From Intelligent Vehicles to Smart Societies: A Parallel Driving Approach

Fei-Yue Wang, *Fellow, IEEE*, Yong Yuan, *Senior Member, IEEE*, Juanjuan Li, Dongpu Cao, Lingxi Li, *Senior Member, IEEE*, Petros A. Ioannou, *Fellow, IEEE*, and Miguel Ángel Sotelo, *Fellow, IEEE*

WELCOME to the third issue of the IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS (TCSS) for 2018.

Let us first share some good news. As you may know, in the past, TCSS did not publish as many pages as promised for several years, and thus the IEEE Periodicals Committee formed a special Rejuvenation Committee to help TCSS and other publications by actively monitoring their activities and offering advice and help. Thanks to the hard work and continued support from our new Editorial Board, we have done a very good job in rejuvenating TCSS. We have witnessed a rapid growth on submissions, rising from 0.157 submissions per day on average (from May 2, 2014 to March 31, 2017), to 0.439 (from April 1, 2017 to November 30, 2017), and now to 0.681 (from December 1, 2017 to May 31, 2018). In 2018, we published 300 pages on average per issue. On June 21, the IEEE Periodicals Committee officially agreed that TCSS is now in good shape and that there is no longer the need for TCSS to be supervised by the Rejuvenation Committee. This is the first such case of a successful rejuvenation for the IEEE journals. Here, we would like to express the special thanks to the members of the IEEE Periodicals Committee, the IEEE Rejuvenation Committee, and also the IEEE Systems, Man, and Cybernetics Society (SMCS) Board of Governors (BoG) for their constructive advice and kind help, especially to Prof. Vladik Kreinovich, Vice President for Publications of IEEE SMCS, for his time and efforts during last year, and also forward the congratulations to all our TCSS editors, reviewers, and authors. GREAT JOB so far!

According to the latest statistics released by Elsevier, TCSS received a 62.5% increase in the number of citations in 2017 and a 69.23% increase in the number of published articles from 2014 to 2016. This resulted in a CiteScore value of 2.36, which is ranked 17th out of 226 publications (i.e., top 8%) in the category of "Social Sciences," and is also in the top 15% and 29% in the categories of "Modeling and Simulation" and "Human–Computer Interaction." TCSS has been indexed by the Emerging Sources Citation Index since January 2018 and other scientific databases including Engineering Index and Scopus is the name of an abstract and citation database of peer-reviewed literature, and we should expect TCSS be included in the Science Citation Index soon.

Fig. 1. Social Media Session for Artificial Intelligence and Cybernetics and the first Internet of Minds Symposium.

We are glad to announce several changes in submissions to TCSS. According to the new IEEE SMC policy, all regular papers submitted to TCSS are normally about 10 Transactions' pages in length, or shorter. Technical correspondences are generally no more than 5 Transactions' pages in length. A mandatory overlength page charge is required for each page in excess of 10 pages for a regular paper and 5 pages for technical correspondences, and there is now a maximum cap of two overlength pages. These changes will be applied to new papers submitted after September 1, 2018.

During the last several months, we have received and approved two new special issue proposals. The titles of these special issues are listed as follows, and we welcome your submissions.

- "Special Issue on Advances of Social Media Analytics for Behavioural Healthcare Systems: Theory, Methods and Applications"
  Guest Editors: Dr. Po Yang, Liverpool John Moores University, Liverpool, U.K.; Prof. Bin Sheng, Shanghai Jiao Tong University, Shanghai, China; Prof. Wenyan Wu, Birmingham City University, Birmingham, U.K.; Dr. Yong Yuan, Institute of Automation, Chinese Academy of Sciences, Beijing, China.
- "Special Issue on Ransomware and Its Social Impacts"
  Guest Editors: Prof. Peter Chin, Department of Computer Science, Boston University, Boston, MA, USA; Dr. Daniel G. Wolf and Dr. Donald L. Goff, Cyber Pack Ventures, Inc., Columbia, MD, USA; Dr. Angelos Keromytis, Defense Advanced Research Project Agency, USA, and Columbia University, USA; Dr. George Cybenko, Dartmouth College, USA; Dr. Rui Qin, Qingdao Academy of Intelligent Industries, Qingdao, China.

Digital Object Identifier 10.1109/TCSS.2018.2862058

Fig. 2. Welcome and opening remark from Prof. Fei-Yue Wang in IV 2018.

In June, we hosted several IEEE conferences. First, the 2018 IEEE International Workshop on Artificial Intelligence and Cybernetics, co-located with the First Internet of Minds Symposium as well as SMC's Spring Executive Committee meeting, was held in Beijing from June 9 to June 10 (Fig. 1). This workshop is co-sponsored by the IEEE SMCS, Chinese Association of Automation, Institute of Automation, Chinese Academy of Sciences, and the Qingdao Academy of Intelligent Industries, and is the first IEEE workshop in China that focuses on the future opportunities and challenges in artificial intelligence research with social impacts. Many of the IEEE SMCS BoG members attended this workshop and delivered keynote speeches on several key areas of IEEE SMCS including system sciences and engineering, human–machine systems, and cybernetics.

