Scanning the Issue and Beyond: Crowdsourcing for Field Transportation Studies and Services

Happy New Year to Everyone! This is the year of the sheep according to the Chinese lunar calendar, which implies a year of happiness in every day, almost! I wish our journal to be a better one in the year of the sheep with your help. So please check @IEEE-TITS (http://www.weibo.com/u/3967923931) in Weibo (an extended Chinese version of Twitter), IEEE ITS Facebook (https://www.facebook.com/IEEEITS), and our Twitter account @IEEEITS (https://twitter.com/IEEEITS) for upcoming news in the IEEE Intelligent Transportation Systems Society, the IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, and the IEEE INTELLIGENT TRANSPORTATION SYSTEMS MAGAZINE. The three sites are still under development, and your participation and any suggestions for their operation are extremely welcome.

SCANNING THE ISSUE

Drive Analysis Using Vehicle Dynamics and Vision-Based Lane Semantics

Ravi Kumar Satzoda and Mohan Manubhai Trivedi

Naturalistic driving studies (NDSs) capture large volumes of drive data from multiple sensor modalities. One of the key steps in NDS is data reduction. One of the objectives of the ongoing NDS, called SHRP2, is to develop tools that automatically reduce the sensor data to higher level semantics. The first step toward automation is the process of extracting mid-level semantic information from raw sensor data. Techniques are proposed to analyze sensor data and extract a set of 23 semantics about lane positions, vehicle localization within lanes, vehicle speed, traffic density, and vehicle trajectory curvature. The proposed techniques are demonstrated using real-world test drives comprising over 150 000 frames of visual data.

Traffic Signal Phase and Timing Estimation From Low-Frequency Transit Bus Data

S. Alireza Fayazi, Ardalan Vahidi, Grant Mahler, and Andreas Winckler

The feasibility of estimating the traffic signal phase and timing from statistical patterns in low-frequency vehicular probe data is demonstrated. A public feed of bus location and velocity data in the city of San Francisco, CA, USA, is used as an example data source. It is possible to estimate, fairly accurately, cycle times and the duration of red lights for fixed-time traffic lights traversed by buses using a few days' worth of aggregated bus data. The start of green lights in real time by monitoring the movement of buses across intersections is further estimated. This results given that each bus sends an update only sporadically (approximately every 200 m) and that bus passages are infrequent (every 5–10 min).

Toward System-Optimal Routing in Traffic Networks: A Reverse Stackelberg Game Approach

Noortje Groot, Bart De Schutter, and Hans Hellendoorn

In the literature, several road pricing methods based on hierarchical Stackelberg games have been proposed in order to reduce congestion in traffic networks. Three novel schemes to apply the extended reverse Stackelberg game are proposed, through which traffic authorities can induce drivers to follow routes that are computed to reach a system-optimal distribution of traffic on the available routes of a freeway. Compared with the original game, the work in this paper relies on the game solution methods and shows that a system-optimal behavior can be reached while taking heterogeneous driver classes into account.

Power Control Game in Multisource Multirelay Cooperative Communication Systems With a Quality-of-Service Constraint

Hailin Xiao and Shan Ouyang

A game-theoretic power control algorithm is proposed to minimize the total power consumption in a cooperative communication network that transmits information from multiple sources to a destination via multiple relays to save energy and improve communication performance. Under the amplify-and-forward relaying scheme, the proposed approach not only selects the best source–relay pair but also obtains the optimal transmission power values while satisfying communication quality of service. Using a game-theoretic model, the impacts of the number of relays on the total power consumption are also analyzed. Numerical results are also provided to corroborate our theoretical results and demonstrate the performance of the proposed approach.

Predicting Perceived Visual and Cognitive Distractions of Drivers With Multimodal Features

Nanxiang Li and Carlos Busso

This paper investigates drivers' behaviors associated with visual and cognitive distractions, both separately and jointly. The scores from the perceptual evaluation are used to define regression models with elastic net regularization and binary classifiers to separately estimate the cognitive and visual distraction levels. The analysis reveals multimodal features that are discriminative of cognitive and visual distractions. Furthermore, this paper proposes a novel joint visual–cognitive distraction space to characterize driver behaviors. A data-driven clustering approach identifies four distraction modes that provide insights to better understand the deviation in driving behaviors that is induced by secondary tasks. Binary and multiclass recognition

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problems demonstrate the effectiveness of the proposed multimodal features to infer these distraction modes defined in the visual–cognitive space.

