Scanning the Issue and Beyond: Transportation and Mobility Transformation for Smart Cities

THE OVERALL performance and current status of IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS (T-ITS) have been reported and discussed in the first Executive Committee (ExCom) meeting of the IEEE Intelligent Transportation Systems Society (ITSS) this year, held in beautiful Saint Thomas, U.S. Virgin Islands. I am glad to inform you that the state of our journal is like the sunny blue sky, white clouds, and lovely beach of the Virgin Islands: bright and pleasant. The ExCom has decided to establish a new platform for ITSS social media presence; thus, our future abstracts will be distributed through the new social media platform.

This issue starts with three survey papers on technology and security for intelligent vehicles. I will go beyond smart cars and share my thinking and view on issues of transportation and mobility transformation for smart living in smart communities and cities.

Intra-Vehicle Networks: A Review

S. Tuohy, M. Glavin, C. Hughes, E. Jones, M. Trivedi, and L. Kilmartin

Automotive electronics is a rapidly expanding area with an increasing number of safety, driver assistance, and infotainment devices becoming standard in new vehicles. Current vehicles generally employ a number of different networking protocols to integrate these systems into the vehicle. The introduction of large numbers of sensors to provide driver assistance applications and the associated high bandwidth requirements of these sensors has accelerated the demand for faster and more flexible network communication technologies within the vehicle. This paper presents a comprehensive overview of current research on advanced intra-vehicle networks and identifies outstanding research questions for the future.

Potential Cyberattacks on Automated Vehicles

J. Petit and S. E. Shladover

It is important to start thinking about the cybersecurity implications of cooperative automated vehicle systems. In this paper, the authors investigate the potential cyberattacks specific to automated vehicles, with their special needs and vulnerabilities. We analyze the threats on autonomous automated vehicle and cooperative automated vehicle. This analysis shows the need for considerably more redundancy than many have been expecting. The authors also raise the awareness to generate discussion about these threats at this early stage in the development of vehicle automation systems.

Hierarchical and Networked Vehicle Surveillance in ITS: A Survey

B. Tian, B. T. Morris, M. Tang, Y. Liu, Y. Yao, C. Gou, D. Shen, and S. Tang

Traffic surveillance has become an important topic in intelligent transportation systems (ITSs), which is aimed at monitoring and managing traffic flow. The authors present a review of the literature on the video-based vehicle surveillance systems in ITS. They analyze the existing challenges in video-based surveillance systems for the vehicle and present a general architecture for video surveillance systems, i.e., the hierarchical and networked vehicle surveillance, to survey the different existing and potential techniques. Then, different methods are reviewed and discussed with respect to each module. Applications and future developments are discussed to provide future needs of ITS services.

A Study of Truck Platooning Incentives Using a Congestion Game

F. Farokhi and K. H. Johansson

The authors introduce an atomic congestion game with two types of agents, i.e., cars and trucks, to model the traffic flow on a road over various time intervals of the day. Cars maximize their utility by finding a tradeoff between the time they choose to use the road, the average velocity of the flow at that time, and the dynamic congestion tax that they pay for using the road. In addition to these terms, the trucks have an incentive for using the road at the same time as their peers because they have platooning capabilities, which allow them to save fuel. The dynamics and equilibria of this game-theoretic model for the interaction between car traffic and truck platooning incentives are investigated.

A Video-Analysis-Based Railway-Road System for Detecting Hazard Situations at Level Crossings

H. Salmane, L. Khoudour, and Y. Ruichek

In this paper, the authors explore the possibility of implementing a smart video surveillance security system that is tuned toward detecting and evaluating abnormal situations induced by users (pedestrians, vehicle drivers, and unattended objects) in level crossing. This intelligent security system starts by detecting, separating, and tracking moving objects shot in the level crossing. Then, a hidden Markov model is developed to estimate ideal trajectories, allowing the detected targets to discard dangerous situations. After this, the level of risk of each target is instantly estimated by using the Dempster–Shafer data fusion technique. The proposed analysis also allows recognizing hazard scenarios. Four hazard scenarios are tested and evaluated with different real video image sequences: presence

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of obstacle in the level crossing, presence of stopped vehicles line, vehicle zigzagging between two closed half barriers, and pedestrian crossing LC area.

Feedback-Based Mainstream Traffic Flow Control for Multiple Bottlenecks On Motorways

G.-R. Iordanidou, C. Roncoli, I. Papamichail, and M. Papageorgiou

Mainstream traffic flow control (MTFC) enabled via variable speed limits (VSLs) has been investigated in previous studies, utilizing various control strategies. In this paper, an extended feedback control strategy is proposed for MTFC enabled via VSLs, considering multiple bottleneck locations. Feedback-based results are compared with optimal control results for the evaluation of the controller using a validated macroscopic model. The performance of the feedback controller is shown to approach the optimal control results, despite the fact that many practical and safety restrictions are additionally considered by the feedback controller.

