Room 4

Data-driven modeling, optimization and scheduling (II)

13:30-15:30

Chair: Yanlin He Beijing Univ. of Chemical Tech.
CO-Chair: Di Yu Beijing Information Sci. & Tech. Univ.

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

Stability Analysis for Car-Following Model Considering Position Error

Yongfu Li Chongqing Univ. of Posts and Telecommunications.
Guang Wu Chongqing Univ. of Posts and Telecommunications.
Hao Zhu Chongqing Univ. of Posts and Telecommunications.
Xiaoming Tang Chongqing Univ. of Posts and Telecommunications.

The car following behavior is a common traffic phenomenon. This paper proposes a novel microscopic model to illustrate the traffic phenomenon based on mathematical simulation approach. Meanwhile, this paper considers the interaction between vehicles. The status information (i.e., velocity and distance) of the preceding vehicle is combined into the proposed model. In addition, the effect of velocity and position delays are also considered in proposed model. In order to further analyze the proposed model and obtain its stability conditions, the stability of the proposed model is analyzed based on the perturbation method. The numerical experiments are conducted and the results show the availability of the proposed model.

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

Data-driven Intelligent Evaluation of Injection-Production Well Pattern

Di Yu Beijing Information Sci. & Tech. Univ.
Rongmin Cao Beijing Information Sci. & Tech. Univ.
Rui Li Beijing Information Sci. & Tech. Univ.

Aiming at the time-varying complexity of heterogeneous reservoirs and the current problem of massive data and tiny information in oilfields, an intelligent evaluation system of injection-production well pattern is developed based on data-driven method and computing with words idea in the paper. At first, based on the digital filtering approach, the production data of oil field is processed and the estimation of injection-production relationship is calculated. Secondly, the enhanced interval approach is used to encode the descriptive words of geological information and injection-production relationship so as to obtain the code book. Thirdly, According to the useful rule bases and perceptual reasoning outputs of oil field production evaluation obtained in the preliminary work, the recommended output of decision is obtained by using the decoder according to Jaccard similarity measure based interval type-ll fuzzy sets. Finally, the effectiveness and practicability of the proposed scheme is testified by production example of inverted nine-point well-pattern of heterogeneous reservoirs with channel sedimentation with the aid of expert verification.

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

Air-floating Corner Reflectors Dilution Jamming Placement Position

Jun Zhang Naval Univ. of Engineering
Shengliang Hu Naval Univ. of Engineering
Lingang Wu Naval Univ. of Engineering
Xueman Fan Naval Submarine Academy, Submarine Combat Software and Simulation Institute
Qing Yang Naval Ship Training Center, Southern Theater Command

In order to cope with the threat of new type anti-ship missiles in active service, an exploratory study on the air-floating corner reflectors is carried out. Firstly, the reasonable placement position of the dilute air-floating corner reflectors is analyzed theoretically. Then, the high resolution range profile of air-floating corner reflectors and warships are obtained by CST simulation .Finally, the similarity of the above two is measured based on the average Euclidean distance. The results show that the five kind of air-floating corner reflectors propounded at the end of the paper have a high similarity to the ship target in high resolution range profile.

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

A Virtual Sample Generation Method Based on Kernel Density Estimation and Copula Function for Imbalanced Classification

Qunxiong Zhu Beijing Univ. of Chemical Tech.
Shixiong Wang Beijing Univ. of Chemical Tech.
Zhongsheng Chen Beijing Univ. of Chemical Tech.
Yanlin He Beijing Univ. of Chemical Tech.
Yuan Xu Beijing Univ. of Chemical Tech.

In the case of imbalanced data, classification models often achieve low accuracy. To solve this problem, this paper proposes a virtual sample generation method based on kernel density estimation and copula function. The kernel density estimation is used to estimate the probability density of each dimension of data, and the joint probability density of the samples is constructed by the copula function. The validation experiments are carried out by applying the proposed method to a numerical simulation and a yeast classification problem. Simulation results show that the proposed method can generate high-quality virtual samples and significantly improve the recognition accuracy.

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

An Improved MPC Integrating Fuzzy PI of an MMC-HVDC System

Jungen Dong Beijing Univ. of Chemical Tech.
Minghui Jia Beijing Univ. of Chemical Tech.
Yongmin Han Beijing Univ. of Chemical Tech.
Zhiqiang Geng Beijing Univ. of Chemical Tech.
Yanhua Zhong Jiangmen Polytechnic

Modular multilevel converter (MMC) has been widely used in high-voltage and high-power transmission because of its high efficiency, low harmonics and low switching frequency. Model predictive control (MPC) can well overcome the difficulty of PI controller parameter tuning and overshooting. However, when the traditional MPC is applied in MMC systems with a great number of submodules, the times of rolling optimizations is too many to realize real-time control. And the existing MPC in the MMC system is to replace the inner loop controller with the MPC, and still retain the outer loop PI controller. Therefore, an MPC integrating the fuzzy PI is proposed. The accuracy requirement of parameter tuning of outer loop controller is reduced by the fuzzy PI control, and then the number of rolling optimizations of the inner control system are reduced by the double-layer MPC. Finally, a 101-level MMC-HVDC system is set up in PSCAD/EMTDC to confirm the feasibility and validity of the method.

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

Experimental Comparison of Some Classical Distance Measures for Time Series Data in Simulation Model Validation

Xiaojun Yang Luoyang Electronic Equipment Test Center of China
Zhongfu Xu Luoyang Electronic Equipment Test Center of China
Haibo Ouyang Luoyang Electronic Equipment Test Center of China
Xing Zhang Luoyang Electronic Equipment Test Center of China

The comparison of simulation-generated time series with observed data is a basic problem in simulation model validation field. Many distance measure methods have been proposed or used by a number of modelers and users to validate simulation models for several decades. However, efforts to evaluate the performance of these methods are rarely published, especially on large datasets. Therefore, in this paper, the accuracies of some classical distance measures in simulation model validation are tested and evaluated on the latest UCR time series archive. Experimental results suggest that Theil's inequality coefficient and Manhattan distance outperform other distance measures, and elastic and normalized distance measures are generally effective to reflect the underlying dissimilarity of time series data. Furthermore, we also expect our work may promote quantitative comparisons by providing a common framework for experimental research in simulation model validation community.

SunA05 **Room 5**

Statistical learning and machine learning in automation field (II)

13:30-15:30

Chair: Dazi Li Beijing Univ. of Chemical Tech.
CO-Chair: Huijin Fan Huazhong Univ. of Sci. and Tech.

13:30-13:50 **SunA05-1**

Feature Extraction for Controller Design by Deep Auto-Encoder Neural Network and Least squares Policy Iteration

Dazi Li Beijing Univ. of Chemical Tech.
Zhudan Chen Beijing Univ. of Chemical Tech.
Xin Ma Beijing Univ. of Chemical Tech.
Qibing Jin Beijing Univ. of Chemical Tech.

Due to the extensively existing complexity and uncertainty of systems, feature extraction based on samples is an important task in controller design. As one of the research hotspots, deep auto-encoder neural network can be used to extract features from raw data. This paper proposed a modified deep auto-encoder neural network (MDAENN). An accelerated proximal gradient (APG) method is proposed in this method. MDAENN has lower computational complexity, easier parameters tuning and better convergence than traditional neural network methods, such as RBF, in feature extraction and reconstruction. Based on the feature extraction, least squares policy iteration (LSPI) is used to design the optimal controller. When the dimension of state space is large or even continuous,

value function approximation (VFA) method is used instead of value function. Experimental results show that the proposed method can successfully deal with feature extraction and learn control policies with low computational complexity.

13:50-14:10 **SunA05-2**

Content Based Image Retrieval via Sparse Representation and Feature Fusion

Han Liu Xi'an Univ. of Tech.
Wenqing Wang Xi'an Univ. of Tech.
Pengfei Jiao Xi'an Univ. of Tech.

During the last two decades, content-based image retrieval (CBIR) has been widely studied. The limitations of low-level feature representation of images have been a thorny issue in image retrieval problems. In this paper, a CBIR algorithm based on sparse representation and feature fusion is proposed, in which global features and local features are combined to retrieve the images. Firstly, the GIST features are used to roughly retrieve the images with similar scene information by measuring Canberra distance. Then, a representation of the local features extracted from the rough retrieval results is obtained by sparse coding and feature pooling. Finally, Euclidean distance is used to measure the similarity of the sparse feature vectors to obtain the retrieval results. The proposed method is tested on the Coil20 and Caltech256 image datasets. The experimental results demonstrate that the proposed algorithm can achieve comparable superior retrieval performance to the existing single feature-based image retrieval algorithms.

14:10-14:30 **SunA05-3**

A Novel YOLOv3-tiny Network for Unmanned Airship Obstacle Detection

Sha Ding Huazhong Univ. of Sci. and Tech.
Fei Long China Special Vehicle Reach Institute
Huijin Fan Huazhong Univ. of Sci. and Tech.
Lei Liu Huazhong Univ. of Sci. and Tech.
Yongji Wang Huazhong Univ. of Sci. and Tech.

Obstacle detection is an important issue in the study of an unmanned airship, which helps the airship to avoid obstacles and reduces the risk of accidences. This paper establishes an obstacle detection network, which is obtained by inserting wisely some 1 ×1 and 3 ×3 convolutional layers at the beginning and the end of the YOLOv3-tiny network. The experimental results show that our novel network leads to a higher accuracy compared to YOLOv3-tiny while with a satisfied processing speed.

14:30-14:50 **SunA05-4**

Output-oriented Software Testing Data Generation Based on Artificial Immune Algorithm

Weixiang Zhang Beijing Institute of Tracking and Telecommunications Technology
Yuhua Qi Beijing Institute of Tracking and Telecommunications Technology
Zhaohui Dou Beijing Institute of Tracking and Telecommunications Technology
Wenhong Liu Beijing Institute of Tracking and Telecommunications Technology
Bo Wei Beijing Institute of Tracking and Telecommunications Technology
Min Zhang Beijing Institute of Tracking and Telecommunications Technology

To achieve software output domain coverage is a challenge to the functional testing of security-critical software. This paper proposed a test data generation method based on artificial immune algorithm using intelligence testing approach. Firstly, based on the analysis of the software output domain coverage problem, we gave the basic idea of applying artificial immune algorithm to software testing, and introduced the general steps of the algorithm. Secondly, we designed the main operators of the artificial immune algorithm, such as antibody affinity evaluation operator, antibody concentration evaluation operator, immune selection operator, clone operator, mutation operator, etc., to achieve the automatic generation of software test data. Finally, several software was used to verify the validity of the method. The verification results show that the method achieves the software output domain coverage, and its effect is better than the genetic algorithm and random testing.

14:50-15:10 **SunA05-5**

Multi-grain Cascade Recurrent Neural Network for Nonlinear Time-varying Process Soft Sensor Modeling

Jinjing Yi Zhejiang Univ.
Le Yao Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

Soft sensor provides accurate online estimation of primary variables based on historical data of secondary variables. Recurrent neural network exhibits better performance on sequence data. Deep forest shows quite robust performance across nonlinear data from different domains. In this paper, a multi-grain cascade recurrent neural network (gcRNN) is put forward to soft sensor modeling for nonlinear time-varying processes. Based on deep forest framework, LSTM and GRU are chosen as individual learners in multi-grain moving window scanning and cascade structure to deal with sequence data. Performance of the proposed method is verified on two industrial cases with different process characteristics. Compared to the PLS, RF, LSTM and GRU soft sensing approaches, the root mean squared errors (RMSE) of gcRNN are the smallest. The prediction results also illustrated that gcRNN achieves better performance for primary variable quality prediction in nonlinear time-varying processes.

15:10-15:30 **SunA05-6**

Big Data Knowledge Mining Based Operation Parameters Optimization of Thermal Power

Hanyu Wang Shanghai Univ.
Li Jia Shanghai Univ.

With the development of electric-power industry, a large amount of historical data of thermal power units are accumulated, conventional optimization methods of operation parameters have the limitations in storage and computation for massive data. To solve the problem, this paper proposes a big data analysis architecture for thermal power based on data processing flow. According to this architecture, a big data mining method for operation parameters optimization based on parallel association rules is presented. Firstly, a new distributed adaptive K-means algorithm is proposed to realize the classification of working conditions based on external constraints, which can improve the computing efficiency and avoid the defect of determining the division number artificially. Then, Spark-based FP-growth algorithm is applied to mine the strong association rules under various working conditions, thus the optimization target values of operation parameters can be obtained by the best strong association rules. Lastly, the excavated optimization target values constitute the historical knowledge database to optimize the real-time operating parameters. The experiment results show that the proposed method in this paper is effective, and can improve the accuracy of operation parameters optimization.

SunA06 Room6
Data-driven Technologies and its applications (I)

13:30-15:30

Chair: Congzhi Huang North China Electric Power Univ.
CO-Chair: Yan Li Shandong Univ.

13:30-13:50 **SunA06-1**

Steel Plate Surface Defect Recognition Method Based on Depth Information

Chang Zhao Beijing Univ. of Chemical Tech.
Haijiang Zhu Beijing Univ. of Chemical Tech.
Xuejing Wang Beijing Univ. of Chemical Tech.

Although steel surface defect recognition based on 2D image data has been extensively researched over the last ten years, it is very difficult for the identification of the defects with depth information in these methods. This paper presents a recognition method of steel plate surface defect through the estimated 3D depth information. In this method, the 3D data of the steel plate surface are first reconstructed using structure from motion (SFM). Then 3D points of the defect are segmented from the 3D reconstructed result of the steel plate surface using a region-growing based 3D information segmentation method. Finally, normal map is estimated from the segmented 3D point cloud, and the smoothness threshold in the normal map is optimized to classify the defect region and other regions. In experiment, the steel plate specimens with different hole sizes and the non-injured region are prepared, and the defect region based 3D information is classified. Experimental results show that the proposed method is efficient and feasible.

13:50-14:10 **SunA06-2**

Simulation of the Array Signals Processing based on Automatic Gain Control for Two-wave Mixing Interferometer

Feiming Qian Beijing Univ. of Chemical Tech.
Haijiang Zhu Beijing Univ. of Chemical Tech.
Guangzhen Xing National Institute of Metrology
Ping Yang National Institute of Metrology

Laser ultrasonic testing represents an attractive method for non-contact measurements with high sensitivity and broad detection bandwidth, which make it possible to measure ultrasound field in some offensive environments. Because of the noise caused by serious scattering, the conventional optical interferometer cannot work properly on rough surfaces. The environmental noise is also a big uncertainty budget for the measuring results. In this paper, an array signals processing method for a new type of two-wave mixing interferometer is introduced. In order to calibrate the displacement of the target, a mirror driven by the piezoelectric transducer introduces a known displacement at a low frequency on the reference beam. In addition, the wavelet neural network (WNN) is applied to denoise the input signals. Moreover, an automatic gain control (AGC) scheme is employed to the output of the photodiode array which can calibrate the output sensitivity. Then according to the output sensitivity, the displacement of the target measured by the diode array can be demodulated. Both the out-plane and in-plane displacements can be measured simultaneously, which may result in a wide usage in non-destructive areas.

14:10-14:30 **SunA06-3**

Multi-objective Optimization of Wind Farm Dispatch Problem By Double-layer Particle Swarm Optimization Algorithm

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

In the process of power dispatch of the wind turbines, the frequent start-up and shut-down will accelerate the performance degradation of the wind turbines. The strategy of adjusting the power output of each wind

turbine through the pitch angle of the blade control system will also reduce the stability margin of wind turbines. In order to reduce the loss caused by frequent changes of start-up and shut-down and improve the stability margin of wind turbines, the double-layer particle swarm optimization (DLPSO) algorithm is proposed, including the binary particle swarm optimization (BPSO) algorithm in the outer layer, and the self-adjusting chaotic particle swarm optimization (SACPSO) algorithm in the inner layer. The wind turbine dispatch model is established, wherein the times of start-up and shut-down, and the mean value of the power limitation index are taken into account in the objective function. Based on the wind turbine dispatch model, the DLPSO algorithm is employed to solve the wind turbine dispatch problem. Extensive experimental results are finally presented to demonstrate the validity and effectiveness of the proposed DLPSO algorithm and the wind turbine dispatch model.

14:30-14:50 **SunA06-4**

Design of Internal Model Control Oriented PID for Typical Thermal Processes in Combined Cycle Unit

Hongqiang Yang Jiangsu Electric Power Co., Ltd. China Energy Investment Corp.
Fanfei Zeng Beijing Guodian Zhishen Control Tech. Co.,Ltd

The internal model control oriented PID control law was proposed for typical thermal processes in the combined cycle unit, and the corresponding parameters tuning approach is also put forward. First of all, the internal model control law is employed to derive a PID parameters tuning approach for the typical thermal processes in the combined cycle unit. Secondly, three different parameters tuning approaches of the PID controller are derived by approximating the pure delay element of the controlled process in three different ways. In addition, the robustness of the closed loop system with the proposed approaches is theoretically analyzed and compared in detail. Then, extensive simulation examples are presented to validate the effectiveness of the proposed approaches. Finally, conclusions are given and future research directions are also pointed out.

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

A Weighted Gene Co-Expression Network Analysis Based on Iterative Learning

Meijuan Yu Shandong Univ.
Yan Li Shandong Univ.
Fengjun Gong Shandong Univ.

Gene co-expression networks are widely used in field of exploring gene function and describe connections not only between genes in the network, but also between gene and trait of biological significance. As a part of building gene co-expression network, the adjacency function plays an important role in describing the connections between genes, which converts the coexpressive measure of each gene pair to its connective weight. A suitable parameter of adjacency function is determined by a biologically motivated criterion known as the scale-free topology fitting index in the gene co-expression network. In generally, the parameter of adjacency function is selected by manually looking up parameter table that is generated with the R software package WGCNA (Weighted Gene Co-Expression Network Analysis - WGCNA). Therefore, the revised algorithm of selecting parameter of adjacency function is proposed. Iterative learning algorithm is used to automatically find the required parameter of adjacency function and the Mouse module-trait relationships are constructed.

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

分数阶权重共表达无标度网络建模方法研究

王文超 山东大学
李岩 山东大学
巩凤珺 山东大学

基于“小样本、大数据”理念和复杂系统反问题网络建模的迫切需求，本文介绍了一类以 **Mittag-leffler** 函数为邻接函数的权重共表达无标度网络建模方法。文中阐述并展示了分数阶邻接函数的性质，特别是其介于幂律函数和指数函数的中间性质。此外，分析了分数阶无标度网络搭建方法中邻接函数参数的意义并给出了整定依据。最后，一个幽门螺杆菌耐药基因相关例题验证了上述结论。

SunB01 **Room1**
Iterative learning control (III) **15:50-17:50**

Chair: Tao Liu Dalian Univ. of Tech.
CO-Chair: Xisheng Dai Guangxi Univ. of Sci. and Tech.

15:50-16:10 **SunB01-1**

Decentralized Control for Large-Scale irregular Systems via Iterative Learning Algorithm

Pengfei Yu Suzhou Univ. of Sci. & Tech.
Qin Fu Suzhou Univ. of Sci. & Tech.
Zhenjie Chen Suzhou Univ. of Sci. & Tech.
Dan Zhang Suzhou Univ. of Sci. & Tech.

This thesis discusses the decentralized iterative learning control problem for general interconnected discrete-time systems, which are interconnected by non-affine nonlinear dynamics. And each subsystem does not have direct transmission from input to output. That is to say, each system is irregular. In view of the structure of the system, the P-type learning algorithm is constructed. Using the iterative converge principle, it is shown that the output tracking error of each subsystem can converge to zero along the iteration axis. The effectiveness of the algorithm is verified by simulation.

16:10-16:30 **SunB01-2**

An Improved Quadratic-criterion-based Iterative Learning Control for Trajectory Tracking of Robotic Arms

Minfeng Zhu Zhejiang Univ.
Lingjian Ye Ningbo Institute of Tech., Zhejiang Univ.
Xiushui Ma Ningbo Institute of Tech., Zhejiang Univ.

In this paper, an improved quadratic-criterion-based iterative learning control approach (Q-ILC) is proposed to obtain better trajectory tracking performance for the robotic arms. Besides of the position error information, which has been used in existing Q-ILC methods for robotic control, the velocity error information is also taken into consideration such that a new norm-optimal objective function is constructed. Convergence and error sensitivity properties for the proposed method are also analyzed. Furthermore, the Extended Kalman Filter (EKF) is utilized to estimate error states, which restrain the effects of model errors and measurement noise. Simulations on a 2DOF Robot manipulator demonstrate that our method achieves faster convergence and better transient performance, compared to the original Q-ILC.

16:30-16:50 **SunB01-3**

Iterative Learning Control for Linear Fractional-order Distributed Parameter Systems with Variable Tracking Trajectory

Xisheng Dai Guangxi Univ. of Sci. & Tech.
Fan Zhang Guangxi Univ. of Sci. & Tech.
Tingting Zhao Guangxi Univ. of Sci. & Tech.

This paper studies the problem of iterative learning control for a linear fractional-order distributed parameter systems with variable tracking trajectory. An improved P-type updating control law is employed to estimate the spatial-temporal varying curve surface iteratively. Then, the sufficient conditions of convergence for output error of the system in the sense of L_2 norm has been revised through rigorous analysis. The numerical results show the effectiveness of the proposed ILC scheme.

16:50-17:10 **SunB01-4**

High-order Internal Model Based Indirect-type Iterative Learning Control Design for Batch Processes with Batch-varying Factors

Shoulin Hao Dalian Univ. of Tech.
Tao Liu Dalian Univ. of Tech.