Information Dissemination Delay in Vehicle-to-Vehicle Communication Networks in a Traffic Stream

Lili Du and Hoang Dao

Analytical formulations to approximate information propagation time delay via a vehicle-to-vehicle communication network formed on a one-way or two-way road segment with multiple lanes are proposed. The proposed study carefully involves several critical communication and traffic flow features in reality and elaborately analyzes the interactions between information and traffic flow under sparse and congested traffic flow conditions. The numerical experiments based on next-generation simulation field data illustrate that the proposed analytical formulations are able to provide very good estimation, with a relative error less than 5%, for the information propagation time delay on a one-way or two-way road segment under various traffic conditions. The proposed work can be further extended to characterize information propagation time delay and coverage over local transportation networks.

Segmentation and Clustering of Car-Following Behavior: Recognition of Driving Patterns

Bryan Higgs and Montasir Abbas

The characteristics of a wide range of driving behaviors linking driving states to the drivers' actions are investigated. The proposed methodology is structured such that a known state can be linked to multiple actions, thus accounting for the effects of the unknown driving state factors. A two-step algorithm was developed and used for segmentation and clustering of driving behaviors. The algorithm segments and clusters car-following behavior based on eight state-action variables: longitudinal acceleration, lateral acceleration, yaw rate, vehicle speed, lane offset, yaw angle, range, and range rate. The results of this methodology are state-action clusters that define the driving pattern of drivers. Characteristics and frequency of recognized driving patterns are provided in this paper, along with the corresponding modeling parameters of each pattern.

Inferring Traffic Signal Phases From Turning Movement Counters Using Hidden Markov Models

Mostafa Reisi Gahrooei and Daniel B. Work

This paper poses the problem of estimating traffic signal phases from a sequence of maneuvers. The problem is modeled as an inference problem on a discrete-time hidden Markov model where maneuvers are observations and signal phases are hidden states. The model is calibrated from maneuver observations using either the classical Baum–Welch algorithm or a Bayesian learning algorithm. The trained model is then used to infer the traffic signal phases on the dataset via the Viterbi algorithm. It is shown that, when the model is trained by the Bayesian learning method with appropriate prior parameters from the Dirichlet distribution, the inferred phases are more accurate in both numerical and field experiments.

Distributed Consensus Strategy for Platooning of Vehicles in the Presence of Time-Varying Heterogeneous Communication Delays

Mario di Bernardo, Alessandro Salvi, and Stefania Santini, Member, IEEE

The aim of this paper is to analyze and solve platooning by treating it as the problem of achieving consensus in a network of dynamical systems affected by time-varying heterogeneous delays due to wireless communication among vehicles. Specifically, the platoon is represented as a dynamical network where: 1) each vehicle, with its own dynamics, is a node; 2) the presence of communication links between neighboring vehicles is represented by the edges; and 3) the structure of the intervehicle communication is encoded in the network topology. A distributed control protocol is presented, which is acting on every vehicle in the platoon and is composed of two terms: a local action depending on the vehicle itself and an action depending on the neighboring vehicles through the communication network. Stability of the platoon is proven by using the Lyapunov–Razumikhin theorem. Numerical results are included to confirm and illustrate the theoretical derivation.

Bluetooth Vehicle Trajectory by Fusing Bluetooth and Loops: Motorway Travel Time Statistics

Ashish Bhaskar, Ming Qu, and Edward Chung

Models have been proposed for temporal and spatial generalization of speed for average travel time estimation. Matching the data from two Bluetooth media scanner (BMS) stations provides individual vehicle travel time. Generally, on the motorways, loops are closely spaced, whereas BMSs are placed few kilometers apart. In this paper, BMSs and loops' data are fused to define the trajectories of the Bluetooth vehicles. The trajectories are utilized to estimate the travel time statistics between any two points along the motorway. The proposed model is tested using simulation and is validated with real data from Pacific motorway, Brisbane, Australia. Comparing the model with the linear interpolation-based trajectory provides significant improvements.

Understanding Taxi Service Strategies From Taxi GPS Traces

Daqing Zhang, Lin Sun, Bin Li, Chao Chen, Gang Pan, Shijian Li, and Zhaohui Wu

This paper intends to uncover the efficient and inefficient taxi service strategies based on a large-scale Global Positioning System (GPS) historical database of approximately 7600 taxis over one year in a city in China. First, the GPS traces of individual taxi drivers are separated and relinked with the revenue generated. The taxi service strategies from three perspectives (passenger-searching strategies, passenger-delivery strategies, and service-region preference) are investigated. Finally, the taxi service strategies are represented with a feature matrix, and the correlation between service strategies and revenue is evaluated. The revenue of taxi drivers is predicted based on their strategies, and the authors achieve a prediction residual as less as 2.35RMB1/h, which demonstrates that the extracted taxi service strategies within this approach well characterize the driving behavior and performance of taxi drivers.

