Scanning the Issue and Beyond: Transportation Games for Social Transportation

THIS issue brings us a few new ways and directions to evaluate the past ITS practices and look into the future applications of intelligent technology for intelligent transportation. Especially, our three review articles address related issues in urban ITS, smart rail systems, and mitigating adverse weather impacts to mobility. For my part, inspired by the current success of Uber-type taxi services, I will discuss the importance and emerging trend of transportation games for social transportation.

Appraisal and Evaluation of Interurban ITS: A European Survey

B. W. Kolosz and S. M. Grant-Muller

Background theory, issues, and gaps concerning the assessment of performance for intelligent transportation systems (ITSs), as well as a review of frameworks proposed by various authors in the field, are presented through: 1) identifying 12 evaluation framework requirements; 2) proposing corresponding solutions to business; and 3) introducing four key performance areas for ITS. The key requirements of ITS from the literature include improved geographical focus, reducing conflicting stakeholder involvement, and to consolidate elements of ITS that are currently calculated in isolation. Current indicators are biased toward economic benefit. The definitions of four key performance areas are adaptability, sustainability, standardization, and data management. To conclude, the introduction of technology requires a paradigm shift in terms of reorganization and realignment of the scope of conventional transport system evaluation.

Wireless Sensor Networks for Condition Monitoring in the Railway Industry: A Survey

V. J. Hodge, S. O'Keefe, M. Weeks, and A. Moulds

The range of sensing technologies has rapidly expanded while sensor devices have become cheaper, which has led to a rapid expansion in condition monitoring of systems, structures, vehicles, and machinery using sensors. In addition, recent advances in networking technologies such as wireless communication and mobile *ad hoc* networking have coupled with the technology to integrate devices. Condition monitoring reduces human inspection requirements through automated monitoring, reduces maintenance through detecting faults before they escalate, and improves safety and reliability. This is vital for the development, upgrading, and expansion of railway networks. This paper focuses on practical engineering solutions, principally which sensor devices are used and what they are used for, and identification of sensor configurations and network topologies. It identifies their respective motivations and distinguishes their advantages and disadvantages in a comparative review.

Potentials of Intelligent Transportation Systems in Mitigating Adverse Weather Impacts to Mobility: A Review

K. C. Dey, A. Mishra, and M. Chowdhury

Adverse road weather conditions, which cause transportation systems to perform far below capacity, can severely affect society's economic output. As elimination of road weather events is not possible, transportation agencies perform proactive and reactive maintenance activities to minimize adverse impacts to keep roadways in optimum condition. While reactive maintenance activities are conducted to clear roadways after the occurrence of extreme weather events, proactive activities minimize these impacts beforehand. Clearly, enhancing the potential of mobile weather data collection by installing weather sensors to connected vehicles will provide real-time data to improve proactive maintenance program to reduce adverse effects and ensure reliable mobility services. The authors focus on current intelligent transportation system (ITS)-based solutions for minimizing road weather impacts and analyzing possible ITS innovations to incorporate climate-related information to improve road weather management activities.

A Measurement-Based Stochastic Model for High-Speed Railway Channels

R. He, B. Ai, Z. Zhong, A. F. Molisch, R. Chen, and Y. Yang

The high-speed railway (HSR) propagation channel has a significant impact on the design and performance analysis of wireless railway control systems. This paper derives a stochastic model for the HSR wireless channel at 930 MHz, which is based on a large number of measurements in 100 cells using a practically deployed and operative communication system. The authors use the Akaike information criterion to select the distribution of the parameter distributions, including variations from cell to cell. The model incorporates the impact of directional base station antennas; includes several previously investigated HSR deployment scenarios as special cases; is parameterized for practical HSR cell sizes, which can be several kilometers; provides a consistent prediction of the propagation in HSR environments; and allows a straightforward and time-saving implementation for simulation.

A Vehicles–Intersection Coordination Scheme for Smooth Flows of Traffic Without Using Traffic Lights

Md. A. S. Kamal, J. I. Imura, T. Hayakawa, A. Ohata, and K. Aihara

A coordination scheme of automated vehicles at an intersection without using any traffic lights is presented. Using

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a two-way communication network, vehicles approaching the intersection from all sections are globally coordinated by considering their states all together in a model predictive control framework. The optimal trajectories of the vehicles are computed based on avoidance of their cross-collision risks around the intersection under relevant constraints and preferences. The vehicle–intersection coordination scheme proposed is evaluated through numerical simulation in a typical test intersection consisting of both multilane and single-lane approaches with turning movements of vehicles. Observations under different traffic flow conditions reveal that the proposed scheme significantly improves intersection performance compared with the traditional signalized intersection scheme.

Intelligent Mobile Video Surveillance System as a Bayesian Coalition Game in Vehicular Sensor Networks: Learning Automata Approach

N. Kumar, J.-H. Lee, and J. J. P. C. Rodrigues

A new intelligent mobile video surveillance system using the concept of Bayesian coalition game and learning automata is discussed. To decrease the delay occurred during transmission of captured video to the nearest access points, the best path is chosen based upon a new metric called a path score, which is computed by each player in the game. For each action performed by the automata, their actions may be rewarded or penalized by a value that can be defined by a sequence by a stochastic environment. According to the reward or penalty received from the environment, the automata update their actions' probability vector. After 15 iterations, the Nash equilibrium is achieved in the game by defining a twice differentiable function in Banach spaces and convergence of sequence is proved using the Cauchy convergence theorem.