Second, the 29th IEEE Intelligent Vehicle Symposium (IV 2018) was held with 24 parallel workshops or sessions and thousands of attendees in Changshu, Jiangsu, China, from June 26 to June 29 (Figs. 2 and 3). IV 2018 is a premier annual technical forum sponsored by the IEEE Intelligent Transportation Systems Society, and this is its second time in China. Together with IV 2018, an on-road autonomous driving demonstration was held at the Chinese flagship Intelligent Vehicle Proving Center, and the second IEEE/IFAC Conference on Blockchain and Knowledge Automation (ICBKA 2018) was also held. ICBKA 2018 is organized by the IEEE SMC Technical Committee on Blockchain and the Technical Committee on Social Computing and Social Intelligence, and focused on blockchain's revolutionary impacts on the increasingly centralized cyber-physical-social systems (CPSS), as well as the novel direction of knowledge automation in dealing with the management of CPSS-type complex social systems. Prof. Fei-Yue Wang served as the General Chair of IV 2018 and ICBKA 2018, and shared his vision on the future trends of blockchain, intelligent vehicles, and, especially, parallel driving that features coevolving physical and artificial drivers. To us, parallel driving is an inevitable development trend of intelligent vehicles that can drive us to the future smart societies. IV will have a significant impact on our societies, especially in the development of computational social systems. Therefore, we would like to share our discussions with some of the IV conference organizers on IV, parallel driving, and their impacts to the future smart societies in the end of this article.

Fig. 3. Poster Sessions of the 29th IEEE Intelligent Vehicle Symposium.

Scanning the Issue

1. Synthetic Social Media Data Generation
Yalin E. Sagduyu, Alexander Grushin, and Yi Shi

This paper presents a novel system, synthetic high-fidelity social media data generator, which jointly generates time-varying, directed, and weighted interaction graph structures and topic-driven text features similar to the input social media data, where a synthetic interaction graph is generated by a social network model and the synthetic text generator is trained under each topic identified by topic modeling. Extensive performance evaluation via a graph and text analysis is provided to demonstrate the statistical fidelity. A data evaluation exercise with human participants is executed to identify how difficult it is for a human to distinguish between tweets. Experimental results show that human participants cannot reliably distinguish between real and synthetic tweets.
2. Timing Matters: Influence Maximization in Social Networks Through Scheduled Seeding
Dmitri Goldenberg, Alon Sela, and Erez Shmueli

This paper suggests a scheduled seeding approach that aims at finding not only the best set of nodes to be seeded, but also the right timing to perform these seedings in social networks. More specifically, the authors identify three different properties of existing contagion models that can be utilized by a scheduled approach to improve the total number of activated nodes: 1) stochastic dynamics; 2) diminishing social effect; and 3) state-dependent seeding. They demonstrate the advantages of the scheduled seeding approach over the traditional initial seeding approach. The analysis in this paper presents an improvement of 10%–70% in the final number of infected nodes when using the scheduled seeding approach. Research findings help in both improving the understanding of information diffusion dynamics and devising better strategies for influence maximization.

3. Tracking Changes in Resilience and Level of Coordination in Terrorist Networks

Vasanthan Raghavan and Alexander G. Tartakovsky

The focus of this paper is on the activity profiles of certain networks that show frequent spurts and downfalls. This paper pursues an alternate statistical nonparametric approach for spurt detection in activity profiles. Their approach is based on binning the count data of activity to form observation vectors that can be compared with each other. Motivated by the majorization theory framework, these vectors are then transformed via certain functions and used in spurt detection and classification. The proposed approach is shown to result in a small number of missed detections and false alarms. Furthermore, since spurt detection is a problem of importance across multiple applications, the nonparametric nature of the approach makes it attractive in these applications.

4. Scenario-Based Insider Threat Detection from Cyber-Activities

Pratik Chattopadhyay, Lipo Wang, and Yap-Peng Tan

This paper proposes a technique for insider threat detection from the time-series classification of user activities. Initially, a set of single-day features is computed from the user activity logs. A time-series feature vector is next constructed from the statistics of each single-day feature over a period of time. Then, a cost-sensitive data adjustment technique is employed. The authors employ a two-layered deep autoencoder neural network, and compare its performance with other popularly used classifiers. Encouraging results are obtained using the CMU Insider Threat Data, which consists of about 14-GB Web-browsing logs. They observe that although a multilayer perceptron has a high recall, it suffers from a lower precision and f-score than the baseline classifiers.

5. Design Optimization of Food Safety Monitoring System With Social Network Analysis

Lixing Wang

This paper proposes a directed graph-based social network model for design optimization of the hazard monitoring network. Following the principles of nodes in social networks, the concepts and calculating methods of k-step observability controllability and accessible node sets are proposed to measure node accessibility. Then, a 0-1 linear programming model is developed for the selection of the optimal monitoring points. The model can be solved by using a common commercial software package. The authors apply the approach to a real local supply network of infant foods to test the validity of the model. Numerical analysis of several randomly generated examples with different parameters shows the validity and effectiveness of the recommended approach.

6. Dynamic Optimization of Employees Work Strategies in a WeChat-Based Evaluation System

Juanjuan Li, Shuai Wang, Yong Yuan, Xiaochun Ni, and Fei-Yue Wang

This paper collects the unique real-world data set from a WeChat-based work performance evaluation system built and used by a medium-sized organization in China, in order to study the optimization of the employees' work strategies, especially the work time determination. Their main results include: 1) the optimal work time is greatly affected by the weight of the reputational utility; 2) the optimal work time is always the threshold time to achieve a certain level or a certain rank; 3) the total utility is with the trend of decreasing after increasing with the growing work time; and 4) the optimal work time does not always make the employee achieve a good work performance.

7. Towards General Robustness Evaluation of Incentive Mechanism Against Bounded Rationality

Zehong Hu and Jie Zhang

This paper focuses on Nash equilibrium, and the authors propose a general robustness formulation as the upper bound of the stable region of equilibrium strategies by generalizing existing bounded rationality models. This paper also shows that different existing robustness formulations of Nash equilibrium can be derived from this general formulation, which verifies the soundness of the authors' formulation. Then, they develop a robustness evaluation framework specifically for incentive mechanisms, of which the key component is the empirical stability test, given a certain level of bounded rationality. Finally, the evaluation framework is validated on three typical but distinct incentive mechanisms, and the robustness computation results conform to their theoretical analysis. The comparison also offers us a good reference for making a proper selection among different designs.

