# Scanning the Issue and Beyond: The Endless ITS Frontier in CSP Spaces

WITH my great pleasure, I would like to announce that Prof. Petros Ioannou of the University of Southern California has been elected as the fourth Editor-in-Chief of IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS by the Board of Governors of IEEE ITS Society on June 27 at its meeting in Seoul, Korea. After three terms and seven years' service, I will step down as the EiC and will be succeed by Petros next year. I am sure that our journal will move to a new and higher level of quality and service under Petros' leadership. For the remaining half of this year, the IEEE ITSS BoG has approved our request to increase our page budget to 3600 to reduce the backlog and be ready to publish the T-ITS monthly in 2016, which would be another milestone in the history of IEEE T-ITS. In addition, to accommodate the rapid and significant development in intelligent vehicle technology recently, our newest journal, IEEE TRANSACTIONS ON INTELLIGENT VEHICLES, will be launched next year. The Seoul BoG meeting has also selected Changshu, a city of Suzhou near Shanghai, as the site of China's new Intelligent Vehicles Proving Center, to host the 2018 IEEE Intelligent Vehicle Symposium, and Prof. Nanning Zheng and I will lead the effort to organize the event.

In July, IEEE ITS Society also opens its first Summer School on Frontiers in ITS: Transportation 5.0 and Beyond, in Qingdao, Shandong, China, the site for the 2014 IEEE Intelligent Transportation Systems Conference (ITSC 2014). Many interesting and exciting topics are addressed there, which I will be back to after scanning the issue.

## SCANNING THE ISSUE

**Managing Electric Vehicles in the Smart Grid Using Artificial Intelligence: A Survey**

*E. S. Rigas, S. D. Ramchurn, and N. Bassiliades*

The wide adoption of electric vehicles (EVs) is seen as a catalyst to the reduction of CO2 emissions. EVs augment the grid with the ability to store/release energy in the network and help optimize the use of energy from intermittent renewable energy sources and allow users to refill their cars in a variety of locations. However, a number of challenges need to be addressed if such benefits are to be achieved. The authors analyzed the employment of artificial intelligence techniques to address the major challenges that arise in the deployment and management of EVs, particularly the AI techniques for energy-efficient EV routing, charging point selection, and integration of EVs into the smart grid.

**Improving Mass Transit Operations by Using AVL-Based Systems: A Survey**

*L. Moreira-Matias, J. Mendes-Moreira, J. F. De Sousa, and J. Gama*

The current state of the art for improving both planning and control on public road transportation using automatic vehicle location (AVL) data is described. It starts by presenting a review on improving the network definition based on historical location-based data. Second, it presents a review on AVL-based evaluation techniques of the schedule plan (SP) reliability, discussing the existing metrics. Then, the different dimensions on improving the SP reliability are presented, as well as the works addressing such a problem. The paper includes model formulations, reference surveys, and formal definitions, as well as an overview of a promising area.

**City Vehicle Routing Problem (City VRP): A Review**

*G. Kim, Y. S. Ong, C. K. Heng, P. S. Tan, and N. A. Zhang*

This paper surveys the city vehicle routing problem (VRP) literature, categorizes city VRP according to the four stakeholders (shipper, carrier, resident, and administrator), and summarizes the constraints, models, and solution methods of VRP in urban cities. City VRPs are also analyzed based on the problem of interests considered by the stakeholders and the corresponding models that have been proposed in response. This review identifies the state of the art of city VRP, highlights the core challenging issues, and suggests some potential underexplored research area.

**Monitoring the Speed, Configurations, and Weight of Vehicles Using an *In Situ* Wireless Sensing Network**

*W. Xue, D. Wang, and L. Wang*

A back-calculation method is presented and applied in the Virginia Tech-developed integrated transportation monitoring system to estimate the speed, weight, and configuration of passing vehicles, based on the pavement responses collected by *in situ* pavement sensors. A Gaussian model is used to describe the distribution of the horizontal strain induced by passing vehicles, whose parameters are correlated with various loading conditions, including the weight and the configuration parameters of the passing vehicles, as proved in finite element simulation and experimental measurements. The whole method is simple and straightforward and can be used conveniently in real-time monitoring.

**A Cognitive Control Approach to Communication-Based Train Control Systems**

*H. Wang, F. R. Yu, L. Zhu, T. Tang, and B. Ning*

A control approach for communication-based train control (CBTC) systems considering both train ground communication

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and train control is investigated. This approach adopts the idea of the information gap to quantitatively describe the effects of train ground communication on train control and considers the linear quadratic cost for the train control performance. In addition, the wireless channel is modeled as finite-state Markov chains with multiple state transition probability matrices for the characteristics of both large- and small-scale fading, which are derived from real field measurement results. Results show that the proposed cognitive control approach can significantly improve the train control performance in CBTC systems.

**A Multimodal ADAS System for Unmarked Urban Scenarios Based on Road Context Understanding**

*C. Guo, J. Meguro, Y. Kojima, and T. Naito*

A stereovision-based multimodal ADAS system, designed for expanding the usability of ADAS functions to normal urban scenarios with unmarked roads, is proposed. The system first detects the physical road boundary and vehicle candidates. Contextual information between the host vehicle, the road, and the road users is subsequently correlated for both low-level object detection improvement and high-level road structure estimation. Then the required ADAS elements are generated based on the correlation results with respect to the system functionalities. Experimental results show that the proposed system could increase the value of the existing ADAS system without major modifications or expense.