Fully Automatic Roadside Camera Calibration for Traffic Surveillance

M. Dubská, A. Herout, R. Juránek, and J. Sochor

Automatic calibration of roadside surveillance cameras is addressed with focus on parameters necessary for measurements in traffic surveillance applications. Contrary to the existing solutions, the authors' approach requires no *a priori* knowledge and works with a very wide variety of road settings and with practically unlimited viewing angles. The main contribution is that it works fully automatically without any per-camera or per-video manual settings or input whatsoever, and it is computationally inexpensive. The approach uses tracking of local feature points and analyzes the trajectories in a manner based on cascaded Hough transform and parallel coordinates. Experiments show that the obtained camera parameters allow for measurements of relative lengths with $\sim$2% mean accuracy.

Multiplatooning Leaders Positioning and Cooperative Behavior Algorithms of Communicant Automated Vehicles for High Traffic Capacity

P. Fernandes and U. Nunes

Multiplatooning leaders' positioning and sizing cooperative behavior strategies are proposed to improve the efficiency of a traffic system of communicant automated vehicles evolving on dedicated lanes. Novel algorithms to ensure high traffic capacity are presented and MATLAB/Simulink-based simulation results are reported. The authors consider a constant spacing between platoons' leaders as a fundamental condition to attain high traffic capacity. New algorithms to maintain interplatoon leaders' constant spacing are proposed, as well as novel algorithms, allowing vehicles to enter the main track cooperatively. Furthermore, a new set of algorithms to improve safety is also presented. A novel agent-based architecture was developed, in which each vehicle consists of two distinct modules: a leader and a follower. Based on MATLAB/Simulink simulations of several scenarios, the new algorithms are assessed and the simulation results are presented, confirming that the proposed algorithms ensure high traffic capacity and vehicle density and avoid traffic congestion.

TraPlan: An Effective Three-in-One Trajectory-Prediction Model in Transportation Networks

S. Qiao, N. Han, W. Zhu, and L. Gutierrez

The authors propose a three-in-one trajectory prediction model called TraPlan, which predicts the possible trajectories of moving objects with relative uncertainty by indexing moving objects in road-constrained transportation networks. The proposed TraPlan model contains three essential techniques: 1) CNR-tree, which is a two-tiered dynamic index structure of moving objects based on transportation networks, uses an R*-tree to manage the static road networks, and employs a low-cost R-tree to index trajectory units of moving objects, which regularly update its location in real time; 2) a region-of-interest discovery algorithm is employed to partition a large number of trajectory points into distinct clusters in the transportation network; and 3) a frequent trajectory pattern-tree-based TP approach, called FTP mining, is proposed to discover frequent trajectory patterns to infer future locations of objects moving within RoIs.

Fast Online Computation of Model Predictive Controller and Its Application to Fuel Economy-Oriented Adaptive Cruise Control

S. E. Li, Z. Jia, K. Li, and B. Cheng

High computational complexity inherently associated with the receding horizon optimization must be addressed to achieve real-time implementation. A generic scale reduction framework to reduce the online computational burden of model predictive controllers (MPCs) is presented. A lower dimensional MPC algorithm is formulated by combining an existing "move blocking" strategy with a "constraint set compression" strategy, which is proposed to further reduce the problem scale by partially relaxing inequality constraints in the prediction horizon. The tradeoff between control optimality and computational intensity is achieved by proper design of the blocking and compression matrices. The fast algorithm has been applied on intelligent vehicular longitudinal automation, implemented as a fuel economy-oriented adaptive cruise controller, and experimentally evaluated by a series of real-time simulations and field tests. These results indicate that the proposed method significantly improves the computational speed while maintaining

satisfactory control optimality without sacrificing the desired performance.

Multispectral Stereo Odometry

T. Mouats, N. Aouf, A. D. Sappa, C. Aguilera, and R. Toledo

The problem of visual odometry for ground vehicles based on the simultaneous utilization of multispectral cameras is investigated. It encompasses a stereo rig composed of an optical and a thermal sensor. The novelty resides in the utilization of the cameras as a stereo setup rather than two monocular cameras of different spectrum. To the best of the authors' knowledge, this is the first time that such a task is attempted. Log-Gabor wavelets at different orientations and scales are used to extract interest points from both images. These are then described using a combination of frequency and spatial information within the local neighborhood. Finally, detailed results validating the proposed strategy are illustrated.

Autonomous Reverse Parking System Based on Robust Path Generation and Improved Sliding Mode Control

X. Du and K. K. Tan

Some commercial vehicle models have been equipped with semiautonomous parking systems to a certain extent. However, gaps to fully automated solutions still exist, and cost considerations further constrain their acceptance among consumers. A low-cost vision-based approach to a fully self-reverse parking system is proposed. Experiment results based on 216 on-field tests under different illumination conditions showed that the proposed system was able to park the vehicle accurately and consistently in all cases with a 4.71-cm RMS offset distance from the center line and 1.24° RMS orientation deviation. With its easy setup and excellent performance, this system can be implemented onto existing vehicles practically and robustly with minimal additional cost.

