

# Scanning the Issue

## Traffic Pattern Mining and Forecasting Technologies in Maritime Traffic Service Networks: A Comprehensive Survey

Z. Xiao, X. Fu, L. Zhang, and R. S. M. Goh

This article is devoted to surveying the latest progress on maritime traffic data mining technologies and maritime traffic forecasting technologies. Through the review, we highlight that maritime traffic patterns and knowledge base are useful for wide-spectrum domain applications such as traffic evaluation, visualization, forecasting, and anomaly detection. Maritime traffic forecasting is an essential component for better situation awareness, which contributes toward early collision alert, traffic hotspot detection, and serves as input for mitigation planning and actions. The development of maritime traffic research in pattern mining and traffic forecasting reviewed in this work affirms the importance of advanced maritime traffic studies and the great potential in sea transport to accommodate the implementation of the Internet of Things (IoT), Artificial Intelligence (AI) technologies, as well as knowledge engineering and big data computing solution.

## A Review of Motion Planning for Highway Autonomous Driving

L. Claussmann, M. Revilloud, D. Gruyer, and S. Glaser

This article presents a review of motion planning techniques over the last decade for autonomous vehicles driving on highways. The state-of-the-art focuses on trajectory generation and decision making, and addresses lane changing, obstacle avoidance, car following, and merging situations. A novel classification, centered on the intrinsic attributes of the methods, is enhanced with a radar charts representation. Furthermore, a comparison table is proposed, following two purposes: 1) referring to an algorithm with an appropriate behavior regarding the problem description, as motion planning techniques are highly dependent on the constraints of perception, control, and environment and 2) giving insights on meta-algorithms for systemic treatment of motion planning. Finally, this article overviews the current and future challenges of implementing motion planning algorithms in a mixed environment with both manually driven and autonomous vehicles.

## State-of-the-Art Pedestrian and Evacuation Dynamics

H. Dong, M. Zhou, Q. Wang, X. Yang, and F.-Y. Wang

This article provides a critical review of the state-of-the-art pedestrian and evacuation dynamics. Types of typical data collection methods are classified and the connections and differences of three observation methods are explored. Pedestrians' complex behaviors characterized by the self-organization

phenomena and movement data characterized by the fundamental diagram are then studied after the data collections, which can be used to calibrate and validate the pedestrian models. The mathematical models for pedestrian dynamics from both tactical level and operational level are also highlighted. The simulation data produced by the mathematical models could further reproduce pedestrian behaviors during the observations and contribute to decision makings for improving the evacuation efficiency. The applications of pedestrian models for behavior analysis, evacuation simulation, and layout design are also presented. Some challenges and future directions in the pedestrian and evacuation dynamics are also put forward.

## Estimating Travel Time Distributions by Bayesian Network Inference

A. Prokhorchuk, J. Dauwels, and P. Jaillet

Travel time estimation is a crucial task for intelligent transportation systems. To account for the uncertainty of travel times in an urban context, a path travel time distribution estimation model is presented. The proposed framework combines Gaussian copulas with Bayesian network inference to accurately estimate travel time distributions even from a sparse data set. Computational experiments are performed on GPS measurements from probe vehicles (taxis) in Singapore. The numerical results show that this approach produces distributions that are closer to empirical ones when compared to various baseline models. Relationships between estimation accuracy and factors such as path length, day of the week, and temporal data resolution are also investigated.

## Semi-Automated Generation of Road Transition Lines Using Mobile Laser Scanning Data

C. Ye, J. Li, H. Jiang, H. Zhao, L. Ma, and M. Chapman

This article recognizes the research gaps and difficulties in generating transition lines (the paths that pass through road intersection) in road intersections from mobile laser scanning (MLS) point clouds. The proposed method contains three modules: road surface detection, lane marking extraction, and transition line generation. The experimental results demonstrate that transition lines can be successfully generated for both T- and cross-intersections with promising accuracy. In the validation of lane marking extraction using the manually interpreted lane marking points, the method can achieve average precision, recall, and F1-score of 90.80%, 92.07%, and 91.43%, respectively. The success rate of the transition line generation is 96.5%. Furthermore, the buffer-overlay statistics (BOS) method validates that the proposed method can generate lane centerlines and transition lines within 20-cm-level localization accuracy from the MLS point clouds.