Online Prediction of Driver Distraction Based on Brain Activity Patterns

Shouyi Wang, Yiqi Zhang, Changxu Wu, Felix Darvas, and Wanpracha Art Chaovalitwongse

This paper presents a new computational framework for the early detection of driver distractions (map viewing) using brain

activity measured by electroencephalographic (EEG) signals and a new framework to prospectively predict the start and end of a distraction period, defined by map viewing. The proposed prediction algorithm was tested on a dataset of continuous EEG signals recorded from 24 subjects. The outcome of this study has a good potential to improve the design of future intelligent navigation systems. Prediction of the start of map viewing can be used to provide route information based on a driver's needs and, consequently, avoid map-viewing activities. Prediction of the end of map viewing can be used to provide warnings for potential long map-viewing duration periods. Further development of the proposed framework and its applications in driver distraction predictions are also discussed.

A Novel Approach for Vehicle Inertial Parameter Identification Using a Dual Kalman Filter

Sanghyun Hong, Chankyu Lee, Francesco Borrelli, and J. Karl Hedrick

This paper proposes a novel algorithm to identify three inertial parameters: sprung mass, yaw moment of inertia, and longitudinal position of the center of gravity. First, a four-wheel nonlinear vehicle model with roll dynamics is presented. The model is used by a dual unscented Kalman filter to simultaneously identify the inertial parameters and the vehicle state. A local observability analysis on the nonlinear vehicle model is used to activate and deactivate different modes of the proposed algorithm. Extensive CarSim simulations and experimental tests show the performance and robustness of the proposed approach on a flat road with a constant tire–road friction coefficient.

HAZOP Study on the CTCS-3 Onboard System

Kaicheng Li, Xiaofei Yao, Dewang Chen, Lei Yuan, and Datian Zhou

This paper presents a process of applying a hazard and operability (HAZOP) study to identify the hazards of Chinese Train Control System Level 3 (CTCS-3) onboard system for the first time, which is composed of two major parts: system models and hazard identification on the examination session. To demonstrate the effectiveness of the HAZOP study, hazard identification on the basis of the functions of the CTCS-3 onboard system and a scenario of temporary speed restriction are considered and employed. The results indicate that existing hazards can be dug out at express speed, which allows the relevant actions to be proposed and implemented to prevent the hazards from spreading to a wide range in the whole CTCS-3 onboard system.

Equity-Oriented Aircraft Collision-Avoidance Model

David Rey, Christophe Rapine, Vinayak V. Dixit, and Steven Travis Waller

This paper focuses particularly on the impact of conflict resolution strategies, which arise in congested networks. Recently, subliminal speed control has been shown to be a promising approach to reduce the impact of air conflicts onto air traffic controllers' workload and potentially improve airspace capacity. This paper addresses this gap by introducing an innovative formulation for the aircraft collision-avoidance problem that integrates the economic profile of flights and promotes equitable solutions. A goal programming-based model designed to minimize the deviation from fair solutions during the resolution of potential conflicts is proposed. The performance of the model is evaluated using a fuel-equivalent conflict resolution scheme, hence offering a sustainable framework to efficiently and equitably resolve air conflicts.

Do We Really Need to Calibrate All the Parameters? Variance-Based Sensitivity Analysis to Simplify Microscopic Traffic Flow Models

Vincenzo Punzo, Marcello Montanino, and Biagio Ciuffo

The main objective of this paper is to provide a robust methodology to simplify car-following models that is to reduce the number of parameters (to calibrate) without sensibly affecting the capability of reproducing reality. Among the novel contributions are a robust design of the Monte Carlo framework that also includes the main nonparametric input of car-following models and a set of criteria for data assimilation in car-following models. The methodology was applied to the intelligent driver model (IDM) and to all the trajectories in the "reconstructed" NGSIM I80-1 dataset. The analysis revealed that the leader's trajectory is considerably more important than the parameters in affecting the variability of model performances. Sensitivity analysis also showed the importance ranking the IDM parameters. Thus, a simplified model version with three (out of six) parameters is proposed. The full and simplified models show comparable performances in the face of sensibly faster convergence of the simplified version.

Automated Road Information Extraction From Mobile Laser Scanning Data

Haiyan Guan, Jonathan Li, Yongtao Yu, Michael Chapman, and Cheng Wang

This paper presents a survey of literature about road-feature extraction, giving a detailed description of a mobile laser scanning (MLS) system (RIEGL VMX-450) for transportation-related applications. This paper describes the development of automated algorithms for extracting road features (road surfaces, road markings, and pavement cracks) from MLS point cloud data. The proposed road-surface extraction algorithm detects road curbs from a set of profiles that are sliced along vehicle trajectory data. Based on segmented road-surface points, georeferenced feature images are created and two algorithms are developed, respectively. A comprehensive comparison illustrates satisfactory performance of the proposed algorithms and concludes that MLS is a reliable and cost-effective alternative for rapid road inspection.

