Guest Editorial
Special Issue on Big Data and AI for Computational Transportation in the Cyber–Physical–Social Space

THE past decades have witnessed the rise and power of big data, artificial intelligence, the Internet of Things (IoT), cloud computing, and parallel systems. These advanced techniques have great potential and capacity to enable new methodology, applications, and dramatic improvements for current intelligent transportation systems (ITS). To this end, developing new concepts/methodology/tools/algorithms/applications for future ITS with these technologies become more important and promising.

The interaction and interoperability between the real world and virtual world are now evolving rapidly which lead ITS into the virtual-real interaction-based parallel transportation systems. Obviously, ITS is a typical class of cyber–physical–social systems, in which physical and cyber elements are tightly conjoined, coordinated, and integrated with human and social characteristics. The IoT devices can sense physical transportation systems in real time, while the social sensor network can monitor traffic state and behavior from cyberspace. The generated large-scale traffic data in the cyber–physical–social spaces have flourished in almost all aspects of ITS, which can provide new insights and perspectives on transportation systems analysis, modeling, and understanding.

More and more transportation management and control tasks require sophisticated and high-performance computational methods/platforms to deal with the complexity and dynamics of traffic environments. Here are some examples: traffic big data processing and analytics with the video and trajectory data, activity pattern mining with the cell phone data, large-scale traffic simulation and traffic signal control. The tight interaction between transportation science and engineering with high-performance computing techniques is needed.

This Special Issue aims to provide a forum for researchers and practitioners in academia, industry, and government to present their latest research findings and engineering experiences in developing and applying big data, AI, and high-performance computing techniques for ITS in integrated cyber, physical, and social spaces.

The accepted articles cover a wide range of ITS topics using big data and AI techniques. They also cover various transportation modes like train, ship, and road transportation. Below is a short summary of the accepted articles.

Metro passenger flow prediction is a strategically necessary demand in an intelligent transportation system. Graph-based neural networks have been widely used in traffic flow prediction problems. Graph convolutional neural networks (GCNs) capture spatial features according to established connections but ignore the high-order relationships between stations and the travel patterns of passengers. In [A1], Wang *et al.* utilize a novel representation to tackle this issue—hypergraph. A dynamic spatio-temporal hypergraph neural network to forecast passenger flow is proposed. In the prediction framework, the primary hypergraph is constructed from metro system topology and then extended with advanced hyperedges discovered from pedestrian travel patterns of multiple time spans. Furthermore, hypergraph convolution and spatio-temporal blocks are proposed to extract spatial and temporal features to achieve node-level prediction. Experiments on historical datasets of Beijing and Hangzhou validate the effectiveness of the proposed method.

In [A2], Wang and Sun propose a dynamic framework to model spatio-temporal traffic data, with a particular application for diagnosing anomalies. The framework focuses on characterizing the variation in system dynamics with a time-varying vector autoregressive model. A low-rank tensor structure is imposed to model the collection of time-varying system matrices. As the temporal factor matrix captures the principal patterns/signatures across all time-varying system matrices, it is a useful tool to diagnose abnormal generative mechanisms and unexpected temporal patterns. Experiments demonstrate the effectiveness of the proposed tensor learning framework with extensive numerical experiments on both synthetic data and real-world spatio-temporal traffic speed datasets. The results show the superiority of the proposed model in uncovering anomalous traffic network dynamics.

Notwithstanding their socioeconomic attractiveness, autonomous ships (MASS) should undergo exhaustive testing to assure liability and trustworthiness before commercial deployment. In [A3], Bakdi *et al.* present data mining methods for extracting, analyzing, and characterizing testbed scenarios considering risk, complexity, and likelihood factors for simulation-based safety and compliance verifications. Atomic test-worthy components are designed from historical navigation conflicts where collision or grounding risk is forecasted within a 15-min horizon. This accurate risk prediction incorporates ship dimensions, actual maneuverability, available sea-room, COLREGs, and traffic separation rules. The dynamic risk graph approach represents spatio-temporal dependencies between nested pairwise conflicts for comprehensive modeling and analysis of

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real-world multi-ship scenarios. These developed methods are simplified mathematically and implemented in a hierarchical super-efficient computational algorithm. The algorithm is validated using AIS big data, vessel registry, digital maps, and nautical chart; It showed potential applications for traffic analysis, autonomy testing, risk control options, and decision-making analysis.

In [A4], Haliem *et al.* present a dynamic, demand aware, and pricing-based vehicle-passenger matching and route planning framework that (1) dynamically generates optimal routes for each vehicle based on online demand, pricing associated with each ride, vehicle capacities, and locations. This matching algorithm starts greedily and optimizes over time using an insertion operation, (2) involves drivers in the decision-making process by allowing them to propose a different price based on the expected reward for a particular ride as well as the destination locations for future rides, which is influenced by supply-and-demand computed by the Deep Q-network, and (3) allows customers to accept or reject rides based on their set of preferences with respect to pricing and delay windows, vehicle type, and carpooling preferences. These (1)–(3) in tandem with each other enforce grouping ride with the most route-intersections together. (4) Based on demand prediction, this framework re-balances idle vehicles by dispatching them to the areas of anticipated high demand using deep reinforcement learning (RL). The experimental results using millions of trips extracted from the New York City Taxi public dataset show the effectiveness of this approach in real-time and large-scale settings.