This paper proposes a high-order internal model (HOIM) based indirect-type iterative learning control (ILC) scheme for batch processes subject to batch-varying initial condition and reference along with external disturbance. A widely used proportional-integral (PI) control structure in practical applications is taken as the inner loop, while the set-point related indirect-type ILC updating law is designed independent of the inner loop to robustly track the desired output trajectory. In comparison with the existing indirect-type ILC methods, the set-point commands and output tracking errors over more than one previous batches are used for the ILC design in terms of an augmented HOIM associated with the initial process state, reference, and external disturbance. By using an equivalent 2D Roesser system description of the closed-loop ILC system, a sufficient condition in terms of linear matrix inequality is established to ensure asymptotic stability of the resulting 2D system together with a 2D H∞ performance under non-zero boundary conditions. Finally, the obtained results are validated by an illustrative example of injection molding.

17:10-17:30 **SunB01-5**

Data-Driven Based Iterative Learning Control for Unknown Linear Discrete-Time System by Adaptive System Identification

Wenbo Zhu Shanghai Univ.
Yong Fang Shanghai Univ.
Lixun Huang Zhengzhou Univ. of Light Industry

This paper considers an iterative learning control (ILC) scheme for unknown linear discrete-time system. ILC updates the system input using error information from previous iteration to sequentially improve the tracking performance. The asymptotic convergence may not be guaranteed when the system model information is uncertain. In this paper, we introduce the adaptive Fourier decomposition (AFD) algorithm to deal with the system identification problem. This adaptive approximation algorithm estimates a system representation using input/output data only. The learning gain of ILC satisfying the convergence condition is obtained according to the estimated system parameters. The effectiveness of system approximation and the tracking performance of ILC based on input/output measurements are verified with simulation results.

17:30-17:50 **SunB01-6**

Adaptive Iterative Learning Algorithm of Strict-feedback Systems with Initial State Error

Jianyong Chen Zhejiang Univ. of Tech.
Wenzhou Vocational College of Sci. & Tech.

This paper presents an adaptive iterative learning control algorithm for a class of strict-feedback systems, which can achieve complete tracking with initial state error over a pre-specified time interval $[t_1; T]$. The unknown parameters are estimated by using differential learning laws, and the backstepping technique is applied to the controller design. A typical series is introduced to guarantee the tracking performance. Theoretical analysis shows that all signals in the closed-loop system remain bounded. Finally, a numerical simulation shows that the effectiveness of the proposed algorithm.

17:50-18:10 **SunB01-7**

Modified PIMR-type ORC for Odd Harmonic Current Suppression in a Single-phase Grid-tied inverter

Shasha Chen Zhongyuan Univ. of Tech.
Qiangsong Zhao Zhongyuan Univ. of Tech.
Univ. of Aeronautics & Astronautics
Sainan Chen Zhongyuan Univ. of Tech.
Yongqiang Ye Zhongyuan Univ. of Tech.
Univ. of Aeronautics & Astronautics

A proportional integral multi-resonant type (PIMR-type) repetitive control (RC) scheme has both a good harmonics attenuation and a fast dynamics response. Nevertheless, the PIMR-type RC is sensitive to the reference frequency fluctuation which is common in distributed power generation systems (DPGS). Moreover, the reference and disturbance signals in single-phase gridtied inverter are only odd harmonics period signals. In this paper, a modified PIMR-type odd RC (PIMR-type ORC) scheme for odd harmonic current suppression is investigated, which needs only a half data memory cells and has a wider frequency bandwidth at reference frequency and odd harmonics frequencies, and then has a faster dynamics response and a better robustness to frequency fluctuation than PIMR-type RC scheme. The stability analysis and parameters design are given in this paper. The results of simulation are presented to prove the feasibility and effectiveness.

SunB02 Room 2
Data-driven fault diagnosis and health maintenance (III)
15:40-17:40

Chair: Guoshan Zhang Tianjin Univ.
CO-Chair: Yanlin He Beijing Univ. of Chemical Tech.

15:50-16:10 **SunB02-1**

Fault Diagnosis Based on Sensitive SVD and Gaussian Process Latent Variable Model

Yang Gao Kunming University of Sci. &Tech.
Yugang Fan Kunming University of Sci. &Tech.
Qingyu Zhang Kunming University of Sci. &Tech.

To solve the problems that the system running state feature in fault diagnosis is sometimes masked by noise and its high dimensionality decreases the fault recognition degree. A fault diagnosis method based on Sensitive Singular Value Decomposition (Sensitive SVD) and Gaussian Process Latent Variable Model (GPLVM) is proposed. The method firstly performs Sensitive SVD analysis on the vibration signal, extracts various time domain features from the reconstructed signal, constructs a high-dimensional feature set, and uses GPLVM to reduce the dimensionality, and then use the reduced feature to establish the Extreme Learning Machine (ELM) fault diagnosis model. The rolling bearing fault detection test shows that the proposed method can effectively reduce the redundancy of features, and the established fault diagnosis model has higher identification accuracy.

16:10-16:30 **SunB02-2**

Pipeline Blockage Detection Based on Sparse Characterization Classification Enhanced by VMD

Linfeng Wu Kunming University of Sci. & Tech.
Zao Feng Kunming University of Sci. & Tech.
Guoyong Huang Kunming University of Sci. & Tech.
Yang Li Kunming University of Sci. & Tech.
Xuefeng Zhu Kunming University of Sci. & Tech.

Regarding the active acoustical method of determining the blocking status in buried pipe using low frequency sound waves as excitation, it has difficulties in distinguishing the different degrees of blocking and eliminating the interference from the pipe components such as lateral connection, a novel approach to identify the blocking fault using the Sparse Representation for Classification (SRC) enhanced by variational mode decomposition was proposed in this paper. Firstly, the acoustic signals collected in the pipeline were decomposed by variational mode decomposition, then sample entropy characteristic parameters were extracted from each component. Secondly, the feature vectors that can effectively represent the signals were used to construct the dictionary and the sparse representation classifier. The experimental results had shown that the method could effectively identify the blocking status in different degrees, the lateral connection could also be discriminated accurately in the pipeline under a small number of samples, which has certain practical value for engineering applications.

16:50-16:50 **SunB02-3**

Multiple Blockage Identification of Drainage Pipeline Based on VMD Feature Fusion and Support Vector Machine

Fei Wang Kunming Univ. of Sci. & Tech.
Zao Feng Kunming Univ. of Sci. & Tech.
Guoyong Huang Kunming Univ. of Sci. & Tech.
Xuefeng Zhu Kunming Univ. of Sci. & Tech.
Yang Li Kunming Univ. of Sci. & Tech.

Aiming at the detection problem of multiple blockage in urban water supply pipelines and drainage pipelines, also the problem of distinguishing commonly used pipe components such as lateral connection from the actual blocking conditions. A multiple-blocking fault identification method based on support vector machine (SVM) combined with a feature extraction approach for component signal are proposed in this paper. Firstly, the variational mode decomposition (VMD) was applied on the acoustic signals collected in the pipeline to obtain a set of finite bandwidth natural mode functions (IMF), multiple time domain indices and center frequencies were extracted as features, then a feature vector set can

be constructed and input into the SVM classifier. The experimental results have shown that the method based on VMD feature fusion and support vector machine can effectively identify the multiple congestion faults of drainage pipelines. In addition, the method was compared with back propagation (BP) neural network and the k-nearest neighbor algorithm (KNN). The results suggest that the proposed method has a better performance on the partial blockage recognition with a small number of training samples.

16:50-17:10 **SunB02-4**

Location and Recognition System for Lightning Fault of Transmission Line Based on Data-driven Technology

Rui Li Beijing Information Sci. & Tech. Univ.
Univ. of sci. & Tech. Beijing
Rongmin Cao Beijing Information Sci. & Tech. Univ.
Yingnian Wu Beijing Information Sci. & Tech. Univ.
Di Yu Beijing Information Sci. & Tech. Univ.

In order to solve the complex and difficult identification problems of overhead transmission line fault diagnosis, and to improve the accuracy of classification effectively, a new method of fault diagnosis for overhead transmission line is proposed in this paper. Firstly, the collected traveling wave signals are processed by HHT (Hilbert-Huang Transform) to realize joint feature extraction in time-frequency domain. And a data-driven lightning strike warning model for transmission lines is adopted. The model includes PCA (principal component analysis), data acquisition and preprocessing, data analysis and prediction, and model online correction. For eliminating the influence of noise and singularity on fault diagnosis; then input training set and production rules to train the intelligent classification method ,by which exact fault diagnosis model was obtained. Finally, apply the algorithm to the intelligent lightning traveling wave monitoring system of an actual 500 kV transmission line, the experimental results show that the proposed method can not only calculate the exact location of fault points, but also accurately classified them that classified both single fault and multi-fault, which opens up a new approach for overhead transmission line to intelligent fault diagnosis.

17:10-17:30 **SunB02-5**

Dynamic Human Body 3D Reconstruction Using Laplacian Deformation

Qi Bian Tianjin Univ.
Guoshan Zhang Tianjin Univ.

Dynamic 3D reconstruction of human body is a key issue in the field of computer vision, especially in the case that human body is undergoing large deformation. A novel human body 3D reconstruction method using Laplacian deformation is proposed for fine reconstruction in the region of large deformation. The preliminary reconstructed model is firstly achieved through warp field. Then large deformed region is detected and fine reconstruction model is finally obtained by use Laplacian deformation in the detected large deformed region. The proposed method is verified in different datasets for reconstructing the whole human body and the human body parts. Laplacian deformation improves the reconstruction accuracy in the detected large deformed region.

17:30-17:50 **SunB02-6**

A Novel Pattern Matching-based Fault Diagnosis Using Canonical Variate Analysis for Industrial Process

Yuan Xu Beijing Univ. of Chemical Tech.
Cuihuan Fan Beijing Univ. of Chemical Tech.
Qunxiong Zhu Beijing Univ. of Chemical Tech.
Yanlin He Beijing Univ. of Chemical Tech.
Qi Hu Shanghai Lixin Univ. of Accounting & Finance

Original data with high dimension and noise are usually directly applied to pattern matching, which will affect the accuracy of models to some extent. To solve this issue, a novel pattern matching method integrating canonical variable analysis with adaptive rank-order morphological filter (CVA-AROMF) is proposed for fault diagnosis in this article. First, canonical variable analysis (CVA) is used to extract the features of training data with sequence correlation and process dynamics, and then the features are used as the template signal of adaptive rank-order morphological filter (AROMF). Second, the noise-bearing test signal is used to match the template morphology waveform under the supervision of different fault template signals. Third, the fault mode is classifieds by finding the minimal distance between the filter output signal and the raw test signal of each fault mode. Simulations based on Tennessee Eastman (TE) process data is performed and the result verifies the accuracy and superiority of this proposed method.

SunB03 Room 3

IS：Advances in AI and its applications 15:50-18:10

Chair: Darong Huang Chongqing Jiaotong Univ.
CO-Chair: Deqing Huang Southwest Jiaotong Univ.

15:50-16:10 **SunB03-1**

On Authenticity Preservation of Positioning in Rounding Autonomous Guided Vehicle

Lu Wang Xinjiang Electric Power Sci. Research Institute
Wenjuan Dong Xinjiang Electric Power Sci. Research Institute
Xingang Wang Xinjiang Electric Power Sci. Research Institute
Hongliang Liu Nari (Beijing) Jiehong Tech. Co.Ltd.
Hongtao Qu Nari (Beijing) Jiehong Tech. Co.Ltd.
Yudong Xing Nari (Beijing) Jiehong Tech. Co.Ltd.

Darong Huang Chongqing Jiaotong Univ.

As an economic and reliable transportation system, rounding autonomous guided vehicle is widely researched and implemented in logistics. However, higher automation implies less involving of manual control, which makes the unattended workshop prone to malicious attacks. Since the operation of rounding autonomous guided vehicle system largely depends on the accuracy of scheduling strategy, authenticity of rounding autonomous guided vehicle position must be preserved to avoid collision, priority breach, steal, etc. In order to ensure the correctness of positioning, a novel location acquisition and authentication scheme is proposed in this paper, with the help of message authentication code and verifiable threshold secret sharing. According to security and performance analysis, our scheme is resistant against chosen plaintext attack and feasible in rounding autonomous guided vehicle environment.

16:10-16:30 **SunB03-2**

Trajectory Tracking Control of Hydraulic Rehabilitation Exoskeleton Leg with Output Constraint

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

This paper addresses the trajectory tracking control of lower limb rehabilitation exoskeleton leg driven by hydraulic actuator with output constraint. A barrier Lyapunov function is utilized to handle the output constraint of the hydraulic actuator. The radial basis functions neural networks are used to approximate the disturbance and unmodeled uncertainties. Under the effect of the designed control scheme, the output constraint problem is well averted, and the involved signals of the rehabilitation exoskeleton are semi globally bounded. The tracking convergence of the closed-loop system is demonstrated by using mathematical method. The performance of the designed controller is illustrated by numerical simulations.

16:30-16:50 **SunB03-3**

A Feature Extraction Method Based on Multi-rhythmic and Co-space Modes for P300 Potential

Guo Chen Chongqing Univ. of Posts &Telecommunications
Xin Deng Chongqing Univ. of Posts &Telecommunications
Yun Tang Chongqing Univ. of Posts &Telecommunications
JianXun Mi Chongqing Univ. of Posts &Telecommunications
Danni Li Chongqing Univ. of Posts &Telecommunications
Kaiwei Sun Chongqing Univ. of Posts &Telecommunications

In order to extract the effective features of EEG data based on P300 potential and improve the classification accuracy of brain-computer interface (BCI) system, a novel method from spatial and frequency domain is proposed in this paper. That is, the multi-rhythm signal and Common Spatial Pattern (CSP) are combined to extract the feature of P300 potential. Meanwhile, this paper uses the elastic networks as classifier which combines with *l1* norm and *l2* norm that not only makes the coefficients sparse, but also avoids losing the inhere t structure among samples from the same class. In this paper, the public EEG data set is used to verify the proposed method and by comparing the traditional CSP method. The experimental results show that the new method provides more frequency-space-related feature information increased by 4.8% compared with the traditional CSP method. It indicates that the proposed method achieves the good performance for the P300 EEG analysis.

16:50-17:10 **SunB03-4**

Health Maintenance Decisions Based on Hazard Rate Function under Degradation Process

An Liu Xian Satellite Control Center
Xiaofei Lu Jiuquan Satellite Launch Center
Shaolin Hu Xian Satellite Control Center
Weihui He Xian Satellite Control Center

The classical Hazard Rate Function (HRF) is typically used to make preventative maintenance (PM) decisions and always estimates HRF based on time to failure data. Even so, PM determination using conventional HRF is not suitable for systems with condition monitoring. The system is stopped checking and maintaining when the measured health state exceeds a predetermined threshold, which is always referred to as a soft failure. Since the application of HRF for PM decision making has great advantages, the classic HRF should be extended to combine soft and hard failure of systems with condition monitoring. In this paper, we define the HRFs of hard and soft failure for system under condition monitoring and propose a method to estimate the HRFs with data of failure time. We discuss in detail the relationship between these two HRFs and the classical HRF. With double stochastic processes (processes of degradation and measured healthy status), the properties of these HRFs are also researched. Further the optimal maintenance decisions are made for non-repairable and repairable systems upon these two types of HRFs. Eventually, the idea of this paper is verified by numerical examples.

17:10-17:30 **SunB03-5**

Detecting and Counting the Moving Vehicles Using Mask R-CNN

Lu Lou Chongqing Jiaotong Univ.
Qi Zhang Chongqing Jiaotong Univ.
Chunfang Liu Chongqing Jiaotong Univ.
Minglan Sheng Chongqing Jiaotong Univ.
Xuan Liu Chongqing Jiaotong Univ.
Huimin Song Chongqing Jiaotong Univ.

In order to make use of the existing video surveillance facilities and improve the ability of urban intelligent traffic integrated management, a novel moving vehicle detecting and tracking method based on traffic video is proposed in this paper. The Mask R-CNN algorithm based on deep learning is used to detect vehicle contours in the complex urban traffic environment, and then the improved Kalman filter is applied to track the vehicle target in the video sequence. The experimental results show that the proposed method can reach 95% average accuracy with 2.86 fps speed, and can effectively deal with different traffic and climates conditions.

17:30-17:50 **SunB03-6**

Vehicles Detection of Traffic Flow Video Using Deep Learning

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

The vehicle detection and tracking are important tasks in intelligent transportation system. The traditional methods of vehicle detection often cause the coarse-grained results due to suffering from the complex environments. YOLO is a pragmatic approach to muti-target detection with a simple and effective algorithms. This paper use YOLO to detect the moving vehicles and use a modified Kalman filter algorithm to dynamically track the detected vehicles, achieving overall competitive performance in day or night. The experimental results shows the method is robust to occluding vehicles or congested roads and can obtain 92.11% average accuracy of vehicle counting at 2.55fps speed.

17:50-18:10 **SunB03-7**

Fast Detection of Lane Lines Based on Convolutional Neural Networks and Connected Components Constraints

Lu Lou Chongqing Jiaotong Univ.
Jinyu Liu Chongqing Jiaotong Univ.
Qi Zhang Chongqing Jiaotong Univ.
Darong Huang Chongqing Jiaotong Univ.
Chenlin Zhou Chongqing Jiaotong Univ.
Jing Han Chongqing Jiaotong Univ.

Lane detection is an important technical basis for the driverless system. The accuracy of lane detection using traditional algorithms could be affected by the complex factors including the unclear lane, the ground traffic signs, and vehicle occlusion. Lane detection based on Deep Learning has the higher accuracy, but its poor real-time performance makes it difficult to apply to in-vehicle computing devices due to the complexity of the deep neural network. Inspired by *LaneNet*, this paper proposes a new method that simplifies the *LaneNet* network structure and uses the connected components constraints to classify the lanes. The experimental results show that the detection algorithm can work in real time with 97.43% accuracy on various datasets of highway, and can also effectively overcome the influence of the complex environmental factors in some scenarios.

SunB04 Room 4

Neural networks, fuzzy systems control in data driven manner (II)

15:50-17:50

Chair: Weisheng Chen Xidian Univ.
CO-Chair: Zunshui Cheng Qingdao Univ. of Sci. & Tech.

15:50-16:10 **SunB04-1**

Brain Emotional Learning Networks with Applications

Shuxue Tian Beijing Univ. of Chemical Tech.
Hongguang Li Beijing Univ. of Chemical Tech.
Yongjian Wang Beijing Univ. of Chemical Tech.

Emotion plays a vital role in human learning, memory and decision-making, which have attracted wide attention in various research fields. To improve the learning speed and performance, a novel Brain Emotional Learning Network (BELN) is developed in this paper, which adds the affective neurons into the model of brain emotional learning and ameliorates the structure of the model. The newly proposed BELN enjoys lower computational complexity, in the sense that two affective coefficients named "anxiety" and "confidence" are added to simulate the changes of emotion in human learning process, which improves the online learning speed of the network. In order to verify the effectiveness of the network, a numerical example and the predictive control of petroleum heating process in a co-current tubular heat exchanger have been studied. The results show that compared with the BP neural network, BELN has better learning speed and recognition ability.

16:10-16:30 **SunB04-2**

An Incremental Conductance Method Based on Fuzzy Control

Guangjian Qin Northeastern Univ.
Xiaofei Che Northeastern Univ.

In order to make full use of solar energy in photovoltaic power generation system, maximum power point tracking (MPPT) is usually required. However, traditional incremental conductance method (INC) with fixed step size can't balance both tracking speed and tracking accuracy, and misjudgment may occur when the environment changes abruptly. To solve the above problems, this paper proposes an incremental conductance method based on fuzzy control. In this method, to track the maximum power point quickly and accurately, the fuzzy controller can adjust the step size automatically according to the information of voltage and power. In addition, we make full use of the fuzzy control rules to improve the anti-interference ability of the system. Finally, a simulation is carried out in Matlab/Simulink. The results show that this method can achieve MPPT quickly and accurately, which has a strong anti-interference ability.

16:30-16:50 **SunB04-3**

Nonlinear Dynamic System Predictions based on Neural Networks with Fruit Fly Optimization Algorithms

Liangyu Qiao Beijing Univ. of Chemical Tech.
Hongguang Li Beijing Univ. of Chemical Tech.
Yongjian Wang Beijing Univ. of Chemical Tech.

Due to the nonlinear and dynamic characteristics of industrial production processes, it is rather difficult to establish accurate process prediction models using traditional techniques. The NARX neural network utilizes the past state of the system's input and output which is suitable for nonlinear dynamic system predictions. The NARX neural network uses LM algorithm to adjust the network weight, which results in excessively relying on the initial weight. In response to this problem, the combination of Fruit Fly Optimization algorithm and LM algorithm is suggested to optimize NARX network weights, leading to better performances for nonlinear dynamic system predictions. Simulation experiments on distillation columns were carried out, showing that the NARX neural network optimized by Fruit Fly Optimization algorithm is satisfied.

16:50-17:10 **SunB04-4**

Hopf Bifurcation and Chaos of a Class of Inertial Two-Neuron System with Time Delay

Yu Wang Qingdao Univ. of Sci. & Tech.
Zunshui Cheng Qingdao Univ. of Sci. & Tech.
RMIT University Melbourne

A complete analysis of Hopf bifurcation and chaos for a class of inertial two-neuron system with time-delay is given in this paper. On the premise of analyzing the bifurcation condition of the system. PIS is used to induce Hop bifurcation and approximate periodic solution. A large number of simulations show that the error between the approximate periodic solution and the original periodic solution is very small, which directly reflects the properties of the periodic solution. Therefore, the use of the specification theorem and the central manifold theorem is avoided to carry out complex calculation. Finally, the chaotic behavior of the system is well demonstrated by simulation. So far, we have discussed the properties of a class of two neurons in detail. It lays a foundation for further discussion of more complex neural network systems.