A Cooperative Train Control Model for Energy Saving

S. Su, T. Tang (Guest Editor ICIRT 2013), and C. Roberts (Guest Editor ICIRT2013)

Increasing attention is being paid to energy efficiency in subway systems in order to reduce the operational cost and carbon emissions. Optimization of the driving strategy and efficient utilization of the regenerative energy are two effective methods to reduce the energy consumption for electric subway systems. Based on a common scenario that an accelerating train can reuse the regenerative energy from a braking train on the opposite track, this paper proposes a cooperative train control model to minimize the practical energy consumption, i.e., the difference between the traction energy and the reused regenerative energy. Case studies based on the Beijing Yizhuang subway line are presented to illustrate the effectiveness of the proposed approach on energy saving.

Tracking Heavy Vehicles Based on Weigh-In-Motion and Inductive Loop Signature Technologies

S.-T. (Cindy) Jeng and L. Chu

Weigh-in-motion (WIM) has been employed as a major technology to collect heavy vehicles' data on the freeways. Because WIM is one of the most costly and sophisticated data collection systems, how to effectively utilize the valuable WIM data and monitor WIM stations' performance are especially important. In this paper, the authors proposed an innovative and yet practical approach for heavy vehicle tracking that combines the use of both WIM data and the inductive loop signature data. The proposed multilevel vehicle reidentification approach was able to generate promising tracking performance with both inductive loop signatures and WIM data applied.

Smart Electrical Infrastructure for AC-Fed Railways With Neutral Zones

E. Pilo, S. K. Mazumder, and I. González-Franco

This paper presents a proposal to modify power supply systems currently used in ac-fed railways with neutral zones in order to allow power-flow routing. The proposed system complements the existing infrastructure with additional power electronic devices connected in parallel to both sides of the neutral zones, allowing control of power flow through adjacent electrical sections. Description and control of such a modified railway system is outlined in this paper. In addition, a mixed integer programming optimization problem is formulated, which minimizes the investment and the operation costs while ensuring the power supply to the train traffic. This optimization model is used to allow a systematic evaluation of the benefits of implementing such a railway smart grid system. Finally, a section of the high-speed line Madrid–Barcelona is used as a case study, and the advantages of the proposed system are quantified in two different scenarios.

Traffic Flow Prediction for Road Transportation Networks with Limited Traffic Data

A. Abadi, T. Rajabioun, and P. A. Ioannou

A major problem in getting traffic flow information in real time is that the vast majority of links are not equipped with traffic sensors. Another problem is that factors affecting traffic flows such as accidents, public events, and road closures are often unforeseen, suggesting that traffic flow forecast is a challenging task. In this paper, the authors first use a dynamic traffic simulator to generate flows in all links using available traffic information, estimated demand, and historical traffic data available from links equipped with sensors. As a case study, the authors predict the flows of a traffic network in San Francisco using a macroscopic traffic flow simulator. Our simulations demonstrate the accuracy of the proposed approach. The traffic flow prediction errors vary from an average of 2% for 5-min prediction windows to 12% for 30-min windows even in the presence of unpredictable events.

Multivehicle Cooperative Driving Using Cooperative Perception: Design and Experimental Validation

S.-W. Kim, B. Qin, Z. J. Chong, X. Shen, W. Liu, M. H. Ang, E. Frazzoli, and D. Rus

In this paper, the authors present a multivehicle cooperative driving system architecture using cooperative perception along with experimental validation. For this goal, they first propose a multimodal cooperative perception system that provides see-through, lifted-seat, satellite, and all-around views to drivers. Using the extended range information from the system, the authors then realize cooperative driving by a see-through forward collision warning, overtaking/lane-changing assistance, and automated hidden obstacle avoidance. They demonstrate the capabilities and features of our system through real-world experiments using four vehicles on the road.

Recognition of Low-Resolution Logos in Vehicle Images Based on Statistical Random Sparse Distribution

H. Peng, X. Wang, H. Wang, and W. Yang

A new vehicle logo recognition method is proposed to treat low-resolution and poor-quality images captured from urban crossings in intelligent transport systems, and the proposed approach is based on statistical random sparse distribution (SRSD) feature and multiscale scanning. The SRSD feature is a novel feature representation strategy that uses the correlation

between random sparsely sampled pixel pairs as an image feature and describes the distribution of a grayscale image statistically. Multiscale scanning is a creative classification algorithm that locates and classifies a logo integrally, which alleviates the effect of propagation errors in traditional methods by processing the location and classification separately. Experiments show an overall recognition rate of 97.21% for a set of 3370 vehicle images, which showed that the proposed algorithm outperforms classical VLR methods for low-resolution and inferior-quality images and is very suitable for onsite supervision in intelligent transportation systems.