**Semisupervised Pedestrian Counting With Temporal and Spatial Consistencies**

*W. Xia, J. Zhang, and U. Kruger*

This paper proposes a semisupervised methodology to extract temporal consistency in a continuous sequence of unlabeled frames that include the moving, merging, and splitting of pedestrians. Besides the temporal consistency, this paper also employs spatial consistency in the sum of pedestrians in subgroups, or subblobs, to determine the total number of pedestrians, or the ground truth. The experimental results show that the proposed semisupervised model, incorporating temporal and spatial consistencies, is more robust and can be trained with relatively small labeled data.

**Taxi-RS: A Taxi-Hunting Recommendation System Based on Taxi GPS Data**

*X. Xu, J. Zhou, Y. Liu, Z. Xu, and X. Zhao*

A taxi-hunting recommendation system is proposed. It aims to process the large-scale taxi trajectory data in order to provide passengers with a waiting time to get a taxi ride in a particular location. The data offline processing system is formulated based on the Hot Spot Scan algorithm and Preference Trajectory Scan algorithm. A new data structure for frequent trajectory graph and an optimized online querying subsystem to calculate the probability and the waiting time of getting a taxi are presented.

**Fuzzy Logic to Evaluate Driving Maneuvers: An Integrated Approach to Improve Training**

*H. Malik, G. S. Larue, A. Rakotonirainy, and F. Maire*

We present a novel intelligent driver training system that analyzes crash risks for a given driving situation, providing avenues for the improvement and personalization of driver training programs. The analysis takes into account numerous variables synchronously acquired from the driver, the vehicle, and the environment. The system then segments out the maneuvers within a drive. The authors present the fuzzy set theory to develop the safety inference rules for each maneuver that is executed during the drive and present a framework and its associated prototype that can be used to comprehensively view and assess complex driving maneuvers and then provide a comprehensive analysis of the drive used to give feedback to novice drivers.

**A Holistic View of ITS-Enhanced Charging Markets**

*F. Malandrino, C. Casetti, and C.-F. Chiasserini*

We consider a network of electric vehicles (EVs) and its components, namely, vehicles, charging stations, and coalitions of stations, and propose a model in which all components interact in a market revolving around the energy for battery recharge. The following aspects are studied: 1) how autonomously operated charging stations form coalitions; 2) the price policy enacted by such coalitions; and 3) how vehicles select the charging station to use, working toward a time/price tradeoff. The main goal is to investigate how equilibrium in such a market can be reached. The model is evaluated in a realistic scenario, focusing on its ability to capture the advantages of the availability of an intelligent transportation system supporting the EV drivers.

**Unsupervised Hierarchical Modeling of Driving Behavior and Prediction of Contextual Changing Points**

*T. Taniguchi, S. Nagasaka, K. Hitomi, K. Takenaka, and T. Bando*

This paper proposes a method called double articulation analyzer with temporal prediction (DDA-TP), which is based on the original DAA model. It models explicitly the duration of chunks of driving behavior on the assumption that driving-behavior data have a two-layered hierarchical structure, i.e., double articulation structure. For this purpose, the hierarchical Dirichlet process hidden semi-Markov model is used for modeling the duration of segments of driving-behavior data. A calculation method for obtaining the probability distribution of the remaining duration of current driving words as a mixture of Poisson distribution with a theoretical approximation for unobserved driving words is also proposed, which can calculate the posterior probability distribution of the next termination time of chunks by explicitly modeling all probable chunking results for observed data.

**Traffic Flow Forecasting for Urban Work Zones**

*Y. Hou, P. Edara, and C. Sun*

In this paper, random forest, regression tree, multilayer feed forward neural network, and nonparametric regression models were developed for forecasting traffic flow for planned work zone events. Both long- and short-term traffic flow forecasting applications were investigated. Models were evaluated using data from work zone events on two types of roadways, a freeway, i.e., I-270, and a signalized arterial, i.e., MO-141, in St. Louis, MO, USA. The results showed that the random forest

model yielded the most accurate long- and short-term work zone traffic flow forecasts. The most influential variables for freeway data were the latest interval's look-back traffic flows at the upstream, downstream, and current locations, whereas the most influential variables for arterial data were the traffic flows from the three look-back intervals at the current location only.

**A Traffic Signal Optimization Model for Intersections Experiencing Heavy Scooter–Vehicle Mixed Traffic Flows**

*C.-L. Lan and G.-L. Chang*

A formulated model for optimizing both the cycle length and signal timings for isolated intersections experiencing heavy scooter–vehicle mixed traffic flows is presented. The model accounts for the interactions between scooter and vehicle flow and reflects the maneuverability of scooters in the queue formation and discharging process. The robustness of the proposed formulations is evaluated with field data and laboratory experiments. The signal optimization model is implemented at an intersection and assessed with a rigorous before-and-after field analysis.

**D2D for Intelligent Transportation Systems: A Feasibility Study**

*X. Cheng, L. Yang, and X. Shen*

The effective and efficient coexistence and cooperation of the vehicular-to-vehicular and vehicular-to-infrastructure communications give rise to a dynamic spectrum management problem. The device-to-device (D2D) communication has recently emerged and was a rapidly adopted solution of a similar problem in cellular networks. This paper for the first time carries out a feasibility study of D2D for ITS based on both the features of D2D and the nature of vehicular networks. To demonstrate the promising potential of this technology, novel remedies necessary to make D2D technology practical as well as beneficial for ITS are also proposed.

