Guest Editorial: Introduction to the Special Issue on Connected vehicles in Intelligent Transportation Systems

Connected Vehicles (CVs) are one of the critical components of Intelligent Transportation Systems. CVs enable any vehicle to act as a smart node, that collects and shares information on vehicles, roads and the surroundings. This information can then be distributed to other vehicles via vehicle-to-vehicle (V2V) communication, and also to road users via vehicle-to-human (V2H) communication, for an improved driving experience. The information can also be forwarded towards traffic control systems via vehicle-to-infrastructure (V2I) communication, for improved traffic management and road safety. Making use of of connected vehicles in intelligent transportation systems will revolutionize the way we drive. Many issues, however, need to be resolved to achieve better performance of connected vehicles. Improvements relate to data processing and storage, development of standards and regulations across all platforms, design and deployment of new communication protocols and system architectures, and the creation and introduction of new services and applications.

This special issue brings together studies that propose novel techniques, algorithms, frameworks, models and solutions to address new challenges related to Internet of Vehicles in Intelligent Transportation Systems, including for example seamless connectivity, infrastructure sharing for real-time traffic management, vehicle tracking, energy efficiency, security and privacy.

For this special issue, seven articles were accepted after at least two rounds of reviews. Each paper has received at least three expert reviews. The accepted papers cover the following interesting topics: i) predicting long-term trajectories of connected vehicles, ii) application of real field connected vehicle data for aggressive driving identification, iii) cooperative and integrated vehicle and intersection control for energy efficiency, iv) smarter cities with parked cars as roadside units, v) vehicle tracking, vi) cost-effectiveness of sharing roadside infrastructure for internet of vehicles, and vii) ecological driving system for connected/automated vehicle.

The first part of this special issue deals with a novel, scalable and effective trajectory sequential mining approach. The approach includes the development of a trajectory prediction (TP) algorithm for connected vehicles, called PrefixTP. Qiao et al. propose an efficient prefix-projection technique to find frequent trajectory patterns of connected vehicles, which examines only the prefix subsequences and projects only their corresponding postfix subsequences into projected sets. An incremental trajectory matching approach, which includes three matching strategies, is proposed to recursively mine frequent sequential patterns over postfix sequences. Extensive experiments were conducted on real world GPS data, and the results show the advantages of the proposed trajectory prediction algorithm in forecasting long-term and variable length of trajectories in a connected vehicle environment.

The next part of the special issue deals with safety applications of real field connected vehicle data on a horizontal curve. Using connected vehicle data, this study models aggressive/risky driving while negotiating a horizontal curve. Jahangiri et al. developed a model using random forest machine learning to classify the value of time to lane crossing (TLC), a proxy for aggressive/risky driving, based on a set of motion-related metrics as features. They demontrate that motion-related variables in the random forest model can accurately reflect drivers' instantaneous decisions and identify their aggressive driving behavior. The results of this study can contribute to the design of warning/feedback systems and control assistance, by transmitting unsafe events through vehicles-to-vehicles (V2V) and vehicles-to-infrastructure (V2I) communications.

The third part of the special issue deals with cooperative and integrated vehicle and intersection control for energy efficiency. This paper explores the opportunity for Cooperative and Integrated Vehicle and Intersection Control for Energy Efficiency called CIVIC-E2 for obtaining a more sustainable transportation system. Hou et al. proposed a two-level approach that jointly optimizes traffic signal timing and vehicles' approach speed, with the objective of minimizing total energy consumption for all vehicles passing through an isolated intersection. More specifically, at the intersection level, a novel dynamic programming algorithm finds the optimal signal timing by explicitly considering the arrival time and energy profile of each vehicle. At the vehicle level, a model predictive control strategy is adopted to ensure that vehicles pass through the intersection in a timely fashion. A simulation study shows that the proposed CIVIC-E2 system can significantly improve intersection performance under various traffic conditions. Compared with conventional fixed-time and actuated signal control strategies, the proposed algorithm can reduce energy consumption and queue length by up to 31% and 95%, respectively.

The fourth part of the special issue addresses smarter cities using parked cars as roadside units. Reis et al. introduce novel mechanisms for parked vehicles to self-organize in order to form efficient vehicular support networks that provide widespread coverage to a city. These mechanisms are innovative in their ability to keep the network of parked cars under continuous optimization, via a multi-criteria decision process. That process can focus on key network performance metrics, and can take into account the battery usage of each car, by rotating roadside unit roles between vehicles. The paper includes the first comprehensive performance study of such a system, making use of realistic models of mobility, parking, and communication, thorough simulations, and an experimental verification of concepts that are key to self-organization. The analysis brings strong evidence that parked cars can serve as an alternative to fixed roadside units, and can organise to form networks that support smarter transportation and mobility.

The fifth part of this special issue focuses on vehicle tracking using surveillance with multimodal data fusion. Zhang et al. present a multimodal data fusion framework for vehicle tracking using surveillance images, fusing the information of two modalities, images and velocities. Images are processed by a color-faster R-CNN method, whereas the Kalman filter handles velocities. Finally, a multimodal data fusion method is applied to integrate these outcomes so that vehicle-tracking tasks can be achieved with low latency at small computational cost. Experimental results suggest the efficiency of the used methods, which can track vehicles using a series of surveillance cameras in urban areas.

The next part of the special issue studies the cost-effectiveness of sharing roadside infrastructure for internet of vehicles. Vehicular networks can improve road safety using Dedicated Short Range Communications (DSRC) technology, but a substantial investment in roadside units (RSUs) is required. If governments share RSUs deployed for safety or smart streetlights with other kinds of service providers, then the respective costs for the government can be reduced. Ligo et al. estimated that government could save about one fifth the nationwide cost of safety RSUs in the U.S. if they were shared with Internet service providers. The authors also estimated an increase in social welfare from sharing safety RSUs. Moreover, the benefits of sharing could increase significantly with growing Internet traffic or DSRC penetration.

The final part of the special issue considers ecological driving system for connected/automated vehicle using a two-stage control hierarchy. To improve vehicle's fuel efficiency when moving on roadways, Huang et al. developed an ecological driving system operating in a connected and automated vehicle (CAV) environment. The system includes three critical functions: traffic state prediction, eco-driving speed control, and powertrain control. According to the real-time traffic information obtained from vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communications, the embedded traffic state prediction model estimates and predicts the average vehicle speeds and traffic densities on freeway subsections. With an objective of minimizing fuel consumption, the eco-driving speed control function follows a two-stage hierarchical framework. The first stage, which is executed at the global level, aims to optimize the travel speed profile of the CAV over a certain period. The second stage is designed to dynamically adjust the CAV's speed and make lane-changing decisions based on local driving conditions. The resulting control parameters will then be forwarded to the powertrain control system. The proposed system is evaluated by means of comprehensive simulation study. The results confirm the effectiveness of the proposed system in reducing fuel consumption.

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