Online Cost-Sharing Mechanism Design for Demand-Responsive Transport Systems

M. Furuhata, K. Daniel, S. Koenig, F. Ordóñez, M. Dessouky, M.-E. Brunet, L. Cohen, and X. Wang

In demand-responsive transport (DRT) systems, one has to design cost-sharing mechanisms for offering fare quotes to potential passengers so that all passengers are treated fairly. The main issue is how the operating costs of the DRT system should be shared among the passengers (given that different passengers cause different amounts of inconvenience to the other passengers), taking into account that DRT systems should provide fare quotes instantaneously without knowing future ride requests. The authors determine the properties of cost-sharing mechanisms that make DRT systems attractive to both shuttle providers and passengers, namely, online fairness, immediate response, budget balance, and ex-post incentive compatibility. They propose a novel cost-sharing mechanism, called proportional online cost sharing (POCS), that provides passengers with upper bounds on their fares immediately after their arrivals, allowing them to accept their fare quotes or drop out. The authors examine how POCS satisfies these properties in theory and computational experiments.

Recognition of Highway Workzones for Reliable Autonomous Driving

Y.-W. Seo, J. Lee, W. Zhang, and D. Wettergreen

In order to be deployed in real-world driving environments, self-driving cars must be able to recognize and respond to exceptional road conditions such as highway workzones because such unusual events can alter previously known traffic rules and road geometry. In this paper, the authors present a set of computer vision methods that recognize, through identification of workzone signs, the bounds of a highway workzone and temporary changes in highway driving environments. Through testing using video data about highway workzones recorded under various weather conditions, their approach was able to perfectly identify the boundaries of workzones and robustly detect a majority of driving condition changes. In addition to these tests, the authors evaluated, using a mock workzone setup, the usefulness of our workzone recognition systems' outputs for safeguarding a self-driving car.

Component GARCH Models to Account for Seasonal Patterns and Uncertainties in Travel-Time Prediction

Y. Zhang, A. Haghani, and X. Zeng

Uncertainty is often associated with travel-time prediction. Traditional point prediction methods only provide point values that are unable to offer enough information on the reliability of prediction results. The recent development of statistical volatility models has provided an effective way to capture uncertainties in data. In the context of travel time prediction, this paper proposes two component GARCH models able to model the trend and seasonal components through decomposition. Travel time data obtained along a freeway corridor in Houston, TX, were used to empirically test the performance of the proposed models. The study results indicate that the proposed models perform well when capturing uncertainties associated with travel time prediction.

SLPA*: Shape-Aware Lifelong Planning A* for Differential Wheeled Vehicles

S. Yoon and D. H. Shim

This paper presents modified A* and Lifelong Planning A* (LPA*) algorithms to facilitate more accurate path finding than existing methods, including the Minkowski sum for differential wheeled vehicles with shape constraints. The authors use a graphical method to check for obstructions without adding the outline of the vehicles to obstacles. The method applies a procedure that enables vehicles to have forward movement with the smallest rotation possible, including their turning directions. Furthermore, the authors show that vehicles can pass through narrow passages because we accurately check for interference against obstacles using the graphical method. Consequently, we demonstrate via a series of simulations that our method can quickly replan a collision-free path while accurately taking into account the shape of vehicles.

GNSS Multipath and Jamming Mitigation Using High-Mask-Angle Antennas and Multiple Constellations

L. Heng, T. Walter, P. Enge, and G. X. Gao

This paper studies the optimal antenna mask angle that maximizes the suppression of interference but still maintains the performance of a single constellation with a low-mask-angle antenna. This paper first proves a novel lower bound on the expectation of dilution of precision (DOP) and derives closed-form formulas that relate the lower bound to antenna mask angle and the number of satellites. Then, through extensive simulations, a variety of optimal mask angles are obtained with respect to different constellation settings, different DOP metrics, and different assumptions of range accuracy. The numerical results highly agree with our theory. Both show that two constellations can match the performance of one with 5°–14° higher mask, and three constellations can match the performance of one with 11°–23° higher mask, depending on the DOP metric and the range error model used.

Green Energy and Content-Aware Data Transmission in Maritime Wireless Communication Networks

T. Yang, Z. Zheng, H. Liang, R. Deng, N. Cheng, and X. Shen

In this paper, the authors investigate the network throughput and energy sustainability of green-energy-powered maritime wireless communication networks. Specifically, they study how to optimize the schedule of data traffic tasks to maximize the network throughput with Worldwide Interoperability for Microwave Access (WiMAX) technology. To this end, they

formulate it as an optimization problem to maximize weight of the total delivered data packets while ensuring that harvested energy can successfully support transmission tasks. The formulated energy and content-aware vessel throughput maximize problem is proved to be NP-complete. The authors propose a green energy and content-aware data transmission framework that incorporates the energy limitation of both infostations and delay-tolerant network throwboxes. The green energy buffer is modeled G/G/1 queue, and two heuristic algorithms are designed to optimize the transmission throughput and energy sustainability.

Efficient Pedestrian Detection via Rectangular Features Based on a Statistical Shape Model

S. Zhang, C. Bauckhage, and A. B. Cremers

The authors propose a simple yet effective detector for robust pedestrian detection. Observing that pedestrians usually appear upright in video data, the authors employ a statistical model of the upright human body where the head, the upper body, and the lower body are treated as three distinct components. The main contribution is to systematically design a pool of rectangular features that are tailored to this shape model. This approach does not avoid exhaustive searches over all possible configurations of rectangular features nor does it rely on random sampling. It thus marks a middle ground among recently published techniques and yields efficient low-dimensional yet highly discriminative features. Experimental results on the well-established INRIA, Caltech, and KITTI pedestrian data sets show that our detector reaches state-of-the-art performance at low computational costs and that our features are robust against occlusions.