**GPS Signal Authentication From Cooperative Peers**

*L. Heng, D. B. Work, and G. X. Gao*

A signal authentication architecture based on a network of cooperative GPS receivers is proposed. A receiver in the network correlates its received military P(Y) signal with those received by other receivers to detect spoofing attacks. This paper describes three candidate structures to implement this architecture and evaluates spoofing detection performance through theoretical analyses and field experiments. It shows that the spoofing detection performance improves exponentially with the increasing number of the other receivers.

**Safe Transitions from Automated to Manual Driving Using Driver Controllability Estimation**

*J. Nilsson, P. Falcone, and J. Vinter*

The authors consider the problem of assessing when the control of a vehicle can be safely transferred from an automated driving system to the driver. A method based on a description of the driver's capabilities to maneuver the vehicle is proposed. Using a vehicle model and reachability analysis, the authors assess whether the states of the vehicle start and remain within the driver's capabilities during the transition to manual driving. The estimation of the driver controllability set for four drivers based on the data collected with real vehicles in highway and city driving is demonstrated. Experimental results show that the proposed method can be implemented with a real system to classify transitions from automated to manual driving.

**Near-Lossless Compression for Large Traffic Networks**

*M. T. Asif, K. Srinivasan, N. Mitrovic, J. Dauwels, and P. Jaillet*

By providing compressed representations for the sensor networks, low-dimensional models can help ease the constraints on system resources that result from the size of the networks combined with the huge volume of the data with high spatial and temporal resolution. Here, a near-lossless compression method for traffic data by applying the principle of lossy plus residual coding is proposed. A low-dimensional model of the network is developed, and Huffman coding is applied in the residual layer. The results show that the proposed method can efficiently compress data obtained from a large and diverse road network while maintaining the upper bound on the reconstruction error.

**Real-Time Monocular SLAM With Low Memory Requirements**

*G. Bresson, T. Féraud, R. Aufrère, P. Checchin, and R. Chapuis*

To localize a vehicle in an unknown environment in high efficiency and low cost, the authors focus on a monocular simultaneous localization and mapping (SLAM) problem and propose a new method called MSLAM based on an extended Kalman filter (EKF). The aim is to provide a solution that has low memory and processing time requirements and can achieve good localization results while benefiting from EKF advantages. To this end, new methods of minimal Cartesian representation allowing users to avoid or hugely decrease the impact of the linearization failures are presented. The approach is compared with a classic SLAM implementation to illustrate the efficiency of the proposed contributions. A public data set presenting a long trajectory (1.3 km) is also used in order to compare MSLAM with a state-of-the-art monocular EKF-SLAM algorithm in terms of accuracy and computational needs.

**A Model to Evaluate the Impact of Headway Variation and Vehicle Size on the Reliability of Public Transit**

*Md. Kamrul Islam, U. Vandebona, V. V. Dixit, and A. Sharma*

A theoretical model to evaluate factors that influence the reliability of public transit systems and examine their performance is developed. The model is based on stochastic variations in passenger arrival, boarding, alighting, and travel time on the regularity of headway along the route with multiple stops, which depends on a Markov chain technique to obtain numerical estimates of performance. The predictions of this model are verified based on replicating the well-observed phenomenal relationship between the mean and variance of delay experienced by passengers. This investigation provides a better understanding of determinants of reliability of public transit systems, and it can be used as an analysis tool by transit planners to evaluate the effectiveness of various policies.

**Model-Based Methodology for Validation of Traffic Flow Detectors by Minimizing Human Bias in Video Data Processing**

*P. Kachroo, N. Shlayan, A. Paz, S. Sastry, and S. K. Patel*

This paper provides a model-based method for analysis and hypothesis testing for paired data in which one source of data has to be validated against another source of data that contains subjective and dynamic errors. This study deals with human observed flow counts collected from traffic videos of freeway cameras. It is based on statistical testing with heteroscedasticity, which is demonstrated through a case study using data from traffic flow detectors and traffic cameras installed on highways in the southern Nevada region. A model for the relationship between the video ratings and the distribution of the human errors is developed, taking into consideration the human bias.

**Analysis of Stochastic k-Coverage and Connectivity in Sensor Networks With Boundary Deployment**

*H. P. Gupta, S. V. Rao, and V. Tamarapalli*

This paper assumes that the wireless sensors in a wireless sensor network (WSN) are stochastically deployed outside a field of interest. The probabilistic expressions for k-coverage and connectivity using exact geometry are then derived for such WSNs. Its utility to estimate the minimum number of sensors required for a desired level of coverage and connectivity is demonstrated afterward. The authors also demonstrate an on-campus traffic monitoring system to count the number of vehicles, detect the direction of vehicle, and identify the vehicle using sensors along both sides of the road.

**A Probabilistic Framework for Joint Pedestrian Head and Body Orientation Estimation**

*F. Flohr, M. Dumitru-Guzu, J. F. P. Kooij, and D. M. Gavrila*

A probabilistic framework for the joint estimation of pedestrian head and body orientation from a mobile stereo vision platform is presented. For both head and body parts, the authors convert the responses of a set of orientation-specific detectors into a probability density function. Head and body orientations are estimated jointly to account for anatomical constraints. The joint single-frame orientation estimates are integrated over time by particle filtering. Experimental results show that the proposed joint probabilistic orientation estimation framework reduces the mean absolute head and body orientation error up to 15° compared with simpler methods.