8. On Automatic Formation of Effective Therapy Groups in Social Networks

Bay-Yuan Hsu, Yi-Feng Lan, and Chih-Ya Shen

This paper proposes an unfamiliarity-aware therapy group selection with Noah's ark principle (UTNA), for automatic selection of therapy group members from the social network. They first analyze the NP-hardness and inapproximability of the UTNA problem. Then, they propose a linear-time dynamic programming algorithm to find the optimal solution for a special case. An effective therapy group discovery algorithm is designed for the general UTNA problem. They also conduct an expert study for validating the problem formulation, and the groups selected by the proposed approach are better than or similar to their manual configurations. In addition, extensive experiments are conducted on three real data sets, and experimental results show that the proposed algorithms outperform other baselines in both efficiency and solution quality.

9. The Affective Evolution of Social Norms in Social Networks

Seyyed Hadi Sajadi, Mohammadamin Fazli, and Jafar Habibi

By using the intrinsic properties of norms, this paper redefines and tunes the Rescorla–Wagner conditioning model in order to obtain an affective model for the spread of social norms. The authors extend this model for a network of people as a Markov chain. The potential structures of steady states of this process are studied. Then, they formulate the problem of maximizing the adoption of social norms in a social network by finding the best set of initial norm adopters. Finally, they propose an algorithm for solving this problem and experiment it on different networks. The experiments show that the proposed algorithm in this paper has superior performance over other methods.

10. Fractal Intelligent Privacy Protection in Online Social Network Using Attribute-Based Encryption Schemes
Wei Wei, Shuai Liu, Wenjia Li, and Dingzhu Du

This paper presents an intelligent privacy protection approach to solve problems of security and privacy protection in online social networks (OSNs). First, the proposed algorithm combines a neural network with a hybrid hierarchy genetic algorithm and radial basis function, which is used to construct a prediction model of OSN security. Then, a support vector machine is applied to preprocess the information of the OSN, and the attribute-based encryption scheme is adopted to encrypt the OSN information. Finally, a particle swarm optimization algorithm is used to improve OSN security and privacy protection. The experimental results demonstrate the effectiveness of the proposed method.

11. Research on the Selection Strategies of Blockchain Mining Pools
Rui Qin, Yong Yuan, and Fei-Yue Wang

This paper mainly studies the pool selection problem faced by miners in blockchain mining, which is an important issued faced by the miners, since different mining pools may adopt different reward mechanisms, and miners can get different rewards in different pools. As different reward mechanisms may bring different risks to miners, they model it as a risk decision problem, and establish a pool selection model based on the maximum likelihood criterion. They also study the effect of N on the miners' optimal pool selection decisions. By utilizing the computational experiments approach, they validate the authors' proposed pool selection strategies, and the results can provide important managerial insights for miners when making their pool selection decisions.

12. Service Bridge: Transboundary Impact Evaluation Method of Internet
Xiao Xue, Giagia Gao, Shufang Wang, and Zhiyong Feng

Based on the assessment model and analysis methods absented in the field of transboundary service, this paper proposes the impact evaluation method of Internet (service bridge) from the prospect of supply and demand matching. With the proposed method, the corresponding computational experiment system is built to evaluate the impact of the Internet mode on different industries. Finally, this paper verifies the method with actual cases, and compares the transboundary impact of Internet in different daily consumption industries. The results show that the "service bridge" method can provide some decision support to the reconstruction of demand value chain in some traditional industries.

13. A Hybrid Privacy Protection Scheme in Cyber-Physical Social Networks
Youyang Qu, Shui Yu, Longxiang Gao, Wanlei Zhou, and Sancheng Peng

This paper proposes a hybrid privacy-preserving scheme considering both location and identity privacy. The privacy protection problem is regarded as the tradeoff between users. They first establish a game-based Markov decision process model, in which the user and the adversary are regarded as two players in a dynamic multistage zero-sum game. To acquire the best strategy for users, they employ a modified state-action-reward-state-action reinforcement learning algorithm. Iteration times decreases because of cardinality reduction from n to 2, which accelerates the convergence process. The experiments with real-world data demonstrate the efficiency and feasibility of the propose method.

14. Applying Probabilistic Model Checking to Financial Production Risk Evaluation and Control: A Case Study of Alibaba's Yu'e Bao
Honghao Gao, Shunyi Mao, Wanqiu Huang, and Xiaoxian Yang

This paper mainly studies the influnce of the purchase amounts and redemptions on user behaviors, by ultilizing Ali Pay datasets published by Alibaba's Yu'e Bao. They first employ a probabilistic model to verify the uncertainty of user behaviors. Then, investors' behaviors are formalized into a Discrete-Time Markov Chain (DTMC) model. After that, they use Probabilistic Computation Tree Logic (PCTL) to determine the probability that users will exhibit purchasing or redemption behaviors, and the probabilistic model-checking tool PRISM is employed to perform automatic verification. Based on the verification results, a strategy evaluation model considering profits and risks is proposed to measure the capital reserve ratio. Finally, they employ a real-world test dataset to conduct experiments to demonstrate the effectiveness of the proposed method.