ExTraCT: Expediting Offloading Transfers through Intervehicle Communication Transmissions

P. Kolios, C. Panayiotou, and G. Ellinas

Data gathered within and around vehicles can be used to improve road safety, traveling efficiency, and passenger comfort and convenience. However, delivering such data to the infrastructure is a challenging task, mainly due to the very large volumes of data traffic produced. A promising approach to support these communication needs is to deliver data traffic opportunistically through the available WiFi access points. The intermittent connectivity of these hotspots and the inherent mobility of the vehicles severely limit the volume of traffic sent at any one instance in time. The latter limitation is studied in this paper, in which decision policies are derived for vehicle-to-vehicle assisted offloading to maximize the transmission opportunities and thus expedite data traffic delivery.

Minimizing the Disruption of Traffic Flow of Automated Vehicles During Lane Changes

D. Desiraju, T. Chantem, and K. Heaslip

Vehicles that are becoming more highly automated are revolutionizing the world's transportation systems for their promise of increased safety and efficiency. The advantage of vehicles incorporating automation is that they do not make the same mistakes as human drivers, such as being distracted or impaired. In order to realize the potential of these vehicles, online dynamically adaptive techniques are needed in order to achieve high throughput and to reduce congestion. An online algorithm to minimize the disruption of traffic flow by optimizing for the number of possible lane changes, arguably one of the most difficult maneuvers for both human and robot drivers, is presented. The proposed algorithm is distributed in nature and makes use of vehicle-to-vehicle and/or vehicle-to-infrastructure communication technology to judiciously make local lane-change decisions while guaranteeing that no collisions will occur.

TripPlanner: Personalized Trip Planning Leveraging Heterogeneous Crowdsourced Digital Footprints

C. Chen, D. Zhang, B. Guo, X. Ma, G. Pan, and Z. Wu

Planning an itinerary before traveling to a city is one of the most important travel preparation activities. Here, a novel framework called TripPlanner is proposed, which leverages a combination of a location-based social network and taxi GPS digital footprints to achieve personalized, interactive, and traffic-aware trip planning. To validate the efficiency and effectiveness of the proposed approach, extensive empirical studies are performed on two real-world data sets, which contain more than 391 900 passenger delivery trips generated by 536 taxis in a month and 110 214 check-ins left by 15 680 Foursquare users in six months in San Francisco, CA, USA.

A Review of Online Dynamic Models and Algorithms for Railway Traffic Management

F. Corman and L. Meng

Railway timetables are developed to make operations robust and resilient to small delays. Disturbances perturb the daily plan, and dispatchers adjust the plan to keep operations feasible and to limit delay propagation. Rescheduling approaches aim at updating the offline timetable at best, in the presence of delays. The authors present a survey of the recent approaches on online railway traffic rescheduling problems, which exhibit dynamic and stochastic aspects. While online static rescheduling has reached a wide degree of dissemination, much is still to be done with regard to the probabilistic nature of the railway traffic rescheduling problems and how to best take uncertainty into account for future states. Open challenges for the future research are finally outlined.

Optimization of Metro Train Schedules With a Dwell Time Model Using Lagrangian Duality Theory

X. Sun, S. Zhang, H. Dong, Y. Chen, and H. Zhu

An optimization method of train schedule for metro lines with train dwell time model according to passenger demand is established with constraints of headway equation, passenger equation, and train dwell time equation, in which the train dwell time is modeled as a function of boarding and alighting passenger volumes. The aim is to minimize the waiting time of passengers and train operation cost. Lagrangian duality

theory is adopted to solve this optimization problem with high dimensionality. Simulation results illustrate that this method is efficient to generate the train schedule. The contribution of this paper is that the dwell time model is introduced in train schedule optimization, which provides a possibility to reduce the operation cost in the precondition that the exchanging time of passengers between platforms and trains is assured.

Video-Based Dynamic Stagger Measurement of Railway Overhead Power Line Using Rotation-Invariant Feature Matching

C. J. Cho and H. Ko

The authors propose an effective method of assessing the reliability of railway overhead power lines by measuring the dynamic stagger of contact wires based on a video monitoring technique. Feature-based image matching techniques that are invariant to rotation and robust to changes in camera viewpoint are employed. A pantograph tilting model is developed from the video data acquired from an actual train based on the motion dynamics of the stagger behavior on moving train platform. The experimental results confirm that the proposed method shows superior performance in all train traveling sequences but especially over the pantograph tilting train motion segment.

Mobile Standards-Based Traffic Light Detection in Assistive Devices for Individuals with Color-Vision Deficiency

A. Almagambetov, S. Velipasalar, and A. Baitassova

A robust, traffic standards-based, and computationally efficient method is presented for detecting the status of the traffic lights without relying on GPS, lidar, radar information, or prior knowledge. The work uses official ITE and BSI standards for defining traffic light colors, as well as integrating a number of fail-safe mechanisms designed to prevent erroneous detection. The algorithm can be easily ported over to an embedded smart camera platform and used as a windshield-mounted driver-assistance device by individuals with CVD. The system can accurately identify the status of the light at 400 ft away from the intersection, reliably detecting solid, faulty, arrow, and high-visibility-signal lights. Over 50 h of video (over 2000 intersections) were tested with the system, containing intersections with one to four traffic lights, governing different lanes of traffic, with 97.5% accuracy of solid light detection.