17:10-17:30 **SunB04-5**

Exponential Stability of Quaternion-Valued Neural Networks with Proportional Delays and Linear Threshold Neurons

Li Li Xidian Univ.
Weisheng Chen Xidian Univ.

A novel quaternionic neural networks (NNs) with proportional delays and linear threshold delays is presented in this paper. By employing Halanay inequality technique and matrix measure method, the problem of global exponential stability (GES) is researched for quaternionic NNs with proportional delays and linear threshold neurons. Some criteria are obtained to guarantee GES of the considered systems. Finally, the effectiveness of the obtained results is proved by numerical examples.

17:30-17:50 **SunB04-6**

Intelligent Recognition Method Based on Deep Learning for Locally Damaged Ship Targets

Xiaoning Zhao China Academy of Launch Vehicle Tech., China Aerospace Sci. & Tech. Corporation
Xiaoyang Xie China Academy of Launch Vehicle Tech., China Aerospace Sci. & Tech. Corporation
Xiangyin Quan China Academy of Launch Vehicle Tech., China Aerospace Sci. & Tech. Corporation
Xiao Sun China Academy of Launch Vehicle Tech., China Aerospace Sci. & Tech. Corporation

Owing to the explosion effect and local ship damage caused by multi-round missile attacks, it becomes very difficult to accurately recognize the specific ship target. To solve this problem, this paper properly combines t convolutional neural network (CNN) with the support vector machine, and proposes a new recognition method for locally damaged ship targets. By migrating the deep convolutional neural network to locally damaged ship targets recognition the proposed technique is able to learn the robust features of locally damaged ship targets, which can avoid difficult manual designed feature extraction processes. When the target characteristics of the ship vary on account of the explosion effect and local ship damage, it performs better than other methods. Since it is difficult to obtain the target samples of military ships, our method introduces transfer learning into the target recognition of ships. By training the CNN with the samples of

general object and using damaged ship samples to fine-tuning characteristic network parameters and classifiers, the ship recognition capacity of our method still achieves excellent performance. The experimental results show that its recognition rate can reach 97%. And it is robust to the explosion effect and local ship damage, which change the target characteristics of the ship.

SunB05 **Room 5**

Statistical learning and machine learning in automation field (III)

15:50-17:50

Chair: Kuangrong Hao Donghua Univ.
CO-Chair: Yugang Fan Kunming Univ. of Sci. & Tech.

15:50-16:10 **SunB05-1**

Rolling Bearing Fault Feature Extraction Method Based on MCKD Combined with Sensitive SVD

Qingyu Zhang Kunming Univ. of Sci. & Tech. Yunnan Institute of Mineral Pipeline Engineering Tech.
Yugang Fan Kunming Univ. of Sci. & Tech. Yunnan Institute of Mineral Pipeline Engineering Tech.
Yang Gao Kunming Univ. of Sci. & Tech. Yunnan Institute of Mineral Pipeline Engineering Tech.

Aiming at the problem that rolling bearing fault features are fairly hard to extract and cannot effectively solve fault, a rolling bearing fault feature extraction method based on MCKD (Maximum Correlated Kurtosis Deconvolution) combined with Sensitive Singular Value Decomposition (SSVD) is proposed. Through the MCKD, the rolling bearing fault signal is denoise processed; then the signal of the denoise is decomposed by the sensitive SVD, and the component signal with rich fault information is filtered by recombination. Finally, the reconstructed signal is analysed by the Hilert Envelope spectrum to obtain the fault feature information. It has been proved by experiments that this method can effectively perform fault diagnosis on the rolling bearing.

16:10-16:30 **SunB05-2**

Time Series Classification Based on FCN Multi-scale Feature Ensemble Learning

Wenshuo Zhou Donghua Univ.
Kuangrong Hao Donghua Univ.
Xuesong Tang Donghua Univ.
Yan Xiao Donghua Univ.
Tong Wang Donghua Univ.

Time series classification problem (TSC) is of great significance in the fields of finance, health care and environment. The full convolutional network is prominent in the classification of time series, but the feature length of the original data extracted by the network is fixed. Since the highly distinguishable local features in time series may have different scales, this paper proposes a multi-scale feature ensemble full convolutional network (MFCN) to extract different scale features and improve the classification accuracy of the network. Finally, 11 excellent time series classification models were compared on 44 UCR data sets, and the results showed that the proposed method obtained the minimum classification accuracy error in 16 data sets, and the average accuracy was also the highest, reaching 87.7%.

16:30-16:50 **SunB05-3**

Finite Element Analysis of Eddy Current Testing of Delamination Defects in Carbon Fiber Reinforced Polymer

Huiyao Zeng Kunming Univ. of Sci. & Tech.
Bo Ye Kunming Univ. of Sci. & Tech.
Jiande Wu Kunming Univ. of Sci. & Tech.
Siqi Luo Kunming Univ. of Sci. & Tech.
Qiongying Kong Kunming Univ. of Sci. & Tech.

Based on the characteristics of electrical anisotropy of carbon fiber reinforced polymer materials, a 3D finite element model for detecting the delamination defect of carbon fiber reinforced polymer materials by eddy current method is established with COMSOL Multiphysics software. By simulating the effects of different frequencies on the coil detection voltage in the presence of delamination defects, the optimal detection frequency was determined. Then aiming at the fiber delamination defects with different radius and thicknesses, the change rule of corresponding detection voltage is analyzed. The results show that when the detection frequency is 2200Hz, the detection coil has the highest sensitivity to the delamination defects, and the detection voltage has a good linear correlation with the radius and thickness of the delamination defects. This conclusion provides theoretical support for the quantitative analysis of the delamination defects in carbon fiber reinforced polymer by eddy current testing.

16:50-17:10 **SunB05-4**

Prediction of Stock Trading Signal Based on Multi-indicator Channel Convolutional Neural Networks

Zhenhua Yang Donghua Univ.
Kuangrong Hao Donghua Univ.
Xin Cai Donghua Univ.
Lei Chen Donghua Univ.
Lihong Ren Donghua Univ.

Stock forecasting has always been a tempting and challenging problem in the field of financial research. Recently, convolutional neural networks have been used to classify trading signals of stock, but different indicator rankings will generate different images when generating data picture. A multi-indicator channel convolutional neural network (MICNN) is proposed to

avoid the uncertainty of image generation. The test results are better than MLP and show that the proposed model has good classification performance, and the results of the simulated trading prove that the trading signals predicted by our method have practical value.

17:10-17:30 **SunB05-5**

A Visual Attention Computational Model Based on Edge Detection

Yuwei Zhang Guangxi Univ. of Sci. & Tech.
Ke Deng Guangxi Univ. of Sci. & Tech.
Yongcai Pan Guangxi Univ. of Sci. & Tech.
Qingzheng Liu Guangxi Univ. of Sci. & Tech.

In view of the inadequacy of Itti's computational model of visual attention mechanism in significance region detection, an improved computational model of visual attention based on edge detection was proposed here. It is based on the human eye's perception advantage of the edge shape information of the target object. On the basis of Itti model, this model can improve the extraction effect of significant regions in visual attention computing model by introducing edge information, and can segment significant regions more accurately. The experiment shows that the success rate of target object contour detection in this method can reach 91%, which is higher than the traditional detection method in calculation speed, and the target object contour recognition effect is better.

17:30-17:50 **SunB05-6**

Underwater Image Enhancement of Improved Retinex Base on Statistical Learning

Lixue Xu Harbin Engineering Univ.
Xiubo Wang Harbin Engineering Univ.
Heilongjiang Institute of Geological Surveying & Mapping
Xudong Wang Heilongjiang Institute of Geological Surveying & Mapping

Underwater image enhancement technology is one of the key parts of underwater image processing, Since under water environment has greater attenuation and scattering effects on reflected light than the onshore environment that lead to uneven imaging, low contrast, color decay, etc. The underwater enhancement process is intended to highlight some key information of the image and eliminate the irrelevant information so as to make the preparations for subsequent scene segmentation, target recognition, target tracking and predictive analysis and processing. In this paper, we will focus on the problem of underwater image with low quality, and analyze the typical methods of box-based image enhancement methods. At the same time, Retinex image enhancement method based on optical analysis was introduced, and this paper proposed an improved enhancement method based on the Retinex methods. First we convert the image into HSV space for saliency analysis, next, learn the parameters of the harmonic HSV space by statistical learning. And then, we use the weights obtained by learning to predict the enhancement parameter for the decay image. Finally, the experiment verified that the method had better adaptability and better effect over the traditional Retinex algorithm in underwater image enhancement.

SunB06 Room6

Data-driven Technologies and its applications (II)

15:50-18:10

Chair: Jing Wang Beijing Univ. of Chemical Tech.
CO-Chair: Xin Xiong Kunming Univ. of Chemical Tech.

15:50-16:10 **SunB06-1**

DCGAN Based Data Generation for Process Monitoring

Yu Du Beijing Univ. of Chemical Tech.
Wenqian Zhang Beijing Univ. of Chemical Tech.
Jing Wang Beijing Univ. of Chemical Tech.
Haiyan Wu Beijing Univ. of Chemical Tech.

The number of samples under fault conditions is usually much smaller than that of samples under normal conditions in chemical industry fault diagnosis field, which is called unbalanced dataset. Due to the existence of such unbalanced datasets, traditional methods are not easy to detect faults. Deep convolutional generative adversarial networks (DCGAN) is used to solve the fault data generation problem in this paper. The deep learning generation model can generate a large amount of fault data, which can be provided for subsequent fault diagnosis research and analysis. Firstly, DCGAN is proposed to generate more fault data based on the existing data. The statistical characteristics of the original data and the generated data are similar, which implies the generation ability of DCGAN performance well. The generated fault data are added to the original dataset to form a new balanced dataset. Then the convolutional neural network (CNN) is used for fault classification, and the fault classification effect is verified to apply in an actual gas-solid fluidized bed equipment.

16:10-16:30 **SunB06-2**

Improved SVDD-WMV Method for Fluidized Bed Multi-sensor Agglomeration Detection

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

Multi-sensor based fluidized bed reactor (FBR) agglomeration monitoring system faces the problem with mismatching from different sensors. Moreover, acoustic signals are sensitive to agglomeration as well as the environment interference, so information fusion method is required to improve the stability of fault

monitoring systems based on acoustic sensors. In this paper, a support vector data description (SVDD) combined with improved weighted majority voting (WMV) method is proposed for FBR. Firstly, sigmoid function is added to each SVDD model, so the Boolean outputs of SVDD are converted to probability estimations to meet the need of information fusion and improve the detection accuracy. Moreover, a multi-penalty parameter is designed to evaluate classifier in different situations, replacing the single overall penalty parameter in general WMV method. Through the penalty vector, performance of each classifier is added to the prior condition of voting. The proposed method is tested in a pilot device. From the test results, it can be concluded that the conflict handling performance of proposed method is enhanced greatly, and the decision risk is reduced. Compared with that of general method, the detection accuracy of proposed method is improved.

16:30-16:50 **SunB06-3**

Performance Assessment of Non-Gaussian Systems Based on Double Error Entropy Minimization

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

Due to the existence of non-Gaussian interference in practical industry, more and more people are studying the parameter identification of non-Gaussian systems. Some results have been achieved. In this paper, a new double error entropy minimization algorithm is proposed for parameter identification of non-Gaussian systems. The algorithm is improved on the basis of the EDA algorithm and the Fixed-Point MEE algorithm. The simulation results show that the proposed algorithm can not only improve the accuracy of parameter identification but also estimate the required interference distribution. The algorithm has been successfully applied to the performance assessment of non-Gaussian systems and achieved good results.

16:50-17:10 **SunB06-4**

Fault Feature Extraction Method of Rolling Bearings based on CITD and FastICA

Tao Wu Kunming Univ. of Chemical Tech.
Xin Xiong Kunming Univ. of Chemical Tech.

To solve the problem that vibration signal is easily affected by noise, which leads to the difficulty of fault feature extraction. This paper proposes a method for rolling bearing fault feature extraction which based on Cubic spline interpolation Intrinsic Time-scale Decomposition (CITD) algorithm and Fast Independent Component Analysis (FastICA) algorithm. Firstly, CITD method was used to decompose the original fault vibration signal, and a series of Proper Rotation (PR) components were obtained. Then the components with abundant fault information are selected by kurtosis criterion to reconstruct the observed signal, and the remaining components are reconstructed to obtain the virtual noise channel signal. FastICA algorithm is used to reduce the noise of reconstructed signal. The Teager-Kaiser Energy Operator (TKEO) is used to demodulate the signal after noise reduction. Finally, FFT transform is applied to the demodulated signal, the fault feature information of the original signal is extracted. Through comparative experiments, the results show that the proposed method can extract the fundamental frequency and frequency doubling characteristic information of rolling bearing faults more clearly and effectively.

17:10-17:30 **SunB06-5**

An Improved Model-free Adaptive Control Algorithm Based on Golden Section

Yu Feng Tianjin Univ.
Na Dong Tianjin Univ.
Yingjie Li Tianjin Univ.
Aiguo Wu Tianjin Univ.

MFAC: The controller is designed to utilize only the I/O data of the controlled system. Any information in the controller that does not contain a mathematical model of the controlled process, which is suitable for complex time-delay systems. For time-delay systems, there are many studies on their stability, but there are relatively few studies on their rapidity. Inspired by the classic model-free adaptive control algorithm, two parameters L 1 and L 2 with the proportion of golden section are introduced in the parameter estimation control scheme. An improved algorithm is proposed. MATLAB simulation experiments show that the improved algorithm can improve control response speed of the time-delay system. Therefore, the effectiveness of improved control algorithm is proved.

17:30-17:50 **SunB06-6**

Empirical Wavelet Transform and its Application in Fault Feature Extraction of Rolling Bearings

Peng Yin Kunming Univ. of Chemical Tech.
Xin Xiong Kunming Univ. of Chemical Tech.

Rolling bearing is one of the most widely used rotating machinery. For easy damage, it is a main problem in its fault diagnosis. Proposed in 2013, The Empirical Wavelet Transform (EWT), an adaptive signal decomposition method combining theoretical background of wavelet transform and the adaptivity of EMD. The theory of EWT is introduced in this essay and EWT is used in the fault feature extraction of rolling bearings for the decomposition of original signal. With kurtosis criterion, desired results are got. Compared with EMD, problems in mode mixing and illusive components is solved by EWT, which has fewer components and better efficiency in analysis.

17:50-18:10 **SunB06-7**

Characteristics of Fusion Temperature of Fly Ashes Generated by the Combustion of Tobacco Rod and Lignite

Yingchun Liu Kunming Univ. of Sci. & Tech.
Hao Zhang Kunming Univ. of Sci. & Tech
Shan Qing Kunming Univ. of Sci. & Tech
Aimin Zhang Kunming Univ. of Sci. & Tech

Fly ashes, as a type of solid wastes, has been widely recycled recently. Its characteristic is directly related to the temperature of the hearth in which it has been heated. The constituents and forms of the fly ashes may vary in the specific reaction atmosphere and temperature. In this paper, the X-ray diffraction (Xrd) and the scanning electron microscope (SEM) were applied to observe the mineral form and crystal components of the fly ashes generated by the combustion of tobacco rod and lignite. The results showed that: the fusion temperature of the fly ashes rised with the increase of the CaO content and the fusion temperature of the fly ashes in the oxidation atmosphere was about 50℃ higher than that in the reducing atmosphere. Through the entire process, the fusion temperature of the fly ashes initially rises with the increase in the percentage of the residual carbon, then decreases and in the end it levels off. The results from this research work can be used as the guidelines for the reutilization of fly ashes in industrial production.

Monday, May 27, 2019

MonA01 **Room 1**
Data-driven Technologies and its applications (II)
10:00-12:00

Chair: Mingwei Sun Nankai Univ.
CO-Chair: Huiyu Jin Xiamen Univ.

10:00-10:20 **MonA01-1**

Active Disturbance Rejection Control of Ship Course Based on Deep Belief Network

Beibei Qin Nankai Univ.
Zengqiang Chen Nankai Univ.
Key Laboratory of Intelligent Robotics of Tianjin
Mingwei Sun Nankai Univ.
Qinglin Sun Nankai Univ.

Allshipsareinherentlyundertheinfluenceofvariousuncertaintyanddisturbancesduringthevoyage. It is unavoidable for ships to exhibit nonlinearity due to the variation of parameters caused by disturbances such as wind, wave and current. Besides, the changes of loading, speed and draft depth also change the parameters, which performs internal uncertainty. Both nonlinearity and uncertainty of the ship model make it difficult to design a controller. To solve this problem, an adaptive active disturbance rejection controller (ADRC) based on deep belief network (DBN) is proposed. The controller takes advantage of DBN's effective deep learning ability to learn the main control parameters of ADRC online. The simulation results show that the adaptive ADRC controller has better tracking performance, better control effect and stronger robustness than traditional linear ADRC controller.

10:20-10:40 **MonA01-2**

Consensus Tracking of Linear Multi-Agent Systems with Exogenous Disturbances

Tongshu Wang Harbin Engineering Univ.
Xuxi Zhang Harbin Engineering Univ.

This paper investigates the problem of consensus tracking for linear multi-agent systems with exogenous disturbances, which the disturbances are generated by linear external exosystems. To solve consensus tracking problem, a distributed adaptive controller for each follower has been considered. For the exogenous disturbances caused by the external systems, a disturbance observer is designed to deal with exogenous disturbances. Supposing that the communication graph among followers is undirected. Then, by applying the Lyapunov function method, the consensus tracking problem with exogenous disturbances was proved. Finally, a simulation is given to illustrate the effectiveness of our results.

10:40-11:00 **MonA01-3**

A Kind of Arbitrary Signal Generator Based on 1D Generative Adversarial Network

Lizhi Cui Henan Polytechnic Univ.
Peichao Zhao Henan Polytechnic Univ.
Keping Wang Henan Polytechnic Univ.
Junqi Yang Henan Polytechnic Univ.
Xuhui Bu Henan Polytechnic Univ.

Mathematical description of a complex signal is very pivotal but nearly impossible in many engineering cases. The emergency of the Generative Adversarial Network (GAN) shows the possibility to train a signal network to be an Arbitrary Signal Generator (ASG), which is only controlled by a random vector with several elements. This paper designs an ASG model based on 1D GAN, which is suitable for calculation of signal or curve with only one dimension. Then, two sets of sine wave and triangular wave are generated by program as the training samples for the ASG model. Several experiments with the different combinations of the training samples and model parameters show that it is possible to use 1D GAN to build an ASG model. Finally, the successful experience about building an ASG is concluded and research directions are discussed in the last section.

11:00-11:20 **MonA01-4**

Limit Cycle Analysis of Linear/ Nonlinear Switching Active Disturbance Rejection Control System

Hui Wan Amy Engineering Univ.
Xiaohui Qi Amy Engineering Univ.
Jie Li Amy Engineering Univ.

Linear/nonlinear switching active disturbance rejection control (SADRC) is a new control methodology which combines the merits of linear active disturbance rejection control (LADRC) and nonlinear active disturbance rejection control (NLADRC). The frequency domain stability of the control system is crucial important in order to be implemented into practical applications. This paper firstly introduced the scheme of SADRC with a focus on the second-order plant, followed by the frequency-domain description of the control system utilizing describing function, and parameters such as observer bandwidth, switching threshold and control gain on existence of limit cycle. Presented results provide a reference for the parameter tuning and show potential application of SADRC.

11:20-11:40 **MonA01-5**

Application of ADRC in Track Alignment Detection System

Yang Lei China North Vehicle Research Institute
Jing Xu China North Vehicle Research Institute
Yongliang Ni China North Vehicle Research Institute
Zhigang Wang China North Vehicle Research Institute
Wenqi Liu China North Vehicle Research Institute

In order to improve the efficiency of track detection, higher requirements are put forward for the stability accuracy of the system in track alignment detection. In this paper, the drive model, control model, disturbance model and measurement error model of the track alignment system are analyzed at the present stage. Under the premise of minimizing the change of the original system, a controller based on ADRC is designed by improving the control algorithm of the existing system. Meanwhile, the relevant control parameters are analyzed. Through MATLAB simulation, the response speed of this algorithm is faster than PID control and the phase lag is reduced in position tracking. It is easy to be implemented in engineering for the control algorithm. In the experiment, the stability accuracy of the system is improved under different frequency disturbance. It provides a powerful guarantee for the efficient track detection, operation and maintenance.

11:40-12:00 **MonA01-6**

Replacing PI Control with First-Order Linear ADRC

Huiyu Jin Xiamen Univ.
Yang Chen Xiamen Univ.
Weiyao Lan Xiamen Univ.

The problem of how to replace an existing continuous-time PI controller with a first-order linear active disturbance rejection controller is investigated. A parametric tuning approach, which is based on the parameters of the PI controller, is proposed. With the first-order linear active disturbance rejection controller generated by the approach, the control system can have almost same gain crossover frequency and phase margin to with the PI controller, while have better performance on rejecting measurement noise and attenuating overshoot when phase margin is not enough.