15. Transaction Fraud Detection Based on Total Order Relation and Behavior Diversity
Lutao Zheng, Guan-Jun Liu, Chungang Yan, and Changjun Jiang

This paper proposes a logical graph of behavior profile (LGBP), which is a total-order-based model to represent the logical relation of attributes of transaction records. Based on the LGBP and users' transaction records, a path-based transition probability can be computed from an attribute to another one. At the same time, an information-entropy-based diversity coefficient is defined in order to characterize the diversity of transaction behaviors of a user, and a state transition probability matrix is also defined to capture the temporal features of transactions of a user. Consequently, they can construct a behavior profile for each user and then use it to verify if an incoming transaction is fraud or not. The experiments over a real data set illustrate that the proposed method is better than three state-of-the-art ones.

16. Analyzing the Flow of Trust in the Virtual World With Semantic Web Technologies
Qingpeng Zhang, Dominic DiFranzo, Marie Joan Kristine Gloria, Bassem Makni, and James A. Hendler

This paper first reviews the research on trust in virtual worlds and Semantic Web as applied in social network analysis, and then presents how to employ Semantic Web technologies to address this issue of how to better store and analyze the complex big data in virtual world and how to explore certain social concepts expressed within a massively multiplayer online game—EverQuest II. Specifically, the relations between mentors and mentees in the game are studied. A logistic regression model is proposed in order to find predictors of mentors and mentees building trust. The research sheds light on how to analyze large-scale data within a virtual world by exploring the flow of trust in

different layers of social networks with the help of Semantic Web technologies.

17. Analyzing the Linguistic Structure of Question Texts to Characterize Answerability in Quora

Suman Kalyan Maity, Aman Kharb, and Animesh Mukherjee

This paper quantifies user-level and question-level linguistic activities, which can nicely correspond to many of the judgment factors such as subjectivity, open-endedness, vagueness, and ambiguity of the questions. It can also be easily measured for each question post and appropriately discriminate an answered question from an unanswered one. The finding is that the way users use language while writing the question text can be a very effective means to characterize answerability. This characterization can be used to predict early if a question remaining unanswered for a specific time period will eventually be answered or not. They also compare their method with similar works, achieving an improvement in accuracy.

18. Cyber-Physical-Social Systems: The State of the Art and Perspectives

Jun Zhang, Fei-Yue Wang, Xiao Wang, Gang Xiong, Feng-Hua Zhu, Yi-Sheng Lv, Jia-Chen Hou, Shuang-Shuang Han, Yong Yuan, Qing-Chun Lu, and Yishi Lee

This paper discusses the current state, trend, and frontiers of development of cyber-physical-social systems (CPSS) in China. The demand for developing CPSS is discussed in detail, followed by the artificial societies, computational experiments, parallel execution (ACP) approach for CPSS and knowledge automation. The development of ACP based on CPSS in transportation, energy, information, Internet of Things, and Internet of Minds (IoM) is discussed to demonstrate the cutting-edge applications in CPSS. Finally, the blockchainized IoM technology and the concepts of parallel society are described.

19. Double Bounded Rough Set, Tension Measure and Social Link Prediction

Suman Kundu and Sankar K. Pal

This paper describes a new approach of viewing a social relation as a string with various forces acting on it. Accordingly, a tension measure for a relation is defined. Various component forces of the tension measure are identified based on the structural information of the network. A new variant of a rough set, namely, double bounded rough set is developed in order to define these forces mathematically. It is revealed experimentally with synthetic and real-world data that positive and negative tensions characterize, relatively, the presence and absence of a physical link between two nodes. An algorithm based on tension measure is proposed for link prediction. Superiority of the algorithm is demonstrated on nine real-world networks, which include four temporal networks.

20. Comments on "SCLPV: Secure Certificateless Public Verification for Cloud-Based Cyber-Physical-Social Systems Against Malicious Auditors"

Feng Wang, Li Xu, and Wei Gao

With the development of cloud storage, how to protect the integrity of the data stored in the cloud becomes the clients' major concern. Recently, Zhang *et al.* proposed a certificateless data integrity auditing scheme for cloud-assisted CPSS. However, the authors find that their scheme has some security flaws, i.e., if a client outsources a file with m block data and tags, the cloud server can store only one block of them, and pass the integrity auditing of the auditor. The authors refer to this attack as storing one block attack, and give an improved scheme to amend these flaws.

21. Scalable Prediction of Global Online Media News Virality

Xiaoyan Lu and Boleslaw K. Szymanski

This paper proposes a scalable community-based probabilistic framework to model the spreading of news about events in online media. They exploit the latent community structure in the global news media and use the affiliation of the early adopters with a variety of communities to identify the events widely reported in the news at the early stage of the spread. The time complexity of the proposed approach is linear in the number of news reports. To demonstrate these features, an inference algorithm is parallelized for a message passing paradigm and tested on an Rensselaer Polytechnic Institute advanced multiprocessing optimized system, and the proposed model can gain an improvement of 20% in the early detection of the most massively reported events compared with the feature-based machine learning algorithm. Its parallelization scheme achieves orders of magnitude speedup.

22. SODAR: Non-Obtrusive Off-Line Social Structure Reconstruction Through Passive Wireless Sensing

Chengwen Luo, Chaoxi Li, Hande Hong, Jianqiang Li, Wei Li, Zhong Ming, and Albert Y. Zomaya

This paper proposes a social learning system named an offline SOcial co-location Detection And network Reconstruction system (SODAR), which exploits wireless probes emitted by the smartphones carried by users to learn and infer their social relationships and reconstruct their offline social structures. The probe capturing and filtering mechanisms collect high-quality wireless probe information, and the passive localization techniques are used to process the data and detect co-location events, which are used for the novel social representation learning. The rich social information contained in the learned social representation vector is used to determine the social distances for each pair of users. The offline social structures will be visualized and reconstructed. They also show that the SODAR system is able to reliably learn social representations for each user and effectively reconstruct the offline social structures.