Longitudinal Model Identification and Velocity Control of an Autonomous Car

J. E. A. Dias, G. A. S. Pereira, and R. M. Palhares

This paper presents the model identification and the velocity control of an autonomous car. Since the determination of the vehicle's model is a difficult step in the design of model-based controllers, the main contribution of this paper is the use of an empirically determined model to this end. In this work, the structure of the model was conceived from the car's physics equations, but its parameters were estimated using data-based identification techniques. An important contribution of this paper is the fact that, although the model is strictly linear, the authors can change its parameters in function of the operation point of the vehicle to represent engine's and transmission's nonlinear behaviors. In addition, in this paper, the authors propose a way to include changes in the longitudinal dynamics caused by automatic gear shifting.

Design of a Mobile Charging Service for Electric Vehicles in an Urban Environment

S. Huang, L. He, Y. Gu, K. Wood, and S. Benjaafar

This paper presents a novel approach to providing a service for electric vehicle (EV) battery charge replenishment. An analytical analysis is first developed for an idealized system with a nearest job next (NJN) service strategy explored for such a system. In an NJN service strategy, the mobile charger services the next spatially closest EV when it is done with its current request. An urban environment approximated by Singapore is then analyzed through simulation. Charging requests are simulated through a trip generation model based on Singapore. In such a realistic environment, an updated practical NJN service strategy is proposed. For an MP mobile charger system in an urban environment such as Singapore, there exists an optimal battery capacity with a threshold battery charge rate. Similarly, the battery swap capacity of an MS system does not need to be large for the system to perform.

Dynamic-Time-Warping-Based Measurement Data Alignment Model for Condition-Based Railroad Track Maintenance

P. Xu, R. Liu, Q. Sun, and L. Jiang

Based on dynamic time warping, a widely used technique in the area of speech signal processing and biomedical engineering, this paper presents a robust optimization model for correcting positional errors of inspection data from Track Geometry Car, a kind of specialized instruments that are extensively used to measure condition of tracks under wheel loadings. An efficient solution algorithm for the model is proposed as well. Applications of the model to inspection data from Track Geometry Car show that positional errors are almost removed from the inspection data regardless of noises in condition parameter measurements and track maintenance interventions, and the model takes 1.5004 s on average to complete the positional error correction for a 1-km-long track segment.

A Pedestrian-Detection Method Based on Heterogeneous Features and Ensemble of Multi-View-Pose Parts

W. Liu, B. Yu, C. Duan, L. Chai, H. Yuan, and H. Zhao

Vision-based pedestrian detection remains a challenging task so far. The detection performance often suffers from the various appearances of pedestrians, the illumination changes, and possible partial occlusions. Aiming at resolving these challenges, in this paper, first, a new linear kernel function is proposed to effectively combine two heterogeneous features, HOG and LBP, which enhances the pedestrian description ability to illumination conditions and cluttered background. Then, a novel multiple view–pose part ensemble detector is proposed in order to better handle pedestrian variability, views, and partial occlusions. Experimental results on public data sets demonstrate that the proposed feature combination method significantly improves the description capabilities of pedestrian features. Compared with the existing multipart ensemble approaches, the proposed multiple view–pose ensemble detector boosts higher detection accuracy.

Road Edge Recognition Using the Stripe Hough Transform From Millimeter-Wave Radar Images

K.-Y. Guo, E. G. Hoare, D. Jasteh, X.-Q. Sheng, and M. Gashinova

Millimeter-wave radar (MMW), used for road feature recognition, has performance superior to optical cameras in terms of robustness in different weather and lighting conditions, as well

as providing ranging capabilities. However, the signatures of road features in MMW radar images are quite different from that of optical images, and even physically continuous features such as road edges will be presented as a set of bright points or spots distributed along the roadside. Therefore, discrimination of the radar features is of paramount importance in automotive imaging systems. To tackle this problem, an approach called the stripe Hough transform is introduced in this paper, allowing enhanced extraction of the geometry of the road path. The performance of the approach is demonstrated by comparison of extracted features from MMW images with the real geometry of the road and with the results of processing by classical Hough transform.

Calibration and Validation of Probabilistic Discretionary Lane-Change Models

V. L. Knoop and C. Buisson

This article reviews methodologies to calibrate and validate probabilistic lane-change models, both microscopically and macroscopically. A likelihood is often used in calibration but does not intuitively show the quality of the model. An example showed that it is possible to have the model calibrated and validated with accurate parameters all having the same error in the validation as in the calibration, but the quality of the model was still bad. Using a likelihood ensures that the stochastic effects are well captured, but the conclusion is that, for validation purposes, one can better use a measure that has physical interpretation and which gives a value indicating the quality of the model for the purpose for which it needs to be used.

