Guest Editorial
Introduction to the Special Issue on Intelligent Rail Transportation

AS DEMAND for rail transportation continues to increase rapidly, significant challenges have emerged in many railway systems in terms of Capacity, Safety and Customer Satisfaction. To deal with these challenges, intelligent technologies, such as artificial intelligence, big data, and machine learning, have been gradually introduced to rail transportation. It is therefore timely and appropriate to have a focused investigation and discussion about Intelligent Rail Transportation. This special issue provides a forum for scientists and engineers working in academia, industry, and government to present their latest research findings and engineering experiences in developing and applying intelligent technologies to improve railway's autonomy, cooperation, and integration.

For the record, a total of 23 submissions were received in response to our open call for papers of special issue. These papers were rigorously evaluated according to the normal reviewing process of the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS. The evaluation process took into consideration factors pertaining to originality, technical quality, presentational quality, and overall contribution. In all, ten papers were accepted for publication. Below is a brief introduction to each of them.

The paper entitled "Maximal information coefficient-based two-stage feature selection method for railway condition monitoring" by Wen *et al.*, establishes a new feature selection method by making use of two-time Maximal Information Coefficient calculations in different stages. By using this proposed two-stage feature selection method, the strong features with low redundancy are reserved as the optimal feature subset, which makes the following classification process have a moderate computational cost and also maintain a good overall performance. The evaluation results show that the proposed selection method can achieve a better classification performance than other existing methods.

The paper entitled "Analysis and design of coil-based electromagnetic-induced thermoacoustic for rail internal-flaw inspection" by Wang *et al.*, presents a novel coil-based electromagnetic-induced thermo-acoustic system for detecting the flaws inside the rail. The fundamental is derived and thus the overall energy density distribution is simulated using the finite element method. This paper gives an overview of the system architecture and describes in detail the design process. The coil and rail are co-simulated, and the inductive power transfer topology is illustrated. The induced ultrasonic wave propagation is simulated and observed inside the rail with flaws. Experimental results demonstrate the proposed design is feasible and the crack with the diameter of 8 mm can be detected in the rail.

The paper entitled "Incipient fault detection for traction motors of high-speed railways using an interval sliding mode observer" by Zhang et al., proposes a stator-winding incipient shorted-turn fault detection method for the traction motors used in China high-speed railways. Firstly, a mathematical description for incipient shorted-turn faults is given from the quantitative point of view to preset the fault detectability requirement. Then, an interval sliding mode observer is proposed to deal with uncertainties caused by measuring errors from motor speed sensors. The active robust residual generator and the corresponding passive robust threshold generator are proposed based on this particularly designed observer. Furthermore, design parameters are optimized to satisfy the fault detectability requirement. This developed technique is applied to an electrical traction motor to verify its effectiveness and practicability.

The paper entitled "Hierarchical model predictive control for coordinated electric railway traction system energy management" by Novak *et al.*, presents a control system for railway energy management based on hierarchical coordination of electric traction substation energy flows and on-route trains energy consumption. The railway system is divided into energy-efficient individual trains energy consumption management as lower level, and the price-efficient electric traction substation energy flows management as higher level. The levels are coordinated through parametric hierarchical model predictive control. Through interactions with the power grid on the higher level, the system is able to provide ancillary services and respond to various grid requests. At the same time, lower level trains driving profiles are adjusted to attain the minimal cost of system operation with timetables and on-route constraints respected. A detailed real case study scenario is put together with presented results showing significant cost and energy consumption reductions achieved.

The paper entitled "A model predictive control approach for virtual coupling in railways" by Felez *et al.*, presents a novel approach in train control systems based on the concept called virtual coupling or train convoys. This approach follows the recent developments in the field of safe platooning of autonomous vehicles. We use a decentralized Model Predictive Control (MPC) framework for each train participating in a

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convoy formation. The paper compares the proposed method with alternative control strategies including the well-studied moving block train control concept. A study of a metro line has been chosen as a first analysis for this control approach. Simulation results for this kind of railway lines demonstrate better performance and benefits of this new concept. We show that the virtual coupling concept substantially reduces headway and distance between trains while guaranteeing safe separation between two consecutive trains at any instant.

The paper entitled "Cooperative prescribed performance tracking control for multiple high-speed trains in moving block signaling system" by Gao et al., addresses the cooperative control for multiple high-speed trains to achieve prescribed performance tracking, i.e., the speed and position of high-speed trains are guaranteed to be confined specific speed limitations and allowed distances ratified by automatic train protection and moving authority, respectively. The proposed control requires no prior information of the empirical parameters of the operational resistances and online adjusts by proper adaptation laws. Theoretical analysis and simulation results are given to demonstrate the effectiveness of the proposed control methods.