### **Platoon Control of Connected Multi-Vehicle Systems Under V2X Communications: Design and Experiments**

*Y. Li, W. Chen, S. Peeta, and Y. Wang*

A new car-following model is proposed by considering the communication probability to capture the car-following behavior of connected vehicles (CVs) equipped with V2X communications. The stability of the proposed car-following model is analyzed using the perturbation method. In addition, a nonlinear consensus-based longitudinal control algorithm is designed by considering the interactions between CVs, and an artificial function-based lateral control algorithm is presented. The convergence of the longitudinal and lateral control algorithms is analyzed using the Hurwitz stable theorem and Lyapunov technique, respectively. Also, the string stability of the vehicular platoon is performed based on the infinity-norm method. Finally, field experiments are conducted using four CVs under the scenarios of platoon forming, vehicle merging, and vehicle diverging. Results verify the effectiveness of the proposed method in terms of the trajectory and velocity profiles.

### **Human Model-Based Active Driving System in Vehicular Dynamic Simulation**

*H. Kimpara, K. C. Mbanisi, J. Fu, Z. Li, D. Prokhorov, and M. A. Gennert*

A new system framework, the human model-based active driving system (HuMADS) for simulating human driver-vehicle interactions is proposed. HuMADS integrates the vehicle controller with models of vehicle dynamics and human biomechanics. It has hierarchical closed-loop architecture for driver-vehicle control systems, including structures and contact interfaces of human and vehicle bodies. HuMADS is based on the OpenSim simulation platform. The usability of the HuMADS is demonstrated through the simulation of coordinated gas/brake pedal operation and wheel-steering in highway driving tasks. The simulated vehicle dynamics and vehicle maneuvers are comparable with previously published experimental data of car-following driving. In addition, the proposed controllers successfully maintain the human body's balance inside the vehicle during vehicle maneuvers.

### **Flight Routing and Scheduling Under Departure and En Route Speed Uncertainty**

*G. G. N. Sandamali, R. Su, and Y. Zhang*

Demand uncertainty is one critical form of uncertainty which has an adverse effect on air traffic flow management (ATFM). This is mainly due to the deviation in departure time and aircraft speed from their scheduled values. In this article, we propose a robust flight routing and scheduling scheme while considering both departure and speed uncertainties. Following robust optimization, we ensure that the capacity violations are eliminated from the system. The ATFM problem is formulated as a mixed integer quadratic programming problem with the objective of minimizing the expected total delay of the system while maintaining required in-trail separation between aircraft even under uncertainty. In addition, we use an optimal flight level assignment and speed

assignment strategies to minimize the system delay and to fully utilize the system capacity. Furthermore, the problem is decomposed into a set of maximum independent sets to reduce the computational complexity in solving large-scale ATFM problems.

### **Analysis of Cooperative Bus Priority at Traffic Signals**

*M. Sereczynski, G. Laskaris, and F. Viti*

This article presents a systematic assessment and identifies the benefits and operational conditions of coordinated driver advisory systems (DAS) and transit signal priority control. Thanks to connectivity, signal adjustments with dwelling and speed advisories can be transmitted in real-time, reducing stops at traffic signals in a signal noninvasive way. Combining in-vehicle advisory with signal priority is shown to reduce stops at signals as well as reduce trip time when compared with TSP used alone. However, when it comes to travel time reduction, TSP is required. A simulation-based analysis indicates that the effectiveness of each combination of control strategies depends on the bus stop placement. When it comes to the reduction of stop frequency at traffic signals, speed and dwell time advisories used together deliver similar performance to an unconditional TSP with green signal extensions and recalls lasting up to 10 s.