23. Extreme-Scale Dynamic Exploration of a Distributed Agent-Based Model With the EMEWS Framework

Jonathan Ozik, Nicholson T. Collier, Justin M. Wozniak, Charles Macal, and Gary An

This paper describes the extreme-scale model exploration with swift (EMEWS) framework, which is capable of efficiently composing and executing large ensembles of simulations and other "black box" scientific applications. EMEWS combines novel stateful tasks with traditional run-to-completion many-task computing and solves many problems relevant to high-performance workflows, including scaling to very large numbers (millions) of tasks, maintaining state and locality information, and enabling effective multiple-language problem solving. They present the high-level programming

model of the EMEWS framework and demonstrate how it is used to integrate an active learning model exploration (ME) algorithm to dynamically and efficiently characterize the parameter space of a large and complex, distributed message passing interface agent-based infectious disease model.

Intelligent Vehicles and Smart Societies

In this section, we introduce recent prevalent research interests, namely, the intelligent vehicles and smart societies. First, the concept and development of intelligent vehicles are described. Then, the perspective on CPSS-based parallel driving technologies is introduced. Finally, the smart cities and intelligent societies with parallel intelligent vehicles are envisioned.

Intelligent Vehicles

Intelligent vehicles initially represent those that can achieve a safer and more efficient operation with inputs of on-board sensors and drivers. These operations include steering, accelerating, lane changing, braking, and others. Now, intelligent vehicles are experiencing rapid development in industrial and academic fields all over the world. Many automobile manufacturers have already equipped their vehicles with some automation functions in the market. In addition, many researchers have built their own automated vehicles for research, testing, and competition.

To realize various automation features, the individual intelligent vehicle needs to be equipped with a variety of sensors, such as Light Detection and Ranging (laser radars), cameras, millimeter-wave radars, global positioning system, and so on. The information from these sensors is fused to achieve three main functions: perception, decision-making and planning, and control. Perception involves recognizing the driving environment surrounding the vehicle, including other vehicles, pedestrians, lane markings, traffic lights, and so on. Decision-making and planning represent finding reasonable speed and trajectory for the vehicle, and decide when to steer, accelerate, and brake. Control means how to realize the commands from the decision-making unit by managing onboard control components.

European roadmap predicts three main milestones for individual intelligent vehicles: 1) conditional automated driving (Level 3) to be available by 2020; 2) higher level automated driving (Level 4/5) in motorways by 2025; and 3) automated driving in urban areas by 2030 with connected driving technologies. Fully autonomous driving in cities is regarded as the most complex and difficult objective, which needs to be reinforced by communication technologies. Hence, connected automated driving is the safe and efficient pattern to make the higher automation feasible in multiple environments.

CPSS-Based Parallel Driving

Connected automated driving signifies that intelligent vehicles need to operate with information via vehicle-to-vehicle and vehicle-to-infrastructure communications. However, how to acquire and leverage these abundant data, how to handle the hostile weather and emergency situations, and how to incorporate these intelligent vehicles into the smart societies are still formidable problems to be solved.

On top of the cyber-physical system, the social element needs to be added to include human behavior and social features. In reality, three parallel worlds can co-exist in CPSS, namely, the physical world, the mental world, and the artificial world. These worlds communicate with each other via the physical space and the cyber space. For connected automated vehicles, the artificial world is treated as the useful and critical component to develop higher automation.

Parallel driving is proposed as a unified approach for transport automation and vehicle intelligence (see Fig. 4 as an illustration). Three worlds co-exist in the parallel driving framework, wherein the physical vehicle and physical behavior exist in the physical world, the realistic dynamics and cognitive attributes of human driver are in the mental world, and artificial vehicles and artificial driving (AVAD) exist in the artificial world.

The individual automated vehicle in the physical world is regarded as a large-scale complex system because of its interdisciplinary, multifield, dynamic, and unpredictable characteristics. The elements in other two worlds are used to improve its driving safety and efficiency. The AVAD in the artificial world could mimic the operation of the physical vehicle and execute complex computational experiments in virtual environments. Furthermore, the AVAD is able to obtain plentiful data for different situations (e.g., emergency events) and acquire optimal policies and solutions to guide the operation in the physical world. The mental world connects the above worlds by human drivers. The driver state/behavior/intention and joint cognition can be monitored in this world and driver–vehicle shared control can also be decided. With the help of virtual vehicle and cognitive behavior, the connected physical vehicles could achieve fully autonomous driving. The core of parallel driving is to use AVAD to deal with complex driving tasks to guide the physical vehicle and utilize physical data to enhance artificial modeling. This process is real time and continuous to make parallel driving better over time.

To implement the parallel driving concept in reality, the parallel driving 3.1 system is proposed and demonstrated in IEEE IV 2018 by International Parallel Driving Alliance (iPDA, consisting of 18 universities/research institutes from China, Europe, and North America), as shown in Fig. 5. This system consists of three main parts: 1) individual autonomous driving systems; 2) remote take-over system; and 3) management and control (M&C) center. The M&C center is used to monitor the vehicle states and decide the control strategies based on the real vehicle data. The objective of the remote take-over system is to manage the intelligent vehicles remotely in real time during emergency situations.

This remote system can take over the vehicle control when the intelligent vehicle has requests or when the M&C center determines whether the vehicle is or will be driving in abnormal situations.