**A Model-Based Joint Detection and Tracking Approach for Multivehicle Tracking With Lidar Sensor**

*B. Fortin, R. Lherbier, and J.-C. Noyer*

A method for joint detection and tracking of vehicles with a scanning laser range finder is presented. The proposed method relies on the raw measurement processing without any detection step, whereas existed methods generally lead to a detection step before any tracking. The solution uses the sequential Monte Carlo methods by incorporating the geometric invariant of the objects of interest and improves the overall performance in multiobject tracking while providing good estimation accuracies. The approach also offers an efficient solution to the problem of multitarget tracking by integrating naturally the track management in the filtering process.

**Modeling and Solving Real-Time Train Rescheduling Problems in Railway Bottleneck Sections**

*L. Chen, C. Roberts, F. Schmid, and E. Stewart*

A mixed integer programming model is proposed to model and solve the real-time train rescheduling problems in bottleneck sections on mainline railways. The problems are solved by an innovative improved algorithm. The model and the algorithms are validated with a case study using Monte Carlo methodology, which demonstrates that the proposed algorithm can reduce the weighted average delay and satisfy the requirements of real-time traffic control applications.

**Toward Crowdsourcing-Based Road Pavement Monitoring by Mobile Sensing Technologies**

*C.-W. Yi, Y.-T. Chuang, and C.-S. Nian*

A smartphone probe car (SPC) system to monitor road pavement is proposed with several features. First, a signal processing heuristic for the extraction of the vertical acceleration components from the accelerometer readings is developed, which enabled the SPC to provide a driver-friendly environment. Then, based on the underdamped oscillation model, a road anomaly indexing heuristic that is representable for road anomalies rather than vehicle conditions is presented. Afterward, a prototype SPC system was implemented, and extensive field tests were undertaken to verify the performance. Furthermore, a DENCLUE-like algorithm was adopted to mine road anomaly information from reported events to demonstrate benefit at the system level.

**Network-Matched Trajectory-Based Moving-Object Database: Models and Applications**

*Z. Ding, B. Yang, R. H. GüTing, and Y. Li*

A number of limitations in existing methods of tracking and managing locations of moving objects make them unsuitable for real-world intelligent transportation systems applications. This paper proposes a network matched trajectory-based moving objects database (NMTMOD) mechanism and a traffic flow analysis method using the NMTMOD, in which the locations of moving objects are tracked through a dense-sampling and batch-uploading strategy. A novel edge-centric network matching method, which is running at the server side, is adopted to efficiently match the densely sampled GPS points to the network. A deviation-based trajectory optimization method is also provided to minimize the trajectory size.

**Near-Infrared-Based Nighttime Pedestrian Detection Using Grouped Part Models**

*Y.-S. Lee, Y.-M. Chan, L.-C. Fu, and P.-Y. Hsiao*

The pedestrian detection problem is investigated. Considering the critical difficulties in effectively detecting a pedestrian for a driving assistant vision system at night, a nighttime part-based pedestrian detection method dividing pedestrian into parts for a moving vehicle with a camera and a near-infrared lighting projector is proposed. By analyzing the spatial relationship between every pair of parts, the confidence of the detected

parts can be enhanced even when some parts are occluded. The pedestrian detection result is refined by a block-based segmentation method.

**Optimal Use of Existing Distribution Feeders to Accommodate Transportation Electrification**

*C.-M. Chan, C.-N. Lu, and Y. L. Lo*

An analytical method to study the optimal topology and maximum capacity of distribution network to accommodate electric vehicles' charging demands is presented. In order to facilitate a large number of EV integrations, the feeder reconfiguration problem is formulated as a discrete nonlinear optimization problem that finds optimal feeders' tie switch locations and their on/off schedule to minimize operation costs and comply with the system operation constraints. A novel stochastic dynamic programming technique is then adopted to solve the problem that includes various uncertainties associated with feeder baseline and EV charging loads.

**Vehicle Logo Recognition System Based on Convolutional Neural Networks With a Pretraining Strategy**

*Y. Huang, R. Wu, Y. Sun, W. Wang, and X. Ding*

An efficient convolutional neural network (CNN) system is proposed for vehicle manufacturer recognition that removes the requirement for precise logo detection and segmentation. We introduce a pretraining strategy to reduce the high computational cost of kernel training in CNN-based systems to enable improved real-world applications. A data set containing 11 500 logo images belonging to ten manufacturers, with 10 000 for training and 1500 for testing, is generated and employed to assess the suitability of the proposed system.

**Efficient Sampling-Based Motion Planning for On-Road Autonomous Driving**

*L. Ma, J. Xue, K. Kawabata, J. Zhu, C. Ma, and N. Zheng*

An efficient motion planning method is presented for on-road driving of the autonomous vehicles based on the rapidly exploring random tree (RRT) algorithm. To address the planning problem of mobile robots and considering the realistic context of on-road autonomous driving, a fast RRT algorithm that introduces a rule-template set based on the traffic scenes and an aggressive extension strategy of search tree is proposed. A model-based prediction postprocess approach is also adopted to enable the generated trajectory be further smoothed, and a feasible control sequence for the vehicle would be obtained.

**Bandwidth Maximization Using Vehicle Arrival Functions**

*G. Gomes*

The offset optimization problem for maximization of two-way progression bands is reintroduced. A new formulation is proposed, which relies on the concepts of relative offset and vehicle arrival functions. An explicit formula for the bandwidth is derived based on these two quantities. The bandwidth maximization problem is then formulated as an unconstrained nonlinear program. The cases of pulse and Gaussian arrivals are considered in detail.