### **AbolDeepIO: A Novel Deep Inertial Odometry Network for Autonomous Vehicles**

*M. Abolfazli Esfahani, H. Wang, K. Wu, and S. Yuan*

This article tackles the problem of inertial odometry by proposing novel triple-channel deep inertial odometry network architecture based on the physical and mathematical models of IMUs. The proposed method is robust to IMU measurement noise and frequency change and outperforms existing techniques on the IMU readings of challenging Micro Aerial Vehicle data set and improves the accuracy by approximately 25%.

### **Automated Evaluation of Semantic Segmentation Robustness for Autonomous Driving**

*W. Zhou, J. S. Berrio, S. Worrall, and E. Nebot*

Small variations in environmental conditions, such as illumination and precipitation can affect the semantic segmentation model performance. Given the reliance on visual information, these effects often translate into poor semantic pixel classification which can potentially lead to catastrophic consequences when driving autonomously. In this article, a novel method for analyzing the robustness of semantic segmentation models is provided. We also provide a number of metrics to evaluate the classification performance over a variety of environmental conditions. The process incorporates an additional sensor (LIDAR) to automate the process and improve system integrity, eliminating the need for labor-intensive hand labeling of validation data. The experimental results are presented based on multiple data sets collected at different times of the year with different environmental conditions. This is important to validate the performance of algorithms applied to autonomous vehicles.

### **An Ensemble Learning-Based Vehicle Steering Detector Using Smartphones**

*Z. Ouyang, J. Niu, Y. Liu, and X. Liu*

An ensemble learning-based vehicle steering behavior detector with normal smartphone sensor is presented. With ensemble learning strategies, model selection and dimension reduction, it is possible to improve the detection accuracy through assembling several selected machine learning models and refined statistical sensor feature.

### **Estimating Carbon Dioxide Emissions of Freeway Traffic: A Spatiotemporal Cell-Based Model**

*Z. He, W. Zhang, and N. Jia*

This article proposes a mesoscopic model of estimating freeway traffic CO<sub>2</sub> emissions from the spatiotemporal traffic (ST) speed diagram. The contributions of the model are as follows. First, the proposed model opens a gate for estimating traffic CO<sub>2</sub> emissions from widely available low-fidelity traffic data since the ST diagram (i.e., the model input) can be constructed by using various traffic flow data, such as loop detector data and low frequency floating car data. Second, this model may be the first emission estimation model that is proposed based on entire traffic flow data, i.e., very detailed dynamics of all vehicles traveling on a freeway segment. Finally, the model indicates that the relationship between complicated ST dynamics and CO<sub>2</sub> emissions can be simply described by using a linear or nearly linear function. Relatively simple emission models are easier to be used in practice.

### **Multi-Objective Optimization for the Vehicle Routing Problem With Outsourcing and Profit Balancing**

*Z. Zhang, H. Qin, and Y. Li*

This research originates from a real-practice that a food importer in Hong Kong employs vehicles from external transport companies to deliver food products to its customers geographically scattered in different locations. The problem considers outsourcing orders to multiple transport companies with profit balancing issues. The goal is to simultaneously optimize the total traveling cost as well as fairness. Extensive computational experiments on benchmark datasets verified the effectiveness of the proposed algorithm. A real-world case study was also conducted to demonstrate the advantage of the algorithm over the manual scheduling approach by the food importer. The introduction of order outsourcing and profit balancing can enrich the studies on logistics and transportation. The dataset and comprehensive experimental results can also serve as baselines for future researchers working on related problems.

