

MPC-570

June 27, 2018

Project Title

Experiments and Modeling for Infrastructure Data-Derived Fuel Economy and Safety Improvements

University

Colorado State University

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Research Needs

Connected and autonomous vehicles (CAV) are an important means by which the US can improve the safety, environmental compatibility, economics, and equity of personal transportation. Vehicle connectivity and automation can also be a means to improve the effectiveness and value of investments in modern traffic management infrastructure. The sensors and signals that enable CAV technology gather a wealth of data that to date has not been available for use by transit agencies. Many studies have considered the ways to use probe vehicle data to enable traffic state estimation, travel time estimation, and other large-scale (scale of 100s of meters), low-bandwidth (periods of 100s of seconds) indicators of travel system state [1]. At present, these indicators have limited value as information inputs to algorithms that might be particularly beneficial to CAVs, because CAVs generally need information about the roadway immediately in front of them (within the 1-100m, 1-30seconds vehicle “safety box”) [2].

It is universally understood that these higher bandwidth, and shorter timescale predictions of near-term vehicle trajectories are necessary to enable many of the ways that CAVs can realize their transportation system-level benefits. For an example, CAVs have the potential to significantly improve the safety of personal mobility, but safety-driven use cases for CAVs require the input of second by second datasets that might include data regarding the presence of speed goals, obstacles, traffic, and more [3]. At present, these datasets must be derived from individual vehicles’ sensing and prediction algorithms, but they could also be derived or augmented by transportation infrastructure datasets. Conceptual use cases might allow the infrastructure to measure and communicate new obstructions to CAVs, rather than have to have each CAV “re-discover” an obstacle stationary in the road. In another example, CAVs have the potential to improve the fuel economy of vehicles through drive cycle prediction and predictive energy management [4]. Research has shown that speed predictions of less than 20 seconds into the future can realize a 10-15% fuel economy improvement [5]. This time scale is difficult to

achieve because it is generally beyond the “line-of-sight” of on-vehicle sensors, but the current set of ATMS-derived traffic flow metrics and states are not informative for deriving speed predictions at this second-by-second scale.

Research Objectives

Research Objective 1 – Dataset Development

This research seeks to synthesize rich vehicle-level datasets derived from experiments with CAV sensors and systems with the state of the art transportation-system level datasets to compose second-by-second vehicle-level Lagrangian predictions of vehicle velocity trajectories, applicable to CAVs.

Research Objective 2 – Prediction and uncertainty quantification of vehicle velocity trajectories under real world driving

By experimenting with a variety of data synthesis techniques, including deep learning, autoregressive artificial neural networks, and nearest trajectory classification, this study will be able to develop ~1Hz predictions of vehicle velocity for any vehicle on the transportation system. As has been demonstrated in previous research, the uncertainty with which these vehicle speed trajectories can be modeled increases with the size of the prediction window into the future. In response, real-world datasets of vehicle navigating the cities of Ft Collins and Denver will be used to quantify the uncertainty of these velocity trajectory predictions.

Research Objective 3 – Quantify the safety and environmental benefits that CAVs can accrue with ATMS infrastructure integration

The overarching objective is to understand the role of ATMS (and other infrastructure) sensors, information, and infrastructure in advancing the safety and environmental benefits of CAVs. We will seek to understand the value in terms of metrics of safety and fuel economy of integrating the datasets available from transportation system infrastructure into the control of CAVs. This experimental study will gather real-world data to quantify uncertainties associated with velocity prediction under various windows of prediction, and will use vehicle level modeling to understand the implications of these vehicle velocity predictions for vehicle safety and fuel economy.

Research Methods

This study seeks to research the synthesis and prediction of second by second vehicle velocity on the bases of vehicle-level information derived from CAV technologies and sensors, and of infrastructure level information derived from ATMS technologies and sensors. This research will use experimental methods to derive real-world datasets that include both vehicle-level and system-level information on transportation system state. These experimental inputs will be input to modeling of vehicle safety margins and fuel economy (through Autonomie and/or custom vehicle modeling software).