**Vehicle Verification Using Features From Curvelet Transform and Generalized Gaussian Distribution Modeling**

*J.-M. Guo, H. Prasetyo, M. E. Farfoura, and H. Lee*

A new feature descriptor is presented for vehicle verification. In the procedure of vehicle verification, an image descriptor is generated from the statistical parameter of the curvelet-transformed (CT) subbands. The marginal distribution of CT output is a heavy-tailed bell-shaped function, which can be approximated as a Gaussian, Laplace, and generalized Gaussian distribution with high accuracy. The maximum-likelihood estimation produces the distribution parameters of each CT subband for the generation of the image feature descriptor. The classifier then assigns a class label for the vehicle hypothesis based on this descriptor information.

**An Autonomous Driving System for Unknown Environments Using a Unified Map**

*I. Shim, J. Choi, S. Shin, T.-H. Oh, U. Lee, B. Ahn, D.-G. Choi, D. H. Shim, and I.-S. Kweon*

Algorithms and systems using Unified Map are studied for autonomous driving without prebuilt maps of roads and traffic signals. The proposed map contains not only the information on real obstacles nearby but also traffic signs and pedestrians as virtual obstacles, which helps to efficiently find paths free from collisions while obeying traffic laws. The proposed algorithms were implemented on a commercial vehicle and successfully validated in various environments.

**Driver Gaze Tracking and Eyes Off the Road Detection System**

*F. Vicente, Z. Huang, X. Xiong, F. De La Torre, W. Zhang, and D. Levi*

An inexpensive vision-based system to accurately detect Eyes Off the Road (EOR) is presented. It has three main components: robust facial feature tracking, head pose and gaze estimation, and 3-D geometric EOR detection. From the video stream of a camera, the system tracks facial features from the driver's face. Using the tracked landmarks and a 3-D face model, the system computes head pose and gaze direction. Later, using a 3-D geometric analysis, it reliably detects EOR. This system does not require any driver-dependent calibration or manual initialization and works in real time.

**Evaluation of the Effects of a Personal Mobility Vehicle on Multiple Pedestrians Using Personal Space**

*T. Q. Pham, C. Nakagawa, A. Shintani, and T. Ito*

The authors developed a simulation model considering the interaction between a personal mobility vehicle (PMV) and pedestrians and investigated the effects of a PMV in pedestrian flows using the concept of personal space (PS). To estimate the mutual effects of a PMV and nearby pedestrians, the invasion ratio and crossing time are introduced as indexes. To ensure pedestrians are comfortable in the presence of a PMV, an assistance system for a PMV is also proposed. Simulation results revealed that the invasion of PS increases with increasing pedestrian density.

**Designing Huge Repositories of Moving Vehicles Trajectories for Efficient Extraction of Semantic Data**

*A. Dacierno, A. Saggese, and M. Vento*

A novel system for efficiently storing and querying large amounts of 3-D data is described, which is specifically designed for making possible the formulation of a wide variety of spatiotemporal 3-D queries. The method is based on a novel 3-D data schema that is reconducted to a set of 2-D schemata, with only the latter ones available in ready-to-use database environments. An implementation of the system over PostGIS is also presented, together with a performance assessment on a huge trajectory database.

**Reducing the Cost of High-Speed Railway Communications: From the Propagation Channel View**

*R. He, Z. Zhong, B. Ai, and K. Guan*

A standardized path loss/shadow fading model for high-speed railways (HSRs) channels based on an extensive measurement campaign in 4594 HSR cells is proposed. The measurements are conducted using a practically deployed and operative GSM-Railway (GSM-R) system to reflect the real conditions of the HSR channels. The model is validated by the measurements conducted in a different operative HSR line. Finally, a heuristic method to design the base stations separation distance is proposed.

**Design of Robust and Energy-Efficient ATO Speed Profiles of Metropolitan Lines Considering Train Load Variations and Delays**

*A. Fernández-Rodríguez, A. Fernández-Cardador, A. P. Cucala, M. Domínguez, and T. Gonsalves*

A method to design robust and energy-efficient speed profiles of automated metro lines is proposed. First, an optimal Pareto front for automatic train operation (ATO) speed profiles robust to changes in train load is constructed. Then, the set of speed profiles to be programmed in the ATO equipment is selected from the robust Pareto front using a particle swarm optimization algorithm to minimize the total energy consumption. The results in the case study showed that the pattern robustness is more restrictive and meaningful than the robust optimization technique as it provides information about shapes that are more comfortable for passengers.

**Reading the Road: Road Marking Classification and Interpretation**

*B. Mathibela, P. Newman, and I. Posner*

The problem of automatically reading the rules encoded in road markings is addressed by classifying them into seven distinct classes: single boundary, double boundary, separator, zig-zag, intersection, boxed junction and special lane. A unique set of geometric feature functions within a probabilistic RUSBoost and conditional random field classification framework is employed to jointly classify the extracted road markings. Thus, the semantics of road scenes can be inferred based on marking classification results. Experimental results show that this framework allows a vehicle to read and interpret road scenes by understanding the rules of the road embodied in road markings.

**On Curve Negotiation: From Driver Support to Automation**

*P. Bosetti, M. Da Lio, and A. Saroldi*

A curve negotiation behavior for producing artificial agents with the ability to negotiate curves in a humanlike way is described. It enables functions implementation at different levels of automation, from driving assistance to fully automated driving. Mainly, it involves the following: 1) a summary of related works and of the subsumption architecture conceptual framework; 2) a detailed description of the function within this framework; 3) experimental data for validation and tuning derived from user tests; 4) guidelines on integration of the function within advanced driver assistance systems with different automation levels, with examples; and 5) a comparison with experimental data of the human curve speed choice models in the state of the art.