### **Identifying the Structure of Cities by Clustering Using a New Similarity Measure Based on Smart Card Data**

*K. Kim*

Identifying the structure of cities has long been studied in urban planning and traffic modeling. This study presents a reliable method that reveals the structure of cities mainly based on clustering analysis using a new similarity measure. This study proposes a new similarity method that considers

not only temporal mobility patterns of areas but also spatial interactions with other areas. Moreover, the study combines spectral clustering repeated several times with hierarchical clustering to obtain a reliable structure that keeps the contiguity of clusters and determine the hierarchy of different areal units. The proposed method is examined using Seoul's public transportation data and compared with other traditional clustering methods.

### **TrajCompressor: An Online Map-Matching-Based Trajectory Compression Framework Leveraging Vehicle Heading Direction and Change**

*C. Chen, Y. Ding, X. Xie, S. Zhang, Z. Wang, and L. Feng*

Massive vehicle trajectory data are continuously sent to the data center via vehicle-mounted GPS devices, causing a number of issues, such as storage, communication, and computation. To solve these issues, this article proposes an online trajectory compression framework consisting of two phases, i.e., online trajectory mapping and trajectory compression. In the phase of online trajectory mapping, we develop a light-weighted yet efficient map matcher, namely SD-Matching to align the noisy and sparse GPS points upon the underlying road network, which fully explores the usage of a vehicle heading direction collected from the GPS trajectory data. In the phase of online trajectory compression, we propose a novel compressor based on the heading change at intersections, namely HCC, aiming at finding a concise and compact trajectory representation. The experimental results demonstrate the good performance of our proposed framework in term of accuracy, compression ratio, and computation time.

### **Cooperative Eco-Driving at Signalized Intersections in a Partially Connected and Automated Vehicle Environment**

*Z. Wang, G. Wu, and M. J. Barth*

A cooperative eco-driving (CED) system targeted for signalized corridors is proposed, focusing on how the penetration rate of CAVs affects the energy efficiency of the traffic network. Role transition protocol and longitudinal control models are developed for different vehicles in the network. A microscopic traffic simulation evaluation is conducted using PTV VISSIM with realistic traffic data collected for the City of Riverside, California. Environmental benefits of the CED system are analyzed by U.S. Environmental Protection Agency's MOtor Vehicle Emission Simulator (MOVES) model.

### **Outliers-Robust CFAR Detector of Gaussian Clutter Based on the Truncated-Maximum-Likelihood-Estimator in SAR Imagery**

*J. Ai, Q. Luo, X. Yang, Z. Yin, and H. Xu*

An outliers-robust CFAR (OR-CFAR) detector of Gaussian clutter based on the truncated-maximum-likelihood-estimator (TMLE) in SAR imagery is proposed. OR-CFAR aims at elevating the detection performance in multiple-target environment, where the parameters used for statistical modeling are over-estimated, resulting in a degradation of the CFAR detection rate. OR-CFAR designs an adaptive threshold



based clutter truncation method to eliminate the high-intensity outliers from the clutter samples in the local reference window, and the probability density function (pdf) of the sea clutter can be accurately modeled through the newly-raised TMLE. Furthermore, the optimal truncation depth used for clutter truncation and pdf modeling is evaluated and selected properly to get the best detection results. OR-CFAR greatly enhances the CFAR detection rate in the multiple-target environment, and it is computationally simple and efficient, which has great application value in crowded harbors and busy shipping lines.

#### **On Link Stability Metric and Fuzzy Quantification for Service Selection in Mobile Vehicular Cloud**

*N. Tamani, B. Brik, N. Lagraa, and Y. Ghamri-Doudane*

The article “On Link Stability Metric and Fuzzy Quantification for Service Selection in Mobile Vehicular Cloud” combines the principles of the relative motion and the tools of fuzzy logics to build an intelligent transport platform where vehicles on the move advertise services (servers) for other mobile vehicles (clients). The authors introduced: 1) a generic relative motion model, as a link stability metric, which vehicles use to form a stable cloud, 2) a cloud service selection approach using fuzzy quantified propositions, to aggregate efficiently both user preferences and service constraints and rank service providers from the most to the least satisfactory, and 3) new parameters for ranking refinement called least satisfactory proportion (lsp) and greatest satisfactory proportion (gsp). The simulation results show that our link stability models a wider range of vehicle motion types, and the fuzzy quantified service selection scheme allows a good successful service consumption rate while reducing latency.