The paper entitled "Distributed cooperative cruise control of multiple high-speed trains under a state dependent information transmission topology" by Bai *et al.*, studies the cruise control problems for high-speed trains running in the moving block signaling system mode. Both coordinated control of cars in a single train and coordinated operation of multiple trains are considered. For a single train, each car is viewed as an intelligent agent that communicates with its neighboring cars, making the train a multi-agent system. For multiple trains on a railway line, each train has access to the information of the trains within its wireless communication range, making all cars in these trains a multi-agent system. A state-dependent undirected graph is defined to describe the underlying communication topology. Distributed control laws are designed for each train that, besides achieving coordinated control of cars among each train, achieve coordinated operation among trains and avoid triggering emergency braking.

The paper entitled "SmartDrive: Traction Energy Optimization and Applications in Rail Systems" by Tian *et al.,* presents the development of SmartDrive package to achieve the application of energy-efficient driving strategy. The train trajectory optimization method, associated driver training and awareness package has been developed for use on tram, metro and some heavy rail systems. A simulator was designed that can simulate the movement of railway vehicles and calculate the detailed power system energy consumption with different train trajectories. Analysis of the results showed that by implementing an optimal speed trajectory, the energy usage in the network can be significantly reduced. A Driver Practical Training System (DPTS) and the optimized line side driving control signage, based on the optimized trajectory were developed for testing. This system instructed drivers to maximize coasting in segregated sections. Field trials and real daily operations in the Edinburgh Tram Line in the UK have shown that energy savings of 10–20% are achievable.

The paper entitled "Energy-saving metro train timetable rescheduling model considering ATO profiles and dynamic passenger flow" does what its title says. They study the cruise control problems for high-speed trains running in the moving block signaling system mode. Both coordinated control of cars in a single train and coordinated operation of multiple trains are considered. For a single train, each car is viewed as an intelligent agent that communicates with its neighboring cars, making the train a multi-agent system. For multiple trains on a railway line, each train has access to the information of the trains within its wireless communication range, making all cars in these trains a multi-agent system. A state-dependent undirected graph is defined to describe the underlying communication topology. Distributed control laws are designed for each train that, besides achieving coordinated control of cars among each train, achieve coordinated operation among trains and avoid triggering emergency braking.

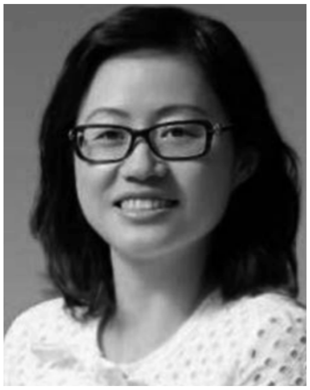
The paper entitled "Availability and performance analysis of train-to-train data communication system" by Song and Schnieder, proposes a new solution of Train-to-train (T2T) communication for railway signaling. With involving the T2T communication channel, the following train can obtain the information of preceding train, and can calculate its own movement authority with the assistance of zone controller. What is more, based on the TOA method the train to train distance can be estimated during the data communication procedure. This paper described the T2T system structure, and discussed different parameters that can affect the performance of the communication system. To evaluate the system availability and performance, the stochastic Petri nets (SPNs) are applied to formalize the communication system. Numerical analysis is carried out with different parameters, which consider both bit error and transmission rates.

HAIRONG DONG, *Guest Editor*
Beijing Jiaotong University
Beijing 100044, China
e-mail: hrdong@bjtu.edu.cn

CLIVE ROBERTS, *Guest Editor*
University of Birmingham
Birmingham B15 2TT, U.K.
e-mail: c.roberts.20@bham.ac.uk

ZONGLI LIN, *Guest Editor*
University of Virginia
Charlottesville, VA 22904 USA
e-mail: zl5y@virginia.edu

FEI-YUE WANG, *Corresponding Guest Editor*
Institute of Automation
Chinese Academy of Sciences
Beijing 100190, China
e-mail: feiyue.wang@ia.ac.cn



Hairong Dong (SM'12) received the Ph.D. degree in general and fundamental mechanics from Peking University, Beijing, China, in 2002. She was a Visiting Scholar with the University of Southampton, Southampton, U.K., in 2006; The University of Hong Kong, Hong Kong, in 2008; City University of Hong Kong, Hong Kong, in 2009; and The Hong Kong Polytechnic University, in 2010, as well as the KTH Royal Institute of Technology, Sweden, in 2011. She is currently a Professor with the State Key Laboratory of Rail Traffic Control and Safety, Beijing Jiaotong University. Her research interests include intelligent train operation control, automatic train operation, and fault-tolerant control. She is currently an Associate Editor of the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, the *IEEE Intelligent Transportation Systems Magazine*, the *Journal of Intelligent and Robotic Systems*, and *Acta Automatica Sinica*.

