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EDITORIAL

Developments in connected and automated vehicles

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Introduction

Connected and Automated Vehicle (CAV) technologies continue to quickly transform transportation systems in a pace that has surpassed our expectations. Different than the past experience with many innovations related to surface transportation, this one is not led by government agencies and major automobile manufacturers only. Technology oriented companies who are not necessarily in the business of transportation, like Waymo, Uber, and Apple are leading the way while traditional and emerging automobile manufacturing companies like GM, Toyota, BMW, and Tesla are also responding and adopting to this change not seen since early 1900's. It is also important to acknowledge the effect of these emerging technologies on other modes of transportation such as air, rail, and water that are not covered in this special issue. Nonetheless, the transformation they are undergoing is as drastic as highways if we notice that there is not a single day that goes by without news related to autonomous delivery drones (Ong, 2018), self-sailing ships (Phys.org, 2018), self-driving freight trains and trucks (Freedman, 2018; Thompson, 2018), and so on.

There are three main pillars fueling this transportation revolution. The first one is the availability of Big Data created by the proliferation of millions of mobile and fixed infrastructure-based sensors and apps that have now become part of our every-day lives. The second pillar is the return of Artificial Intelligence and Machine Learning (AI/ML) technologies (Upenn.edu 2018) fueled by the rapid growth and availability of Big Data and unprecedented computational power offered by new super computers that can be deployed in our smart phones or cars. Companies like NVIDIA (Nvidia.com 2018), IBM, and Intel have introduced special chip sets that allow real-time computation for AI/ML algorithms (Metz, 2018). Lastly, the change in the propulsion technologies, i.e., the arrival of electric and alternative fuel vehicles that are more amenable to autonomous driving.

In spite of all these positive developments, there are also many challenges that remain. One of the key challenges is safety. Public as well as government are paying increasing attention to the safety impacts of these new CAV technologies that are still in their infancy in terms of real-world deployment. Deployment of CAV technologies in a real-world driving environment where interaction with traditional vehicles and other road users such as pedestrians and bicyclists can be a considerable challenge. This was further evidenced by the Tesla vehicle crash that ended up with the fatality of driver on March 23, 2018 (DigitalTrends.com 2018) and the Uber vehicle crash that killed a pedestrian in Arizona on March 18, 2018 (Stewart, 2018). Thus, there is a great need to be aware of such safety risks and develop deployable CAV algorithms that are robust to minimize safety risks. This requires an unprecedented level of scrutiny in testing, validation, and certification of these technologies that are far beyond the current state-of-practice.

The second part of this special issue on CAV begins with a paper (Shladover, 2018) offering an overview and a brief history of CAVs. Development of novel operational algorithms under different driving conditions such as adverse weather and highly congested urban streets has become increasingly important for the successful deployment of CAVs. This special issue includes two papers (Li, Chen, Lin, Xu, & Wang, 2018; Sezer, 2018), specifically dealing with the development of such operational models and algorithms that are expected to enhance CAV safety.

There are also many questions about system-wide impacts of CAVs in terms of various operational performance measures such as congestion and vehicle-miles traveled. Will the auto ownership and the use of transit be affected by CAVs? Is it realistic to expect major capacity improvements when human drivers cease to control

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their vehicles? What are the expected changes in travel demand and network-level congestion and emissions due to the introduction of CAVs? Will there be new fleet managers that will own and operate autonomous vehicle fleets for moving people and goods? Clearly, it is possible to increase the number of these important and challenging questions that will need to be answered to better plan our transportation systems. In this special issue, there are three papers (Kim, Hobeika, & Jung, 2018; Liu, Kan, Shladover, Lu, & Ferlis, 2018; Olia, Razavi, Abdulhai, & Abdelgawad, 2018) that address similar system related questions from different perspectives.