MonA02 Room 2
Data-driven fault diagnosis and health maintenance (IV) 10:00-12:00

Chair: Heqing Sun ABB Corporate Research Center
CO-Chair: Ying Du 63758 Unit of PLA

10:00-10:20 **MonA02-1**

Health Monitoring of Strain Wave Gear on Industrial Robots

Heqing Sun ABB Corporate Research Center
Jiafan Zhang ABB Corporate Research Center

Industrial robots play important parts in modern industries, and the low performance or even sudden breakdown of robots will cause losses due to poor product quality and plant down time. Robot condition monitoring technologies draw much attention from both academia and industry to study how to discover abnormality of robot as early as possible to minimize damages. Strain wave gear has been widely applied in industrial robot because of its desirable and attractive properties, such as small backlash and high compactness. This paper focuses on health monitoring solution of strain wave gear on industrial robots, mainly including sensor type selection and feature extraction. The proposed solution is verified on strain wave gear from Harmonic Drive and on thousands of ABB industrial robots in the factories.

10:20-10:40 **MonA02-2**

Root Cause Diagnosis with Error Correct Model Based Granger Causality

Ting Xie Shanghai Univ.
Jianguo Wang Shanghai Univ.
Zhongtao Xie Shanghai Univ.
Yuan Yao National Tsing-Hua Univ.
Junjiang Liu Baoshan Iron and Steel Co Ltd.

With the rise of data science, data-based fault root diagnosis methods have attracted widespread attention. Among these methods, the Granger causality test is one of the most common methods which can infer causal associations between signals based on temporal precedence. However, there are some strong constraints when using this method. First, the time series analyzed should be stationary. Besides, the GC is based on the linear model. In the actual process, the system is often nonlinear, and the time series caused by the fault are mostly nonstationary. In this paper, error correction model is introduced into the root cause diagnosis to

solve the problem that Granger causality can't be applied to non-stationary time series analysis directly. The effectiveness of the proposed method is illustrated by two cases of TE process.

10:40-11:00 **MonA02-3**

Satellite Telemetry Anomaly Morphology Extraction Based on Normal Mode Gap Mining

Ying Du 63758 Unit of PLA
Yueru Wang 63758 Unit of PLA
Shaojun Chen 63758 Unit of PLA
Xiang Yang 63758 Unit of PLA
Hui Liao 63758 Unit of PLA
Chao Sun 63758 Unit of PLA

It is difficult for conventional data mining methods to find out non-frequent and long-sequence satellite telemetry anomaly morphology, and the mining results are not compact and lack of time continuity. In this paper, an anomaly morphology extraction algorithm NPGM-AMEA for telemetry data based on normal pattern gap mining is proposed. Firstly, the satellite telemetry parameters are discretized by KT-Means algorithm, and the original telemetry parameters are converted into feature strings. Secondly, the feature pattern mining is carried out to obtain the feature pattern of telemetry normal sequence, that is, the frequent closure of feature string; Then, the gap between adjacent normal feature modes is located to obtain the location of the abnormal pattern; Finally, the abnormal feature string between the normal mode gaps are extracted and the abnormal curve shape of telemetry state is obtained by matching the abnormal feature string with the time series data. The correctness and reliability of the method are verified by the simulation experiment of abnormal shape mining of the telemetry parameters of a certain type of satellite.

11:00-11:20 **MonA02-4**

A Comparison Study of K-gap Metric Calculation Based on Different Data-driven Stable Kernel Representation Methods

He Li Peking Univ.
Ying Yang Peking Univ.
Yuhan Zhang Peking Univ.
Liang Qiao Peking Univ.
Zhengen Zhao Uni. of Sci. & Tech. Beijing
Zhichen He Nanjing Univ. of Aeronautics & Astronautics

K-gap metric is an innovative tool for fault diagnosis system design and analysis. In this paper, different methods of data-driven stable kernel representation (SKR) are investigated for the purpose of K-gap metric calculation. Three existing methods are compared by definitions of SKR and calculation procedures. The first difference between these methods lies in their different definitions of SKR. The comparison result shows that the one which is unified with model-based SKR is the better definition version. The second difference is the different noise reduction techniques applied to process data, which have influences on numerical result. Based on the above comparison, a new method is proposed with more accuracy in K-gap metric calculation by using the prior knowledge from model-based method. Finally, a numerical example compare and illustrate the accuracy in K-gap computation of four data-driven SKR methods.

11:20-11:40 **MonA02-5**

Early Fault Diagnosis of High Pressure Diaphragm Pump Check Valve Based on VMD-HMM

Yuanjie Chen Kunming Univ. of Sci. and Tech.
Guoyong Huang Kunming Univ. of Sci. and Tech.
Zao Feng Kunming Univ. of Sci. and Tech.

In The fault signal of the large-sized reciprocating high-pressure diaphragm pump check valve is relatively weak, and it is difficult to identify the early wear breakdown failure, early stuck valve fault and normal state vibration signal, An early fault diagnosis method for check valves based on the combination of variational mode decomposition (VMD) and hidden markov model (HMM) is proposed. Firstly, the check valve vibration signals of different states are subjected to variational mode decomposition, and then the different features of each layer of IMF components are extracted to form a feature vector set, and vector quantization processing of feature vector sets. Then, multiple HMM models are trained by selecting feature quantities in different states. Finally, the feature quantities of the test samples are input to different HMM models. In the middle, the check valve fault type is determined by comparing the log likelihood probability values. The experimental results show that the method can effectively identify the fault type of the check valve, and the accuracy rate reaches 96.0%.

11:40-12:00 **MonA02-6**

Fault Diagnosis of Multi-source Heterogeneous Information Fusion Based on Deep Learning

Funa Zhou Henan Univ.
Yifan He Henan Univ.
Haotian Han Henan Univ.

The complexity and diversity of equipments presented in the development of modern industrial technology brings the wide application of deep learning in fault diagnosis. However, the multi-source heterogeneous data collected from different sensors applied in industrial production cannot be used by traditional neural networks directly, which registers a difficulty to fault diagnosis based on deep learning. In addition, with only one of the data used, traditional deep learning fault diagnosis methods ignores the correlation between heterogeneous data, which may result in the loss of useful information and the accuracy of fault diagnosis. To solve the above problems, a fault diagnosis framework based on deep learning for multi-source heterogeneous data fusion is proposed. In the feature learning stage, stack self-encoder (SAE) and convolution neural network

(CNN) are used to extract deep features from one-dimensional vibration data and two-dimensional image data respectively, and then feature fusion fault diagnosis is carried out. It solves the problem that traditional neural network can't make full use of multi-source heterogeneous data, and improves the accuracy of fault diagnosis. What's more, the bearing data of Case Western Reserve University are used to verify the validity of the diagnosis method proposed in this paper.

MonA03 **Room 3**
Statistical learning and machine learning in automation field (IV) **10:00-12:00**

Chair: Yi Liu Zhejiang Univ. of Tech.
CO-Chair: Bo Ye Kunming Univ. of Sci. Engineering Research Center for Mineral Pipeline Transportation of Yunnan Province

10:00-10:20 **MonA03-1**

Shipwrecks Detection Based on Deep Generation Network and Transfer Learning with Small Amount of Sonar Images

Lixue Xu Harbin Engineering Univ.
Xiubo Wang Harbin Engineering Univ.
Xudong Wang Heilongjiang Institute of Geological Surveying and Mapping.

The application of deep learning sonar target detection is severely limited due to the small amount of sonar images, especially for submarine shipwreck. Aiming to overcome the over-fit of training problem and improve accuracy of detection, we proposed a method which combine deep generation networks and transfer learning for sonar shipwrecks detection. Specifically, in deep generation network, we used similarity measurement to improved optimization, which generate high quality fake image and laid the further foundation of data. Then, in transfer learning detection, we used multi-layer adaptation and multi-core MMD to fine-tune and frozen pre-trained model, prevent the problem of over-fit and improve the generalization and stability of the system. And we combined the methods of regional suggestion and regression for target detection to guarantee precision of detection. Finally, the contrast experiment of sonar shipwrecks is carried out the effectiveness of the proposed method.

10:20-10:40 **MonA03-2**

Sparse Denoising of Eddy Current Signals from Conductive Material Defects Based on K-SVD Dictionary Learning

Weiquan Deng Kunming Univ. of Sci. & Tech.
Bo Ye Kunming Univ. of Sci. & Tech.
Jiande Wu Kunming Univ. of Sci. & Tech.
Xiaodong Wang Kunming Univ. of Sci. & Tech.
Jun Bao Kunming Univ. of Sci. & Tech.
Chen Chen Kunming Univ. of Sci. & Tech.

Eddy current testing technology is widely used in the defect detection of conductive material and the integrity assessment of key components. Because the eddy current signal is easily affected by the complex electromagnetic environment during the testing process, it causes a lot of noise in the signals, which affects the analysis of eddy current signals. Based on the sparse and redundant representation of eddy current signals, a dictionary learning method based on K-means singular value decomposition (K-SVD) for adaptive sparse representation is studied. The noisy signals are sparsely decomposed on the redundant dictionary constructed by learning, and then the sparse representation vector is reconstructed, and the noise is processed into the residual to be discarded in the reconstruction process, thereby achieving the separation of the signal and the noise to achieve the denoising effect of the eddy current signal. Finally, the experimental results verify the accuracy and effectiveness of the proposed method in eddy current signal denoising.

10:40-11:00 **MonA03-3**

Dual Attention Message Passing Model for Scene Graph Generation

Zhendong Li Beijing Jiaotong Univ.
Gaoyun An Beijing Jiaotong Univ.
Songhe Feng Beijing Jiaotong Univ.
Qiuqi Ruan Beijing Jiaotong Univ.

Recently, scene graph has emerged as a powerful tool for enhancing the performance of scene understanding. Many algorithms have been proposed to generate scene graph and most of them include message passing process which is used to transfer information between nodes in scene graph. However, these algorithms did not fully consider the imbalance of information transmission in their message passing process. To address this defect, a novel Dual Attention Message Passing (DAMP) model consisted of internal and external attention mechanisms is proposed in this paper, which can regulate and control information transmission robustly. In our model, external attention mechanism is used to determine the importance of all nodes to the target node, and internal attention mechanism is used to reinforce correlated information between the source node and target node. On Visual Relationship Detection datasets, the proposed model can achieve comparable results with the state-of-the-arts.

11:00-11:20 **MonA03-4**

Nonlinear Variational Bayesian Factor Regression for Inferential Sensor Modeling

Zeyu Yang Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Weiming Shao Zhejiang Univ.
Le Yao Zhejiang Univ.

Inferential sensors are mathematical methods to

describe the dependence of quality-related variables called primary variables on those easy-to-measure variables called secondary variables. For majority complex cases in biological and chemical industrial processes with especially nonlinear characteristics, traditional VBFR-based inferential sensor method may not function well because of its linearity assumption on the process data. To tackle the issue that nonlinear relationships exist between input and output variables, an enhanced nonlinear variational Bayesian factor regression (NVBFR) approach is proposed for inferential sensing. On the basis of the probabilistic modeling method, with incorporation of nonlinear mapping, this paper aims to extend the linear probabilistic inferential sensor into the nonlinear form. To evaluate the feasibility and efficiency of the developed Inferential sensors, a real industrail process example is demonstrated.

11:20-11:40 **MonA03-5**

Transfer Learning Soft Sensor for Product Quality Prediction in Multi-grade Processes

Chao Yang Zhejiang Univ. of Tech.
Bocheng Chen Zhejiang Univ. of Tech.
Zhiwen Wang Liming Vocational Univ.
Yuan Yao National Tsing-Hua Univ.
Yi Liu Zhejiang Univ. of Tech.

For multi-grade chemical processes, current data-driven soft sensor models built in a specific operating condition cannot be directly applied to predict product qualities of other conditions. A simple transfer learning method namely domain adaptation extreme learning machine (DAELM) is presented to construct a soft sensor model in multi-grade processes with limited labeled data. In addition, an effective strategy is developed to fast select the model parameters. By exploring and utilizing useful information from different operating conditions, the prediction accuracy can be improved. Compared with traditional soft sensors, the prediction results of two multi-grade chemical processes validate the advantages of DAELM.

11:40-12:00 **MonA03-6**

Eddy Current C-scan Image Segmentation Based on Otsu Threshold Method

Chen Chen Kunming Univ. of Sci. & Tech.
Bo Ye Kunming Univ. of Sci. & Tech.
Jiande Wu Kunming Univ. of Sci. & Tech.
Xiaodong Wang Kunming Univ. of Sci. & Tech.
Weiquan Deng Kunming Univ. of Sci. & Tech.
Jun Bao Kunming Univ. of Sci. & Tech.

Gradation distribution of the C-scan image is uneven, the defect area and the background area are mixed, it is difficult to achieve quantitative analysis of test pieces. This paper proposes a method to segment the C-scan image of the surface defects of aluminum plate specimens by Otsu threshold method. Binary image containing contour features of defective areas can be segmented by this method, specific geometric parameter information of the defect area can be obtained by tracing the binary image. The validity of the proposed method was verified by quantitative analysis of this aluminum plate specimens. Meanwhile, the performance of different image segmentation methods are compared, it can be seen from the results of measurement errors that Otsu threshold method can accurately identify the contour of the defect area, and the segmentation of the defect area is complete.

MonA04 Room 4

Statistical learning and machine learning in automation field (V) 10:00-12:00

Chair: Shan Liu Zhejiang Univ.
CO-Chair: Yong Chen Univ. of Electronic Sci. & Tech. of China.

10:00-10:20 **MonA04-1**

Betel Nut Classification Method Based on Transfer Learning

Hengquan Cai Zhejiang Univ.
Shan Liu Zhejiang Univ.

Betel nut is one of the main chewing hobby in the world. The traditional methods of betel nut classification are mostly based on handcrafted features, and the classification stability is poor. To solve this problem and reduce labor costs for manual extraction of image features, this paper applies convolutional neural network to betel nut, and adopts parameter transfer strategy to realize transfer learning. The dataset of betel nut was constructed by shooting different types of betel nut with betel nut grading equipment. Aiming at the problem of insufficient samples, some parameters of AlexNet are transferred and fixed, new fully connected layers are build. Make full use of betel dataset to train and test the network. The experimental results indicate the proposed method is effective and low labor cost.

10:20-10:40 **MonA04-2**

Run-to-run Trajectory Prediction of Uneven-length Batch Processes Using DTW-LSTM

Feifan Shen Ningbo Institute of Tech. Zhejiang Univ. Jiangnan Univ.
Lingjian Ye Ningbo Institute of Tech. Zhejiang Univ.
Saite Fan Zhejiang Univ.
Zhiqiang Ge Zhejiang Univ.
Zhihuan Song Zhejiang Univ.

This paper handles with the problem of the run-to-run trajectory prediction of batch processes with uneven batch length. Most current data-driven works focus on the run-to-run variations during both batch trajectory modeling and prediction stages. However, batch-to-batch correlations should be drawn extreme attentions to when gradual changes exist in batch

sequence. To obtain a better batch trajectory prediction performance of uneven-length batch processes, dynamic time warping (DTW) and long-short term memory (LSTM) neural network are introduced in this work to extract batch-to-batch correlations. Firstly, the recursive DTW is used to synchronize uneven batch samples. Then, the LSTM neural network is introduced to extract the run-to-run batch correlations during the trajectory modeling stage. Finally, online batch trajectory prediction can be implemented according to the offline LSTM model. A simulation based on the fed-batch penicillin fermentation process is provided to testify the effectiveness of the proposed method.

10:40-11:00 **MonA04-3**

An Improved Clustering Algorithm Based on Cluster Weight Coefficient

Qiaoling Wang Tongji Univ.
Fei Qiao Tongji Univ.
Weichang Kong Tongji Univ.
Youhao Jiang Tongji Univ.

Clustering algorithms are typical unsupervised machine learning algorithms, which are widely used in many fields. As a popular clustering algorithm, K-means has a good performance, but it has difficulties in determining initial clustering centers and the number of clusters. Canopy algorithm is often used to support K-means as a coarse clustering process. The results obtained from Canopy are set as the initial clustering centers of K-means. However, the thresholds of Canopy are often randomly selected, which makes the clustering result inaccurate. In this paper, we improve the threshold selection of the traditional Canopy and the criterion function of the traditional K-means. As a result, a novel Cluster-Weight-based Canopy-Kmeans (CWC-Kmeans) is proposed. In order to evaluate the proposed algorithm, comparison experiments are conducted with UCI standard datasets and bearing nonstandard dataset. By typical clustering evaluation indices, CWC-Kmeans has better clustering results than the traditional Canopy and the traditional K-means. Thus, the superiority of CWC-Kmeans is proved.

11:00-11:20 **MonA04-4**

Defect Detection and Location of Yarn-dyed Shirts Based on Denoising Convolutional Self-encoder

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

A defect detection algorithm for dyed shirts with supervised framework relies on a large number of labeling samples and high modeling cost. This paper proposes an automatic detection and location method for color fabric defects based on unsupervised denoising convolution self-encoder. Firstly, a shirt image data set containing 66 kinds of yarn-dyed patterns and a total of 11900 pieces was constructed. Then, Gaussian noise was added to the defect-free samples, and a depth-deconvolution convolution self-encoder was used to construct the image of the yarn-dyed shirt piece. The denoising reconstruction model performs reconstructive repair on the noise interference; Then, the residual of the image is tested and the reconstructed image is calculated, and the slice defect region is detected and located using a mathematical morphology algorithm. The experimental results show that the image reconstruction model and residual image analysis algorithm based on denoising convolution self-encoder can effectively detect and locate the defective area of the dyed shirt piece without relying on the label sample.

11:20-11:40 **MonA04-5**

Backstepping Based Sliding-mode Sensorless Control of Permanent Magnet Synchronous Motor

Peikun Zhu Univ. of Electronic Sci. & Tech. of China.
Yong Chen Univ. of Electronic Sci. & Tech. of China.
Xuejian Wang Univ. of Electronic Sci. & Tech. of China.
Peng Zhang Chongqing Hongjiang Machinery Co.
Penghao Li Chongqing Hongjiang Machinery Co.

In order to solve the problem that permanent magnet synchronous motor (PMSM) cannot be applied with sensors in a specific environment, considering the uncertainty of load torque, a sensorless sliding mode control of PMSM based on backstepping method is proposed. Firstly, by replacing the sign function with the sigmoid function, the high frequency buffeting caused by the traditional sliding mode observer is avoided. Secondly, the rotor speed and position are extracted by the PLL, the low-pass filter and phase compensation module are eliminated, and the sliding mode observer is designed. Then, considering the uncertain influence of load torque, a backstepping control algorithm was designed to control the PMSM, and its stability was proved by Lyapunov stability analysis. Finally, the simulation is carried out on Matlab/Simulink. The results show that the sensorless control algorithm can effectively estimate rotor speed and position, the system has good dynamic and static characteristics.

11:40-12:00 **MonA04-6**

Root Cause Diagnosis of Plant-wide Oscillation using Spectral Granger Causality based on Phase Resampling Test

Ting Xie Shanghai Univ.
Jianguo Wang Shanghai Univ.
Zhongtao Xie Shanghai Univ.
Yuan Yao National Tsing-Hua Univ.
Chao Xu Baoshan Iron and Steel Co. Ltd.

Plant-wide oscillation is very common in industrial

process. When an oscillation occurs in a control unit during the process, the oscillation will propagate through the connectivity between the units which will cause problems such as poor product quality and high cost. Therefore, root cause diagnosis of plant-wide oscillation is very important. This paper applies the spectral Granger causality based on phase resampling test for root cause diagnosis in the plant-wide oscillation. Phase resampling test is a new method of statistical significance test. A numerical example demonstrates the effectiveness of the phase resampling test. Moreover, an industrial application case study is shown to demonstrate the feasibility of the proposed method.

MonA05 **Room 5**
IS: Multi-agent control and its learning-based methods
10:00-12:00

Chair: Deyuan Meng Beihang Univ.
CO-Chair: Zonggang Li Lanzhou Jiao tong Univ.

10:00-10:20 **MonA05-1**

Analysis of Opinion Dynamics in Social Networks Subject to Time-Varying Topologies

Yuxin Wu Beihang Univ.
Deyuan Meng Beihang Univ.
Jingyao Zhang Beihang Univ.
Long Cheng Institute of Automation, Chinese Academy of Sci.
Univ. of the Chinese Academy of Sci.

For social networks, the interactions among agents and the relative self-confidence of each agent compared with the effects of its neighbors generally change over time. This requires using time-varying signed digraphs to describe the opinion forming processes of agents, where the positive and negative edges can represent cooperations and antagonisms, respectively. In this paper, an improved opinion dynamics model instead of the conventional Laplacian-type model is exploited with allowance of the potential variation of relative self-confidence of each agent, which can be reflected by the diagonal dominance degree. It is shown that both the structural characteristics of social networks and the diagonal dominance degrees determine the opinion forming performances, and some sufficient conditions related to these two factors are proposed to establish the bipartite consensus and stability results of agents. Two simulation examples are provided to illustrate the obtained opinion forming behaviors.

10:20-10:40 **MonA05-2**

Finite-time Surrounding Control of Multi-agent Systems with Multiple Targets

Li Zhang Lanzhou Jiao tong Univ.
Zonggang Li Lanzhou Jiao tong Univ.
Pu Gao Lanzhou Petrochemical Polytechnic

We investigate the circle surrounding control problem of multiple targets, in which communication topology is undirected and connected. First of all, an estimator is given for each agent to obtain the geometric center of multiple targets in a finite time. Combined with such an estimator, a distributed controller is presented such that all agents can achieve a circular formation and rotate around the geometric center of multiple targets. Meanwhile, agents enclose all targets. Especially, the position of each agent in circular formation can be arbitrary arranged by adjusting the time-varying coefficients. Simulations demonstrate the correctness of the estimator and the surrounding control protocol.