Smart Societies

Today, how to build smart cities is on the agenda of research and development worldwide. More advanced technologies

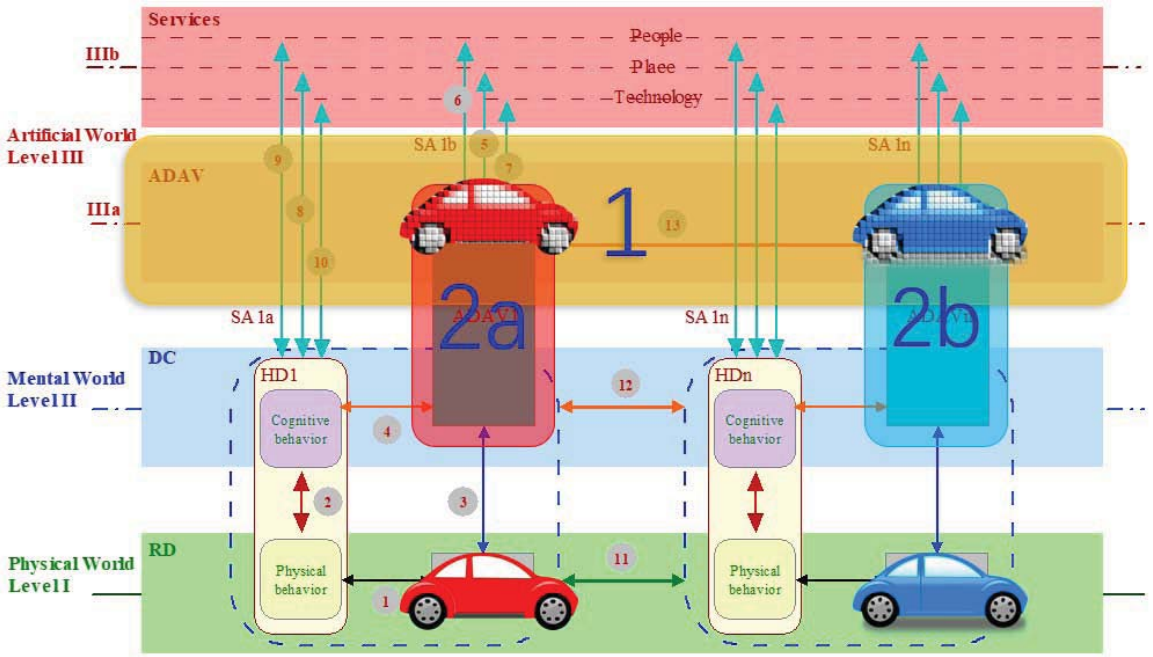


Fig. 4. Parallel driving architecture. RD: real driving; DC: driver cognition; HD: human driver; RV: real vehicle; ADAV: artificial driver and artificial vehicle; SA: situation awareness.

Fig. 5. Parallel driving 3.1 demo at IEEE IV 2018 by iPDA.

(e.g., artificial intelligence) are exploited to handle pollution, resources, and economy in these cities. By adding parallel driving into the transportation system, adding parallel blockchain into the economy, adding the parallel medical systems into the hospital, and adding parallel agriculture into the farming, these cities are becoming emerging topics for smart societies, raising many new issues for computational social systems.

Focusing on the parallel driving in smart societies, the available information from infrastructure, people, grid, and vehicle can make the connected vehicles as parallel vehicle platooning. With the multiple levels of M&C centers, digital virtual artificial vehicles, and advanced computational algorithms, the parallel vehicle platooning can improve the road capacity and operation efficiency and effectiveness in smart societies. Furthermore, the real physical society is also modeled in the artificial world and managed by the upper M&C center. By doing this, the vehicle, transportation, and society can all be managed as parallel systems so as to enhance the safety, efficiency, and effectiveness attributes.

The ACP approach has been applied to solve and settle the parallel driving of smart societies at this point. The A component is used to model and analyze the real transportation system with many virtual artificial systems.

Then, diversified computational experiments are designed and conducted in the C component using big data, deep learning, and artificial intelligence technologies to derive optimal control polices. Finally, the P component is responsible for interacting with the physical and artificial societies via real-virtual interaction. The artificial system is promoted and the actual system is guided through the A-C-P steps to achieve smart societies.

To summarize, CPSS-based parallel driving is the ultimate transportation pattern in future smart societies. The interconnections and interactions between its physical, social, and cyber elements make such systems an emerging and interesting research topic and also a typical application of computational social systems in the future.

FEI-YUE WANG
The State Key Laboratory for Management and Control of Complex Systems
Institute of Automation
Chinese Academy of Sciences
Beijing 100190, China
e-mail: feiyue.trans@gmail.com

YONG YUAN
The State Key Laboratory for Management and Control of Complex Systems Institute of Automation Chinese Academy of Sciences Beijing 100190, China Qingdao Academy of Intelligent Industries Qingdao 266109, China

JUANJUAN LI
The State Key Laboratory for Management and Control of Complex Systems Institute of Automation Chinese Academy of Sciences Beijing 100190, China Qingdao Academy of Intelligent Industries Qingdao 266109, China

DONGPU CAO
Department of Mechanical and Mechatronics Engineering University of Waterloo Waterloo, ON N2L 3G1, Canada

LINGXI LI
Department of Electrical and Computer Engineering Indiana University-Purdue University Indianapolis, IN 46202 USA

PETROS A. IOANNOU
Department of Electrical Engineering-Systems University of Southern California Los Angeles, CA 90007 USA

MIGUEL ÁNGEL SOTELO
Computer Engineering Department Polytechnic School University of Alcalá 28801 Madrid, Spain

Fei-Yue Wang (S'87–M'89–SM'94–F'03) received the Ph.D. degree in computer and systems engineering from the Rensselaer Polytechnic Institute, Troy, NY, USA, in 1990.