A Novel Vehicle Reversing Speed Control Based on Obstacle Detection and Sparse Representation

Z. Zhang, H. Xu, Z. Chao, X. Li, and C. Wang

A vehicle safety method for reversing speed control based on obstacle detection and sparse representation is described, which includes three steps, namely, binocular–cameras obstacle detection and segmentation, obstacle tracking and recognition, and vehicle reversing speed control algorithm. First, a binocular–cameras system is used to detect obstacles as the vehicle is reversing. Using disparity computation and triangulation, we can get all objects' distance information in the rear of a vehicle. Second, the framework of particle filter and sparse representation are used to track and identify the main obstacles such as human or animal bodies, vehicles, or any other objects. Finally, the vehicle reversing speed control algorithm, which controls the electronic throttle opening and automatic braking prior to collisions, makes the reversing control safer and more reliable. This system has been field tested on the Dodge SUV, and the performance evaluation demonstrates the validity of the proposed method.

Robust Wheel Torque Control for Traction/Braking Force Tracking Under Combined Longitudinal and Lateral Motion

T. Hsiao

The author proposes an observer-based tire force control scheme, which guarantees to achieve the desired longitudinal tire force accurately and robustly with respect to tire model uncertainties, changes in road conditions, and simultaneous lateral motion. Convergence of the force estimation and tracking errors is rigorously proved by the Lyapunov method. Then, simulations are conducted to verify the robust and accurate performance in longitudinal tire force estimation and tracking under a series of severe driving conditions.

Calibration of Nonoverlapping In-Vehicle Cameras With Laser Pointers

W. Zou and S. Li

A new approach to calibrating inward- and outward-facing in-vehicle cameras using a laser pointer is introduced. A method is presented in which the two cameras can be connected by a laser emitted from a laser pointer. The laser pointer is mounted on a calibration board so that the laser ray's pose within the calibration board's coordinate system can be calculated. Two algorithms are presented based on this idea, i.e., the coplanar method and the collinear method, and their performance is compared with that of the conventional mirror-based method through simulations and experiments. In contrast to other methods, the proposed method is simple, practical, and especially well suited to the calibration of nonoverlapping in-vehicle cameras in a factory or garage.

Recognizing Text-Based Traffic Signs

J. Greenhalgh and M. Mirmehdi

The authors propose a novel system for the automatic detection and recognition of text in traffic signs. A scene structure is used to define search regions, in which traffic sign candidates are then found. Maximally stable extremal regions (MSERs) and hue, saturation, and value color thresholding are used to locate a large number of candidates, which are then reduced by applying constraints based on temporal and structural information. A recognition stage interprets the text contained within detected candidate regions. Individual text characters are detected as MSERs and grouped into lines before being interpreted using optical character recognition. Recognition accuracy is vastly improved through the temporal fusion of text results across consecutive frames. The method is comparatively evaluated and achieves an overall f-measure of 0.87.

***Why so Many People?* Explaining Nonhabitual Transport Overcrowding With Internet Data**

F. C. Pereira, F. Rodrigues, E. Polisciuc, and M. Ben-Akiva

A probabilistic data analysis model, which uses public transport smartcard data to detect large crowds, is proposed. The model breaks each nonhabitual overcrowding hotspot into a set of explanatory components. The potential explanatory components are initially retrieved from social networks and special events websites and then processed through text-analysis techniques. Finally, for each such component, the probabilistic model estimates a specific share in the total overcrowding counts. The authors validate with synthetic data and then test our model with real data from the public transport system of Singapore, focused on three case study areas. The authors demonstrate that it is able to generate explanations that are intuitively plausible and consistent both locally and globally. This model is directly applicable to any other domain sensitive to crowd formation due to large social events.

A Prototype Integrated Monitoring System for Pavement and Traffic Based on an Embedded Sensing Network

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

A wireless sensing network was installed on Virginia State Route 114 in October 2011. Since then, Virginia Polytechnic Institute and State University has been developing an integrated monitoring system of pavements and traffic. The achievement of our study includes a prototype system, which can monitor pavement conditions and collect traffic information simultaneously using the same embedded sensing network. In the sensing network, the sensors are ranged in longitudinal and transverse groups, and the compositions, characteristics, and functionalities of the two arrangements are introduced. The two monitoring patterns of the system, i.e., continuous monitoring and periodic testing, are explained, and the data processing methods in the two patterns are illustrated. The whole system is presented combining hardware and software, and a flowchart is used to clarify its component and function modules.

Development of an Optimal Operation Approach in the MPC Framework for Heavy-Haul Trains

L. Zhang and X. Zhuan

An operation control approach for heavy-haul trains to optimize their performance, including operation safety, service quality, and energy consumption, is proposed. Following a model predictive control method, the controller is capable of scheduling a train to optimally operate during a long section of the rail track. In the cost function, two penalty factors are presented, one for the braking forces and one for coupler damping effects. The penalty for braking forces is employed to reduce energy waste incurred by braking. The penalty for coupler damping is introduced to alleviate the cyclic vibration of couplers, which link adjacent cars in the train. The damping penalty is also expected to reduce energy wasted by coupler damping and corresponding maintenance/replacement cost of the dampers. In addition, the weight of the velocity tracking term in the objective function is modified to vary dynamically according to the train's velocity to improve the train's overall performance.