#### **Cooperative Control of Metro Trains to Minimize Net Energy Consumption**

*Y. Bai, Y. Cao, Z. Yu, T. K. Ho, C. Roberts, and B. Mao*

A model framework on real-time cooperative control of multiple metro trains is presented for energy saving of a metro line with pre-determined timetable. A cooperative co-evolutionary algorithm is developed to attain solutions to the model. Case studies demonstrate that the proposed approach always performs better in energy saving than the previous studies focusing on separate train control and offline timetable optimization, from no disturbance to a good range of train delays. The results also reveal that partial motoring in train acceleration and partial braking in station stopping utilize more regenerative energy and reduce net energy consumption than full motoring/braking does.

#### **Platooning Control for Heterogeneous Sailboats Based on Constant Time Headway**

*C. Viel, U. Vautier, J. Wan, and L. Jaulin*

This article addresses the problem of platooning control for a fleet of heterogeneous sailboats. Platooning maintains constant time headway (CTH) between sailboats following a circular path, a complex problem for sailboats due to the influence of wind direction. First, the desired acceleration based on the CTH and the sailboat velocity needed to converge to the

platooning is defined. Second, control of sailboat orientation to manage the sailboat acceleration is proposed. The proposed platooning strategy adapts to the specific characteristics of sailboats, which are different from other motorized marine vehicles. Two tack strategies can be used for the method: the first is to regulate the sailboat velocity; the second is to go in front of the wind while staying in a short corridor. Desired acceleration for fulfilling the platooning has been derived and validated. The simulation results demonstrate the effectiveness of the proposed approach, with comparison to an optimal receding horizon control algorithm.

#### **A Driving-Behavior-Based SoC Prediction Method for Light Urban Vehicles Powered by Supercapacitors**

*H. Wang, G. Zhou, R. Xue, Y. Lu, and J. A. McCann*

A driving-behavior-based State of Charge (SoC) prediction algorithm is proposed to overcome range anxiety in the application of light urban vehicles powered by supercapacitors. This algorithm can determine whether drivers can reach their destinations while also predicting the SoC if drivers were to return the trip. The SoC of supercapacitors is predicted based on the recorded historical data, including the output power, speed and driving distance. Actual driving experimental results show that the total prediction error is less than 3% of the real SoC at a different initial SoC and temperature.

#### **Hierarchical-Distributed Optimized Coordination of Intersection Traffic**

*P. Tallapragada and J. Cortés*

The problem of coordinating vehicular traffic at an intersection and on the branches leading to it in order to minimize a combination of total travel time and the energy consumption is considered. A provably safe hierarchical-distributed solution that balances computational complexity and optimality of the system operation is proposed. In the design, a central intersection manager communicates with vehicles heading toward the intersection, groups them in clusters, and determines an optimal schedule of passage through the intersection for each cluster. Vehicles in each cluster receive their schedule and implement distributed control to ensure system-wide inter-vehicular safety while respecting speed and acceleration limits, conforming to the assigned schedule, and seeking to optimize their individual trajectories. The analysis establishes that the different aspects of the hierarchical design operate in concert and that the safety specifications are satisfied. The simulations compare the performance of the proposed scheme against optimized signal-based coordination over a wide range of parameters.