**Analysis of Traffic Performance of a Merging Assistant Strategy Using Cooperative Vehicles**

*R. Scarinci, B. Heydecker, and A. Hegyi*

A novel merging assistant strategy that exploits cooperative systems to reduce congestion at motorway junctions is presented. The new system groups main carriageway vehicles together and collects the intervehicle spaces into gaps that are usable by merging traffic and will facilitate the coordinated entry of platoons of vehicles released by an on-ramp traffic signal. The performance of this new system is evaluated using microscopic simulation. Results show how the use of cooperative systems can improve the merging maneuver and thus lead to a reduction of congestion on motorways.

**Frailty Models for the Estimation of Spatiotemporally Maximum Congested Impact Information on Freeway Accidents**

*Y. Chung and W. W. Recker*

Models for the estimation of the temporal and spatial extent of congestion impact caused by accidents are developed. Applying a previously developed procedure to capture the spatiotemporal accident impacts based on binary integer programming, the procedure provides a foundation for models of 1) maximum spatial distance to the end of the congestion region affected by each accident and 2) maximum time affected by congestion resulting from each accident. Using these procedures, factors critical to spatiotemporal congestion impacts of freeway accidents are identified.

**Design of Traffic Safety Control Systems for Emergency Vehicle Preemption Using Timed Petri Nets**

*Y.-S. Huang, Y.-S. Weng, and M. Zhou*

Timed Petri nets (TPNs) are adopted to model the preemption of emergency vehicle systems. The proposed approach clearly presented the traffic light behaviors in terms of conditions and events that cause the preemption of phases being changed. A new emergency vehicle preemption policy to ensure that emergency vehicles can pass through intersections with no or less delay is also proposed. It demonstrates how the developed models enforce the phase of traffic transitions by a reachability graph with time information. This is the first work that employs

TPNs to model an emergency vehicle preemption system and identify its urgent spectacles for the purpose of their complete avoidance.

**Traffic Signal Optimization for Oversaturated Urban Networks: Queue Growth Equalization**

*K. Jang, H. Kim, and I. G. Jang*

A signal optimization algorithm that aims to equalize queue growth rates across links in oversaturated urban roadway networks is developed. It postpones queue spillbacks that form at the localized sections of networks. Its performance is evaluated by simulating traffic conditions with optimized signal settings on an idealized $3 \times 3$ roadway network under various oversaturated demand scenarios. Simulation experiments show that the signal settings optimized by the queue growth equalization algorithm outperform those optimized using the conventional signal optimization software.

**Queue Length Estimation Using Connected Vehicle Technology for Adaptive Signal Control**

*K. Tiaprasert, Y. Zhang, X. B. Wang, and X. Zeng*

A mathematical model for real-time queue estimation using connected vehicle technology from wireless sensor networks is presented. The objective is to estimate the queue length for queue-based adaptive signal control. A discrete wavelet transform is applied to the queue estimation algorithm for the first time. Experimental results illustrate the proposed model in both pretimed control and actuated control with a microscopic simulator, VISSIM, which indicates that the proposed algorithm is able to estimate the queue length from VISSIM in the test case with pretimed signal control reasonably well.

**Multiple Concentric Gating Traffic Control in Large-Scale Urban Networks**

*M. Keyvan-Ekbatani, M. Yildirimoglu, N. Geroliminis, and M. Papageorgiou*

The feedback-based gating concept is introduced along with a new gating strategy for concentric cities based on the notion of the macroscopic or network fundamental diagram. The strategy considers the levels and times of congestions in the urban network. Remarkable extensions while distributing the ordered controller flow to the gated traffic signals are also included. A greater part of the San Francisco, CA, USA, urban network is used as test bed within a microscopic simulation environment, which shows the network-wide mean speed and average delay per kilometer are much improved compared to the single perimeter gating and nongating simulation scenarios.

**Learning-Based Driving Events Recognition and Its Application to Digital Roads**

*C. D'Agostino, A. Saidi, G. Scouarnec, and L. Chen*

One extremely challenging problem faced in automatic recognition of driving events is that, as only in-vehicle driving data must be used, the number of driving events is usually quite large. The authors propose a learning-based driving events classification method that is trained and tested with a real driving events database. The digital road concept is also introduced, which is consisted by simulated road data used in the truck design process to quantify the behavior of a truck, particularly in terms of fuel consumption. While a digital road typically contains far less driving information, the authors show that the proposed driving events recognition models can still be applied for a more realistic assessment of truck characteristics.

**Automated Extraction of Urban Road Facilities Using Mobile Laser Scanning Data**

*Y. Yu, J. Li, H. Guan, and C. Wang*

A novel algorithm for rapidly extracting urban road facilities by using mobile laser scanning data is proposed. A detailed description and implementation of the proposed algorithm is provided using mobile laser scanning data collected by a state-of-the-art RIEGL VMX-450 system. This algorithm is successfully applied to the extraction of 3-D street light poles, traffic signposts, and bus stations from 3-D point clouds acquired by the RIEGL VMX-450 system. Comparative studies demonstrate that the proposed algorithm works efficiently and feasibly for automated and rapid extraction of urban road facilities.

