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Caltrans Division of Research, Innovation and System Information

Research Notes

A Roadmap For Flow Smoothing Via Connected And Automated Vehicles(CAV) In California

Conduct simulations on how vehicle autonomy (level 2 and above) can reduce of stop and go traffic and improve energy efficiency.

Advanced Research

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Project Title:
Connected and Automated Vehicles Cross Cutting Research

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WHAT IS THE NEED?

As companies continue to integrate automation features into their releases, the state of multiple-vehicle coordination today is not at the forefront of the agenda of the industry. This is mostly because the innovation ecosystem of traffic automation is only at the infancy of multiple vehicle coordination for traffic management.

The idea of leveraging the advances of automation of single vehicles for traffic management is precisely the motivation behind this research.

Today, a large variety of mainstream vehicles (e.g., Toyota RAV-4 for example) come with some standard degree of automation (e.g., automatic cruise control, lane departure steering assist, etc.), while the technology available in state-of-the-art high-end vehicles (e.g., Tesla) enables the coordination of multiple level-2 enabled vehicles to smooth traffic. The existing research team is part of a larger project aimed at studying wave-smoothing connected autonomous vehicles connected automated vehicles into live congested traffic in order to reduce the system-level energy consumption.

WHAT ARE WE DOING?

In this first task, the contractor will develop a series of robustness tests (ranging from easy to difficult) in simulation so that the contractor can confidently narrow down our list of controllers. The work will involve developing a simulation environment (microsimulator) which exhibits traffic waves in a range of settings.

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For this the contractor will continue to leverage the I-210 simulation testbed built by the Connected Corridors team and expand the results to the I-680 in Danville. Vehicle controllers will be subjected to these varied scenarios and assessed on their abilities to smooth waves, reduce system-level energy consumption, and behave in a socially acceptable manner.

In this second task, the contractor will design a workflow to facilitate easy implementation of controllers onto the test vehicles. The control vehicles will be two Toyota Rav-4's equipped with comma.ai interface packages that the contractor has already purchased. The workflow will include a code translation step (from python to Simulink) and a verification unit test to confirm the expected actuation outputs from the vehicle.

The remaining vehicles in the contractor's fleet will be deployed in a distributed fashion onto the testbed as data collectors. While they will be human-driven vehicles, they will also need to be equipped with interface packages (e.g. comma.ai or similar) so that the collected data can be post-processed and analyzed. This third task will ensure that the remaining vehicles are sufficiently equipped and that the contractor has all the hardware and software infrastructure to access the data.

WHAT IS OUR GOAL?

The goal of this specific project is to advance our understanding of how controller policies transfer from simulation environments to real-world implementations in California.

WHAT IS THE BENEFIT?

The preliminary work previously has demonstrated that such a reduction is already possible, with a test run in a preliminary form in Arizona, leading to the 40% reduction mentioned above (see Figure 3, left).Current numerical simulations, leveraging the I-210 Connected Corridors model already indicate that 10% reduction in energy consumption is possible with a 5% penetration rate of level-2-enabled connected automated vehicles on that freeway.

As a part of that overall thrust, the goal of this project specifically is to advance Caltrans understanding of policy transfer from simulation to reality and to demonstrate it in California. The I-210 testbed could be a specific deployment site. Caltrans is also envisioning some Bay Area Centric test sites, such as I-680, I-880 or I-80. In order to bridge our ongoing deep-reinforcement learning research to real-world implementation, we seek to perform robustness testing in the form of controlled small-scale tests on California roadways in 2022. These small-scale tests will simultaneously serve as a seed for future CAV deployments and traffic research in the State of California.

WHAT IS THE PROGRESS TO DATE?

An I-210 simulation was used to facilitate training controllers with varying flow conditions. Robustness testing is done with a different simulator with multiple scenarios: (a) shockwave, (b) bottleneck (c) freeflow. With each of these scenarios, the human driver behavior model can be varied for increased aggression (acceleration/deceleration and lane change frequency) and the density of automated vehicles. A new shockwave or freeflow scenario can be generated with any real driven trajectory in any highway setting. The bottleneck scenario can be generated with varied severity of congestion to match the observed capacity reduction. The controllers that were developed/trained, are shown to transfer well to new environments. As such, we have obtained a key understanding of what constitutes a good controller and the combinations that give rise to such performances, namely speed planners that provide sufficient preemption to lower level controllers and lower level controllers that have the right balance of obeying the speed planner and not falling too far behind in traffic. Over the course of one week (from November 14th to November 18th) a fleet of 100 smart vehicles driving in morning rush hour traffic on Interstate 24 in South Nashville, TN were used to test findings from the simulations. The vehicles equipped with adaptive cruise control, were used in an effort to help mitigate human-caused phantom traffic jams. Researchers also utilized 300 ultra-HD cameras along the I-24 corridor to collect additional data points. Using vehicle to vehicle communication, AI algorithms adjust vehicle speeds based on information far ahead of the vehicle. Initial tests show a reduction in phantom traffic jams. Researchers are currently reviewing data collected and revising the AI algorithm.