Sustainable Transportation Management System for a Fleet of Electric Vehicles

S. Mehar, S. Zeadally, G. Rémy, and S. M. Senouci

Transportation agencies in various countries, along with several standardization organizations, have proposed different types of energy sources as alternatives to fossil fuel to achieve a more eco-friendly and sustainable environment. However, to achieve this goal, there are significant challenges that still need to be addressed. A survey on sustainable transportation systems that aim to reduce pollution and greenhouse gas emissions is presented, which describes the architectural components of a future sustainable means of transportation; reviews current solutions, projects, and standardization efforts related to green transportation with particular focus on electric vehicles; and highlights the main issues that still need to be addressed to achieve a green transportation management system. To address these issues, an integrated architecture for sustainable transportation management systems is presented.

Joint Fuzzy Relays and Network-Coding-Based Forwarding for Multihop Broadcasting in VANETs

C. Wu, S. Ohzahata, Y. Ji, and T. Kato

Providing an efficient multihop forwarding of broadcast messages has been a challenging problem due to vehicle movement, limited wireless resources, and unstable signal strength. Here, a broadcast protocol is proposed, which can provide a low message overhead and high packet dissemination ratio. The proposed scheme uses a fuzzy logic algorithm to choose the next hop relay nodes and uses network coding to improve the packet dissemination ratio without increasing the message overhead. By using the fuzzy logic algorithm, the protocol can choose the best relay node by taking intervehicle distance, vehicle velocity, and link quality into account. Network coding is used to improve the packet reception ratio by utilizing the broadcast nature of wireless channels. We show the effectiveness of the proposed scheme by using both theoretical analysis and computer simulations.

Secure and Privacy-Preserving Smartphone-Based Traffic Information Systems

S. Gisdakis, V. Manolopoulos, S. Tao, A. Rusu, and P. Papadimitratos

The continuing increase in smartphone penetration, combined with the current wide coverage of cellular infrastructure, renders smartphone-based traffic information systems an attractive option. The main purpose of such systems is to alleviate traffic congestion, which exists in every major city. Nevertheless, to reap the benefits of smartphone-based traffic information systems, we need a holistic solution that will address their security and privacy along with their effectiveness. This is the motivation of the authors' work: by leveraging state-of-the-art cryptographic schemes and readily available telecommunication infrastructure, to present a comprehensive solution for smartphone-based traffic estimation that is provably secure, accountable, and privacy-preserving. With a full-blown implementation of the system, on actual smartphones, and an extensive assessment of its accuracy and efficiency, the

authors move a step forward toward the actual deployment of trustworthy traffic information systems.

Spatiotemporal Analysis of Bluetooth Data: Application to a Large Urban Network

P.-A. Laharotte, R. Billot, E. Côme, L. Oukhellou, A. Nantes, and N.-E. El Faouzi

A methodological contribution to the use of Bluetooth data for the spatiotemporal analysis of a large urban network is presented through the concept of the Bluetooth Origin–Destination (B-OD) Matrix, which is built from a network of 79 Bluetooth detectors, located within the Brisbane, Australia, urban area. The results show that the characteristics of urban networks can be effectively represented through B-OD matrices. A comparison with loop detector data enables an assessment of the results' significance. Then, the spatiotemporal structure of the network is analyzed with two different clustering analyses, namely, latent Dirichlet allocation (LDA) and K-means. While LDA is used to detect temporal pattern, the K-means algorithm highlights Bluetooth fundamental diagram classes. By highlighting hidden structures of a large area, the algorithms' outputs allow us to provide the road operators with a fine spatiotemporal analysis of their network in terms of traffic conditions.

On Closed-Loop Bike Availability Prediction

A. Schlote, B. Chen, and R. Shorten

The effect of customer choices in bicycle-sharing systems based on bike availability predictions is studied, which shows that such systems may lead to flapping behavior between bike stations. The consequences of flapping instability include a poor user experience and suboptimal usage of the available bike stock. The authors propose a simple assignment strategy aimed at eliminating flapping and balancing demand at each station based on actual availability.

Impact of Communication Erasure Channels on the Safety of Highway Vehicle Platoons

L. Xu, L. Y. Wang, G. Yin, and H. Zhang

Packet loss in block erasure channels creates a randomly switching networked system that impacts control performance significantly. This paper employs the safety of highway vehicle platoons as a platform to study such an impact. By autonomous intervehicle coordination, a platoon can potentially enhance safety, improve highway utility, increase fuel economy, and reduce emissions. By comparing different information structures, which utilize radar distance sensors and wireless communication channels, the authors characterize some intrinsic relationships between communication resources and control performance. The findings here provide useful guidelines in communication resource allocations and vehicle coordination in vehicle safety problems.