Vehicle Localization Using In-Vehicle Pitch Data and Dynamical Models

Emil I. Laftchiev, Constantino M. Lagoa, and Sean N. Brennan

This paper describes a dynamic model-based method for the localization of road vehicles using terrain data from the vehicle's onboard sensors. Road data are encoded using linear dynamical models, and then, during travel, the location is identified through a continuous comparison of a bank of linear models. This approach has several advantages. First, it creates computationally efficient linear model map representations of the road data. Second, the use of linear models eliminates the need for metrics during the localization process. Third, the localization algorithm is a computationally efficient approach that can have a bounded localization distance in the

absence of noise given certain uniqueness assumptions for the data. Fourth, encoding road data using linear models has the potential to compress the data while retaining the sensory information. Lastly, performing only linear operations on observed noisy data simplifies the creation of noise mitigation algorithms.

Discovering Regions Where Users Drive Inefficiently on Regular Journeys

Victor Corcoba Magaña and Mario Muñoz-Organero

This paper proposes a mechanism to optimize fuel consumption on regular routes. The idea is to find out in which areas a driver usually realizes inefficient actions from the point of view of energy consumption. To detect inefficient areas, the system uses vehicle telemetry: acceleration, deceleration, engine speed, engine load, and vehicle speed. A fuzzy logic system determines whether the driver drove efficiently or not in a region. Then, when the driver drives in the same route, the system predicts if the driver will return to a similar inefficient driving pattern in the nearby region. The results show that the system reduces fuel consumption by 7.33% on average, and even in certain cases, fuel saving is more than 10%.

Inferring the Travel Purposes of Passenger Groups for Better Understanding of Passengers

Youfang Lin, Huaiyu Wan, Rui Jiang, Zhihao Wu, and Xuguang Jia

To overcome the constraint of the independent and identical distribution assumption of traditional classifiers, a novel iterative classification approach based on the idea of collective inference is proposed. First, cotravel networks are constructed by extracting social relations between passengers from their historical travel records, which are available in carriers' passenger information systems. Then, a series of sophisticated features are generated for each passenger group in the context of cotravel networks to capture the link structure information between passengers, and the overlapping relations between passenger groups are used to capture the probabilistic dependence between their labels. Finally, the labels of all the groups are inferred in an iterative way. Experimental results on a real dataset of passenger travel records in the field of civil aviation demonstrate that our proposed iterative classification approach can efficiently infer the travel purposes of passenger groups.

Artificial Co-Drivers as a Universal Enabling Technology for Future Intelligent Vehicles and Transportation Systems

Mauro Da Lio, Francesco Biral, Enrico Bertolazzi, Marco Galvani, Paolo Bosetti, David Windridge, Andrea Saroldi, and Fabio Tango

This position paper introduces the concept of artificial "co-drivers" as an enabling technology for future intelligent transportation systems. In the first section, the design principles of co-drivers are introduced and framed within general human–robot interactions. In the second section, the co-driver developed for the European Union project interactive is presented as an example instantiation of this notion, demonstrating how it conforms to the guidelines. Substantive experimental results are presented, and the limitations and performance of the current implementation are clarified. The last section analyzes the impact of the co-driver technology. In particular, a range of application fields is identified, showing how it constitutes a universal enabling technology for both smart vehicles and cooperative systems, and naturally sets out a program of future research.

Travel Time Reliability Versus Safety: A Stochastic Hazard-Based Modeling Approach

Samer H. Hamdar, Alireza Talebpour, and Jing Dong

This paper presents a modeling approach to link stochastic acceleration and lane-changing behavior to travel time reliability on congested freeways. Individual driving behavior is represented by a prospect-theory-based model that takes into account uncertainty and risk evaluation in terms of gains and losses while following a lead vehicle. Given a set of stimuli, the stochastic acceleration model generates acceleration probability distribution functions rather than deterministic acceleration values. In addition, the lane-changing decision is represented by a stochastic hazard-based duration model that accounts for the surrounding traffic conditions. Numerical results from Monte Carlo simulations demonstrate that the proposed microscopic stochastic modeling approach produces realistic macroscopic traffic flow patterns and can be used to generate travel time distributions.