He joined the University of Arizona, Tucson, AZ, USA, in 1990, where he became a Professor and the Director of the Robotics and Automation Laboratory and the Program in Advanced Research for Complex Systems. 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 joined the Laboratory of Complex Systems and Intelligence Science, CAS, as the Director, where he was the Vice President for Research, Education, and Academic Exchanges with the Institute of Automation from 2006 to 2010. In 2011, he was the State Specially Appointed Expert and the Director of the State Key Laboratory for Management and Control of Complex Systems, Beijing. His current research interests include methods and applications for parallel systems, social computing, parallel intelligence, and knowledge automation.

Dr. Wang was the General or Program Chair of more than 30 IEEE, INFORMS, ACM, and ASME conferences. He was the President of the IEEE ITS Society from 2005 to 2007, the Chinese Association for Science and Technology, USA, in 2005, and the American Zhu Kezhen Education Foundation from 2007 to 2008. He was the Vice President of the ACM China Council from 2010 to 2011, and the Chair of IFAC TC on Economic and Social Systems from 2008 to 2011. He is currently the President-Elect of the IEEE Council on RFID. Since 2008, he has been the Vice President and the Secretary General of the Chinese Association of Automation. He was the Founding Editor-in-Chief (EiC) of the *International Journal of Intelligent Control and Systems* from 1995 to 2000 and *IEEE ITS Magazine* from 2006 to 2007. He was the EiC of *IEEE Intelligent Systems* from 2009 to 2012 and the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS from 2009 to 2016. He is currently the EiC of the IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS, and the Founding EiC of the IEEE/CAA JOURNAL OF AUTOMATICA SINICA and the IEEE CHINESE JOURNAL OF COMMAND AND CONTROL. He was a fellow of INCOSE, IFAC, ASME, and AAAS. He was a recipient of the National Prize in Natural Sciences of China and the Outstanding Scientist by ACM for his research contributions in intelligent control and social computing in 2007, the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS Outstanding Application and Research Awards in 2009, 2011, and 2015, and the IEEE SMC Norbert Wiener Award in 2014.

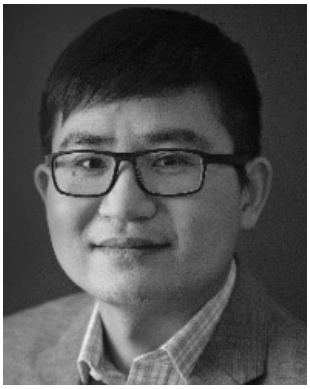
Yong Yuan (M'15–SM'17) received the B.S., M.S., and Ph.D. degrees in computer software and theory from the Shandong University of Science and Technology, Qingdao, China, in 2001, 2004, and 2008, respectively.

He is currently an Associate Professor with the State Key Laboratory for Management and Control of Complex Systems, Institute of Automation, Chinese Academy of Sciences, Beijing, China, and the Vice President of the Qingdao Academy of Intelligent Industries, Qingdao. He has authored over 90 papers published in academic journals and conferences. His current research interests include blockchain, cryptocurrency, and smart contract.

Dr. Yuan currently is the Associate Editor of IEEE TRANSACTIONS ON COMPUTATIONAL SOCIAL SYSTEMS, and also the Associate Editor of *Acta Automatica Sinica*. He is the Chair of the IEEE Council on RFID Technical Committee on Blockchain, Co-Chair of the IEEE SMC Technical Committee on Blockchain, and also the Director of the Chinese Association of Automation Technical Committee of Blockchain. He is the Secretary General of the IEEE SMC Technical Committee on Social Computing and Social Intelligence and the Chinese Association of Artificial Intelligence Technical Committee on Social Computing and Social Intelligence, the Vice Chair of the IFAC Technical Committee on Economic, Business and Financial Systems (TC 9.1), the Chair of the ACM Beijing Chapter on Social and Economic Computing, the Vice Director and Secretary General of the Chinese Academy of Management Technical Committee on Parallel Management.

Juanjuan Li (M'17) received the B.S. and M.S. degrees in economics from the Renmin University of China, Beijing, China, in 2008 and 2010, respectively. She is currently pursuing the Ph.D. degree with the Beijing Institute of Technology, Beijing.

She is currently an Assistant Professor with the State Key Laboratory for Management and Control of Complex Systems, Institute of Automation, Chinese Academy of Sciences, Beijing. Her current research interests include computational advertising, business intelligence, and blockchain.



Dongpu Cao (M'13) received the Ph.D. degree from Concordia University, Montreal, QC, Canada, in 2008.

He is currently an Associate Professor and the Director of the Driver Cognition and Automated Driving Lab, University of Waterloo, Waterloo, ON, Canada. He holds one U.S. patent. He has authored over 170 publications. His current research interests include vehicle dynamics and control, driver cognition, automated driving, and parallel driving.

Dr. Cao was a recipient of the ASME AVTT2010 Best Paper Award and the 2012 SAE Arch T. Colwell Merit Award. He serves as an Associate Editor for the IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY, the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, the IEEE/ASME TRANSACTIONS ON MECHATRONICS, the IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS, and the *ASME Journal of Dynamic Systems, Measurement and Control*. He has been a Guest Editor for *Vehicle System Dynamics*, and the IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS: SYSTEMS. He has served on the SAE International Vehicle Dynamics Standards Committee and a few ASME, SAE, and IEEE technical committees, and serves as the Co-Chair for the IEEE Intelligent Transportation Systems Society Technical Committee on Cooperative Driving.