Efficient Compression of 4D-Trajectory Data in Air Traffic Management

S. Wandelt and X. Sun

In this paper, the authors propose two techniques for compressing air traffic 4-D trajectories. Their first technique analyzes a set of samples and computes a prediction for the most likely picked successor coordinate by a random walker. The second technique, referential compression, compresses a 4-D trajectory as a collection of subtrajectory pointers into a reference trajectory. The authors evaluate our algorithms on trajectory data from the demand data repository provided by EUROCONTROL. They show that a combination of our referential and statistical compression techniques compresses 4-D trajectories of all air traffic over Europe in the year 2013 from 60 GB down to 0.78 GB, achieving a compression ratio of more than 75:1. The compression ratio for our techniques increases with the number of to-be-compressed flights, whereas standard compression techniques achieve a fixed compressed ratio for any number of flights.

Spatial Inference of Traffic Transition Using Micro–Macro Traffic Variables

S. Thajchayapong and J. A. Barria

This paper proposes an online traffic inference algorithm for road segments where local traffic information cannot be observed directly. Using macro–micro traffic variables as inputs, the algorithm consists of three main operations. First, it uses interarrival time (time headway) statistics from upstream and downstream locations to spatially infer traffic transitions at an unsupervised piece of segment. Second, it estimates lane-level flow and occupancy at the same unsupervised target site. Third, it estimates individual lane-level shockwave propagation times on the segment. Using real-world CCTV data, it is shown that the proposed algorithm outperforms previously proposed methods.

Traffic Flow Prediction with Big Data: A Deep Learning Approach

Y. Lv, Y. Duan, W. Kang, Z. Li, and F.-Y. Wang

Over the last few years, traffic data have been exploding and we have truly entered the era of big data for transportation. Existing traffic flow prediction methods mainly use shallow traffic prediction models and are still unsatisfying for many real-world applications. This situation inspires us to rethink the traffic flow prediction problem based on deep architecture models with big traffic data. In this paper, a novel deep learning-based traffic flow prediction method is proposed, which considers the spatial and temporal correlations inherently. The stacked autoencoder model is used to learn generic traffic flow features, and it is trained in a greedy layerwise fashion. To the best of our knowledge, this is the first time to apply the deep architecture model using autoencoders as building blocks to represent traffic flow features for prediction. In addition, experiments demonstrate that the proposed method for traffic flow prediction has a superior performance.

Nonparametric Technique Based High-Speed Road Surface Detection

M. Wu, S.-K. Lam, and T. Srikanthan

Existing road surface detection methods attempt fitting the road surface into rigid models (e.g. planar, clothoid, or B-spline), thereby restricting to road surfaces that match specific models. In addition, the curve fitting strategies employed in such techniques incur high-computational complexity, making them unsuitable for in-vehicle deployments. In this paper, the authors propose an efficient nonparametric road surface detection algorithm that exploits the depth cue. The proposed method relies on four intrinsic road scene attributes observed under stereo geometry and has been shown to reliably detect both planar and nonplanar road surfaces efficiently. Extensive evaluations are performed on three widely used benchmarks (i.e., enpeda, KITTI, and Daimler), encompassing many complex road scenarios. The experimental results show that the proposed algorithm significantly outperforms the well-known techniques both in terms of detection accuracy and runtime performance.

A Nonstationary Wideband MIMO Channel Model for High-Mobility Intelligent Transportation Systems

A. Ghazal, C.-X. Wang, B. Ai, D. Yuan, and H. Haas

For a proper design and evaluation of high-speed trains' (HSTs) wireless communication systems, accurate channel models that can mimic the underlying channel characteristics for different HST scenarios are needed. In this paper, a novel nonstationary geometry-based stochastic model (GBSM) is proposed for wideband multiple-input–multiple-output HST

channels in rural macrocell scenarios. The corresponding simulation model is then developed with angle parameters calculated by the modified method of equal areas. Numerical and simulation results demonstrate that the proposed channel models have the capability to characterize the nonstationarity of HST channels. The statistical properties of the simulation model, verified by the simulation results, can match those of the proposed theoretical GBSM. Excellent agreement is achieved between the stationary intervals of the proposed simulation model and those of relevant measurement data, demonstrating the utility of the proposed channel models.

A Stochastic Emergency Vehicle Redeployment Model for Effective Response to Traffic Incidents

C. Lei, W.-H. Lin, and L. Miao

This paper studies the stochastic emergency vehicle redeployment problem for effective response to traffic incidents. Both potential service demands and unavailable time of emergency vehicles already in service are treated under uncertainty. The authors develop a stochastic programming model for the problem, aiming at optimizing the system-wide performance by adjusting the scheduling plan to reposition emergency vehicles when some emergency vehicles become temporarily unavailable in response to service calls. An enhanced version of the L-shaped method is developed to solve the model. A new set of lower bound constraints is created to improve the quality of the lower bound. The computational results show that the proposed method yields a tighter lower bound and converges faster to the optimal solution than the conventional L-shaped method. A comparative analysis of different strategies is conducted, which indicate that better system performance can be achieved by explicitly incorporating the information about the status change of emergency vehicles currently in service into the routing and scheduling plan.