In [A5], Yuan *et al.* address the speed–distance trajectory tracking control problem for railway trains to facilitate the effectuation of automation train operation (ATO). By proposing a new virtual parameter learning-based approach, we develop an adaptive control that exhibits twofold new features with comparison to the existing literature: 1), while the nonlinear operational resistance and railway line gradient profile are unknown, the proposed control not only bears a quite computationally inexpensive simplicity in structure but also achieves accurate tracking control with respect to the speed–distance trajectory benefiting by the virtual parameter learning approach and requiring no function approximators with a linearized structure to cope with the uncertain dynamic nonlinearities in real time, and 2) by introducing a nonlinear error transformation, the protection enveloping problem, which is generally introduced by the onboard automatic train protection and wayside subsystems, operating independently from the ATO subsystem in practice, are considered explicitly to the control design for ATO for the first time. By invoking the Lyapunov stability theorem, the resulting closed-loop system is guaranteed to be globally stable with rigorous analysis and proof.

WEIFENG LV, *Guest Editor*
School of Computer Science and Technology
Beihang University
Beijing 100191, China
e-mail: lwf@buaa.edu.cn

YISHENG LV, *Guest Editor*
State Key Laboratory for Management and Control of Complex Systems
Institute of Automation
Chinese Academy of Sciences
Beijing 100049, China
e-mail: yisheng.lv@ia.ac.cn

ANDREAS A. MALIKOPOULOS, *Guest Editor*
Department of Mechanical Engineering
University of Delaware
Newark, DE 19716 USA
e-mail: andreas@udel.edu

ELENI I. VLAHOGIANNI, *Guest Editor*
Department of Transportation Planning and Engineering
National Technical University of Athens
10682 Athens, Greece
e-mail: elenivl@central.ntua.gr

FEI-YUE WANG
Institute of Automation
Chinese Academy of Sciences
Beijing 100049, China
e-mail: feiyue.wang@ia.ac.cn

APPENDIX: RELATED ARTICLES

[A1] J. Wang, Y. Zhang, Y. Wei, Y. Hu, X. Piao, and B. Yin, "Metro passenger flow prediction via dynamic hypergraph convolution networks," *IEEE Trans. Intell. Transp. Syst.*, early access, Apr. 21, 2021, doi: 10.1109/TITS.2021.3072743.

[A2] X. Wang and L. Sun, "Diagnosing spatiotemporal traffic anomalies with low-rank tensor autoregression," *IEEE Trans. Intell. Transp. Syst.*, early access, Jan. 1, 2021, doi: 10.1109/TITS.2020.3044466.

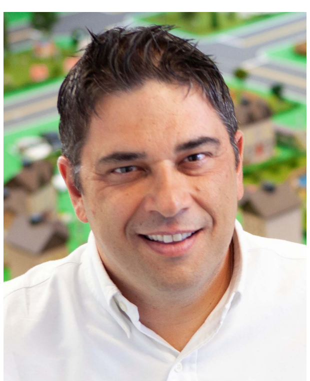
[A3] A. Bakdi, I. K. Glad, and E. Vanem, "Testbed scenario design exploiting traffic big data for autonomous ship trials under multiple conflicts with collision/grounding risks and spatio-temporal dependencies," *IEEE Trans. Intell. Transp. Syst.*, early access, Jul. 16, 2021, doi: 10.1109/TITS.2021.3095547.

[A4] M. Haliem, G. Mani, V. Aggarwal, and B. Bhargava, "A distributed model-free ride-sharing approach for joint matching, pricing, and dispatching using deep reinforcement learning," *IEEE Trans. Intell. Transp. Syst.*, early access, Aug. 4, 2021, doi: 10.1109/TITS.2021.3096537.

[A5] Z. Yuan, L. Yan, Y. Gao, T. Zhang, and S. Gao, "Virtual parameter learning-based adaptive control for protective automatic train operation," *IEEE Trans. Intell. Transp. Syst.*, early access, Mar. 23, 2021, doi: 10.1109/TITS.2021.3066447.

Weifeng Lv is currently a Professor with Beihang University, China. He is also the Vice President with Beihang University, the Vice Director with the National Laboratory of Software Development Environment, the Director with the National Engineering Research Center for Science and Technology Resources Sharing Service, and the Chief Secretary with China Software Industry Association. He has published more than 100 peer-reviewed journals and conference papers, and applied for more than 20 patents. He is the Leader of the Group of National Smart City Standard. His research interests include big spatio-temporal data analytics, smart city, crowd intelligence, and crowdsourcing. He has received one Second Prize of the National Science and Technological Invention Award, one Second Prize of the National Science and Technological Progress Award, and three First Prizes of the Provincial and Ministerial Science and Technology Award. He was awarded the National High-Level Personnel of Special Support Program (Ten Thousand Talents Plan) and a Distinguished Professor of the Chang Jiang Scholars Program.