#### **Optimal Access Management for Cooperative Intersection Control**

*A. I. Morales Medina, F. Creemers, E. Lefeber, and N. van de Wouw*

This work presents an intersection access management methodology that optimizes the crossing sequence of an automated intersection. A high-level hybrid queuing model is proposed to describe the dynamics of the vehicle queues

associated with each intersection lane. This model, including constraints, is used to design an optimal access management approach based on Model Predictive Control that minimizes the time that the vehicles spend within the intersection, thereby optimizing the traffic throughput of the intersection. The performance of this methodology is studied by means of two representative examples. The impact of the design parameters of the optimal access management approach is shown for a T-intersection case study. Moreover, using a real-life five-lane intersection case study, the proposed approach is compared to a vehicle-actuated traffic light approach, and a first come first served approach. The comparison shows the benefits of the automated optimal serving of vehicles from different lanes.

### **Offline and Online Electric Vehicle Charging Scheduling With V2V Energy Transfer**

*A.-M. Koufakis, E. S. Rigas, N. Bassiliades, and S. D. Ramchurn*

In this article, we propose offline and online scheduling algorithms for the charging of electric vehicles (EVs) in a single charging station (CS). The station has available limited energy from renewable energy sources (RES). Moreover, the EVs are capable of and willing to participate in vehicle-to-vehicle (V2V) energy transfers, which are used for reducing the charging cost and increase RES utilization. The algorithms are centralized and aim to minimize the total charging cost for the EVs. A novel technique called virtual demand is developed that increases the demand of already existing EVs, in order to store renewable energy and later transfer it via V2V to EVs that will arrive at the CS in the future. This technique is used for mitigating the inefficiency due to the uncertainty about future actions that real-time scheduling entails.

### **Placement Optimization of Multiple Lidar Sensors for Autonomous Vehicles**

*T.-H. Kim and T.-H. Park*

In autonomous vehicles, the problem with Lidar placement is finding a Lidar position that reduces the dead zone and improves the point cloud resolution. A Lidar placement method is thus proposed for the multiple Lidar systems of autonomous vehicles to resolve this problem. With the introduction of the Lidar occupancy grid, the problem is formulated as an optimization problem. A genetic algorithm is subsequently applied to solve the optimization problem. The experimental results using commercial Lidars are subsequently presented to show the usefulness of the proposed method.

### **How Do Drivers Allocate Their Potential Attention? Driving Fixation Prediction via Convolutional Neural Networks**

*T. Deng, H. Yan, L. Qin, T. Ngo, and B. S. Manjunath*

Understanding how drivers allocate their potential attention and where/what drivers mainly look at are important and challenging problems for driving assistance systems. An eye-tracking data set from 28 experienced drivers are published in this article. Based on the multiple drivers'

attention allocation data set, a convolutional–deconvolutional neural network (CDNN) is proposed to predict the drivers' eye fixations. The experimental results indicate that the proposed model outperforms the state-of-the-art saliency models and predicts drivers' attentional locations more accurately.

### **Mechanisms for Cooperative Freight Routing: Incentivizing Individual Participation**

*I. Kordonis, M. M. Dessouky, and P. A. Ioannou*

In today's road network, drivers make uncoordinated selfish routing decisions. These decisions may easily congest an uncongested route, as many drivers choose the same route to minimize their travel time without accounting for the fact that others do the same. This article proposes coordination mechanisms for a specific category of drivers of high impact, truck drivers. Mechanisms use monetary incentives, fees, and informed suggestions to balance the traffic load and improve the overall traffic conditions and time delays experienced by both truck and passenger vehicle drivers. The distinguishing feature of these mechanisms is that they take into account the uncertainty of the traffic conditions and allow for a bi-directional flow of information. Particularly, truck drivers inform the mechanism about their origin-destination pair, and the mechanism returns the proposed routes and the imposed fees or incentives. Additionally, the mechanisms are budget balanced, do not penalize the truck drivers compared to the user equilibrium, and assure voluntary participation. A numerical example using the Sioux-Falls network demonstrates the efficiency of the proposed mechanisms.