A Brain–Computer Interface-Based Vehicle Destination Selection System Using P300 and SSVEP Signals

Xin-an Fan, Luzheng Bi, Teng Teng, Hongsheng Ding, and Yili Liu

This paper proposes a novel driver–vehicle interface for individuals with severe neuromuscular disabilities to use intelligent vehicles by using P300 and steady-state visual evoked potential brain–computer interfaces (BCIs) to select a destination and test its performance in the laboratory and real driving conditions. Experimental results from 16 participants collected in the laboratory and real driving scenarios show that the average accuracy of the system in the real driving conditions is about 99% with an average selection time of about 26 s. The proposed system improves the accuracy of the destination selection compared with a single P300 BCI-based selection system, particularly for those participants with relatively low level of accuracy in using the P300 BCI.

A Self-Adaptive Parameter Selection Trajectory Prediction Approach via Hidden Markov Models

Shaojie Qiao, Dayong Shen, Xiaoteng Wang, Nan Han, and William Zhu

The existing algorithms for trajectory prediction of objects in moving objects' databases focus on discovering frequent moving patterns or simulating the mobility of objects via mathematical models. A hidden Markov model-based trajectory prediction algorithm called HMTP is proposed to solve the problem that those mathematical models fall short in describing the position and behavior of moving objects in a network-constraint environment. A self-adaptive parameter selection algorithm called HMTP* is also proposed, which captures the parameters necessary for real-world scenarios in terms of objects with dynamically changing speed. Experimental results demonstrate that the effect of critical parameters on the prediction accuracy in the proposed paradigm, in regard to HMTP*, can greatly improve the accuracy when compared with HMTP when subjected to randomly changing speeds.

Efficient Road Detection and Tracking for Unmanned Aerial Vehicle

Hailing Zhou, Hui Kong, Lei Wei, Doug Creighton, and Saeid Nahavandi

Unmanned aerial vehicle (UAV) has wide applications in a variety of fields. Detection and tracking of a specific road in UAV videos plays an important role on automatic UAV navigation, traffic monitoring, and ground-vehicle tracking and also very helpful on constructing road networks for modeling and simulation. In this paper, an efficient road detection and tracking framework in UAV videos is proposed. High efficiency is attributed to two aspects: Road detection is performed only when it is necessary, and most work in locating road is done rapidly via very fast homography-based tracking. Experimental results indicate the effectiveness of our proposed framework, with the precision of 98.4% and processing 34 frames/s for 1046*595 videos on average.

Nighttime Visibility Analysis and Estimation Method in Presence of Dense Fog

Romain Gallen, Aurélien Cord, Nicolas Hautière, Éric Dumont, and Didier Aubert

A standard night visibility index is defined. A methodology to detect the presence of night fog and characterize its density in images grabbed by an in-vehicle camera is proposed. A first approach evaluates the presence of fog around the vehicle due to the detection of the backscattered veil created by the headlamps. A second approach evaluates the presence of fog due to the detection of halos around light sources ahead of the vehicle. Both approaches are illustrated with actual images of fog. The main applications for such a system are, for instance, automation or adaptation of vehicle lights, contextual speed computation, and reliability improvement for camera-based systems.

Emergency Railway Transportation Planning Using a Hyperheuristic Approach

Yu-Jun Zheng, Min-Xia Zhang, Hai-Feng Ling, and Sheng-Yong Chen

Railways have played a significant role in disaster relief transportation in China. This paper presents an emergency railway transportation problem that is to use limited transport capability to meet the urgent relief transportation requirements. A set of individual heuristic operators is integrated into a hyperheuristic framework, which performs a stochastic search on the low-level heuristics by using feedback of their performance in the process of problem solving. Computational experiments show that the hyperheuristic exhibits significant advantages over the individual heuristics. The problem model and the hyperheuristic solution approach have been also successfully applied to the emergency railway transportation in the 2013 Dingxi earthquake, China.

Parallel Monitoring for the Next Generation of Train Control Systems

Junfeng Wang, Jungang Wang, Clive Roberts, and Lei Chen

This paper processes a design concept and architecture for the next generation of train control systems (NGTCSs). Some key technologies, such as parallel monitoring, system-level "fail-safe," data sharing and fusion, common cause error avoidance, and the illegal or incorrect operation of alarms by railway workers, are considered. This paper also details the principle and method of parallel monitoring for some key operations such as train tracking interval, interlocking, and train speed limit protection. NGTCS is a highly intelligent monitoring system that represents system engineering theory, system safety, deeper integration, and data fusion between subsystems and parallel monitoring on critical subjects.

Validation Methods for Digital Road Maps in Predictive Control

Peter Kock, Ralf Weller, Andrzej W. Ordys, and Gordana Collier

Digital road maps obtained from different providers have different qualities, and the prediction model that uses slope, curve radius, and other information can only be tested with the map. A method is presented that enables a quality benchmark from altitude and slope information of different sources together with a vehicle longitudinal dynamic model with only one driving experiment and before the predictive control application is ready or used. This paper presents methods to evaluate altitude and slope information from digital road maps, to find local map errors using a vehicle model, to benchmark different maps with a vehicle model, and to find the most suitable map for a predictive control application.