Yisheng Lv (Senior Member, IEEE) is currently an Associate Professor with the State Key Laboratory for Management and Control of Complex Systems, Institute of Automation, Chinese Academy of Sciences. He is also with the School of Artificial Intelligence, University of Chinese Academy of Sciences. His research interests include artificial intelligence, intelligent control, intelligent transportation systems, and parallel traffic management and control systems.



Andreas A. Malikopoulos (Senior Member, IEEE) received the Diploma degree in mechanical engineering from the National Technical University of Athens, Greece, in 2000, and the M.S. and Ph.D. degrees from the Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI, USA, in 2004 and 2008, respectively. He is the Terri Connor Kelly and John Kelly Career Development Associate Professor with the Department of Mechanical Engineering, University of Delaware, the Director of the Information and Decision Science (IDS) Laboratory, and the Director of the Sociotechnical Systems Center. Prior to these appointments, he was the Deputy Director and the Lead with the Sustainable Mobility Theme of the Urban Dynamics Institute, Oak Ridge National Laboratory, and a Senior Researcher with the General Motors Global Research and Development. His research spans several fields, including the analysis, optimization, and control of cyber–physical systems; decentralized systems; stochastic scheduling and resource allocation problems; and learning in complex systems. The emphasis is on applications related to smart cities, emerging mobility systems, and sociotechnical systems. He is a member of SIAM and AAAS, and a fellow of ASME. He was an Associate Editor of IEEE TRANSACTIONS ON INTELLIGENT VEHICLES and IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS from 2017 to 2020. He is currently an Associate Editor of *Automatica* and IEEE TRANSACTIONS ON AUTOMATIC CONTROL.

Eleni I. Vlahogianni (Member, IEEE) is currently an Associate Professor with the Department of Transportation Planning and Engineering, National Technical University of Athens, Athens, Greece. Her primary research field and professional expertise are traffic flow analysis, modeling, and forecasting. Other research fields and expert professional involvement include mobility modeling, driving analytics, ICT applications to transportation, intelligent transportation systems, traffic management, and advanced technologies for monitoring transportation infrastructures. She has a strong algorithmic background, which includes nonlinear dynamics, applied statistical modeling, data mining and machine learning techniques, and computational intelligence. She is a member of the Board of Governors of IEEE ITS Society (2019–2021). She is an Associate Editor of the *Transportation Research Part C: Emerging Technologies*, the *International Journal of Transportation Science and Technology*, the *Journal of Big Data Analytics in Transportation*, the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, and *IEEE Intelligent Transportation Systems Magazine*.

Fei-Yue Wang (Fellow, IEEE) received the Ph.D. degree 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 the Director of the Robotics and Automation Laboratory (RAL) and the Program in Advanced Research for Complex Systems (PARCS). In 1999, he founded the Intelligent Control and Systems Engineering Center, 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 "100 Talent Program" from CAS. In 2002, he was appointed as the Director with the Key Laboratory of Complex Systems and Intelligence Science, CAS. From 2006 to 2010, he was the Vice President for research, education, and academic exchanges with the Institute of Automation, CAS. In 2011, he became the State Specially Appointed Expert and the Director with the State Key Laboratory for Management and Control of Complex Systems. His current research focuses on methods and applications for parallel systems, social computing, parallel intelligence, and knowledge automation. He was the President of IEEE ITS Society from 2005 to 2007, the Chinese Association for Science and Technology (CAST, USA) in 2005, and the American Zhu Kezhen Education Foundation from 2007 to 2008; and the Vice President of the ACM China Council from 2010 to 2011. Since 2008, he has been the Vice President and the Secretary General of the Chinese Association of Automation. He is an Elected Fellow of INCOSE, IFAC, ASME, and AAAS. He received the Second Class National Prize in Natural Sciences of China and was awarded the Outstanding Scientist by ACM for his work on intelligent control and social computing in 2007, the IEEE ITS Outstanding Application and Research Awards in 2009 and 2011, and the IEEE SMC Norbert Wiener Award in 2014. Since 1997, he has been serving as the General or the Program Chair for more than 20 IEEE, INFORMS, ACM, and ASME conferences. He was the Founding Editor-in-Chief of the *International Journal of Intelligent Control and Systems* from 1995 to 2000 and *IEEE Intelligent Transportation Systems Magazine* from 2006 to 2007. He was the Editor-in-Chief of IEEE INTELLIGENT SYSTEMS from 2009 to 2012 and IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS from 2009 to 2016. He is currently the Editor-in-Chief of *China's Journal of Command and Control*.