Lane Departure Identification for Advanced Driver Assistance

V. Gaikwad and S. Lokhande

In this paper, a technique for identifying the of unwanted lane departure of a traveling vehicle on a road is proposed. The novelty of the proposed algorithm is an identification of the lane departure using only three lane-related parameters based on Euclidean distance transform to estimate departure measure. Use of Euclidean distance transform in combination with PLSF keeps false alarm around 3% and lane detection rate above 97% under various lighting conditions. Experimental results indicate that the proposed system can detect lane boundaries in the presence of several image artifacts, such as the lighting changes, poor lane markings, occlusions by a vehicle, and issues on accurate lane departure warning in a short time interval. The proposed technique shows the efficiency with some real video sequences.

Distributed Traffic Signal Control Using the Cell Transmission Model via the Alternating Direction Method of Multipliers

S. Timotheou, C. G. Panayiotou, and M. M. Polycarpou

In this paper, we model the multiple-intersection traffic signal control problem using the cell transmission model as a mixed integer linear program. The solution of the problem is facilitated by its special structure, which allows both temporal and spatial decomposition. Temporal decomposition is employed to reduce problem size by solving subproblems of smaller time window compared with the original problem. Temporal subproblems can be further spatially decomposed into subproblems associated with different intersections, which are jointly solved by exchanging messages between neighboring intersections. The proposed distributed solution strategy is composed of two phases. First, the relaxed linear problem is reformulated and distributedly solved via the alternating direction method of multipliers. Second, two distributed rounding schemes are developed to solve the original problem. Simulation results indicate that the proposed solution strategy is scalable to large transportation topologies, is suitable for online execution, and provides close to optimal results.

A Low-Cost Hardware Architecture for Illumination Adjustment in Real-Time Applications

Y.-H. Shiau, P.-Y. Chen, H.-Y. Yang, and S.-Y. Li

In this paper, the authors propose a fast and efficient illumination adjustment algorithm that is suitable for low-cost very large-scale integration implementation. Experimental results show that the proposed method requires the least number of operations and achieves comparable visual quality, as compared with previous techniques. To further meet the requirement of real-time image/video applications, the 16-stage pipelined hardware architecture of the method is implemented as an intellectual property core. The proposed design yields a processing rate of about 200 MHz by using TSMC 0.13-μm technology. Since it can process one pixel per clock cycle, for an image with resolution of QSXGA (2560×2048), it requires about 27 ms to process one frame, which is suitable for real-time applications. In some low-cost intelligent imaging systems, the processing rate can be slowed down and our hardware core can run at very low power consumption.

Constructed Data Pilot-Assisted Channel Estimators for Mobile Environments

Z. Zhao, X. Cheng, M. Wen, L. Yang, and B. Jiao

This paper focuses on the channel estimation problem in vehicular scenarios, which is very challenging in view of the extremely time-varying characteristics of mobile channels. Specifically, the authors propose a novel channel estimator named constructed data pilot (CDP) estimator for the current communication standards by fully exploiting the channel correlation characteristics across two concatenated symbols. On the basis of the CDP estimator, they further resort to two efficient techniques to improve its performance over the entire signal-to-noise-ratio (SNR) region. For the first technique, the time-variant mobile channel is modeled as a first-order Markov process so that the exact autocorrelation value of the two adjacent symbols can be derived. For the second technique, the SNR is estimated and serves as *a priori* information. Simulation results reveal that our proposed channel estimators outperform existing alternatives with lower computational complexity.

Analysis and Modeling of Pedestrian Crossing Behavior During the Pedestrian Flashing Green Interval

M. Iryo-Asano, W. K. M. Alhajyaseen, and H. Nakamura

The objective of this study is to analyze and model the probabilistic behavior of pedestrians after the onset of PFG, which contains pedestrians' decision of whether to give up crossing, as well as pedestrian speed distribution. Empirical data analysis showed that longer crosswalks lead to significantly higher pedestrian stop probabilities. Furthermore, there is a significant difference between pedestrians' speeds in the first and second halves of crosswalks. The results of a Monte Carlo simulation showed that the estimated models closely represent the overall stochastic behavior of pedestrians from the onset of PFG until the completion of crossing.

A Train Localization Algorithm for Train Protection Systems of the Future

M. Lauer (Magazine AE) and D. Stein

This paper describes an algorithm that enables a railway vehicle to determine its position in a track network. The system is based solely on onboard sensors such as a velocity sensor and a Global Navigation Satellite System (GNSS) sensor and does not require trackside infrastructure such as axle counters or balises. This paper derives a probabilistic modeling of the localization task and develops a sensor fusion approach to fuse the inputs of the GNSS sensor and the velocity sensor with the digital track map. The authors describe how to treat ambiguities and stochastic uncertainty adequately. Moreover, they introduce the concept of virtual balises that can be used to replace balises on the track and evaluate the approach experimentally. This paper focuses on an accurate modeling of sensor and estimation uncertainties, which is relevant for safety critical applications.