**Managing Emergency Traffic Evacuation With a Partially Random Destination Allocation Strategy: A Computational-Experiment-Based Optimization Approach**

*Y. Lv, X. Zhang, W. Kang, and Y. Duan*

A partially random destination allocation strategy for emergent traffic evacuation management is proposed. A metamodel-based simulation optimization method is applied to design the strategy, which uses a quadratic polynomial as a metamodel, and within which a degree-free trust region algorithm is embedded as the solution algorithm. The performance of the proposed method is evaluated based on a subnetwork of Beijing, China, with two different traffic demands. Computational experiments show that the proposed method yields a well-performed strategy, leading to reduced network clearance times.

**Smooth and Controlled Recovery Planning of Disruptions in Rapid Transit Networks**

*L. Cadarso, G. Maróti, and Á. Marín*

An integrated model for the recovery of the timetable and the rolling stock schedules is presented. A new approach to deal with large-scale disruptions is considered with a limited number of simultaneous schedule changes and controlled length of the recovery period. Computational tests are reported on realistic problem instances of the Spanish rail operator RENFE and demonstrate the potential of this approach by solving different variants of the proposed model.

**The Driving Safety Field Based on Driver–Vehicle–Road Interactions**

*J. Wang, J. Wu, and Y. Li*

Existing methods that evaluate driving safety only consider limited factors, and their interactions perform inadequately, whereas it is difficult for kinematics- and dynamics-based vehicle driving safety assistant systems to adapt to increasingly complex traffic environments. A new concept called the driving safety field is proposed. The concept makes use of field theory to represent risk factors owing to drivers, vehicles, road conditions, and other traffic factors. Moreover, a unified model of the

driving safety field is constructed. The driving safety field can reveal driver–vehicle–road interactions and their influences on driving safety, as well as predict driving safety trends owing to dynamic changes.

**Multiobjective Optimization for Train Speed Trajectory in a CTCS High-Speed Railway With a Hybrid Evolutionary Algorithm**

*W. Shangguan, X.-H. Yan, B.-G. Cai, and J. Wang*

The optimization approach for the speed trajectory of a high-speed train in a single section is studied. First, the authors take the energy consumption as the measure of satisfaction of the railway company, and the trip time is being regarded as the passenger satisfaction criterion. Then, the authors present optimal speed trajectory searching strategies under different track characteristics by dividing the section into some subsections according to different speed limitations. After that, a multiobjective optimization model for the speed trajectory is developed. In addition, to obtain the Pareto frontier of train speed trajectory, a hybrid evolutionary algorithm is designed to solve the model.

**Prediction of Railcar Remaining Useful Life by Multiple Data Source Fusion**

*Z. Li and Q. He*

A methodology to predict remaining useful life (RUL) of both wheels and trucks is presented. It fuses data from three types of detectors, including wheel impact load detector, machine vision systems, and optical geometry detectors. Missing data are handled by missForest, a random forests-based nonparametric missing value imputation algorithm. Numerical tests show that the proposed methodology can accurately predict RUL of the components of a railcar, particularly in a middle-term range.

**Development of Efficient Nonlinear Benchmark Bicycle Dynamics for Control Applications**

*E. X. Wang, J. Zou, G. Xue, Y. Liu, Y. Li, and Q. Fan*

We present a symbolic method for modeling a nonlinear multibody bicycle with holonomic and nonholonomic constraints. The method is developed for robotic multibody dynamics. It shows that the nonlinear dynamics of the bicycle satisfies an underactuated manipulator equation and demonstrated an analytic method to solve the vehicle pitch angle from a quartic equation. This reduced analytic model offers insights into understanding complex nonlinear bicycle dynamic behaviors and enables the development of an efficient model that is suitable for real-time control outside of the linear regime.

**Vehicle Type Classification Using a Semisupervised Convolutional Neural Network**

*Z. Dong, Y. Wu, M. Pei, and Y. Jia*

A vehicle type classification method that uses a semisupervised convolutional neural network from vehicle frontal-view images is proposed. We introduce sparse Laplacian filter learning to obtain the filters of the network with large amounts of unlabeled data in this paper. Unlike traditional methods using handcrafted visual features, this method is able to automatically learn good features for the classification task. Experimental results on our own dataset and a public dataset demonstrate the effectiveness of the proposed method.

**Exponential Contrast Restoration in Fog Conditions for Driving Assistance**

*M. Negru, S. Nedevschi, and R. I. Peter*

An efficient single-image enhancement algorithm suitable for daytime fog conditions is proposed. The algorithm is based on an original mathematical model and considers the exponential variation in fog density to the distance. The model is inspired by the functions that appear in a partition of unity in the differential geometry field. The quantitative and qualitative evaluation proves the mathematical model is able to obtain superior reconstructions of the original fog-free image, in both homogeneous and heterogeneous fog conditions.

**Real-Time Detection of Traffic From Twitter Stream Analysis**

*E. D'Andrea, P. Ducange, B. Lazzerini, and F. Marcelloni*

A real-time monitoring system for road-traffic event detection from Twitter stream analysis is presented. The system retrieves tweets according to several search criteria and then performs the classification of tweets. The traffic detection system was employed for real-time monitoring of several areas of the Italian road network, allowing for detection of traffic events almost in real time, often before online traffic news web sites. It employed the support vector machine as a classification model and achieved an accuracy value of 95.75% by solving a binary classification problem.