10:40-11:00 **MonA05-3**

Formation Control of Heterogeneous Multi-Agent Systems with Time-Delay Based on Output Regulation

Xiaoyang Meng Lanzhou Jiao tong Univ.
Yajiang Du Lanzhou Jiao tong Univ.
Zonggang Li Lanzhou Jiao tong Univ.
Yinjuan Chen Lanzhou Jiao tong Univ.

This note considers the formation control of heterogeneous multi-agent systems with time delay, in which all agents are divided into a leader and followers. Here, the output regulation method is employed such that followers track the leader and finally converge to a desired formation as there exists communication time-delay. For this purpose, a distributed observer is proposed for each follower to estimate the state of the leader, and then employ a feedback controller to update its states. As the distances among followers and leader are predefined, we have shown that the considered heterogeneous multi-agent systems with time-delay can achieve the desired formation. Simulation example is included to illustrate the validity of the proposed method.

11:00-11:20 **MonA05-4**

Gene Identification for Small Cell Lung Cancer via Combining Affinity Propagation Clustering and Conditional Mutual Information

Juntao Li Henan Normal Univ.
Mingming Chang Henan Normal Univ.
Qinghui Gao Henan Normal Univ.
Xuekun Song Henan Univ. of Chinese Medicine

Small cell lung cancer (SCLC) accounts for a small proportion of lung cancer types, but its mortality rate is the highest owing to the rapidly early development. Identifying the key genes of SCLC will be of great significance for targeted therapy. In this paper, a new gene identification method is proposed by combining affinity propagation (AP) clustering and conditional mutual information (CMI). AP clustering is firstly presented to divide genes of SCLC into 49 groups. Then gene significance in each group is evaluated by CMI. Eight genes with highest significance in corresponding

groups and four exemplars whose significance is larger than two-thirds of the maximum significance index are identified as key genes of SCLC after literature search in NCBI database.

11:20-11:40 **MonA05-5**

Neural Network-Based Finite-Time Trajectory Tracking Control of Uncertain Robotic Manipulators

Liang Sun Univ. of Sci. & Tech. Beijing
Yuanji Liu Univ. of Sci. & Tech. Beijing
Wei He Univ. of Sci. & Tech. Beijing

The problem of finite-time trajectory tracking control is studied for rigid-link robotic manipulators. The non-singular fast terminal sliding mode controller combining with RBF neural network is designed to ensure that the tracking errors converge to a small neighborhood of zero in a finite time. The radial basis function is employed to compensate the parametric uncertainty and uncertain external disturbances. The non-singular fast terminal sliding mode control scheme is adopted to improve fast convergence of tracking errors. Moreover, the stability of system is proved rigorously in the Lyapunov framework. Numerical simulation results of two-link robot manipulators illustrate the effectiveness of the proposed controller.

11:40-12:00 **MonA05-6**

Adaptive Neural Control for Euler-Lagrange Systems with Unknown Control Direction

Fanfeng Meng Qingdao Univ.
Lin Zhao Qingdao Univ.
Jinpeng Yu Qingdao Univ.

In this paper, the adaptive neural network control is proposed for Euler-Lagrange systems with unknown control direction. The command filters based virtual control signal, adaptive update law and error compensation mechanism are designed respectively under the Nussbaum type function, which can guarantee that the joint position tracking error reaches to a desired region when the control direction is unknown. The used finite-time command filter can guarantee that the output of the command filter fast approximate the differential of virtual signal.

MonA06 Room 6

Model-free adaptive control **10:00-12:00**

Chair: Xuhui Bu Henan Polytechnic Univ.
CO-Chair: Wenlong Yao Qingdao Univ. of Sci. & Tech.

10:00-10:20 **MonA06-1**

Data Driven Control for a Class of Nonlinear SISO Systems with Uniform Quantizer using Encoding and Decoding Mechanism

Panpan Zhu Henan Polytechnic Univ.
Xuhui Bu Henan Polytechnic Univ.
Jiaqi Liang Henan Polytechnic Univ.
Yanling Yin Henan Polytechnic Univ.

Faced with the problem of heavy network transmission burden, the issue of data quantization for a class of nonlinear single input and single output (SISO) systems is discussed in this paper. An approach based on data driven control with uniform quantizer using encoding and decoding mechanism (DDCUQ-E-D) is proposed. This method merely uses the input and output data (I/O) of the controlled system to estimate the pseudo partial derivative (PPD), which means that it does not need concrete mathematical model of the system. Through the method of contraction mapping, the stability of system and the convergence of tracking error are verified. Finally, a numerical simulation is provided to illustrate the applicability and effectiveness of the DDCUQ-E-D approach.

10:20-10:40 **MonA06-2**

Time Delay Estimation based Model Reference Adaptive Control for Robot Manipulators

Saim Ahmed Nanjing Univ. of Sci. & Tech.
Haoping Wang Nanjing Univ. of Sci. & Tech.
Yang Tian Nanjing Univ. of Sci. & Tech.

Generally model-reference adaptive control (MRAC) is designed using known regression matrix. However, the formulation of regression matrix is difficult for more degree of freedoms (DOFs) of robot manipulator and sometime impossible to compute for many applications. In this work, MRAC using time delay estimation (TDE) named (MRAC-TDE) is proposed to avoid complex calculation of regression matrix and provides model-free control. Therefore, TDE is devised to estimate the unknown dynamics and MRAC is used to update the control gains. The closed-loop stability of system is investigated using the Lyapunov stability criterion. In the end, to validate the effectiveness of the proposed method, simulations are illustrated the appropriateness of proposed MRAC-TDE.

10:40-11:00 **MonA06-3**

Model-free Adaptive Sliding Mode Vector Control for Dynamic Positioning Podded Propulsion Motor Based on Anti-load Disturbance

Wenlong Yao Qingdao Univ. of Sci. & Tech.
Jiali Wang Qingdao Univ. of Sci. & Tech.
Zhen Pang Qingdao Univ. of Sci. & Tech.
Ronghu Chi Qingdao Univ. of Sci. & Tech.

This paper is concerned with a model-free adaptive sliding mode (MS) vector controller design for unstable dynamic speed performance caused by load disturbance in dynamic positioning (DP) podded permanent magnet synchronous propulsion motor (PMSPM) control system. PMSPM dynamic speed equation and speed discrete system are first established. Then, the sliding mode controller is designed, and the model-free adaptive controller is introduced for the discrete time system considering load disturbance, the ESO algorithm

is introduced to estimate the disturbance unknowns and give the pseudo partial derivative estimation algorithm. Finally, a MS vector control scheme for PMSPM is proposed by combining vector control and verified by MATLAB/Simulink. The dynamic speed performance of PMSPM verifies the effectiveness of the controller design.

11:00-11:20 **MonA06-4**

MIMO Model-Free Adaptive Control Color Background Image Extraction to Video

Di Lu Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Qingdao Univ.

The current video background image extraction methods mainly obtain the gray background image, and the gray image processing is very sensitive to the interference noise, which brings great difficulty in detecting and tracking of moving target accurately. In order to overcome the above problems, a novel color background image extraction method is proposed using the idea of model free adaptive control method. The method introduces the pseudo-Jacobian matrix of the system and combines RGB three-channel historical data of pixels to establish the color background image extraction and update. The proposed method that under different video conditions is compared with the traditional gray background image extraction methods. The results show that the method can extract the color background image intuitively, and the separated foreground is closer to the ground truth of the video target.

11:20-11:40 **MonA06-5**

Model Free Adaptive Attitude Control of Launch Vehicle Using Iterative Feedback Tuning

Zunyao Yang Beijing Jiaotong Univ.
Xian Yu Beijing Jiaotong Univ.
Shangtai Jin Beijing Jiaotong Univ.
Zhongsheng Hou Beijing Jiaotong Univ.
Qingdao Univ.

An improved model free adaptive control (MFAC) based the iterative feedback tuning (IFT), called IFT-MFAC, is applied to the launch vehicle in this paper. The designed controllers for the launch vehicle with three channels, including the pitch channel, yaw channel and roll channel, are determined based the full form dynamic linearization method by optimizing a given control criterion function. Then the determined controller in each channel is transformed into a parameterized form, and controller parameters are tuned by using the IFT method. During the parameter tuning, the Davidon-Fletcher-Powell (DFP) method is adopted to avoid the matrix inversion in the traditional IFT method. The simulation results demonstrate the effectiveness of IFT-MFAC for the attitude control of launch vehicle.

11:40-12:00 **MonA06-6**

Exponential Stabilizability Analysis for Constrained Switched System

Yunyun Jin Shanghai Univ.
Yang Song Shanghai Univ.
Shanghai Key Laboratory of Power Station Automation Tech.
Taicheng Yang Univ. of Sussex
Weiyan Hou Zhengzhou Univ.
Mira Schülle Univ. of Duisburg-Essen

This paper considers the global exponential stabilizability (GES) of a switched linear system under language constraints, which can be described by a nondeterministic finite state automaton. Firstly, the automaton is represented as a labeled diagraph to reduce the problem to the GES analysis in strongly connected components. Secondly, we analysis the properties of the lifted labeled diagraph, which can express the dwell time constraints intuitively. Based on the lifted labeled diagraph, we generalize the Lyapunov-Metzler condition to an M-step version, and propose a less conservative condition based on S-procedure. Finally, a numerical example is provided to demonstrate the S-procedure condition.

MonB01 Room 1

IS: Intelligent optimization and control of urban road traffic **13:30-15:30**

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

13:30-13:50 **MonB01-1**

On-line Simulation System of Urban Road Traffic Signal Control Based on Scene Driven

Wang Li North China Univ. of Tech.
Lili Zhang North China Univ. of Tech.
Lingyu Zhang North China Univ. of Tech.
Min Li North China Univ. of Tech.
Haibo Zhang North China Univ. of Tech.
Kailong Li North China Univ. of Tech.
Weijie Xiu North China Univ. of Tech.

In this paper we present a scene-driven urban road traffic control online simulation system called SDUTCS. With this system, managers and researchers can realize the construction and simulation of various types of traffic scenarios, the rapid development and optimization of new control strategies, and the application of effective control strategies to actual traffic management. Firstly, the parallel system concept is adopted to realize the deep integration of the real-time traffic control system and the real-time simulation system, and the visual hardware and software in the loop system is used for display. Secondly, the virtual scene base engine and the strategy agent engine are put forward in the system design. By designing a common control strategy API to achieve data and control strategy

separation, help researchers focus on the control algorithm itself without paying attention to the detection data and basic data, and use the detection data and GIS data to complete the automatic calibration of simulation parameters to ensure traffic simulation accuracy. Finally, in order to verify the real-time and stability of the simulation system, simulations were carried out using different scale road networks in Shunyi District of Beijing and Weifang City of Shandong Province, which proved the advantages of the simulation subsystem in performance and simulation scale.

13:50-14:10 **MonB01-2**

Parameter Calibration of Microscopic Traffic Simulation Model Based on Floating Car Data

Lingyu Zhang North China Univ. of Tech.
Dehui Sun North China Univ. of Tech.
Li Wang North China Univ. of Tech.
Haibo Zhang North China Univ. of Tech.

Aiming at the problems of heavy workload of basic data collection, complicated manual parameters calibration and inaccurate calibration in the traditional microscopic traffic simulation model parameter calibration, an adaptive microscopic traffic simulation model parameter calibration method based on floating car data is proposed. First, the basic data of the simulation road network were obtained by using the floating car technology. Secondly, the parameters calibration process of the microscopic traffic simulation model was constructed, and the self- adaptive orthogonal genetic was used to achieve the model parameters calibration. Finally, using the actual data of the South Ring Road main line, District Changping, Beijing to simulate and verify. The results show that the proposed method in this paper can not only reduce the workload of manual calibration, but also the model parameter calibration is more accurate, which proves the feasibility and effectiveness of the method.

14:10-14:30 **MonB01-3**

A Regional Logistics System Based on Connected Vehicles

Jing Fang North China Univ. of Tech.
Xiaohui Deng China Highway Engineering Consultants Corporation.
Haoyuan Ni North China Univ. of Tech.
Xinyu Li North China Univ. of Tech.
Lu Bai North China Univ. of Tech.
Pangwei Wang North China Univ. of Tech.

With the development of intelligent transportation system, connected vehicles (CV) have become an important technology of regional logistics system. However, the increasing number of express delivery and the higher service level demanded by users have become the urgent problems to be solved. At present, the Last Station of Logistics between delivery point and delivery destination needs a lot of labors to complete, and the delivery mode cannot fully meet the demands of customers. This paper takes regional logistics transportation system as the main research object. By constructing dynamic path optimization algorithm and customized logistics mode of sending and receiving goods, a regional shared logistics transportation system is built based on CV and intelligent terminal. The application of the system in residential areas, campuses and other regional locations can improve the traffic situation to a certain extent, improve customer satisfaction, provide new delivery options for the logistics industry, optimize the overall logistics system, and realize the real intelligent logistics model.

14:30-14:50 **MonB01-4**

Analysis of Urban Arterial Macroscopic Fundamental Diagram

Zhonghe He North China Univ. of Tech.
Ming Chen North China Univ. of Tech.
Hongjia Wang North China Univ. of Tech.
Li Wang North China Univ. of Tech.

Arterial Macroscopic Fundamental Diagram (AMFD) can directly show the arterial traffic status, which plays a guiding role in the formulation of arterial timing schemes. Therefore, this paper presents the AMFD model and used the method of combining the actual data with the VISSIM simulation software to reproduce the road traffic conditions, utilizing data extraction to draw the AMFD and analyze its influencing factors. The influencing factors include the distance between intersections, signal control mode and offset control, etc.

14:50-15:10 **MonB01-5**

Queuing Equilibrium Control of Urban Intersection Based on Floating Car Data

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

In recent years, the queuing equilibrium research based on traditional detector data is limited by the influence of data loss, resulting in inaccurate arrival rate and dissipation rate of the obtained vehicles. Based on this problem, this paper proposes a method of using the vehicle trajectory characteristics in the floating car data without calculating the arrival rate. Firstly, the genetic algorithm is used to find the optimal queuing intensity sequence. Then, by the relationship between the queue length and the green time, the green time of each phase is adjusted in real time, and the queue length equalization is realized, which effectively reduces the green light loss time. Through VISSIM simulation verification, the queuing delay and queuing intensity of each phase are reduced.

15:10-15:30 **MonB01-6**

Traffic State Entropy Evaluation of Urban Road Network Based on Floating Car Data

Haibo Zhang North China Univ. of Tech.
Xiaoming Liu North China Univ. of Tech.
Quan Zhang North China Univ. of Tech.

Urban road network traffic state discrimination is the basis of traffic control and dynamic induction in intelligent transportation systems, and it's also an important content of traveler information services. Hence, based on the floating car data and map layer data, the road network micro-indicator set and macro-level indicators have been established. Then the macro and micro evaluation method of road network been proposed by using the gray system theory and information entropy theory, which is based on gray correlation entropy. The rationality and effectiveness of the method proposed in this paper have been verified by actual data.

MonB02 Room 2
IS: Data-driven modeling and optimal control (I)
13:30-15:30

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

13:30-13:50 MonB02-1

Centerness Peak Based Clustering and Image Segmentation

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

The density peak based clustering algorithm is presented by assuming that cluster centers are local density peaks, and utilizes local density relationship to detect cluster centers. This algorithm has been shown to be effective and efficient in some experiments. However, by studying the clustering mechanism in depth, we find that it may not be appropriate to treat density peaks as cluster centers in some cases. On one hand, the cluster centers obtained this way are often inconsistent with human intuition. On the other hand, local density difference across clusters is likely to influence the cluster center identification result. To relieve this problem, we present centerness as an alternative criterion of cluster center detection. The centerness criterion reflects to which degree the neighborhood of one data is filled with the nearest neighbors evenly, and is calculated with a histogram based method in our approach. By selecting cluster centers from centerness peaks, the clustering can be accomplished in a similar way as density peak algorithm. Our approach relieves the aforementioned problems of density peak algorithm, and performs well in experiments with synthetic and real datasets.

13:50-14:10 MonB02-2

Learning Medical Diagnosis via Scaled Convex Hull-Based SK Algorithm

Yuqing Liu Bohai Univ.
Qiangkui Leng Bohai Univ.
Shurui Wang Bohai Univ.

Machine learning algorithms, especially support vector machines (SVMs), were from the very beginning designed and used to analyze medical datasets. As a geometric dual representation of SVMs, Schlesinger-Kozinec (SK) algorithm achieves classification by solving the nearest point pair between convex hulls. However, the initial SK algorithm is only for linear separable problems. For non-separable problems, it needs to perform appropriate convex hull transformation, i.e., so-called scaled convex hull (SCH). This paper first gives the theory foundation of scaled convex hull. Then, the SK algorithm as well as its kernelization process is further explained. At last, we employ the SCH and the kernel SK (KSK) algorithm to carry out medical diagnostic tasks. The results show that compared with other well-known machine learning algorithms, the SCH-based KSK algorithm can achieve higher prediction accuracy.

14:10-14:30 MonB02-3

A Novel Method of Fault Detection Method for TEP Based MIPCR

Aihua Zhang Bohai Univ.
Chengcong Lv Bohai Univ.
Xing Huo Bohai Univ.
Zhiyong She Bohai Univ.

Principal component regression (PCR) is not only a kind of multivariate statistical method, but also a type of data-driven method. The improved PCR (IPCR) optimizes the performance of fault detection for Tennessee Eastman process (TEP). IPCR could solve the unsatisfactory detection performance generated by the incomplete sample decomposition. Multiple IPCR (MIPCR) is a novel improved method relative to IPCR. It uses multiple quality variables to detect product quality at the same time. And the results, obtained via MIPCR, are fused. Then screening the variables via the fault performance is done. Simulations for Tennessee Eastman process (TEP) are presented with PCR, IPCR and MIPCR. Via the simulations, the validity and superiority of MIPCR are all verified.

14:30-14:50 MonB02-4

A Novel MPIPCR Diagnosis Algorithm with Quality-Related Faults for TEP

Wenxiao Gao Bohai Univ.
Zhongdang Yu Bohai Univ.
Zhiqiang Zhang Bohai Univ.
Aihua Zhang Bohai Univ.

Multivariate statistics, such as principal component analysis (PCA), principal component regression (PCR) and partial least squares (PLS), etc., has been putted a broader exposure by the researchers. Typically, the improved PCR has strengthened the detection ability for quality-related faults. However, its detection ability for both quality-unrelated faults and regression faults still needs to be promoted. Considering the advantages of Mahalanobis distance and Pearson coefficient, they all can compare the relevance of two samples. Therefore, both Mahalanobis distance and Pearson coefficient are all employed to do a comparison for the procedure variables and quality variables, respectively. Then, the procedure variables of the highest quality-related are selected for modeling before IPCR, which defined MPIPCR. MPIPCR not only keeps the virtue, the fault detection ability for the quality-related faults, of IPCR but also adapts to the quality-unrelated faults and regression faults. The Tennessee Eastman Process (TEP) is applied to the comparison of PLS and MPIPCR in the simulation to verify the validity of the results.

14:50-15:10 **MonB02-5**

SocialRT: A Recommendation Method Based On Social Trust

Xing Xing Bohai Univ.
Zhixin Meng Bohai Univ.
Hanting Chu Bohai Univ.
Jianyan Luo Bohai Univ.
Tiansheng Qu Bohai Univ.
Zhichun Jia Bohai Univ.

With the advent of online social networks, the approach of recommendation based on social network has emerged. However, some recommendation algorithms based on the trust network do not fully mine the information of user's trust relationships. To alleviate such problems, we propose a socialRT method, which is a social recommendation trust method based on joint matrix decomposition. The proposed socialRT method collective factorizes the following relationship matrix and the social trust relationship matrix to obtain the recommendation model. We have conducted experiments on Sina Weibo dataset, the experimental results demonstrate that the proposed recommendation method leads to a substantial increase in recommendation quality.

15:10-15:30 **MonB02-6**

Attitude Tracking Control of 3-DOF Helicopter Based on Disturbance Observer

Liang Liu Bohai Univ.
Jing Wang Bohai Univ.
Bing Xiao Bohai Univ.

Based on the disturbance observer design approach, this paper deals with the attitude tracking control problem for a 3-DOF helicopter with uncertainty and external disturbance. Firstly, the disturbance observers are used to estimate the uncertainty and the external disturbance of the 3-DOF helicopter. Then, with the aid of the estimations and backstepping design method, the new nonlinear tracking controllers with disturbance compensations are proposed. And, it is verified that the resulting closed loop 3-DOF helicopter system is asymptotically stable by employing Lyapunov stability theory. Finally, simulation results demonstrate the effectiveness of the proposed design approach.

MonB03 Room 3
IS: Autonomous and intelligent control of UAV (I)
13:30-15:30

Chair: Chaofang Hu Tianjin Univ.
CO-Chair: Yimin Zhou Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.

13:30-13:50 **MonB03-1**

New Integration-Enhanced Newton Algorithm for Real-Time Tracking Control of Robot Manipulators

Lin Wei Lanzhou Univ.
Long Jin Lanzhou Univ.
Rui Zhang China Research Institute of Radiowave Propagation
Xiuchun Xiao Guangdong Ocean Univ.
Mei Liu Lanzhou Univ.
Jingwen Yan Univ. of Shantou
Jiliang Zhang Lanzhou Univ.