A Genetic-Algorithm-Based Approach to Solve Carpool Service Problems in Cloud Computing

Shih-Chia Huang, Ming-Kai Jiau, and Chih-Hsiang Lin

This paper describes an advance carpool system that is called the intelligent carpool system. It provides carpoolers use of the carpool services via the smart handheld device anywhere and at any time. For the help of coordinating the ride matches via the carpool service agency, a genetic-based carpool route and matching algorithm for this multiobjective optimization problem called the carpool service problem is proposed. The genetic-based carpool route and matching algorithm is proven to result in superior results involving the optimization objectives of carpool service problem than other algorithms. Furthermore, it operates with a significantly small amount of computational complexity to response the match results in the reasonable time, and the processing time is further reduced by the termination criteria of early stop.

Switching-Based Stochastic Model Predictive Control Approach for Modeling

Ting Qu, Hong Chen, Dongpu Cao, Hongyan Guo, and Bingzhao Gao

In this paper, a stochastic model predictive control (SMPC) approach is proposed to model the driver steering skill that effectively incorporates the random variations in road friction and roughness; a multipoint preview approach and a piecewise affine model structure are developed to mimic the driver's perception of the desired path and the nonlinear internal vehicle dynamics. The SMPC method is then used to generate a steering command by minimizing a cost function, including the lateral path error and ease of driver control. The proposed switching-based SMPC driver steering control framework offers a new approach for driver behavior modeling.

A Novel Centralized TDMA-Based Scheduling Protocol for Vehicular Networks

Rongqing Zhang, Xiang Cheng, Liuqing Yang, Xia Shen, and Bingli Jiao

This paper proposes a novel centralized time-division multiple-access (TDMA)-based scheduling protocol for practical vehicular networks based on a new weight-factor-based scheduler. This proposed scheduling weight factor mainly consists of three parts: the channel quality factor, the speed factor, and the access category factor. In addition, a resource-reusing mode among multiple vehicle-to-vehicle (V2V) links is permitted if the distances between every two central vehicles of these V2V links are larger than a predefined interference interval. Compared with the existing medium-access-control protocols in vehicular networks, the proposed centralized TDMA-based scheduling protocol can significantly improve the network throughput and can be easily incorporated into practical vehicular networks.

Optimization of Evacuation Traffic Management With Intersection Control Constraints

Hui Fu, Adam J. Pel, and Serge P. Hoogendoorn

Route guidance instructions are crucial in the implementation of an evacuation plan. Considering that travelers' compliance with these instructions is controllable by adopting traffic management at intersections, a simulation-based framework for optimizing traffic management is presented with the objective function of maximizing evacuation efficiency with uncertain budget constraint. The specific analyses on network performances provide some practical insights. In reality, mandatory traffic management is unnecessary as the optimal instructions are unavailable. Well-staged departure and appropriate enforcement of traffic management at intersections are recommended, which contribute to extensive distribution of traffic flow and then highly efficient evacuation.

A Linear Time and Space Algorithm for Optimal Traffic Signal Duration at an Intersection

Sameh Samra, Ahmed El-Mahdy, and Yasutaka Wada

Finding an optimal solution of traffic signal control duration periods is a computationally intensive task. It is typically $O(T^3)$ in time and $O(T^2)$ in space, where T is the length of the control interval in discrete time steps. This paper proposes a linear time and space algorithm for traffic signal control problem. The algorithm provides for an efficient dynamic programming formulation of the state space that prunes nonoptimal states early on. This paper proves the correctness of the algorithm and provides an initial experimental validation. This paper also conducts and simulates study compared with other typical control methods. Results show significant improvement in the average waiting time metric with respect to all other methods.

Automatic Parallel Parking in Tiny Spots: Path Planning and Control

Hélène Vorobieva, Sébastien Glaser, Nicoleta Minoiu-Enache, and Saïd Mammar

This paper presents the automatic parallel parking for a passenger vehicle with a highlight on the path-planning method and on the experimental results. The path-planning method consists of two parts. First, the kinematic model of the vehicle, with corresponding geometry, is used to create a path to park the vehicle in one or more maneuvers if the spot is very narrow. This path is constituted of circle arcs. Second, this path is transformed in a continuous-curvature path using clothoid curves. In order to execute the generated path, control inputs for steering angle and longitudinal velocity depending on the traveled distance are generated. Therefore, the traveled distance and the vehicle pose during a parking maneuver are estimated. Finally, the parking performance is tested on a prototype vehicle.