Expected Outcomes

This project has two primary expected outcomes. 1) a quantification of the value of integrating AMTS-type datasets with CAV-derived datasets in terms of safety and fuel economy benefits. 2) a comparison of various techniques for short-term, small-scale vehicle velocity trajectory prediction.

Relevance to Strategic Goals

- Safety
- Environmental Sustainability

This research is well-aligned with the MPC strategic research objectives seeking to understand:

- Retrofits and multiple uses of infrastructure to create efficiencies and reduce barriers to opportunity. At present, the investment in traffic management sensors and infrastructure is made on the basis of the ability to control and manage traffic. One of the results of this study will be a quantification of the ways that this infrastructure investment can also improve the safety and efficiency of CAVs.
- Data modeling and analytical tools to evaluate effects of investment. Similarly, the deployment of CAVs will require simultaneous deployment of new transportation infrastructure technologies. This study will help to quantify the incremental safety, economy, and environmental benefit that the transportation system may be able to accrue when fully integrated with the information needs of CAVs.

Educational Benefits

This research will support a graduate student in their pursuit of a Master of Science degree in Mechanical Engineering at Colorado State University.

In addition, this research will be used to develop teaching modules for a set of courses offered at Colorado State University as part of a certificate in Hybrid Electric Vehicle Engineering. The relevant courses would include Hybrid-Electric Vehicle Powertrains - MECH 527 (CRN 70945), and Transportation Electrification - MECH 680A4 (CRN 70576). Both of these courses are graduate level courses studying the technologies of modern transportation systems including relevant subjects such as transportation system modeling, transportation big-data, and real-world drive cycle derivation.

Technology Transfer

This research will be performed in collaboration with a set of partners who will contribute to the technology transfer aspects of this research. CSU has undertaken research on CAVs under the funding and guidance of multiple automotive OEMs (including Toyota, Nissan, and GM), and CSU will share the results of these studies directly with the technical experts at these companies. In addition, this project will be performed in collaboration with Fort Collins Utilities, Traffic Operations Department. By sharing the results of this work with these OEMs and a modern traffic operations utility, we can develop an understanding of how to commercialize the technologies, systems and algorithms to their application.

Work Plan

1. Velocity trajectory prediction based on CAV vehicle data only
2. Velocity trajectory prediction based on CAV vehicle data and Infrastructure data
3. Technology Transfer to Automotive OEMs and Transportation Stakeholders

In Task 1, a speed prediction method is developed, and trained with real-world driving data gathered only from the subject vehicle (a local data collection method). In previous work, we have performed this type of prediction using an artificial neural network classifier. This classifier used the vehicle's current GPS coordinates and past vehicle speed trajectory to select the most similar future trajectory from among a set of learned speed trajectories gathered at that GPS coordinate [6]. Follow up research has demonstrated the value of including CAV-specific sensing technologies (including machine vision, RADAR, and LIDAR) for vehicle speed trajectory prediction [7]. To continue to build out a dataset of real-world CAV-relevant vehicle data, CSU will perform experiments to gather data from real-world driving in and around Fort Collins, CO. Data to be gathered through these experiments includes 1Hz vehicle velocity, vehicle GPS location, the position and velocity of vehicles within line of sight, the state of traffic signals within line of sight, and more for 10-20 experimental driving routes and driving conditions. CSU possesses the equipment and analysis algorithms to be able to derive this type of information from a fleet of instrumented vehicles. Various novel techniques for predicting the vehicle speed on the basis of these inputs (NNARX, Deep Learning, Classifier methods, etc.) will be compared post-hoc to defend the choice of a baseline vehicle-centric velocity trajectory algorithm. A tradeoff analysis will quantify the tradeoff between prediction window and velocity prediction fidelity. We anticipate this task to conclude by the end of the 4th month of the project.

Project Cost

Total Project Costs:	\$120,000
MPC Funds Requested:	\$60,000
Matching Funds:	\$60,000
Source of Matching Funds:	Faculty time and effort

References

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