Development and evaluation of CAV technologies

Paper by Shladover (2018) provides an introduction about the development of Connected Vehicles (CVs) and Automated Vehicles (AVs). The paper presents initiatives from the U.S. Department of Transportation that led to various CV applications related to vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), etc. The paper also described the history of AVs with related concepts that can be traced back to the late 1930's, providing details about the levels of driving automation systems, and challenges that need to be overcome. This paper advocates for stronger synergy between CVs and AVs because they are complementary and they can improve the operation of the transportation system and traffic safety. The technological challenges listed at the end of paper, range from cybersecurity to system design. The paper offers CAV researchers and practitioners a glimpse of many issues that still need to be studied and addressed.

The Paper by Sezer (2018) proposes a new model for making safer decisions for overtaking at two-way roads. This model employs an approach based on Mixed Observability Markov Decision Process (MOMDP) to be able to handle uncertainties in both observations and the system itself. The results of the proposed MOMDP approach is also compared with the Time to Collision (TTC) approach that is traditionally used in many automotive problems including adaptive cruise control, collision control and warning, and overtaking. The results of the MOMDP approach demonstrated its effectiveness in dealing with uncertainties compared with the TTC approach under complex real-world scenarios. Moreover, the results presented in the paper show that the model has become more cautious with increased level of uncertainties and then responded to such complex conditions by changing its decision-making mechanism automatically. The paper concludes by expressing the needs for further research to deploy this proposed approach in real-world driving conditions where more complicated overtaking scenarios due to interaction with additional vehicles of different types can be encountered.

Using a calibrated simulation network, Kim et al. (2018) evaluate the performance of V2V applications in an urban network. Distance of information propagation and speed estimation error are used to measure the V2V performance for event-based and periodic applications for the peak hour and non-peak hour, under different V2V market penetration rates. It is found that as the market penetration of V2V increases, the distance of information propagation increases and the speed estimation error decreases. Such trends may differ slightly under different traffic conditions (peak or non-peak) and for different types of applications (event-based or periodic applications). The findings of this research are useful for the real-world deployment of V2V and CV applications in general.

Li and colleagues (2018) investigate the dynamic all-red extension (DARE) framework using CV technologies for adaptive signalized intersections to solve the red-light running (RLR) problems. RLR is formulated as a binary classification problem using support vector machines (SVMs) based on various features including those related to vehicle trajectories, speeds, accelerations, and distance to the intersection. The DARE framework based on the proposed RLR model can improve the performance by 15–20% as shown by a field experiment, thus significantly improving intersection safety.

Olia and colleagues (2018) study freeway capacity under mixed traffic flow of regular human-driven vehicles and automated vehicles. They classify AVs as (1) cooperative AVs that can communicate with other vehicles and the infrastructure, and (2) autonomous AVs that do not have such communication capability. By integrating AVs' behavior into car-following and lane-changing models of a traffic simulation platform, this study investigates the lane capacities under different mix of cooperative AVs and autonomous AVs. It is found that if all vehicles are cooperative AVs, the freeway capacity can be dramatically improved, while autonomous AVs do not significantly increase the freeway capacity. The findings in the paper may provide useful insights to decision makers regarding the potential benefits of AVs as a function of the types of AV technologies and the market penetration of AVs.

In Liu et al. (2018), the impact of cooperative adaptive cruise control (CACC) on the merge capacity of a multilane freeway segment is investigated. The authors first calibrate the car-following and lane-changing behaviors of both CACC vehicles and manually driven vehicles using field-collected data in a microscopic traffic simulation. Various CACC market penetration rates are then tested for merge locations of a multilane freeway segment. The results indicate that the merge capacity increases quadratically with the increase of the CACC market penetration. The maximum merge capacity may reach 3080 vehicles per hour per lane under 100% market penetration. The authors also find that on-ramp traffic can reduce the merge capacity. However, even with such disruption of on-ramp traffic, the merge capacity still increases quadratically with the penetration of CACC. The results in this paper clearly demonstrate the benefit of CACC as an intermediate step before fully automated driving can be achieved.

Closing remarks

It is our hope that the second volume of the CAV special issue provides useful information that can further advance the burgeoning field of CAVs. The goal is to present papers ranging from overall system and technology overview to the development of specific algorithms. Clearly, this is a very dynamic and fast-moving field that is going to change many aspects of our lives in the next several decades.

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