An Integrated Control Model for Headway Regulation and Energy Saving in Urban Rail Transit

B. Ning, J. Xun, S. Gao, and L. Zhang

An integrated control method is proposed to optimize train headway by adjusting the train arrival time at stations. The adjustment of train arrival time is achieved by using an analytical method and then the speed profile for each train is calculated by a suboptimal method, which has been applied in a practical system. Through simulation, the CPU time for calculating optimal train arrival time and speed profile is analyzed, respectively. The analysis demonstrates that the proposed method satisfies the real-time requirements for solving the headway regulation problem. By adopting the proposed method, the average passenger waiting time and the energy consumption can be decreased. In particular, the proposed method has better performance when dispatch headway is large.

An Improved Exact e-Constraint and Cut-and-Solve Combined Method for Biobjective Robust Lane Reservation

P. Wu, A. Che, F. Chu, and M. Zhou

A new biobjective lane-reservation problem through exclusively reserve lanes from an existing transportation network for special transport tasks with given deadlines is investigated. The objectives are to minimize the total negative impact on normal traffic due to the reduction of available lanes for general-purpose vehicles and to maximize the robustness of the lane-reservation solution against the uncertainty in link travel times. The authors define the robustness for the lane-reservation problem and formulate a biobjective mixed integer linear programming and develop an improved exact e-constraint and a cut-and-solve combined method to generate its Pareto front. Computation results for an instance based on a real network topology and 220 randomly generated network instances with up to 150 nodes, 600 arcs, and 50 tasks demonstrate that the proposed method is able to find the exact Pareto front, and that the proposed cut-and-solve method is more efficient than the direct use of optimization software CPLEX.

Predictive and Multirate Sensor-Based Planning Under Uncertainty

M. C. Mora and J. Tornero

A general formulation of a predictive and multirate reactive planning method for intelligent vehicles is introduced, which tackles path planning and trajectory planning for intelligent vehicles in dynamic environments with uncertainty, where the kinodynamic vehicle constraints are also taken into account. It is based on the potential field projection (PFP) method, which combines the classical potential field method with the multirate Kalman filter estimation. PFP takes into account the future object trajectories and their associated uncertainties, i.e., what makes it different from other look-ahead approaches. Here, a new potential field is included in the Lagrange–Euler formulation in a natural way, accounting for the vehicle dynamics. The resulting accelerations are translated into control inputs that are considered in the estimation process. This leads to the generation of a local trajectory in real time that fully meets the constraints imposed by the kinematic and dynamic models of the intelligent vehicle.

How the Autonomic Nervous System and Driving Style Change With Incremental Stressing Conditions During Simulated Driving

A. Lanatà, G. Valenza, A. Greco, C. Gentili, R. Bartolozzi, F. Bucchi, F. Frendo, and E. P. Scilingo

This paper reports on the autonomic nervous system (ANS) changes and driving style modifications as a response to incremental stressing load during simulated driving. Fifteen subjects performed a driving simulation experiment consisting of three driving sessions. Starting from the first session, in which participants performed a steady motorway driving, the experimental protocol includes two additional driving sessions with incremental stress load. The second stressing load implied an incremental psychological load, consisting of a battery of time-pressing arithmetical questions, added to the mechanical stimuli. In this paper, the ANS changes were investigated in terms of heart rate variability, respiration activity, and electrodermal response along with mechanical information. In particular, significant statistical differences were found among the three driving sessions with increasing stress level both in ANS responses and mechanical parameter changes. In addition, a good recognition of these sessions was carried out by pattern classification algorithms achieving an accuracy value greater than 90%.

Raindrop-Tampered Scene Detection and Traffic Flow Estimation for Nighttime Traffic Surveillance

C.-C. Yu, H.-Y. Cheng, and Y.-F. Jian

An intelligent highway surveillance system that performs self-diagnosis and detects the conditions when the camera is seriously tampered by raindrops at night is introduced, which provides solutions to analyze the traffic flow under the challenging nighttime raindrop tampered conditions. By extracting effective features via salient region detection and block segmentation, the vehicle numbers in consecutive frames form a vehicle number sequence. The authors propose a mapping model to acquire the desired per-minute traffic flow from the vehicle number sequence. The model utilizes state transfer likelihoods and takes into account the length of the segmented vehicle number sequence. The experiments on highly challenging data sets have demonstrated that the proposed system can effectively estimate the traffic flow for raindrop-tampered highway surveillance cameras at night.

Dense Stereo-Based Robust Vertical Road Profile Estimation Using Hough Transform and Dynamic Programming

J. K. Suhr and H. G. Jung

A dense stereo-based robust vertical road profile estimation method is proposed, in which the vertical road profile is modeled by a cubic B-spline curve. To robustly estimate a cubic B-spline curve, the proposed method utilizes a two-step strategy that initially estimates a piecewise linear function and then obtains a cubic B-spline curve based on the initial estimation result. Hough transform and dynamic programming are utilized for estimating a piecewise linear function to achieve robustness against outliers and guarantee optimal parameters. In the experiment, performance evaluation and comparison were conducted using three publicly available databases. The result shows that the proposed method outperforms the three previous methods in all databases. In particular, its performance is superior to the others in the cases of a large proportion of outliers and road surfaces distant from the ego-vehicle.