Lingxi Li (S'04–M'08–SM'13) received the B.E. degree in automation from Tsinghua University, Beijing, China, in 2000, the M.S. degree from the Institute of Automation, Chinese Academy of Sciences, Beijing, in 2003, and the Ph.D. degree in electrical and computer engineering from the University of Illinois at Urbana–Champaign, Champaign, IL, USA, in 2008.

Since 2008, he has been with the Department of Electrical and Computer Engineering and also with the Transportation Active Safety Institute, Indiana University-Purdue University Indianapolis, Indianapolis, IN, USA, a university-wide multidisciplinary signature research center, where he is currently an Associate Professor with the Department of Electrical and Computer Engineering, Purdue School of Engineering and Technology. His current research interests include modeling, analysis, control, and optimization of complex systems, intelligent transportation systems, intelligent vehicles, discrete event systems, active safety systems, robotics and automation, and human factors. He holds two patents. He has authored and/or co-authored over one book and over 80 journal/conference papers. His research has been sponsored by federal agencies, industrial partners, and the university.

Dr. Li was a recipient of the Remarkable Paper Award at ACM ICUIMC in 2011, the Indiana University Trustees Teaching Award in 2012, the Outstanding Editorial Service Award for the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS in 2012, and the IUPUI Prestigious External Awards' Recognition in 2013. He has served as the program chair, the program co-chair, the publication chair, the registration co-chair, and a program committee member for a number of international conferences. He is currently a Board of Governors' Member of the IEEE Intelligent Transportation Systems Society.

Petros A. Ioannou (S'80–M'83–SM'89–F'94) received the B.Sc. degree (Hons.) from University College London, London, U.K., in 1978, and the M.S. and Ph.D. degrees from the University of Illinois at Urbana–Champaign, Champaign, IL, USA, in 1980 and 1982, respectively.

In 1982, he joined the Department of Electrical Engineering-Systems, University of Southern California, Los Angeles, CA, USA, where he is currently the A.V. Bal Balakrishnan Chair Professor. He is also the Director of the Center of Advanced Transportation Technologies, University of Southern California. He also holds courtesy appointments with the Department of Aerospace and Mechanical Engineering and the Department of Industrial and Systems Engineering. He is the Associate Director of Research with the METRANS Transportation Center, University of Southern California.

Dr. Ioannou is a fellow of the International Federation of Automatic Control and the Institution of Engineering and Technology. He was a recipient of the Outstanding Transactions Paper Award from the IEEE Control System Society in 1984, the 1985 Presidential Young Investigator Award for his research in adaptive control, the IEEE Intelligent Transportation Systems Society (ITSS) Outstanding ITS Application Award in 2009, the 2009 IET Heaviside Medal for Achievement in Control from the Institution of Engineering and Technology, the IEEE ITSS Outstanding ITS Research Award in 2012, and the 2016 IEEE Transportation Technologies Award in 2015.

Miguel Ángel Sotelo received the Dr.Eng. degree in electrical engineering from the Technical University of Madrid, Madrid, Spain, in 1996, the Ph.D. degree in electrical engineering from the University of Alcalá (UAH), Madrid, in 2001, and the M.B.A. degree from the European Business School, Genève, Switzerland, in 2008. In 1997, he was a Research Visitor with the RSISE Department, Australian National University, Canberra, ACT, Australia. He was the Director General of the Guadalab Science and Technology Park, Guadalajara, Spain, from 2011 to 2012, and the Head of the Robe Safe Research Group from 2006 to 2010. In 2010, he was the Dean of the Technical School, UAH, where he was also the Vice Dean from 2004 to 2010. From 2009 to 2015, he was the CEO of Vision Safety Technologies Ltd., Madrid, a spin-off company established to commercialize computer vision systems for road infrastructure inspection. He is currently a Full Professor with the Department of Computer Engineering, UAH, the Head of the INVETT Research Group, and the Vice President for international relations with UAH. He holds 15 national patents and one PCT patent. He has authored over 200 refereed papers in journals and international conferences. His current research interests include driverless vehicles, cooperative ITS systems, and traffic technologies.

Dr. Sotelo was a member of the IEEE ITS Society Board of Governors from 2012 to 2014, the IEEE ITS Society Executive Committee, and the Steering Committee of the IEEE TRANSACTIONS ON INTELLIGENT VEHICLES. He was a recipient of the Prize for the Best Team With Full Automation of GCDC2016, the 2013 ITSS Outstanding Application Award, the 2010 Outstanding Service Award of the IEEE ITS Society, the Best Research Award in the Domain of Automotive and Vehicle Applications in Spain in 2002 and 2008, the 3M Innovation Awards in the category of eSafety in 2003, 2004, and 2009, and the Best Young Researcher Award of UAH in 2004. He served as the General Chair of the 2012 IEEE Intelligent Vehicles Symposium, and the program chair and a member of program/organizing committees for more than 30 international conferences. He is the President-Elect of the IEEE ITSS in 2017. He was an Associate Editor of the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS from 2008 to 2015, a member of the Editorial Board of *The Open Transportation Journal* from 2006 to 2015, the President of the Spanish Chapter of the IEEE ITS Society from 2015 to 2016, and an Editor-in-Chief of the ITSS Newsletter from 2013 to 2014. He has been an Editor-in-Chief of the *IEEE Intelligent Transportation Systems Magazine* since 2014. From 2004 to 2010, he served as an Auditor and an Expert with the FITSA Foundation for RTD Projects in the domain of automotive applications. He has served as a Project Evaluator, a Rapporteur, and a Project Reviewer for the European Commission in the field of ICT for intelligent vehicles and cooperative systems in the VI and VII Framework Programs.