A Runtime Integrity Monitoring Framework for Real-Time Relative Positioning Systems Based on GPS and DSRC

K. Ansari, Y. Feng, and M. Tang

This paper provides a three-layered framework to monitor the positioning performance requirements of real-time relative positioning (RRP) systems of the cooperative intelligent transport systems that support cooperative collision warning (CCW) applications. These applications exploit state data of surrounding vehicles obtained solely from the Global Positioning System (GPS) and dedicated short-range communications (DSRC) units without using other sensors. To this end, this paper argues for the need for the GPS/DSRC-based RRP systems to have an autonomous monitoring mechanism since the operation of CCW applications is meant to augment safety on roads.

A Practical Wireless Attack on the Connected Car and Security Protocol for In-Vehicle CAN

S. Woo, H. J. Jo, and D. H. Lee

Security issues have not been treated properly in CAN, although CAN control messages could be life critical. With the appearance of the connected car environment, in-vehicle networks (e.g., CAN) are now connected to external networks (e.g., 3G/4G mobile networks), enabling an adversary to perform a long-range wireless attack using CAN vulnerabilities. In this paper, the authors show that a long-range wireless attack is physically possible using a real vehicle and malicious smartphone application in a connected car environment. They also propose a security protocol for CAN as a countermeasure designed in accordance with current CAN specifications and evaluate the feasibility of the proposed security protocol using CANoe software and a DSP-F28335 microcontroller. The results show that the proposed security protocol is more efficient than existing security protocols with respect to authentication delay and communication load.

Time- and Frequency-Varying K-Factor of Non-Stationary Vehicular Channels for Safety-Relevant Scenarios

L. Bernadó, T. Zemen, F. Tufvesson, A. Molisch, and C. F. Mecklenbräuker

The authors characterize the distribution of the envelope of the first delay bin in vehicle-to-vehicle channels by means of its Rician K-factor. They analyze the time–frequency variability of this channel parameter using vehicular channel measurements at 5.6 GHz with a bandwidth of 240 MHz for safety-relevant scenarios in intelligent transportation systems (ITSs). They show that the small-scale fading of the envelope of the first delay bin is Rician distributed with a varying K-factor. The later delay bins are Rayleigh distributed. We demonstrate that the K-factor cannot be assumed to be constant in time and frequency. The causes of these variations are the frequency-varying antenna radiation patterns and the time-varying number of active scatterers and the effects of vegetation. The authors also present a simple but accurate bimodal Gaussian mixture model, which allows capturing the K-factor variability in time for safety-relevant ITS scenarios.

Joint Human Detection From Static and Mobile Cameras

J. Miseikis and P. V. K. Borges

Efficient pedestrian detection is a key aspect of many intelligent vehicles. In this context, vision-based detection has gained increased popularity. Algorithms proposed often consider that the camera is mobile, onboard a vehicle, or static, mounted on infrastructure. In contrast, the authors consider a pedestrian detection approach that uses information from mobile and static cameras jointly. The proposed method finds applicability in industrial environments, where industrial vehicle localization is becoming increasingly popular. The authors implemented and tested the system on an automated industrial vehicle, considering both manned and autonomous operations. They present a thorough discussion on practical issues (resolution, lighting, subject pose, etc) related to human detection in the scenario considered. Experiments illustrate the improved results of the joint detection compared with traditional independent static and mobile detection approaches.

Vehicle Scheduling of an Urban Bus Line via an Improved Multiobjective Genetic Algorithm

X. Zuo, C. Chen, W. Tan, and M. Zhou

In this paper, a methodology is presented to create a set of Pareto solutions for vehicle scheduling of urban bus lines. First,

a set of candidate vehicle blocks is generated. Then, multiple block subsets are selected from this candidate set by an improved multiobjective genetic algorithm combined with a departure-time adjustment procedure to obtain multiple Pareto solutions. To encode a solution, we propose a coding scheme that has relatively short coding length and low decoding complexity. This approach is applied to a real-world vehicle scheduling problem of a bus line in Nanjing, China. Experiments show that this approach is able to quickly produce satisfactory Pareto solutions that outperform the actually used experience-based solution.

A Methodology for Denoising and Generating Bus Infrastructure Data

F. Pinelli, F. Calabrese, and E. Bouillet

Together with the availability of new mobility data, the development of new intelligent transport systems (ITSs) has increased in order to provide new key performance indicators toward the improvement of the management of traffic awareness in cities. ITSs rely on accurate transit infrastructure data that often contain erroneous information (e.g., inconsistencies, out of dates). In this paper, the authors propose a new methodology that makes use of GPS traces to automatically detect or correct bus stop locations, reconstruct bus route shapes, and estimate time schedules. The methodology performs different steps: 1) data cleaning and detection of trips; 2) bus stop extraction through data mining techniques; 3) route shape reconstruction; and 4) time schedule estimation. A case study using real GPS data from the City of Dublin is performed.