Special Issue Papers

A Distributed Framework for Coordinated Heavy-Duty Vehicle Platooning

Jeffrey Larson, Kuo-Yun Liang, and Karl H. Johansson

This paper attempts to maximize the amount of fuel saved by coordinating platoon formation using a distributed network of controllers. These virtual controllers, placed at major intersections in a road network, help coordinate the velocity of approaching vehicles so that they arrive at the junction simultaneously and can therefore platoon. This control is initiated only if the cost of forming the platoon is smaller than the savings incurred from platooning. In a large-scale simulation of the German Autobahn network, the savings surpass 5% when only a few thousand vehicles participate in the system.

Deduction of Passengers' Route Choices From Smart Card Data

Evelien van der Hurk, Leo Kroon, G´bor Maróti, and Peter Vervest

This paper proposes a method to deduce the chosen route of passengers based on smart card data and validates this method on a real-life data set. The method deduces the correct route for about 95% of the journeys per day in our validation sample and also in the case of disruptions. Moreover, it is shown how this method can be used to analyze and evaluate passenger service by a case study based on a real-life data set of railways in The Netherlands, the largest passenger railway operator in The Netherlands.

Efficient Road Scene Understanding for Intelligent Vehicles Using Compositional Hierarchical Models

Daniel Töpfer, Jens Spehr, Jan Effertz, and Christoph Stiller

This paper presents a novel compositional hierarchical framework for road scene understanding that allows for reliable estimation of scene topologies. Lanes and roads are represented in a hierarchical compositional model in which nodes represent parts of roads and edges represent probabilistic constraints between pairs of parts. A key benefit is the representation of lanes and roads as a set of common parts, which makes it applicable to scenes with rich topological diversity while bringing along the much desired computational efficiency. Based on inference algorithm using nonparametric belief propagation, a depth-first message passing for lane detection is proposed. Empirical results show that depth-first message passing requires significantly lower computation for performance comparable to classical belief propagation.

A Macroscopic Traffic Data-Assimilation Framework Based on the Fourier–Galerkin Method and Minimax Estimation

Tigran T. Tchrakian and Sergiy Zhuk

This paper proposes a new framework for macroscopic traffic state estimation. It is a robust "discretize" then "optimize" strategy, based on the Fourier–Galerkin projection method and

minimax state estimation. A Fourier–Galerkin reduced model to a macroscopic model of traffic flow is assigned, described by a hyperbolic partial differential equation. Taking into account *a priori* estimates for the projection error, the minimax method is applied to construct the state estimate for the reduced model that gives the estimate of the Fourier–Galerkin coefficients associated with a solution of the original macroscopic model.

Online Data-Driven Adaptive Prediction of Train Event Times

Pavle Kecman and Rob M. P. Goverde

This paper presents a microscopic model for accurate prediction of train event times based on a timed event graph with dynamic arc weights. The process times in the model are dynamically obtained using processed historical track occupation data, thus reflecting all phenomena of railway traffic captured by the train describer systems and preprocessing tools. The graph structure of the model allows applying fast algorithms to compute prediction of event times even for large networks. The accuracy of predictions is increased by incorporating the effects of predicted route conflicts on train running times due to braking and reacceleration.

Powered Two-Wheeler Riding Pattern Recognition Using a Machine-Learning Framework

Ferhat Attal, Abderrahmane Boubezoul, Latifa Oukhellou, and Stéphane Espié

A machine-learning framework is used in this paper for riding pattern recognition. The problem is formulated as a classification task to identify the class of riding patterns using data collected from 3-D accelerometer/gyroscope sensors mounted on motorcycles. These measurements constitute an experimental database used to analyze powered two-wheeler rider behavior. Several well-known machine-learning techniques are investigated for both discrete and continuous cases. An approach for sensor selection is proposed to identify the significant measurements for improved riding pattern recognition. The experimental study shows the effectiveness of the proposed methodology and the effectiveness of the hidden Markov model approach in riding pattern recognition.

Graceful Degradation of Cooperative Adaptive Cruise Control

Jeroen Ploeg, Elham Semsar-Kazerooni, Guido Lijster, Nathan van de Wouw, and Henk Nijmeijer

To partially maintain the favorable string stability properties of cooperative adaptive cruise control (CACC), a control strategy for graceful degradation of one-vehicle look-ahead CACC is proposed based on estimating the preceding vehicle's acceleration using onboard sensors. In addition, a switching criterion is proposed in the case that the wireless link exhibits an increased latency but does not (yet) suffer from persistent packet loss. Simulations and experiments show that the proposed strategy results in a noticeable improvement of string stability characteristics.