Passenger Segmentation Using Smart Card Data

L.-M. Kieu, A. Bhaskar, and E. Chung

Transit passenger market segmentation enables transit operators to target different classes of transit users for targeted surveys and various operational and strategic planning improvements. However, the existing market segmentation studies in literature have generally been done using passenger surveys, which have various limitations. The Smart Card (SC) data from an automated fare collection system facilitates the understanding of multiday travel pattern of transit passengers and can be used to segment them into identifiable types of similar behaviors and needs. We propose a comprehensive methodology for passenger segmentation using solely SC data and adopt the density-based spatial clustering of application with noise algorithm to mine travel pattern of each SC user. An *a priori* market segmentation approach then segments transit passengers into four identifiable types. The methodology proposed assisting transit operators to understand their passengers and provide them oriented information and services.

Real-Time Estimation of Lane-to-Lane Turning Flows at Isolated Signalized Junctions

S. Lee, S. C. Wong, C. C. C. Pang, and K. Choi

The authors develop rule- and model-based approaches for the real-time estimation of lane-to-lane turning flows. Their aim is to determine the turning proportions of vehicles based on detector information at isolated signalized junctions and thereby establish effective control strategies for adaptive traffic control systems. The entrance lane of a vehicle detected in an exit lane is identified according to a set of specified rules in the rule-based approach. Meanwhile, the model-based approach is used to identify the most probable turns in a set of potential upstream entrance lanes. Both computer simulations and real-world traffic data show that the model-based approach outperforms the rule-based approach, particularly when turning-on-red is allowed, and is capable of accurate estimation under a wide range of traffic conditions in real time. However, the rule-based approach is simpler and does not require calibration, which are positive assets when no prior data are available for calibration.

Curvilinear Coordinate-Based Object and Situation Assessment for Highly Automated Vehicles

J. Kim, K. Jo, W. Lim, M. Lee, and M. Sunwoo

A novel curvilinear coordinate-based approach to improve object and situation assessment performance for highly automated vehicles under various curved road conditions is proposed. The approach integrates object information from radars and lane information from a camera with three steps: track-to-track fusion, curvilinear coordinate conversion, and lane assessment. The developed algorithm is verified and evaluated through experiments using a real-time embedded system. The results show that the proposed curvilinear coordinate-based approach provides excellent performance of object and

situation assessment in respect of accuracy and computational efficiency in real-time operation.

Modeling Social Influence on Activity–Travel Behaviors Using Artificial Transportation Systems

S. Chen, Z. Liu, and D. Shen

A deep understanding of people's activity–travel behaviors is critical and essential for effective travel demand forecasting and management. Although it is acknowledged that social interactions play an important role in people's decision-making behaviors, our understanding of how they shape and impact activity–travel behaviors of people is still limited. Therefore, for the first time, this paper introduces social learning into artificial transportation systems to model their influence on activity–travel behaviors. Based on a specified artificial transportation system, three types of universal social interactions are modeled and studied. The results indicate that our models can make artificial agents learn to decide the best behavior, form habitual choices, and emerge fashion gradually.

Reducing Interferences in VANETs

D. Zelikman and M. Segal

Mobile *ad hoc* networks (MANETs) are networks that are created on-the-fly (*ad hoc*) between various mobile nodes without requiring an infrastructure. The mobile nodes can move around, and the network would automatically reconfigure itself to allow connectivity. Vehicular *ad hoc* networks (VANETs) are a subclass of MANETs that are expected to have a key role in the intelligent transportation systems (ITSs) of the future. VANETs provide vehicle-to-vehicle and vehicle-to-roadside communication in order to support safety and comfort applications. Despite being a subclass of MANETs, VANETs have fundamentally different behavior [1]. This paper presents a scheme consisting of a MAC protocol and a clustering algorithm designed to reduce interferences in VANETs. The scheme, which is intended for safety applications in highway environments, employs dynamic multihop clustering, allows better utilization of network resources, and improves network performance.

Comments on "Model-Independent Adaptive Fault-Tolerant Output Tracking Control of 4WS4WD Road Vehicles"

A. K. Singh and R. Potluri

This article shows that the concept of model independence floated in the commented paper "Model-Independent Adaptive Fault-Tolerant Output Tracking Control of 4WS4WD Road Vehicles" (*IEEE Trans. Intell. Transp. Syst.*, vol. 14, no. 1, pp. 169–179, Mar. 2013) arises from one of the multiple significant errors in mathematical modeling and does not arise if a correct model is used. As these errors, if left uncorrected, are a potential source of future errors in the emerging area of 4WS4WD vehicles, this article provides detailed discussions and corrections.

A Note on "Model-Independent Adaptive Fault-Tolerant Output Tracking Control of 4WS4WD Road Vehicles"

D.-Y. Li and Y.-D. Song

Singh and Potluri [1] suggest that they have spotted three "errors" in the dynamic model presented in [2]. Upon carefully examining the model in the paper and the claims made by Singh and Potluri, the authors believe that no such errors exist in the model. A detailed explanation is provided.

Discrete-State Encoding in Hybrid-State Systems for Intelligent Vehicle Control and Estimation

A. Kurt

This paper develops an encoding scheme for discrete-state systems as part of a hybrid-state hierarchy. The codes are based on commands between subsystems, in the sense that the interactions of the discrete states with the continuous states are exploited to attach significance to what each discrete state does to the continuous subsystem. The resultant codeset is independent of how the discrete-state transitions are designed, and conventional tools such as truth tables and K-maps are easily applicable in the binary representation of the codes. Code-based representations of every possible combination of commands/behaviors governed by the discrete subsystem are useful in a number of design scenarios, an example of which is the generation of a consistent norm for discrete states. Such a norm is demonstrated to be useful in hybrid-state estimation.