Intercultural Analyses of Time-to-Collision in Vehicle–Pedestrian Conflict on Urban Midblock Crosswalk

X. Jiang, W. Wang, and K. Bengler

In traffic conflict techniques, time-to-collision (TTC) is suggested to be a surrogate measure of conflict severity. In order to address the differences in conflict situation between driving cultures, field traffic data have been collected by video recording and image processing at urban midblock crosswalks both in Beijing, China, and in Munich, Germany. Focusing on the vehicle–pedestrian (VEH–PED) conflict, by identification of filed observation, conflict situation, and TTC calculation, trajectory-based data matrix is created for understanding the entire conflict process. TTC distribution and relationships between TTC and PED-/VEH-based parameters are investigated with intercultural comparison. Special cases in China, where traffic noncompliance is common, are also studied as a complement to normal VEH–PED conflicts. The research will hopefully lay the groundwork in the target of providing advanced driver assistance system adaptation databases in the future.

Performance Evaluation of GNSS for Train Localization

D. Lu and E. Schnieder

Global Navigation Satellite Systems (GNSSs) are applicable to deliver train locations in real time. This train localization function should comply with railway functional safety standards; thus, the GNSS performance needs to be evaluated in consistent with railway EN 50126 standard [reliability, availability, maintainability, and safety (RAMS)]. This paper demonstrates the performance of GNSS receiver for train localization. First, the GNSS performance and railway RAMS properties are compared by definitions. Second, the GNSS receiver measurements are categorized into three states (up, degraded, and faulty states), and the relations between the states are illustrated into a stochastic Petri net model. At last, the performance properties are evaluated using real data collected in the High Tatra Mountains railway track in Slovakia. The property evaluation is based on the definitions represented by the modeled states.

Transportation and Mobility Transformation for Smart Cities

In February, Prof. Nanning Zheng and I went to Changshu, a midsize city near Shanghai, China, for the final discussion on various issues regarding the establishment of China's first Intelligent Vehicle Proving Center (IVPC). The goal is to make IVPC a world center for the demonstration and advancement of technology and services for transportation and mobility transformation in future smart living in smart cities.

Before the meeting, I spent some time reading materials related to transportation and mobility transformation research and implementation. In addition to the extensive recent coverage by media on the University of Michigan's Mobility Transformation Center, I found an interesting final report on the Transportation Transformation Project by MZ Strategies, LLC. Yes, technology innovation is the key to transformation so far. As witnessed by Google's self-driving cars, Uber, DiDi Dache, etc., technology-driving mobility and transportation innovation is growing exponentially. Right after last year's IEEE Intelligent Transportation Systems Conference in Qingdao, China, a group of my own students started a venture that uses social networking media and Uber-like methods for social logistics. However, overall and around the world, governmental and public agencies are slow to respond and adapt. To speed up the mobility and transportation transformation for smart living in smart communities or smart cities, we need more than just technology, we need to consider and include dynamics of social organizations and cultures, and we need a comprehensive systems engineering approach that accommodates and embraces diversified disciplines, fields, thinking, behaviors, and cultures.

For me, current ITS projects are still too much field or discipline centric, traffic, vehicular, infrastructural, computers, control, communication, web, services, and so on, issues and problems are addressed mostly independently, sometimes integrated only at the small-scale or local levels. To many, and in many senses, total integration in physical space is something of an impossible mission: a hopeful journal to nowhere due to various forbidding economic, legal, ethical, or scientific barricades on the road. This is true to a large degree, but now, Cyberspace offers us a new mechanism of overcoming these barricades and an augmented reality infrastructure of integrating technology, systems, and societies for transformation in transportation and mobility. Total integration in cyberspace still faces many hurdles, but much less daunting, and should be feasible for implementation with models for artificial or software-defined transportation systems, methods for computational experiments, and tools for parallel execution of actual

and virtual operations and organizations. I believe that this will be the future for ITS and for future transportation and mobility research, development, and applications.

The emergence of and enthusiasm for smart cities and smart living provide a unique opportunity for realization of transportation and mobility transformation. The ITS professional community as a whole needs to think and plan for total integration in a full and ultralarge scale: from social logistics, economic development, and community service to personal mobility and seamless connection between smart homes to smart societies via intelligent transportation systems. New directions that we have promoted in the IEEE T-ITS over the last few years, from total traffic control, parallel driving, social transportation, computational transportation, transportation 5.0, and transportation knowledge automation to many others, will be critical for the development of next-generation transportation and mobility systems for smart living in smart cities. Virtual reality transportation and augmented reality mobility can used to greatly accelerate the process, reduce the cost, and improve the quality of conceiving, designing, testing, evaluating, implementing, and operating smart systems for future transportation and mobility, whereas cyber-physical-social systems would be the ideal venue to link and integrate these systems with our future life.

A quarter century ago, many regions/countries and professional organizations had proposed reference architectures or models for ITS; now, we need to develop national or international reference architectures for transportation and mobility transformation for smart living in smart communities and cities.

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