It is of great significance to enhancing and maintaining accurate real-time output for tracking control which has been diffusely confronted in robotics. Note that, for most traditional algorithms, utilizing a neural controller for convergence and a filter for dealing with noises is a habitual method. However, there always exists interplay of the neural controller and filter that prevents these existing traditional algorithms from keeping stable when encountering tracking control problem, which results in large lagging errors. To this end, a novel integration-enhanced Newton (IN) algorithm aided with the superior integration control is proposed and inherently robust to a variety of noises, which is proved thoroughly by corresponding theoretical analyses and further employed to realize tracking control of robot manipulators successfully.

13:50-14:10 **MonB03-2**

Accurate Localization of Defective Circular PCB Mark Based on Sub-Pixel Edge Detection and Least Square Fitting

Zhen Wu Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.
Shenzhen College of Advanced Technology, University of Chinese Academy of Sci.

Fan Chen Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.
Shenzhen College of Advanced Technology, University of Chinese Academy of Sci.
Guoyuan Liang Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.
Yimin Zhou Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.
Xinyu Wu Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.
Wei Feng Shenzhen Institutes of Advanced Technology (SIAT), Chinese Academy of Sci.

High-precision positioning of PCB Mark plays an important role in the production of PCB. This paper proposes a high-accuracy method to recognize and locate the defective circular PCB Mark. Firstly, the template matching is used to extract the interested Mark region. And then Canny operator which has good noise resistance is used to detect the edges of the Mark. On the basis of angle features analysis of each small edge, the regular and similar edges are retained and the deformed or noisy edges are removed, which is the key process to reduce the influence of the defective edges. After that, the retained edges are used to fit an ellipse by least square method. Finally, the sub-pixel edge points near the ellipse are used to fit an ellipse again more accurately. The experimental results indicate that the positioning error of our method is small. And when processing the deformed or noisy Mark images, our method is robust and can achieve better results than Hough transform and the least square fitting based on sub-pixel edge points.

14:10-14:30 **MonB03-3**

Real-Time Object Detection based on Unmanned Aerial Vehicle

Qingtian Wu Shenzhen Institutes of Advanced Technology(SIAT), Chinese Academy of Sci.
Yimin Zhou Shenzhen Institutes of Advanced Technology(SIAT), Chinese Academy of Sci.

In this paper, a real-time image detection system for unmanned aerial vehicle (UAV) is presented. First, the You Only Look Once (YOLO) detector is retrained to detect and recognize objects in UAV images fast and accurately. The retrained YOLO detector possesses a tradeoff between quickly objects identification and precisely objects localization, accounting for 4 general moving objects (i.e., car, bus, truck and pedestrian) in UAV images. Second, extra 4,000 UAV images shot by the embedded UAV camera are fed into the YOLO which is used to predict bounding-box with label probabilities from a full image. The YOLO is compared with the Faster Region Convolutional Neural Network, as well as other deep-learning frameworks for object detection. Field experiments on UAV videos shot in various backgrounds are performed to testify that the proposed system can detect objects in UAV images effectively and robustly, achieving a real-time detection speed at 15 frames per second and a satisfying accuracy on the wild test set of 400 UAV images with a Graphic Processing Unit (GPU) acceleration.

14:30-14:50 **MonB03-4**

Segmentation Trajectory Optimization of Nonlinear Power Components in Series HEV

Shumin Ruan Beijing Institute of Tech.
Yue Ma Beijing Institute of Tech.
Fei Qi Beijing Institute of Tech.
Huimin Zhang Beijing Institute of Tech.

In order to improve the acceleration response of hybrid vehicles, this paper applies Radau pseudo-spectral method to solve the trajectory optimization problem of vehicle acceleration. The mathematical model of engine-generator, battery pack and electric motor is established, and the optimal control problem of vehicle acceleration time is constructed. As for the problem is strongly nonlinear. The problem is transformed into a nonlinear programming problem by Radau pseudo-spectral method, and the numerical solution is carried out. The rotational speed and torque trajectory curves of the engine-generator set and the motor are obtained. The simulation results show that Radau pseudo-spectral method can optimize the working curve of various components of hybrid vehicles and improve response speed.

14:50-15:10 **MonB03-5**

Target-based Visual Navigation with Channel-aware Network

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

Visual navigation is major content of robot control, especially those based on target. We propose a channel-aware deep siamese actor-critic network for target-based visual navigation task. Compared with previous target-driven network, our model can obtain a joint representation of siamese network's output feature by using distance fusion method, and the approach significantly accelerates convergence of model's training. We improve the model performance to make the agent reach the goal in shorter path during the navigation by inserting a modified Squeeze-and-Excitation block in siamese layers, in which way the model can take dependencies between visual feature channels into consideration.

15:10-15:30 **MonB03-6**

Control Performance Simulation for Hypersonic Vehicle Model with Actuator Faults

Xiaofang Wei Tianjin Univ.
Chaofang Hu Tianjin Univ.
Na Wang Tianjin Polytechnic Univ.

This paper analyzes the time-domain and frequency-domain characteristics of hypersonic vehicle faulty model based on the longitudinal model. Three types of faults that occur in the elevator deflection of hypersonic vehicle are given: loss of effectiveness fault, random drift fault and lock-in-place fault. The simulations are performed in the time-domain and frequency domain respectively. In the time-domain, faults are applied on the nominal fault-free model at a certain time in the case of stable flight of the nominal system without any fault-tolerant strategy. By comparing the states of the nominal system in the stable flight with the states after the fault occurs, the influence of various faults on the stability of the hypersonic vehicle flight system is analyzed. In the frequency-domain, by comparing the Bode plot and the Nyquist curve of the nominal model and the faulty model of hypersonic vehicle, the influence of the faults on the model itself is analyzed.

MonB04 Room 4

Neural networks, fuzzy systems control in data driven manner (III) 13:30-15:30

Chair: Huanqing Wang Bohai Univ.
CO-Chair: Yantao Tian Jilin Univ.

13:30-13:50 **MonB04-1**

EEG-Based Emotion Recognition with Deep Convolution Neural Network

Huimin Shao Shanghai Univ.
Jianguo Wang Shanghai Univ.
Yu Wang Shanghai Univ.
Yuan Yao National Tsing-Hua Univ.
Junjiang Liu Baoshan Iron and Steel Co. Ltd.

Emotions are closely related to people's work and life. Emotional analysis and recognition is not only an urgent need to solve certain mental illnesses, but also has broad application prospects in the fields of human-computer interaction, entertainment and medical care. Therefore, it is of great value to classify emotional EEG signals. This paper introduces CNN (Convolutional Neural Networks) into the process of emotional EEG recognition. The innovation of this method is to adjust the convolution kernel of the CNN to adapt to the input of EEG signals. The classification accuracy of 0.8579 is achieved in the three-classification emotional EEG signal.

13:50-14:10 **MonB04-2**

A Method for EEG Contributory Channel Selection based on Deep Belief Network

Jingru Su Shanghai Univ.
Jianguo Wang Shanghai Univ.
Zhongtao Xie Shanghai Univ.
Yuan Yao National Tsing-Hua Univ.
Junjiang Liu Baoshan Iron and Steel Co. Ltd.

In order to obtain better performance in BCI systems, multi-channel electrodes are often used to collect EEG signals. However, using multi-channel electrodes may cause inconvenience to the EEG signal acquisition work, and may cause problems such as slow system operation and poor performance. This paper proposes a new contributory channel selection method based on data driven method, which realizes the optimal selection of channels by means of the Deep Belief Network with strong learning ability for high-dimensional vectors. First, the DBN model is trained through the continuous adjustment of the parameters, which result in an optimal DBN model. Then, the distribution of the weights in the first layer of the obtained optimal DBN model are analyzed and the channels with larger weights are selected as the optimal channel combination to achieve the purpose of channel selection. The experimental results show that there are different channel selection results among individuals,

and the EEG classification accuracy similar to or higher than that of using high-density channels can be obtained by using selected fewer channels, which enhances the practicability of the BCI system.

14:10-14:30 **MonB04-3**

Adaptive Neural Control for a Class of Uncertain Nonlinear Systems with Input Delay

Siwen Liu Bohai Univ.
Huanqing Wang Bohai Univ.
Shijia Kang Bohai Univ.

This paper proposes a control scheme for a class of non-strict-feedback systems with input delay based on adaptive neural network technology. An appropriate auxiliary system is utilized to cope with the difficulties appeared in input delay. Through the utilization of backstepping, a controller based on adaptive neural network technique is proposed in this paper. The controller design enables the states in the system to be bounded. The main significance of this research is that an intelligent control scheme is extended to a class of nonlinear systems with non-strict-feedback form and input delay. Finally, an example is given to prove the effectiveness of the control method.

14:30-14:50 **MonB04-4**

A Deep Neural Network Method for Detection and Tracking Ship for Unmanned Surface Vehicle

Weiwei Kong Navy Research Academy
Tianjiang Hu Sun Yat-sen Univ.

Unmanned sea-surface platforms are generally employed for a large variety of applications, such as ecological monitoring, ocean exploration, port traffic management and safeguarding maritime rights. Although the radar-based solutions provide the target information in a wide range under the all-weather condition, the optical-based sensors are stilled need for an autonomous surface vehicle operation to avoid the close-in surface target. In this paper, we focused on devising a real-time solution for the sea-surface vehicle target detection from an uncrewed surface vehicle. Detecting the sky-sea line for image registration as input, then use the VGG-based Siamese Network to track the ship target. We test the proposed algorithms on several datasets, and the results show the real-time capability and high accuracy.

14:50-15:10 **MonB04-5**

Design and Implementation of Intelligent Window Control System based on Multi-sensor Fusion

Tao Liu Qilu Univ. of Tech.
Hongqian Lu Qilu Univ. of Tech.
Zihao Wei Qilu Univ. of Tech.

This paper proposes a new intelligent window based on multi-sensor fusion. The intelligent window is controlled by ARDUINO UNO development board. It has the functions of "Automatic Control" "Manual Control" and "Close". In the automatic control mode, the window will be controlled based on parameters such as humidity, temperature, light intensity, wind speed and air quality. This project is based on the arduino MCU, PM2.5 detection, air temperature and humidity detection technology to design, mainly in "safety, intelligent, practical, market-oriented" four unity as the objective concept, combining technology and humanized function, under the full consideration the user demand for Windows made intelligent Windows system can easy life.

15:10-15:30 **MonB04-6**

Fault Tolerant Control to Ensure String Stability of Cooperative Adaptive Cruise Control under Communication Interruption

Guangming Nie Jilin Univ.
Zixu Hao Jilin Univ.
Feng Zhao Jilin Univ.
Yantao Tian Jilin Univ.

Due to the channel blockage, poor signal or equipment failure and other reasons, communication interruptions will occur between CACC vehicles. The loss of traffic data may cause the instability of the vehicle string and cause the collision accident. To solve this problem, a substitution of CACC is proposed in this paper. It can address the issue of string instability caused by the delay of the time gap change in the case of communication interruption in the CACC motorcade. Finally, the effectiveness of the algorithm in guaranteeing the stability of the string is verified by comparison and analysis of simulation experiments.

MonB05 Room 5
IS: data-based ADP and RL for optimal control
13:30-15:30

Chair: Qinglai Wei Institute of Automation, Chinese Academy of Sci.
CO-Chair: Qingmin Yang Zhejiang Univ.

13:30-13:50 **MonB05-1**

Optimal and Stable Control for Two-Player Zero-Sum Game Using Adaptive Dynamic Programming

Liao Zhu Institute of Automation, Chinese Academy of Sci.
Ruizhuo Song Univ. of Sci. & Tech. Beijing
Qinglai Wei Institute of Automation, Chinese Academy of Sci.
Zhanyu Yang Institute of Automation, Chinese Academy of Sci.
Bo Zhao Institute of Automation, Chinese Academy of Sci.
Beijing Normal Univ.

In this paper, an optimal and stable iteration learning scheme is developed for two-player zero-sum game (ZSG) in the discrcte-time nonlinear systems. In the implementation of developed algorithm, the optimal and stable solution of Hamilton-Jacobi-Isaacs can be obtained based on adaptive dynamic programming (ADP). First, in order to obtain the optimal control policies, value iteration approach is employed with the proof of convergence given. Second, based on Lyapunov theory, an easy condition is proposed to get the stable control laws. Third, neural networks arc used to implement the developed algorithm. Finally, a simulation example is included to verify the present method.

13:50-14:10 **MonB05-2**

Data-Driven Optimal Fault-Tolerant Control for Unknown Linear Systems

Qinmin Yang Zhejiang Univ.
State Key Laboratory of Industrial Control Tech.
Zhengwei Ruan Zhejiang Univ.

In this paper, optimal fault-tolerant control is investigated for a class of unknown linear systems with multiple actuators subject to actuator faults. To tackle the problem of actuator faults and maintain the nearly optimal systems performance, a novel optimal fault-tolerant control strategy is proposed on account of the real system information, without the necessity of complete knowledge of system matrices. It consists of a switching function method, a novel adaptive control law and an optimal control policy. By optimizing a cost

function, an optimal adaptive controller is found to stabilize the system with the approximate dynamic programming technique. The switching function related to the optimal control policy is implemented to locate and reduce the impact of the faulty actuators automatically. Furthermore, all the signals of the closed-loop system are ensured to be uniformly bounded and the stability analysis is rigidly given. Finally, some simulation studies are provided to verify the merits of the proposed method.

14:10-14:30 **MonB05-3**

An Accelerated Linear Approximation Method in Deep Actor-Critic Framework

Dazi Li Beijing Univ. of Chemical Tech.
Yu Zheng Beijing Univ. of Chemical Tech.
Tianheng Song Beijing Univ. of Chemical Tech.
Qibing Jin Beijing Univ. of Chemical Tech.

Reinforcement learning is considered to be one of the main methods of general artificial intelligence, which can realize self-learning of machines through interaction with the environment. In this paper, a modified version of deep reinforcement learning algorithm based on the Actor-Critic framework is proposed. Unlike traditional updated methods, the algorithm proposed in this paper adopts a special on-policy method, which we called Accelerated Linear Approximation Method in Deep Actor-Critic Framework (ALA-AC). When the network is trained to a certain extent, the networks' parameters of some layers are frozen, and the remaining layers' parameters are trained for better strategy and faster training speed.

14:30-14:50 **MonB05-4**

Adaptive Optimal Output Tracking Control of Completely Unknown Linear Two-time-scale Systems

Chunyu Yang China Univ. of Mining & Tech.
Jianguo Zhao China Univ. of Mining & Tech.
Shanshan Zhong China Univ. of Mining & Tech.
Linna Zhou China Univ. of Mining & Tech.

In this note, the infinite horizon optimal output tracking control problem for two-time-scale systems is investigated. The problem is transformed into an optimal regulator problem of the augmented system which is constructed based on the command generator and the original system. The adaptive dynamics programming technique is utilized to learn the optimal solution in real time without relying on the knowledge of system dynamics. By the structured cost function parameter matrix for a full-order model, ill-conditioned numerical issue of two-time-scale systems is overcome. The proposed algorithm has a rigorous convergence proof. Finally, a DC system is given to show the feasibility of the proposed scheme by simulation.

14:50-15:10 **MonB05-5**

Multi-Agent Cooperative-Competitive Environment with Reinforcement Learning

Siyu Huang Huazhong Univ. of Sci. & Tech.
Bin Hu Huazhong Univ. of Sci. & Tech.
Ruiquan Liao Yangtze Univ.
Jiangwen Xiao Huazhong Univ. of Sci. & Tech.
Dingxin He Huazhong Univ. of Sci. & Tech.
Zhi-Hong Guan Huazhong Univ. of Sci. & Tech.

This paper studies the multi-agent pursuit-evasion problem. When the mathematical model of agent is unknown, it's effective to use machine learning algorithm to design the policy of each agent. According to the cooperation among pursuers and competition between evaders and pursuers, we choose deterministic policy gradient of reinforcement learning as our basic approach. In this study, we redesign the reward function and the structure of neural network to adapt to the actual environment where evader has greater speed and accelerated speed than pursuers. The character of this algorithm is that it only takes coordinates of agents as controller input without other information like speed, in particular, this algorithm would keep effective even the environment transform to higher dimensional space. Finally, we verify the validity of our algorithm in experiment.

15:10-15:30 **MonB05-6**

PID-compensated ANN Inverse Control with Application in Superheated Steam Temperature Control of Supercritical Boiler Unit

Liangyu Ma North China Electric Power Univ.
Meng Yan North China Electric Power Univ.
Yongjun Wang North China Electric Power Univ.

Considering the nonlinearity, large inertia and large time delay of superheated steam temperature system of the supercritical boiler unit, the nonlinear dynamic neural network inverse models of superheated steam temperature water-spray desuperheating system were established, and the historical operation data of the unit were used to train and verify the models. Based on the trained models, neural network inverse controllers with PID compensation links were constructed, and a real-time control program was programmed in MATLAB. With the full-scope simulation system of the 600MW supercritical unit, the superheated steam temperature control simulation tests were carried out under setpoint value disturbance and continuous variable load disturbances. The results show that the neural network inverse control scheme with PID compensation can effectively reduce the control deviation of superheated steam temperature and greatly shorten the process stabilization time.

MonB06 Room 6

IS: Parameter estimation and adaptive control

15:50-17:50

Chair:Shubo Wang Qingdao Univ.

CO-Chair:Xuehui Gao Shandong Univ. of Sci.&Tech.

13:30-13:50 **MonB06-1**

K-filter Observer Based Optimal Robust Guarantee Cost Control for Uncertain Nonlinear Servo System with Immeasurable States

Minlin Wang Changcheng Institute of Metrology & Measurement
Beijing Institute of Tech.
Xueming Dong Changcheng Institute of Metrology & Measurement
Xuemei Ren Beijing Institute of Tech.

In this paper, a K-filter observer based optimal robust guarantee cost controller is proposed for uncertain nonlinear servo system with immeasurable states to achieve the precision load tracking. By using a K-filter observer to estimate both the system states and the nonlinearities, an adaptive dynamic surface control is designed to make the system output track a given reference command. However, since the parameter uncertainties may influence the system tracking performance, an optimal robust guarantee cost control is developed to combine with the adaptive dynamic surface control to stabilize the uncertain system and guarantee the system cost function less than or equal to a given upper bound. The Lyapunov theory proves the stability of the closed-loop control system. Simulation results based on a servo system are conducted to illustrate the efficiency of the proposed control scheme.

13:50-14:10 **MonB06-2**

Adaptive Tracking Control of Voltage-Driven Robotic Manipulators with Output Constraints

Dong Xu Zhejiang Univ. of Tech.
Qiang Chen Zhejiang Univ. of Tech.
Kexin Ding Zhejiang Univ. of Tech.
Yurong Nan Zhejiang Univ. of Tech.
Liang Tao Zhejiang Univ. of Tech.

This paper proposes an adaptive tracking control scheme for voltage-driven robotic manipulators with output constraints to achieve satisfactory tracking performance. To overcome the design difficulty from output constraints, a tangent boundary Lyapunov function (tBLF) is first introduced to keep the errors remain within the allowable range of the constraints. Then, RBF neural networks are employed to approximate the uncertainties in the system, and a tracking differentiator (TD) is applied to obtain the differentiation of the virtual control laws in the back stepping design. Finally, the comparative simulations are given to illustrate the effectiveness of the proposed scheme.

14:10-14:30 **MonB06-3**

Data-Driven Tracking Controls of Multi-input Augmented System Based on ADP Algorithm

Yongfeng Lv Beijing Institute of Tech.
Xuemei Ren Beijing Institute of Tech.
Shuangyi Hu Beijing Institute of Tech.
Linwei Li Beijing Institute of Tech.
Jing Na Kunming Univ. of Sci. & Tech.

The data-driven optimal tracking controls (OTC) for the unknown multi-input system are proposed in this paper, and a novel tuning law is used to update NN weights in the learning scheme. First, the formula of the OTC for the multi-input NZS game is presented. A three-layer neural network (NN) data-driven model is introduced to approximate the unknown system, and the input dynamics are obtained. Then, to solve the OTC as a regulation optimal problem, an augmentation multi-input system is constructed with the tracking error and command trajectory. Moreover, we use a reinforcement learning based data-driven NN method to online learn the optimal value functions for each input, which is directly used to calculate the optimal tracking control associated with each performance index function. The convergence of the NN weights is proved. Finally, a simulation is presented to verify the feasibility of our algorithm in this paper.

14:30-14:50 **MonB06-4**

Predictor-Based Tracking and Synchronization Control for Multi-Motor Drive Servo Systems

Shuangyi Hu Beijing Institute of Tech.
Xuemei Ren Beijing Institute of Tech.
Yongfeng Lv Beijing Institute of Tech.

A novel predictor-based adaptive robust control (PARC) strategy for multi-motor drive servo systems is proposed in this paper. The proposed controller consists of a predictor-based tracking controller and a synchronization controller. The state predictor is able to update the neural network weights using the prediction error and the load tracking error, which guarantees a smooth and fast estimation for the unknown nonlinearity without incurring high-frequency oscillations. A cross-coupling synchronization control method is adopted in the synchronization controller to achieve motor synchronization with high-precision. Simulation results on four-motor drive servo system have indicated the efficacy of proposed method.

14:50-15:10 **MonB06-5**

Method of Power Grid Fault Diagnosis Using Intuitionistic Fuzzy Petri Nets with Inhibitor Arcs

Mingyue Tan Shandong Univ. of Sci. & Tech.
Jiming Li Shandong Univ. of Sci. & Tech.
Shasha Zhao Shandong Univ. of Sci. & Tech.
Xuezhen Cheng Shandong Univ. of Sci. & Tech.