Stereovision-Based Multiple-Object Tracking in Traffic Scenarios Using Free-Form Obstacle Delimiters and Particle Filters

Andrei Vatavu, Radu Danescu, and Sergiu Nedevschis

This paper presents a stereovision-based approach for tracking multiple objects in crowded environments. The proposed technique relies on measurement data provided by an intermediate occupancy grid, derived from processing a stereovision-based elevation map, and on free-form object delimiters extracted from this grid. A particle filter-based solution for tracking visual appearance-based free-form obstacle representations is used in this paper. A Rao–Blackwellized particle filter is used to solve the high-dimensionality state-space problem. The proposed solution combines the efficiency of the rigid model with the benefits of a flexible object model.

Microsimulation Analysis of Practical Aspects of Traffic Control With Variable Speed Limits

Eduardo Rauh Müller, Rodrigo Castelan Carlson, Werner Kraus, Jr., and Markos Papageorgiou

In this paper, local feedback mainstream traffic flow control is applied in microscopic simulation for an on-ramp merge bottleneck. The more realistic variable speed limit application at specific points instead of along an entire freeway section produces a slower traffic response to speed limit changes. In addition, the nonlinear capacity flow/speed limit relation observed in the microscopic model is more pronounced than what was observed at the macroscopic level. Significant improvements in traffic conditions are obtained after appropriate modifications in the control law.

Call for Crowdsourcing for Field Transportation Studies and Services

Since 2012, I have tried many times to drive by myself in order to have some real field taste of Beijing's traffic problems. Those experiences are quite useful for me, but sometimes they are also quite dangerous. One time I was horned by over a dozen angry drivers behind my car since I was still waiting anxiously for the traffic light in front of me to turn green while the tiny green light indicating to go had actually been on for almost half a minute in my far right with a distance about 30 meters away! Last summer, I almost had three accidents while try to have a feeling of crossing the city without GPS navigation from the center to Beijing's International Conference Center in the northeast corner of Ring 5. I was confused by traffic signs along the way and was bouncing back and forth between Ring 3 and Ring 4, then Ring 5. Finally, I had to turn my GPS on just to make sure about my driving direction and call friends for road information. It took almost 5 hours to complete a trip that normally should take only 1 hour to finish, but I should feel fortunate since I was able to reach my destination before the rush hours. After this experience, I decided to pay a taxi driver and one of my students to collect the information I need for field transportation studies. So far, I have a plenty of words or complaints or suggestions to say about traffic signs, traffic equipment, and traffic fences that separate lances physically in both cities of Beijing and Qingdao (or Tsingdao) but, most of all, about people's driving and traveling behaviors and metropolitan traffic management styles.

However, my enthusiasm for more field transportation investigation was stopped suddenly by a conversation with my niece, who is completing her MS degree in Engineering Management. While I was telling her the traffic problems I had experienced, she said she never noticed them since she always use her smart

phone for instruction, not the traffic sign on roadside. What a generation gap! I talked to my students and young colleague about this, basically they told me that I am almost "Out," and I should use the crowdsourcing that I had championed for social computing a long time ago for field transportation field studies and services. After a few days of searching the Web, I feel strongly that we should invent and popularize more digital tools that enable citizens to exert power over institutions and decision makers for design, construction, maintainence, and management of transportation infrastructure and systems. So this is my call:

1) We should construct platforms similar to OpenStreetMap for traffic and transportation for lowering the barriers of taking the first civil steps at scale so people can generate and see related information easily, and make them available free to all. Call them OpenTrafficMap or RealTrafficMap? Actually, Automotive Navigation Data (AND) has participated in OpenStreetMap already by donating a complete road data set for The Netherlands and trunk road data for China and India.
2) We should establish organizations similar to MySociety for traffic and transportation for cultivating a strong accountability and a thriving civil society that are vital to mobility and impossible without engagement with government and communities. We should turn MySociety to MyTransportation, and FixMyStreet to FixMyTraffic, and so on.
3) We should create activities similar to that of Waze to gather location data and other traffic information from volunteers for learning driving times and providing routing and real-time traffic updates. With such software, people can report accidents, traffic jams, and speed and police traps, and can update roads, landmarks, house numbers, as well as identify the cheapest fuel station nearby or along routes. Unfortunately, Google acquired Waze last year. We need more open and free software for better traffic and good transportation.
4) In the end, we need an open and free knowledge system for traffic and transportation, similar to Wikipedia, to host, connect, facilitate, and collect information from these platforms, organizations, and activities, where transportation knowledge automation tools or transportation knowledge robots play a critical role to make of use of those easy and efficient.

When those platforms, organizations, activities, and knowledge systems are available, I am confident that crowdsourcing will be a normal manner of collecting traffic and transportation information, and field transportation studies and services will be in a new era.

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