Clive Roberts (M'12) received the Ph.D. degree from the University of Birmingham, Birmingham, U.K. His Ph.D. dissertation was on condition monitoring of railway infrastructure. Over the last 14 years, he has developed a broad portfolio of research aimed at improving the performance of railway systems. He leads the University's contribution in a number of large EPSRC, European Commission, and industry funded projects. He works extensively with the railway industry in Britain and overseas. He currently leads a team of 11 research fellows and 16 Ph.D. students. He is currently a Professor of railway systems with the University of Birmingham, where he is also the Director of the Birmingham Centre for Railway Research and Education.

Zongli Lin (F'07) received the B.S. degree in mathematics and computer science from Xiamen University, Xiamen, China, in 1983, the M.Eng. degree in automatic control from the Chinese Academy of Space Technology, Beijing, China, in 1989, and the Ph.D. degree in electrical and computer engineering from Washington State University, Pullman, WA, USA, in 1994. He is currently a Ferman W. Perry Professor with the School of Engineering and Applied Science, University of Virginia. His current research interests include nonlinear control, robust control, and control applications. He was an elected member of the Board of Governors of the IEEE Control Systems Society from 2008 to 2010 and from 2019 to 2021. He has served on the operating committees of several conferences and is the Program Chair of the 2018 American Control Conference. He currently chairs the Technical Committee on Nonlinear Systems and Control of the IEEE Control Systems Society and serves on the editorial boards of several journals and book series, including the *Automatica, Systems & Control Letters*, the *Science China Information Sciences*, and the Springer/Birkhauser book series *Control Engineering*. He is a fellow of the IFAC and the American Association for the Advancement of Science. He was an Associate Editor of the IEEE TRANSACTIONS ON AUTOMATIC CONTROL (2001–2003), the IEEE/ASME TRANSACTIONS ON MECHATRONICS (2006–2009), and the *IEEE Control Systems Magazine* (2005–2012).

Fei-Yue Wang (F'04) received the Ph.D. in computer and systems engineering from Rensselaer Polytechnic Institute, Troy, NY, USA, in 1990. He joined the University of Arizona in 1990 and became a Professor and Director of the Robotics and Automation Lab (RAL) and Program in Advanced Research for Complex Systems (PARCS). In 1999, he founded the Intelligent Control and Systems Engineering Center at the Institute of Automation, Chinese Academy of Sciences (CAS), Beijing, China, under the support of the Outstanding Overseas Chinese Talents Program from the State Planning Council and "100Talent Program" from CAS, and in 2002, was appointed as the Director of the Key Lab of Complex Systems and Intelligence Science, CAS. From 2006 to 2010, he was Vice President for Research, Education, and Academic Exchanges at the Institute of Automation, CAS. In 2011, he became the State Specially Appointed Expert and the Director of the State Key Laboratory for Management and Control of Complex Systems.

Dr. Wang's current research focuses on methods and applications for parallel systems, social computing, parallel intelligence and knowledge automation. He was the Founding Editor-in-Chief of the *International Journal of Intelligent Control and Systems* (1995–2000), Founding EiC of *IEEE ITS Magazine* (2006–2007), EiC of IEEE INTELLIGENT SYSTEMS (2009–2012), and EiC of IEEE TRANSACTIONS ON ITS (2009–2016). Currently he is EiC of IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS, Founding EiC of IEEE/CAA JOURNAL OF AUTOMATICA SINICA, and *Chinese Journal of Command and Control*. Since 1997, he has served as General or Program Chair of more than 20 IEEE, INFORMS, ACM, and ASME conferences. He was the President of IEEE ITS Society (2005–2007), Chinese Association for Science and Technology (CAST, USA) in 2005, the American Zhu Kezhen Education Foundation (2007–2008), the Vice President of the ACM China Council (2010–2011), and the Vice President and Secretary General of Chinese Association of Automation (CAA, 2008–2018). Since 2019, he has been the President of CAA Supervision Council. Dr. Wang has been elected as Fellow of IEEE, INCOSE, IFAC, ASME, and AAAS. In 2007, he received the National Prize in Natural Sciences of China and was awarded the Outstanding Scientist by ACM for his research contributions in intelligent control and social computing. He received IEEE ITS Outstanding Application and Research Awards in 2009, 2011 and 2015, and IEEE SMC Norbert Wiener Award in 2014.