Aiming at the uncertainty of information in power grid fault diagnosis and meeting the requirements of real-time online fault diagnosis, A method of power grid fault diagnosis using intuitionistic fuzzy Petri Nets with inhibitor arcs is proposed, in which the effect of inhibitor arcs to the relay protection configuration is considered, and intuitionistic fuzzy logic is employed to deal with the uncertain alarm messages/information. Firstly, according to the topology analysis of power grid and relay protection configuration setting rules, the Petri Nets with inhibitor arcs is used to reflect the protection logic relationship on the model structure. Then, the intuitionistic fuzzy set is taken into account to handle the complex fault data situation of certain information and uncertain information. Finally, the results of testing cases using the IEEE-39 node system show that this method can effectively deal with the mis-operation of multiple circuit breakers in complex data environment and accurately diagnose complex faults of power grid under uncertain information.

15:10-15:30 **MonB06-6**

Adaptive Fuzzy Output Feedback Control for Input-saturated System Based on Nonlinear Tracking Differentiator

Guofa Sun Qingdao Univ. of Tech.
Hanbo Yu Qingdao Univ. of Tech.
Wei Wei Qingdao Univ. of Tech.

This paper proposes an adaptive fuzzy output feedback control approach based on nonlinear tracking differentiator for a class of strict feedback systems with input saturation, unknown nonlinear functions and unmeasurable states. Fuzzy logic systems (FLSs) are used to approximate the unknown nonlinear function and a fuzzy state observer is designed to estimate the unmeasured state of the system. The nonlinear tracking differentiator (TD is used to estimate the differential of command signal which avoids the problem of "explosion of complexity" in traditional backstepping control. The compensation signal is introduced to eliminate the filtering error caused by the nonlinear tracking differentiator. The proposed approach guarantees stability of the closed-loop system and all signals are bounded. Finally, simulation examples are provided to check the effectiveness of the proposed approach.

MonC01 Room 1
IS: Data-driven smart transportation 15:50-17:50

Chair: Guangyue Xue China Transport Telecommunications & Information Center
CO-Chair: Lichun Yang Jiangsu Automation Research Institute

15:50-16:10 **MonC01-1**

Displaying Method of Remote Sensing Images Based on the Domestic Independent Controllable Platform

Lichun Yang Jiangsu Automation Research Institute
Guangfu Ge Jiangsu Automation Research Institute
Dan Yang Jiangsu Automation Research Institute
Yingyan Gu Jiangsu Automation Research Institute

In order to improve the level of informationization and equipment construction of the army, and build a self-controllable remote sensing image processing system, a reading and displaying method is proposed for remote sensing images based on the open source raster geodatabase geospatial data abstraction library (GDAL) and the cross-platform application framework Qt. The GDAL is employed to read and sample remote sensing images, which are then displayed and rendered by the Qt graphical view framework. The experimental results show that the proposed method can run successfully on the Windows platform and the embedded real-time Delta operating system (Delta OS) platform, free from limitation of the operating environment of commercial remote sensing software platform. The proposed method can effectively improve the displaying of large-scale remote sensing images and computer's memory efficiency, and promote the development of remote sensing image processing system under the domestic independent controllable platform.

16:10-16:30 **MonC01-2**

Online Spatial Registration of 2D/3D Sensor Networks

Jianghuai Pan Jiangsu Automation Research Institute
Lichun Yang Jiangsu Automation Research Institute

Aiming at the problem of information missing in spatial registration 2D/3D sensor network, two online spatial registration algorithms based on information superposition and information complement dimension are proposed. Information superposition method establishes a bias estimation model based on the superposition conditions of the true values of the same target for each sensor, and estimates the registration bias by least square method. The information compensation dimension method uses to fill the missing data of 2D sensor, and transforms the 2D/3D sensor registration problem into the 3D/3D sensor network registration problem, and used 3D/3D registration algorithm to solve 2D/3D registration problem, the simulation results of these two algorithms are given in this paper.

16:30-16:50 **MonC01-3**

Comparative Study on Identification Models of Early Cotton Pests and Diseases at Canopy Scale

Shasha Liu China Academe of Aivil Aviation Sci. & Tech.
Yubin Xu China Academe of Aivil Aviation Sci. & Tech.
Yong Zhao China Academe of Aivil Aviation Sci. & Tech.
Kejian Yuan China Academe of Aivil Aviation Sci. & Tech.

Ye Tian Shandong Taian Kaiyuan Middle School

This paper proposed a quantitative identification method for cotton pests and diseases based on actual measured canopy hyperspectral remote sensing data. The Vegetation Index (VI) and the Continuous Wavelet Transform (CWT) were utilized for spectral feature discriminant analysis to distinguish cotton pest and disease samples from normal samples. The Fisher discriminant analysis model was adopted to identify the type of pests and diseases and then cross-validated to provide technical support for preventing and controlling of cotton pests and diseases. The results showed that the overall recognition accuracy of the recognition model established by the Continuous Wavelet Transform and the Vegetation Index were 97.50% and 94.16%, respectively.

16:50-17:10 **MonC01-4**

Aerodrome Clearance Monitoring and Management based on Multi-source High Resolution Remote Sensing Data

Yubin Xu China Academe of Aivil Aviation Sci. & Tech.
Yan Ma China Academe of Aivil Aviation Sci. & Tech.
Jing Guo China Academe of Aivil Aviation Sci. & Tech.
Xuhui Wang China Academe of Aivil Aviation Sci. & Tech.
Shasha Liu CAST Zhongyu New Tech. Development Co.
Li Ma China Academe of Aivil Aviation Sci. & Tech.

FAA and ICAO have clear specification for aerodrome clearance management, which is vital for ensuring safe takeoff, flight and landing to aircrafts. This work proposed a new method to identify obstacles and evaluate potential hazards, which will make great contribution for clearance management and help mitigate possible risk in aviation security framework. This came up with new fully automatic methodology to detect environmental building change and OISs surface penetration based on multi-source high resolution remote sensing data. Shape extraction and classification of obstacles will be figured out from stereo paired images. This kind of clearance remote spatial patrol can be done every a few days, which is very suitable for wide area where is huge difficult to reach and human patrol pattern may miss. The application in Changshui International Airport proved to be very effective strategy to update obstacles database and manage clearance. More importantly, it helps guarantee aerodrome terminal operation safety.

17:10-17:30 **MonC01-5**

Research on GPS/BDS Single Point Velocity Measurement Considering Direction Constraints

Bingqi Zhang China Transport Telecommunications & Information Center

High precision velocity measurement is an important function of Global Navigation Satellite System, which is widely used in transportation, high-dynamic positioning, aeronautical gravity, geophysics and other fields. The GNSS velocity measurement model based on Doppler observations can achieve centimeter-level high-precision velocity measurement. The measurement quantity in this model is instantaneous velocity, which is not affected by the motion state. However, due to the influence of noise, the accuracy of Doppler range rate measurement is mostly cm/s level and is influenced by the geometric structure of satellites. With the development of GNSS and increase of satellites number, the accuracy of multi-system velocity measurement is further improved. In velocity measurement, information such as direction of velocity may be obtained from map information of road or orbit. Herein such constraint information in GNSS speed measurement system can improve the accuracy of velocity measurement, especially in areas with poor observation environment such as high occlusion. Static experiments show that under good observation environment, the accuracy of eastward velocity can be improved by 30% and northward velocity by 35% considering plane direction constraints of velocity. In high occlusion area, the accuracy of eastward velocity can be improved by 52% and northward velocity by 43% considering the plane direction constraints of velocity.

17:30-17:50 **MonC01-6**

Information Enterprise Architecture for Smart Transportation System

Guangyue Xue China Transport Telecommunications & Information Center
Yunpeng Wu China Transport Telecommunications & Information Center
Yubin Xu China Academy of Civil Aviation Sci. & Tech.

A novel information enterprise architecture (IEA) is proposed in this paper for the smart transportation system (STS) which is system of systems (SoS) implemented by data-centric engineering. To analyze the data and information model of the complex transportation information system, viewpoints description method proposed in Department of Defense Architecture Framework (DoDAF) is adopted to represent the elements of the STS. An IEA of STS is implemented by adopting the DoDAF views and transportation data detailed analysis in diagrammatic representation for top layer design to support decision making.

MonC02 Room 2
IS：Data-driven modeling and optimal control (II)
15:50-17:50

Chair: Aihua Zhang Bohai Univ.
CO-Chair: Kun Li Bohai Univ.

15:50-16:10 **MonC02-1**

Prediction and Modeling for Interval Time of the Intermittent Pumping Well Based on Parallel System

Kun Li Bohai Univ.
Wensu Xu Bohai Univ.
Ying Han Bohai Univ.
Yi'an Wang Bohai Univ.
Fawei Ge Bohai Univ.

In actual oilfield production, the intermittent pumping wells interval time is mainly determined by production experience. In this paper, a modeling and prediction method for the interval time based on parallel system is presented. Through different computational experiments in the artificial system, a reasonable interval time is got to guide the actual pumping system to reach an optimal state. Based on the proposed method, the intermittent pumping well can be improved by decreasing the energy consumption and ensuring the stable production at a high level. A case study is carried out, and its results illustrate the proposed method is effective

16:10-16:30 **MonC02-2**

Multiple Fault Diagnosis for Sucker Rod Pumping Systems Based on Matter Element Analysis with F-statistics

Ying Han Bohai Univ.
Kun Li Bohai Univ.
Fawei Ge Bohai Univ.

Dynamometer cards can reflect different down-hole working conditions of sucker rod pumping wells. It has great significances to realize multiple fault diagnosis for actual oilfield production. In this paper, the extension theory is used to build a matter-element model to describe the fault diagnosis problem of the sucker rod pumping wells. The correlation function is used to calculate the correlation degree between the diagnostic fault and many standard fault types. The diagnosed sample and many possible fault types are divided into different combinations according to the correlation degree; the F-statistics of each combination is calculated and the "unbiased transformation" is used to find the mean of interval vectors. Larger F-statistics means greater differences within the faults classification; and the minimum F-statistics reflects the real multiple fault types. Case study shows the effectiveness of the proposed method.

16:30-16:50 **MonC02-3**

A Multi-class Classification Algorithm Based on Hypercube

Yuping Qin Bohai Univ.
Yuanyue Zhao Bohai Univ.
Xiangna Li Beijing Guo Dian Tong Network Tech. Co.
Qiangkui Leng Bohai Univ.

A multi-class classification algorithm based on hypercube is proposed. For each class of training samples, a minimum hypercube that surround all samples is constructed in sample space. If two hypercubes intersect, the hypercube centers are used as the benchmark for compression. For a sample to be classified, its class label is determined according to the hypercube in which it is located. If this sample is not in any hypercube, the distances from the sample to the center of each hypercube are calculated firstly, and then the class label is determined by the nearest neighbor rule. The experimental results show that the training speed and classification speed of the proposed algorithm are improved significantly while ensuring the classification accuracy, especially in the case of large dataset and large number of classes.

16:50-17:10 **MonC02-4**

The Analysis of Stator System Natural Frequency Calculation Method on Transverse Flux Permanent Magnet Motor

Wei Wang Bohai Univ.
Hao Zhang Bohai Univ.

The stator and armature coils of the transverse flux permanent magnet motor are perpendicular to each other in space. Its core size and coil size are independent of each other, size can be arbitrarily selected in a certain range. Thus the high torque density is suitable for some special occasions. First of all, the finite element build accurate stator system model. Secondly we calculated modal of the motor, according to the results of calculation analysis concluded that the stator system analytic calculation of the equivalent model. The above work has been the calculation formula of the stator system natural frequency that provide calculation basis for transverse flux motor vibration noise analysis.

17:10-17:30 **MonC02-5**

Iterative Learning Control with Optimal Learning Gain for Recharging of Lithium-ion Battery

Chaolun Wang Sun Yet-Sen Univ.
Tengfei Xiao Sun Yet-Sen Univ.
Xiao-Dong Li Sun Yet-Sen Univ.

Lithium-ion battery has been widely used by the virtue of its high energy density and longevity. It is required that the lithium-ion battery ought to be recharged and discharged with the guarantee of safety and reliability in the applications. In this paper, a P-type iterative learning control (ILC) algorithm is introduced to manage the charging process of lithium-ion battery described by the equivalent circuit model as a special case of non-linear distributed parameter system. For practical implementations, the monotone convergence is analyzed and guaranteed in the sense of Lebesgue-p norm. Furthermore, an optimal learning gain is selected in order to achieve rapid convergence speed. A practical simulation using parameters identified by real lithium-ion battery is built up to verify the effectiveness of proposed control scheme.

17:30-17:50 **MonC02-6**

Emergency Decision-Making of Cluster Supply Chain Based on Scenario Analysis and Case-Based Reasoning

Hong Xue Beijing Tech. & Business Univ.
Yue Wu Beijing Tech. & Business Univ.
Miao Zhang Beijing Tech. & Business Univ.
Jingxuan Wang Beijing Tech. & Business Univ.

Aiming at the unpredictability of cluster supply chain unconventional emergency, this paper proposes a case-based reasoning (CBR) emergency decision-making method for cluster supply chain unconventional emergency based on scenario analysis. In the unconventional emergency scenario, the unconventional emergency scenario knowledge representation structure is constructed based on the pressure-state-response (PSR) model, and then a bayesian network-based cluster supply chain unconventional emergency scenario analysis network model is created to deduce the characteristic values of emergency decision-making indicators of new cases. The case retrieval algorithm based on the multidimensional cloud model is used for case matching. The weights of indexes are determined based on the entropy weight method. The simulation experiment results verify the effectiveness of the proposed method, which provides theoretical support for the emergency decision-making of unconventional emergency in the cluster supply chain.

MonC03 Room 3
IS：Autonomous and intelligent control of UAV (II)

15:50-17:50

Chair: Chaofang Hu Tianjin Univ.
CO-Chair: Yimin Zhou SIAT, Chinese Academy of Sci.

15:50-16:10 **MonC03-1**

An Improved Kalman Filter Based on Self-adaptive Adjustment Parameters

Shenglun Yi Beijing Institute of Tech.
Xuemei Ren Beijing Institute of Tech.
Tingli Su Beijing Tech. & Business Univ.

This paper considers an improved Kalman filter (KF) for a non-Gaussian system, when an adaptive statistics model is applied to capture the systematic characteristics in real time. The problem is formulated as self-adaptive adjustment parameters (SAPs) updating by the recursive least squares (RLS) algorithm. These parameters are shown to admit adaptive statistics model to characteristics of which applies and extends results given earlier in "Online denoising based on the second-order adaptive statistics model" (S. L. Yi and X. B. Jin et al., Sensors, 17(7), 1668, 2017.). Simulations comparing the improved KF based on the SAPs to the standard KF and the past algorithm illustrate a satisfactory performance when applied to self-adaptive adjustment parameters. Simulation results show that the proposed algorithm can gradually converge with a small performance loss.

16:10-16:30 **MonC03-2**

Gait Conversion of Quadruped Bionic Robot Based on CPG Control

Hongjun San Kunming Univ. of Sci. and Tech.
Hao Chen Kunming Univ. of Sci. and Tech.
Mingfang Chen Kunming Univ. of Sci. and Tech.
Yongxia Zhang Kunming Univ. of Sci. and Tech.

Gait control is one of the difficulties in motion control of quadruped bionic robots. In this paper, the Hopf harmonic oscillator is used to generate the gait control signal, and then the network topology of the inter-foot coordination control is established. Secondly, the gait conversion of the quadruped bionic robot is realized by changing the connection weight matrix of the CPG network. Finally, the simulation of oscillation signal is generated by MATLAB software to verify effectiveness of the gait switching of the quadruped robot. The simulation results show that the oscillating signal can easily produce breakpoints at the switching position when it is adjusted in non-integral period. When gait switching is performed on the quadruped bionic robot, the breakpoint should be avoided as much as possible, because the existence of the breakpoint has a certain influence on the stability of the robot.

16:30-16:50 **MonC03-3**

Modeling and Dynamic Simulation of TI Worm Drive based on GearTrax

Jianghua Pu Kunming Univ. of Sci. and Tech.
Xuejun Wang Kunming Univ. of Sci. and Tech.
Peng Wu Kunming Univ. of Sci. and Tech.
Hongjun San Kunming Univ. of Sci. and Tech.
Mingfang Chen Kunming Univ. of Sci. and Tech.

Rail transport conveyer is a kind of special transportation equipment commonly used in the metallurgical industry. One of the crucial reasons leading to the inefficient/poor reliability and low kinetic accuracy of rail transport conveyer is closely related to the transmission system. A precise three-dimension solid model of the TI worm and worm gear is established, which serves as the main transmission structure is built with GearTrax and Solid Edge. ADAMS simulation analytic software is utilized to conduct kinematic simulation analysis through inputting modeling of worm transmission structure in rail transport lifting system with Hertz contact theory, and the change rules of driven link bevel tooth rotation speed and worm and gear engaging force are obtained and analyzed. Therefore, it has improved the reliability and efficiency of rail transport conveyer transmission system, and a reference method is provided for 3D solid modeling of TI worm transmission and the dynamics modeling and analysis of worm and gear transmission

mechanism.

16:50-17:10 **MonC03-4**

Mobility Analysis of a Hybrid Mechanism based on POC Equations and its Kinematic

Jiupeng Chen Kunming Univ. of Sci. and Tech.
Hongjun San Kunming Univ. of Sci. and Tech.
Mingfang Chen Kunming Univ. of Sci. and Tech.
Kaixiang Zhang Kunming Univ. of Sci. and Tech.
Daoyi Zhang Kunming Univ. of Sci. and Tech.

T Institutional innovation is a challenging task. For parallel mechanisms, a new type of branch structure and a new branch combination scheme can be considered as the innovative design of the topology of the parallel mechanism. At present, there are three main methods for the synthesis of parallel mechanisms, namely, displacement subgroup method, screw theory method and position and orientation characteristic (POC) equations. Degree of freedom analysis is an indispensable part of mechanism synthesis, and is also the foundation of mechanism kinematics. A 5 degrees-of-freedom (DOF) hybrid mechanism was researched in this paper based on a 3-DOF translational parallel mechanism with parallelogram linkage and 2-DOF serial mechanism. Firstly, the characteristics of this topology structure were introduced, and the mobility of the mechanism was analyzed by POC equations. Secondly, according to the space vector relation between the moving platform and the fixed base, the direct kinematics of parallel part were deduced via an analytical method and the inverse kinematics was performed by D-H method. Finally, In order to verify the efficiency of the kinematics algorithm, a set of given arguments about mechanism could be put into the kinematics algorithm to obtain the corresponding changes of displacements and the position of the moving platform. The error of the inverse and direct kinematics was analyzed by an example of machining a complex surface, which shows that the proposed algorithms are effective and have satisfactory computation precision.

17:10-17:30 **MonC03-5**

Cyclic Loading Test Facility for Ballast Bed of High-speed Railway

Xuejun Wang Kunming Univ. of Sci. and Tech.
Jianghua Pu Kunming Univ. of Sci. and Tech.
Peng Wu Kunming Univ. of Sci. and Tech.
Hongjun San Kunming Univ. of Sci. and Tech.
Mingfang Chen Kunming Univ. of Sci. and Tech.

In this paper, a new full-scale indoor ballasted ballast bed cyclic loading test-bed is introduced. Based on the actual operation of high-speed train, the corresponding relationship between the simulation parameters of loading process and the actual operation parameters is analyzed, and the hydraulic transmission and control system of the cyclic loading test-bed, which can simulate the actual operation of vehicles are designed. According to the simulated parameters and test methods of the cyclic loading test bench, the hydraulic circuit is built, and the electro-hydraulic proportional key technology is used to precisely control the hydraulic circuit. The principle and characteristics of the hydraulic system of the test-bed are emphatically expounded, and the performance of the test model is verified by comparing the test results.

17:30-17:50 **MonC03-6**

Simulation Analysis for Remote Filed Eddy Current Testing of Unidirectional Carbon Fiber Reinforced Plastic

Yiding Zhang Kunming Univ. of Sci. and Tech.
Bo Ye Kunming Univ. of Sci. and Tech.
Jiande Wu Kunming Univ. of Sci. and Tech.
Qi Zhang Kunming Univ. of Sci. and Tech.
Xinjian Wei Kunming Univ. of Sci. and Tech.

In order to detect the defect of unidirectional Carbon Fiber Reinforced Plastic (CFRP), the simulation model of remote field eddy current testing (RFECT) was established by the finite element simulation software COMSOL, and the influence of excitation coil size, working frequency and the axial distance of coils on the detection results were comprehensively compared. Finally, the optimal parameters of the remote field eddy current testing model are determined. By analyzing the unidirectional CFRP magnetic flux density component under the influence of the remote field eddy current, it is found that the magnetic flux density z component can be used as the feature for defect detection, which provides a research idea for the effective identification of defects.

MonC04 Room 4

IS: Intelligent and learning control of nonlinear system

15:50-17:50

Chair:Zhouhua Peng Dalian Maritime Univ.
CO-Chair:Yongming Li Liaoning Univ. of Tech.

15:50-16:10 **MonC04-1**

Zeroing-Type Recurrent Neural Network for Solving Time-Dependent Lyapunov Equation with Noise Rejection

Jingkun Yan Lanzhou Univ.
Long Jin Lanzhou Univ.
Rui Zhang China Research Institute of Radiowave Propagation.
Hongxin Li Lanzhou Univ.
Jiliang Zhang Lanzhou Univ.
Huiyan Lu Lanzhou Univ.

It is well known that many engineering communities are confronted with the problem of Lyapunov equation (LE) solving, and a mass of methods are proposed to solve the problem under the circumstance of no-noise.