**A Novel Approach for Vehicle Detection Using an AND–OR Graph-Based Multiscale Model**

*Y. Li, M. J. Er, and D. Shen*

A novel approach for detecting multiscale vehicles with time-varying vehicle features based on a multiscale AND–OR graph (AOG) model is proposed. The approach consists of two steps: construction of a multiscale AOG model and an inference process for vehicle detection. Based on this multiscale model, an inference process using local features is integrated with a process using global features to detect multiscale vehicles. To evaluate the performance of our proposed method, a validation experiment, a quantitative evaluation, and a contrasting experiment are conducted. Experimental results show that the proposed approach can efficiently detect multiscale vehicles.

**Recommendations Supporting Situation Awareness in Partially Automated Driver Assistance Systems**

*F. Wulf, M. Rimini-Döring, M. Arnon, and F. Gauterin*

The development and evaluation of certain human–machine interface mechanisms is studied. It is hypothesized that such mechanisms have a positive impact on a driver's situational awareness and resulting driving safety. Based on the mechanisms' evaluation results, a system presenting the secondary task's display in the vehicle's head-up display is proposed. Thus, the driver is expected to be able to keep the vehicle's environment in his or her peripheral field of view without being distracted too much. At the same time, relevant elements to

operate the secondary task should be located on the steering wheel.

**The Use of Intent Information in Conflict Detection and Resolution Models Based on Dynamic Velocity Obstacles**

*G. Adrián M. Velasco, C. Borst, J. Ellerbroek, M. M. (René) van Paassen, and M. Mulder*

A fully analytical closed mathematical form for velocity obstacles (VOs) as an intuitive and flexible calculation method is proposed. Study cases for specific traffic situations are explored, and possibilities to extend the method to the third dimension are discussed. Analysis showed that the calculation of the VOs with intent information could show self-curve intersections when maneuvers at close distance are required.

**Intelligent Hybrid Electric Vehicle ACC With Coordinated Control of Tracking Ability, Fuel Economy, and Ride Comfort**

*Y. Luo, T. Chen, S. Zhang, and K. Li*

A novel adaptive cruise control (ACC) system to enhance the energy efficiency and control system integration for intelligent HEVs (i-HEV ACC) is developed. The controller is proposed within the framework of nonlinear model predictive control, and a position-based nonlinear longitudinal intervehicle dynamics model is developed. A coordinated optimal control problem for both the tracking safety and the fuel consumption is formulated subject to the constraints on stable tracking. A multistep offline dynamic programming optimization and an online lookup table are used to implement the real-time control algorithm. Experiments are further conducted to demonstrate that the proposed i-HEV ACC achieves enhanced performance and cooperation in traffic safety, fuel efficiency, and ride comfort.

**The Endless ITS Frontier in CSP Spaces**

On the day it was issued 70 years ago in July, Vannevar Bush's report *Science: The Endless Frontier*, was greeted by front page headlines in the *New York Times*. Since then, the report has come to occupy a biblical status in science policy and become a pillar of support for the prerogatives of fundamental and unfettered research and development. Inspired by the report and also to celebrate the 70th anniversary of its publication, as well as the 10th anniversary of the IEEE Intelligent Transportation Systems (ITS) Society, we decided last year at IEEE ITSC to have the IEEE ITSS Summer School on Frontiers in ITS: Transportation 5.0 and Beyond, the first summer school of the IEEE ITS Society, which is supported and operated by the Qingdao Academy of Intelligent Industries (QAII) and IEEE ITS Shandong Chapter, from July 12 to July 17, 2015 in Qingdao.

The summer school has eight speakers and 60 researchers and graduate students from four countries/regions, topics ranging from artificial intelligence, traffic visualization, deep learning, social transportation, natural language processing, active safety systems, data-driven and model-driven approaches, and social media and movement for traffic intelligence, to benefit cost analysis for life-saving transportation improvement. My lecture is on parallel transportation and transportation 5.0, covering my long-term basic research and recent investigation on ITS, from ACP-based ITS, ITS knowledge automation, total traffic control, social signal and social transportation, to parallel driving and driving knowledge robots for automated partially to autonomous vehicles. The Summer School is still in process as I am writing this editorial, and I hope it will be a big success and great start for our Summer School program.

Science is the endless frontier, and the potential for ITS research, development, and application is also endless. Since the first trial almost 50 years ago of applying hierarchical intelligent control systems based on a combination of artificial intelligence, operations research, and control technology for urban traffic operations in the city of Indianapolis, Indiana, by the late Prof. George N. Saridis, my former Ph.D. advisor, I have been often asking myself the question: Where is the big "I" of Intelligence in ITS research and applications? Now it seems that the satisfactory answer to the question is near: the big I cannot come from the physical world alone; it must come from Karl Popper's combined three worlds of physical, mental, and artificial, or in engineering terms, the integrated Cyber–Social–Physical Spaces. Uber, DiDi Dache, or DiDi Taxi Calling, and their recent fierce competition in China, has provided strong support and a showcase for my observation. In other words, intelligence, especially intelligence in ITS that involves human and social behaviors, must be derived from and based on the principle of virtual-real duality and related virtual-actual interactive parallel intelligence. The term CSP for cyber–social–physical is identical with the term CPSS for cyber–physical–social systems, but now I feel the original term CSP, as used in my report for the establishment of the CAST (Complex Adaptive Systems for Transportation) Laboratory 15 years ago, is more appropriate. Especially, this is in line with the ACP approach that uses artificial societies/systems for achieving agility, computational experiments for providing a mechanism of focusing, and parallel execution for the ensure of convergence to the goal or objectives in uncertain, diversified, and complex operations, such as transportation.

Transportation in CSP is the endless frontier, now and future.

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