Lateral Vehicle State and Environment Estimation Using Temporally Previewed Mapped Lane Features

A. Brown and S. N. Brennan

A model-based method to estimate lateral planar vehicle states using a forward-looking monocular camera, a yaw rate gyroscope, and an *a priori* map of road superelevation and temporally previewed lane geometry is proposed. Theoretical estimator performance from a steady-state Kalman filter implementation of the estimation framework is calculated for various look-ahead distances and vehicle speeds. Application of this filter structure to real driving data is also explored, along with error characteristics of the filter on straight and curved roads, with both superelevated and flat profiles. The effect of superelevation on estimator performance is found to be significant. Experimental and theoretical analyses both show that the benefits of state estimation using previewed lane geometry improve with increasing lane preview, but this improvement diminishes due to increased lane tracking errors at distances beyond 20 m ahead of the vehicle.

Transportation Games for Social Transportation

Recently, I read an article on Uber's business model and its bidding mechanism for real-time matching of demands and supplies, which claims that this model has revolutionized customers' riding experiences, released fragmentized values, reconstructed social networks for connection beyond mobility, and should win the Nobel Prize for Economics. Having never used the Uber service myself, I am unable to judge the article's claim from my personal experience, but I believe Uber's phenomenal growth from \$200K to \$40B in value and from cabs to airplanes in vehicles, in just five years, must mean something significant. When discussing this with my students in game theory, they told me a few interesting stories of frauds for profits by Uber's taxi drivers. However, I am still convinced that

Uber's practice, or in general, Transportation Games, will gain momentum shortly for fair and efficient mobility, and beyond, in this increasingly connected world.

Through pervasive applications of smart phones, GPS, and other mobile devices, along with social media platforms such as WeChat, Facebook, and Twitter, individuals now can generate, obtain, and share real-time traffic information, and traffic operation centers can notify, direct, and interact with them and vehicles, together creating and altering traffic strategies via crowdsourcing, rather than the traditional fashion of command and control. To me, this offers us an exciting window of opportunity for various emerging live and grand Transportation Games in a new world, actually in three worlds: Physical World, Mental World, and Artificial World, in the sense of Karl Popper's Worlds I, II, and III. Technically, I would like to call it the Era of Transportation in Cyber–Social–Physical (CSP) space, or the age of parallel transportation. Transportation games, or computational transportation games in CSP, to be more precise, will be the key to the success of ITS in this new age. This is an important issue that I should return to for a deep discussion later.

Dynamic ridesharing service providers, such as Uber and Didi, provide primitive but powerful mechanisms and platforms for real transportation games in the real world. In just a few years, they have presented many interesting but complicated patterns of interactions and behaviors for mobility with various levels of social, economic, and engineering complexity. For example, The Washington Post reports that Uber's dynamic price mechanism "Surge Pricing" actually "reduces demands for cars" since "less people want a car for a higher price" and "shift drivers to areas of high demand" instead of "create new supply," as pointed out vividly by the Times, that Uber's fee in Sydney "hikes upwards of four times their normal rate" after "an armed assailant burst into a city cafe and took hostages." In China, the leading ridesharing company, Didi, has used a variant of Dutch auctions to match drivers and customers in the same area: a customer can set and modify her or his own price and a driver can grab his or her favored orders according to customers' prices and destinations, creating a complicated game scenario among operators, drivers, and customers, a powerful display of smart phone supported social transportation games for business operations.

Transportation games have a long history in transportation research: Wardrop's selfish routing games in 1952, Rosenthal's congestion games in 1973, and Monderer and Shapley's potential games for heavy-duty vehicles in 1996 are just a few examples. More recently, Stackelberg strategies have been widely employed and experimented for transportation and mobility, e.g., Krichene *et al.* in 2012 and Bayen in 2013 have studied Stackelberg routing strategies on parallel networks with horizontal queues for reducing traffic congestion, under the assumption that the central authority can incentivize the routes of a subset of players on a network and the remaining players choose their routes selfishly. Such "soft" traffic suggestions, rather than "hard" traffic controls, could be an ideal match with the total or complete traffic control approach I have proposed in the Editorial from Transactions on Intelligent Transportation Systems, Vol. 15, No. 2, 2014.

Just before I am finishing this editorial, I sadly learn that John F. Nash and his wife were killed in a taxi crash in New Jersey. Nash, born in the year of 1928 when game theory was invented by John von Neumann, was a pioneer in games. Nash equilibrium has played a central role game research, and Nash strategy has been used widely in earlier transportation games. Personally I have a deep and special interest in game theory. Thirty years ago when writing my PhD dissertation on coordination theory of intelligent machines, I tried both machine learning and game-theoretic approach, with Nash, Cooperative, and Stackelberg strategies. As social networks and connected societies are becoming normal of our life, we should speed up our work in transportation games for social transportation, and make our ITS real smart, in human's terms.

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