Whereas, noise is inevitable during actual experiments due to all kinds of factors, and models with resistance to noises are needed. To fill this lacuna, this paper proposes a zeroing-type recurrent neural network (ZTRNN) model for the task of solving the time-dependent LE. Additionally, the original zeroing neural network (OZNN) model is described for the purpose of comparison. Rigorous theoretical analyses concerning the convergence and the resistance to noises of the ZTRNN model are presented. Further, a numerical example of the time-dependent LE is solved by using the ZTRNN model and the OZNN model separately. Computer simulations are carried out perfectly and the results verify the feasibility and resistance to noises of the ZTRNN model, reflecting that the ZTRNN model outperforms the OZNN model in terms of resistance to noises.

16:10-16:30 **MonC04-2**

Adaptive Neural Inverse Optimal Control for a Class of Strict Feedback Stochastic Nonlinear Systems

Feng Cao Liaoning Univ. of Tech.
Tingting Yang Liaoning Univ. of Tech.
Yongming Li Liaoning Univ. of Tech.
Shaocheng Tong Liaoning Univ. of Tech.

This study develops an adaptive neural inverse optimal control method for a class of stochastic nonlinear systems. Neural networks (NN) are used to approximate the unknown nonlinear functions. The designed inverse optimal control strategy avoids the objective of solving the Hamilton-Jacobi-Bellman (HJB) equation and devises an optimal controller, which is related to the meaningful cost functional. Based on adaptive backstepping algorithm and Lyapunov stability theory, it is proved that the proposed control strategy guarantees the asymptotic stability in probability of the control systems and solves the inverse optimal problem.

16:30-16:50 **MonC04-3**

A DSC Based Adaptive Control Scheme for a Class of Uncertain Non-lower Triangular Nonlinear Systems

Gang Sun Hunan Institute of Tech.
Jiangxi Univ. of Sci. and Tech.
Mingxin Wang Hunan Institute of Tech.

An adaptive tracking controller design method is developed for a class of nonlinear systems with non-lower triangular form and linear parameterized uncertainties by combining backstepping and dynamic surface control (DSC) technology. In the design, traditional backstepping design process is used to establish control laws recursively, and unknown parameters of control laws are estimated online. By using DSC technology, the problem of circular structure of the controller is eliminated. Stability results of closed-loop system show that the uniform ultimate boundedness of closed-loop system signals can be guaranteed. Besides, the steady state tracking error of the system can be adjusted to a small neighborhood of zero by selecting appropriate control parameters. The efficacy of the designed approach is demonstrated via a numerical simulation example.

16:50-17:10 **MonC04-4**

Data-Driven Online Adaptive Optimal Control for Linear Systems with Completely Unknown Dynamics

Jun Zhao Kunming Univ. of Sci. and Tech.
Jing Na Kunming Univ. of Sci. and Tech.
Guanbin Gao Kunming Univ. of Sci. and Tech.
Yuyao Xiao Beijing Institute of Tech.
Zhuoyue Song Beijing Institute of Tech.

This paper develops a novel method to address the optimal control problem of systems with unknown dynamics. An adaptive identifier is first constructed based on the vectorization operator and Kronecker products, where we can reconstruct the unknown system dynamics based on the measurable input and output data. A recently proposed adaptive law is used to guarantee the convergence of the identifier parameters. Then, a data-driven technology is applied to online solve the derived algebraic Riccati equation (ARE). For this purpose, we apply the Kronecker's products on the ARE such that another adaptive law is employed to online estimate the parameters involved in the ARE with guaranteed convergence. Simulation results are given to illustrate the effectiveness of the proposed method.

17:10-17:30 **MonC04-5**

Event-triggered Modular Neural Network Control for Containment Maneuvering of Second-order MIMO Multi-agent Systems

Yibo Zhang Dalian Maritime Univ.
Lu Liu Dalian Maritime Univ.
Dan Wang Dalian Maritime Univ.
Zhouhua Peng Dalian Maritime Univ.
Gang Sun Jiangxi Univ. of Sci. and Tech.

An event-triggered modular neural network controller is designed for containment maneuvering of second-order MIMO nonlinear multi-agent systems under an undirected graph. For the distributed containment maneuvering controller, the estimation loop and the control loop are designed separately. In the estimation loop, an estimator is developed to design the adaptation law. The uncertain nonlinear dynamics is identified by using the neural network. An event-triggered mechanism is utilized for reducing the communication burden of followers. In the control loop, a local control law are designed based on a modified dynamic surface control method. By using an event-triggered mechanism, the path update law is designed and the communication burden of leaders is reduced. The closed-loop system is proved to be input-to-state stable. Besides, the closed-loop system is analyzed to exclude Zeno

behavior. A numerical example is given to reveal the efficacy of the proposed event-triggered controller for containment maneuvering of second-order nonlinear MIMO multi-agent systems.

17:30-17:50 **MonC04-6**

Feedback Control of Switched Linear Systems with Event-triggered Link

Xiaoqian Luo Bohai Univ.
Xinxin Wang Bohai Univ.
Tai-Fang Li Bohai Univ.

The paper mainly studies the event-triggered control of switched linear systems with partially random coefficient using average dwell time switching technique. Samplings are active when a triggering condition is satisfied. On every sampling instant, new state and the switching information are transferred to controller. Compared with the zero-order holder, a dynamic controller is introduced in closed-loop to approximate the plant behavior. A sufficient condition guaranteeing stability is established by using Lyapunov function method. A related example is presented finally.

MonC05 **Room 5**

IS: Adaptive learning and repeat control for nonlinear system **15:50-17:50**

Chair: Qiuzhen Yan Zhejiang Univ. of Water Resources and Electric Power
CO-Chair: Lingwei Wu Taizhou Univ.

15:50-16:10 **MonC05-1**

Sliding Mode Repetitive Control Based On a Novel Reaching Law

Jie Zhang Hangzhou Huadian Xiasha Cogeneration Co.

The chattering occurs when the system works under the controller which is based on the traditional reaching law. This paper proposes a novel reaching law to avoid the system chattering by using a mathematical expression to replace the switching function in the traditional reaching law. The discrete time expression of the novel reaching law is given. And the design of discrete time sliding mode repetitive controller which based on the novel reaching law is presented to achieve perfect tracking. The periodic perturbations are rejected completely. The monotone decreasing region, absolute attraction layer and steady state error are derived to characterize the reaching phase of the sliding mode. Numerical simulation demonstrates the effectiveness of the proposed repetitive control strategy.

16:10-16:30 **MonC05-2**

Chattering-Free Reaching Law based Discrete-Time Sliding Mode Repetitive Control

Pan Mei Taizhou Univ.
Lingwei Wu Taizhou Univ.
Zhiming Lin Taizhou Univ.

This paper is concerned with the tracking control of uncertain discrete-time system subject to periodic disturbance. A new discrete-time sliding mode repetitive control is applied to address the control problem. A measure of the periodic disturbance rejection is embedded in the reaching law, and the periodic disturbance is rejected completely. In order to characterize the perfect tracking performance, we derive the expressions for the range of the quasi-sliding mode (QSM) band, the absolute attractive layer, and the monotone decreasing region. Numerical simulation results are given to validate the effectiveness and superiority of the presented control method.

16:30-16:50 **MonC05-3**

Attracting Law based Discrete Multi-Periodic Repetitive Control

Lingwei Wu Taizhou Univ.
Pan Mei Taizhou Univ.
Zhiming Lin Taizhou Univ.
Na Su Taizhou Univ.

This paper presents a discrete multi-periodic repetitive control design approach for the problem of a general multiperiodic disturbance rejection. Both the nonlinear-saturation function and the measure of multi-periodic disturbance rejection are suggested to form an attracting law (AL), and by which an multi-periodic repetitive controller is developed. The multi-periodic disturbances are rejected, and the perfect tracking is achieved. In order to characterize the tracking performance, the absolute attractive layer and the steady-state error band are derived. Simulation results are given to verify the effectiveness and superiority of the proposed method.

16:50-17:10 **MonC05-4**

周期非匹配含死区输入系统的重复控制

严求真 浙江水利水电学院信息工程学院
蔡建平 浙江水利水电学院信息工程学院

针对一类扰动周期与参考信号周期之间无公共倍数且执行机构含输入死区的非参数不确定系统，为实现对参考信号的跟踪，本文提出一种双周期重复控制方法.基于 Lyapunov 方法设计控制器，结合鲁棒方法与双周期重复学习方法处理非参数不确定性、死区非线性特性与周期性扰动，利用完全限幅学习方法估计未知参数.经过足够多个周期的重复运行后，可实现系统输出在整个重复周期上无误差跟踪参考信号.最后，通过仿真示例验证所提控制方法的有效性.

17:10-17:30 **MonC05-5**

Adaptive Iterative Learning Control of Nonlinear Systems with Input Saturation

Huihui Shi Zhejiang Univ. of Tech.
Qiang Chen Zhejiang Univ. of Tech.
Kaijie Chen Zhejiang Univ. of Tech.
Mingxuan Sun Zhejiang Univ. of Tech.

This paper presents an adaptive iterative learning control for a class of nonlinear systems with input saturation. The input saturation is approximated by a smooth hyperbolic tangent function based on the mean-value theorem. Then, an integral Lyapunov function is constructed to avoid the potential singularity problem caused by the differential of unknown gain functions. A radial basis function neural network (RBFNN) is employed to approximate the unknown system nonlinearity, and the combined adaptive laws are designed to estimate NN weight and the bound of the approximation error, respectively. With the proposed scheme, the tracking error is guaranteed to converge into a neighborhood of zero in the sense of L^2-norm within the finite iterations, and numerical simulations show the effectiveness of the proposed scheme.

17:30-17:50 **MonC05-6**

Distributed Switching Learning Control for Nonlinear Multi-agent Systems with Unknown Control Directions and Input Disturbances

Xinglong Niu North Univ. of China
Peng Liu North Univ. of China
Tiehua Ma North Univ. of China

In this paper, we studies the leader-following consensus for a class of uncertain nonlinear multi-agent systems (NMASs) via switching learning control method. The novelties are reflected in the unknown input disturbances, unknown Lipschitz rate and unknown control directions. These unknowns make the consensus problem different from the existing related literature. To capture these unknowns, we propose a distributed consensus protocol based on a switching logic scheme, which guarantees the leader-following consensus.

MonC06 Room 6
Big data and its applications in modeling and control

15:50-17:50

Chair: Tianzhen Wang Shanghai Maritime Univ.
CO-Chair: Ming Xu Beihang Univ.

15:50-16:10 **MonC06-1**

三星编队的 InSAR 不变构型设计

罗强 国防科技大学
郑亚茹 北京航空航天大学
徐明 北京航空航天大学

InSAR 系统通过在特定的构型上布置多颗卫星，可以实现单程干涉测量；但编队构型面临被 J2 项摄动破坏的危险。本文基于 J2 不变轨道的微分修正算法，设计保持系统有效垂直基线的编队构型。通过对相对动力学的分析发现：除非有无穷多个卫星参与编队，否则 InSAR 的系统有效垂直基线不可能被配置在常值上。抛弃基线不变的概念，本文转而研究如何保持该基线在常值附近波动；通过蚁群算法优化配置，从而得到在 J2 摄动下，近似保持有效垂直轨迹基线的 InSAR 构型；同时，数学仿真表明该构型具有较好的绝对定位精度。

16:10-16:30 **MonC06-2**

Non-Cooperative Flying-around Mission: Configuration Design, Relative Navigation and Control

Yaru Zheng Beihang Univ.
Jinfeng Zhou China Academy of Space Tech.
Ming Xu Beihang Univ.

This paper studies configuration design, relative navigation and control of non-cooperative flying-around mission J_4-perturbed elliptic orbit. J_2-perturbation is generally considered in most circumstances of satellites around the Earth, while the relative motion is under J_4-pertuabation to achieve more precise results. The key problem of flying-around mission is orbital control, a more general method is established which considers remote maneuvers, reconfiguration, flying-around and escape. Based on the orbital control in the paper, the initial conditions of object and tracking satellite are as appropriate but not unique. The Extended Kalman Filter is introduced to enhance the robustness of relative navigation system in cases of noises and errors caused by the measurements. With the introduce of Extended Kalman Filter in relative navigation and J_4 perturbation in relative motion, simulation results of the flying-around mission configuration design are more persuasive.

16:30-16:50 **MonC06-3**

Development and Application of Workshop Virtual Monitoring System Based on Unity

Luyao Xia Tongji Univ.
Jianfeng Lu Tongji Univ.
ChenLing Zhang Tongji Univ.
Sheng Wang Tongji Univ.
Hao Zhang Tongji Univ.

The enterprise workshop production site is full of complex information and in complicated situation, so the traditional monitoring system cannot meet the demands of the information interaction between workshop management and operational levels. In order to solve these problems, this paper is about to build virtual models that accurately map workshop resources and a virtual monitoring system that reflects the production status in real time which can help the workshop managers to timely and roundly monitor the manufacturing resources such as the workshop equipment and production status. The system builds the data logic model of the workshop manufacturing resources based on the 3D workshop model, which adopts Thrift framework to establish the data interaction between the virtual workshop layer and bottom layer, and uses the real-time production data to drive the 3D virtual model. Then the system renders the virtual scene and builds a human-computer interaction interface on the Unity3D platform. Finally, this paper takes a workshop system as an example to establish a virtual monitoring system integrating VR and AR technology, and verifies the effectiveness of the system.

16:50-17:10 **MonC06-4**

Model Analysis and Design of 3D Printing Control System Based on Cement Components

Hongqian Lu Qilu Univ. of Tech.
Renren Wang Qilu Univ. of Tech.

This design mainly analyzes and designs a 3D printing equipment model based on extrusion curing of raw materials. The working principle of the device is that the CAD model of the building to be printed is first used, and the program is written directly by point-by-point comparison interpolation method. The program is then stored as a device control system. When printing is required, only the corresponding program is called. And the system will control the servo driver, drive the servo motor, the servo motor drives the mechanical arm sprinkler head to move on the XYZ axis through the gear drive. At the same time, the system sends out a signal to drive the feeding motor to drive the screw rod to start feeding. The electromagnetic valve of the nozzle opens and starts to print and construct the building according to the program written by interpolation algorithm.

17:10-17:30 **MonC06-5**

A Fusion Optimization Method Based on Observation Tracking and Extremum Seeking for Photovoltaic System

Yutao Cheng Shanghai Maritime Univ.
Tianzhen Wang Shanghai Maritime Univ.
Tianhao Tang Shanghai Maritime Univ.
François Auger Nantes Univ.

Maximum power tracking control is indispensable for Photovoltaic system to gain higher output power. For nonlinear system as photovoltaic system, extremum seeking control algorithm can reach good control effect. In view of the contradiction between tracking performance and algorithm complexity, and the problem of misjudgment when environment changes, a fusion optimization method based on observation tracking and extremum seeking is proposed in this paper, the fuses step based on the output power difference. The experimental results show that the optimized algorithm can further improve the conversion efficiency and performance compared with other algorithms while maintaining low complexity and implementation cost.

17:30-17:50 **MonC06-6**

An Auxiliary Model Construction Method for System Identification and its Application to an Indoor Multicopter Platform

Zeqing Ma Beihang Univ.
Jinrui Ren Beihang Univ.
Yifan Lin Beihang Univ.
Quan Quan Beihang Univ.

In this paper, an auxiliary modeling method for system identification is proposed for multicopter dynamic modeling. By utilizing an auxiliary controller called damper during the modeling and identification process, the unstable attitude angle and angular rate channels of multicopters can turn to be stable so as to obtain the parameterized dynamic model without safety problems led by traditional methods and large-space requirement. Through an application to an indoor fixed quadcopter system, simulation results demonstrate the feasibility of the proposed method for the multicopter dynamic modeling.

Saturday, May 25, 2019, Grand Bay View International Hotel, Dali (大理海湾国际酒店)						
8:00-8:20	Opening ceremony, Venue: Multi-Function Hall, Chair: Prof. Chenghong Wang					
8:20-9:20	Keynote Address 1: A Lifelong Cooperative Learning Approach, Prof. Marios M. Polycarpou, Venue: Qianqiusui Hall, Chair: Prof. Zhiqiang Gao					
9:20-10:20	Keynote Address 2: Neural Graph Processing, Prof. Cesare Alippi, Venue: Qianqiusui Hall, Chair: Prof. Dongbin Zhao					
10:20-10:50	Tea Break and Photo					
10:50-11:30	Distinguished Lecture 1：Intelligent Control of Autonomous Flapping-Wing Robotic Aircraft, *Prof. Wei He*, Venue: Qianqiusui Hall, Chair: Prof. Chiang-Ju Chien					
11:30-12:10	Distinguished Lecture 2：Adaptive Parameter Estimation and Control via Parameter Error: A New Framework, *Prof. Jing Na*, Venue: Qianqiusui Hall, Chair: Prof. Zhongsheng Hou					
12:10-13:30	Lunch					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
13:30-15:30	SatA01	SatA02	SatA03	SatA04	SatA05	SatA06
	Iterative learning control (I)	Data driven control (I)	Neural networks, fuzzy systems control in data driven manner (I)	Data-driven modeling, optimization and scheduling (I)	Statistical learning and machine learning in automation field (I)	Applications of data-driven methods to industrial processes
15:30-15:50	Tea Break					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
15:50-17:50	SatB01	SatB02	SatB03	SatB04	SatB05	SatB06
	Best Paper Award Finalist	Data-driven fault diagnosis and health maintenance (I)	Technology of complex big-data systems and applications	IS: Uncertainty rejection and data driven	IS: Data-driven fault diagnosis and health management	IS: Data-driven based state estimation and ADRC
18:00-20:00	Dinner					
Sunday, May 26, 2019, Grand Bay View International Hotel, Dali (大理海湾国际酒店)						
8:20-9:20	Keynote Address 3：Data-Based Approaches to Attack Optimization and Sensor Scheduling in Cyber-Physical Systems, Pr*of. Guang-Hong Yang*, Venue: Qianqiusui Hall, Chair: Prof. Zengqiang Chen					
9:20-10:00	Distinguished Lecture 3：Big data analytics in the process industry: distributed modeling and applications, *Prof. Zhiqiang Ge*, Venue: Qianqiusui Hall, Chair: Prof. Jiande Wu					
10:00-10:20	Tea Break					
10:20-11:00	Distinguished Lecture 4:Data Driven and Optimization for Extended State Observer based Control and Filter, *Prof. Wenchao Xue*, Venue: Qianqiusui Hall, Chair: Prof.Tianguang Chu					
11:00-11:40	Distinguished Lecture 5:Statistical Process Monitoring and Fault Diagnosis for Chemical Process, *Prof. Jing Wang*, Venue: Qianqiusui Hall, Chair: Prof. Zhihuan Song					
12:00-13:30	Lunch					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
13:30-15:30	SunA01	SunA02	SunA03	SunA04	SunA05	SunA06
	Iterative learning control (II)	Data-driven fault diagnosis and health maintenance (II)	Data driven control (II)	Data-driven modeling, optimization and scheduling (II)	Statistical learning and machine learning in automation field (II)	IS: Data-driven Technologies and its applications (I)
15:30-15:50	Tea Break					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
15:50-17:50	SunB01	SunB02	SunB03	SunB04	SunB05	SunB06
	Iterative learning control (III)	Data-driven fault diagnosis and health maintenance (III)	IS: Advances in AI and its applications	Neural networks, fuzzy systems control in data driven manner (II)	Statistical learning and machine learning in automation field (III)	IS: Data-driven Technologies and its applications (I)
18:00-20:00	Dinner					
Monday, May 27, 2019, Grand Bay View International Hotel, Dali (大理海湾国际酒店)						
8:20-9:00	Distinguished Lecture 6:On stochastic consensus of linear multi-agent systems with noises, *Prof. Long Cheng*, Venue: Qianqiusui Hall, Chair: Prof. Mingxuan Sun					
9:00-9:40	Distinguished Lecture 7: Data-driven Cooperation Control Approach for Networked Multi-agent Systems, *Prof. Xuhui Bu,* Venue: Qianqiusui Hall, Chair: Prof. Mingxuan Sun					
9:40-10:00	Tea Break					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
10:00-12:00	MonA01	MonA02	MonA03	MonA04	MonA05	MonA06
	ADRC technology and applications	Data-driven fault diagnosis and health maintenance (IV)	Statistical learning and machine learning in automation field (IV)	Statistical learning and machine learning in automation field (V)	IS: Multi-agent control and its learning-based methods	Model-free adaptive control
12:00-13:30	Lunch					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
13:30-15:30	MonB01	MonB02	MonB03	MonB04	MonB05	MonB06
	IS: Intelligent optimization and control of urban road traffic	IS: Data-driven modeling and optimal control (I)	IS: Autonomous and intelligent control of UAV (I)	Neural networks, fuzzy systems control in data driven manner (III)	IS: data-based ADP and RL for optimal control	IS: Parameter estimation and adaptive control
15:30-15:50	Tea Break					
Time/Room	Room 1	Room 2	Room 3	Room 4	Room 5	Room 6
15:50-17:50	MonC01	MonC02	MonC03	MonC04	MonC05	MonC06
	IS: Data-driven smart transportation	IS: Data-driven modeling and optimal control (II)	IS: Autonomous and intelligent control of UAV (II)	IS: Intelligent and learning control of nonlinear system	IS: Adaptive learning and repeat control for nonlinear system	Big data and its applications in modeling and control
18:00-20:00	Closing Ceremony and Banquet, Chair: Prof. Xiongxiong He					