### **Utilization Management and Pricing of Parking Facilities Under Uncertain Demand and User Decisions**

*A. Mirheli and L. Hajibabai*

Excessive cruising to find vacant parking spots can cause extra congestion and travel delays, particularly in highly congested neighborhoods, imposing negative socio-economic impacts. This study develops a stochastic dynamic pricing scheme to regulate travelers' parking decisions with the objective of effective space utilization over time. The problem is formulated as a bi-level optimization program to simultaneously maximize the parking agency's revenue and minimize total travelers' costs under uncertain user demand and parking occupancy. The problem is reformulated into an equivalent single-level model and solved using a stochastic look-ahead technique based on the Monte Carlo tree search algorithm. Numerical experiments confirm that the proposed methodology solves the problem efficiently. Furthermore, a set of sensitivity analyses has been conducted to draw managerial insights.

### **Consistent Population Synthesis With Multi-Social Relationships Based on Tensor Decomposition**

*P. Ye, F. Zhu, S. Sabri, and F.-Y. Wang*

A general methodological issue of population synthesis with multiple social relationships is identified. In addition, a tensor decomposition method is proposed to generate such consistent population including more than two types of social organizations. Tested in Chinese national

population synthesis which involves individual, household, and enterprise, the new method, compared to existing approaches, can respect constraints from multiple social organizations without reducing accuracy and lead to stable and small errors in total. The source code is available from <https://github.com/PeijunYe/MulSocPopSyn.git>.

### **Unsupervised Stereo Matching Using Confidential Correspondence Consistency**

*S. Joung, S. Kim, K. Park, and K. Sohn*

Stereo matching aims to perceive the 3D geometric configuration of scenes and facilitates a variety of computer vision and advanced driver assistance systems (ADAS) applications. Recently, deep convolutional neural networks (CNNs) have shown dramatic performance improvements for computing the matching cost in stereo matching. However, the performance of CNN-based approaches relies heavily on data sets, requiring a large number of ground truth which needs tremendous works. To overcome this limitation, we present a novel framework to learn CNNs for matching cost computation in an unsupervised manner. Our method leverages an image domain learning combined with stereo epipolar constraints. By exploiting the correspondence consistency between stereo images, our method selects putative positive samples in each training iteration and uses them to train the networks. We further apply a positive sample propagation scheme to leverage additional training samples. Our unsupervised learning method is evaluated with two kinds of network architectures, simple and precise CNNs, and shows comparable performance to that of the state-of-the-art methods including both supervised and unsupervised learning approaches on KITTI, Middlebury, HCI, and Yonsei data sets. This extensive evaluation demonstrates that the proposed learning framework can be applied to deal with various real driving conditions.

### **Rapid and Robust Background Modeling Technique for Low-Cost Road Traffic Surveillance Systems**

*K. Garg, N. Ramakrishnan, A. Prakash, and T. Srikanthan*

A low complexity background modeling technique for vehicle detection to realize low-cost yet real-time traffic surveillance sensors. An adaptive Bayesian classification framework has been proposed that effectively deals with varying road scene conditions such as illumination changes, camera jitter, slow-moving traffic, and stationary vehicles, without sacrificing the real-time performance capability. The experimental results show that the proposed method can run at over 80 f/s on a low-cost embedded platform—Odroid-XU4, while achieving comparable accuracy to the current state-of-the-art techniques that are typically executed on high-end PCs.

### **Irregular Travel Groups Detection Based on Cascade Clustering in Urban Subway**

*L. Wang, Y. Zhang, X. Zhao, H. Liu, and K. Zhang*

An effective method is proposed to recognize irregular travel groups based on the smart card data in the subway. Important information relating to the temporal organization of journeys and activities is captured based on the activity sequence of each passenger and similarity between irregular passengers is measured analyzing the spatial-temporal correlations. The experimental results show that the proposed method can recognize various types of irregular travel patterns and the detected irregular passengers' movement areas are consistent with the ground truth.

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