DRISI
Caltrans Division of Research, Innovation and System Information

Research Notes

Traffic Operations

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Project Title:
Testing of Combined Variable Speed Advisory (VSA) and Coordinated Ramp Metering (CRM) for Freeway Traffic Control

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Robust Design, Analysis and Evaluation of Variable Speed Limit Control in a Connected Environment with Uncertainties

Develop variable speed limit controllers to be used for congestion management at bottlenecks, incidents and closure of lanes.

WHAT IS THE NEED?

Connected vehicles via vehicle to vehicle (V2V) as well as vehicle to infrastructure (V2I) communications will open the way to manage and control traffic in a much more effective way than in today's traffic where sensing and control actions are very limited. While vehicle technologies are moving faster it is just a matter of time before infrastructure will follow and provide the necessary instrumentation for V2I communication.

The technology of V2I has been around for several decades and has been tested in automatic toll collection and other applications. One of the main remaining issues is the cost of investment and decision making. In order to properly evaluate the cost, however, stakeholders need to understand the potential benefits of traffic control techniques such as that of variable speed limit (VSL) control.

Despite considerable research in the area of VSL control and the deployment of such technologies in various places, mostly in Europe, the full potential benefits of VSL as reported in the literature are controversial and often conflicting. The lack of consistency in the benefits of VSL may be attributed to various factors that include accuracy of the models used, lack of robustness of the VSL controllers and lack of rigorous analysis to support and explain simulation results etc.

In this project, the researchers plan to design, analyze, and evaluate robust variable speed limit control techniques that take into account modeling and measurement uncertainties that are inevitable in a real traffic environment and therefore more practical and generate consistent benefits.

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WHAT ARE WE DOING?

The research team first plan to design robust variable speed limit (RVSL) controllers that take into account the presence of modeling uncertainties, inaccuracies in measurements, unmeasurable disturbances and noise which are inevitable in a real traffic environment. We then plan to establish analytically that these controllers have guaranteed stability and convergence properties and reach equilibrium states that are as close to the optimum as possible despite traffic modelling uncertainties. Optimality will mean maximum possible throughput at bottlenecks, incidents, etc.

Subsequently, we plan to demonstrate our analytical results and benefits of the designed RVSL schemes. First, by using macroscopic simulation models then by using more realistic microscopic simulation models. The microscopic models will focus on the high truck traffic areas on I-710.

The Environment Protection Agency (EPA) model Motor Vehicle Emission Simulator (MOVES) will be used to evaluate the emissions and impact on environment with RVSL and without RVSL. Performance criteria that include travel time, number of stops, number of lane changes, emissions, and fuel economy will be used to quantify the benefits of the proposed RVSL in comparison to no control.

WHAT IS OUR GOAL?

Our goal is to develop traffic flow control strategies that can make traffic flow more efficient by better managing incidents and bottleneck traffic. This can be achieved by using communication technologies to provide the necessary information which allows the development of efficient traffic flow controllers such as variable speed limit control.

WHAT IS THE BENEFIT?

The purpose of this project is to address the issue of robustness in the design of VSL and bring such schemes closer to a successful implementation with consistent and well understood benefits.

The development of VSL algorithms and their demonstrated benefits under this project will motivate their use in controlling congestion during incidents and bottlenecks in highways, which is of interest to Caltrans and transportation authorities in general.

Upcoming communication technologies that involve V2V and V2I will open the way for much more intelligent approaches to manage traffic in a way that prevents congestion or achieves a more effective control when it happens.

Analyzing and quantifying the benefits of RVSL control, using realistic scenarios and validated microscopic traffic simulations, could motivate transportation authorities to move faster in making changes in the existing infrastructure. Changes would allow the implementation of more effective traffic flow control techniques such as the proposed RVSL control. The implementation of RVSL control is expected to improve mobility, reduce emissions and enhance safety.

WHAT IS THE PROGRESS TO DATE?

Research team built a macroscopic simulation model for the proposed multi-section controller to alleviate freeway bottleneck congestion caused by lane. This model is used to describe the traffic behavior and capture more complex traffic flow phenomena, such as the capacity drop and bounded acceleration. The VSL commands are computed based on flow and density measurements in a feedback manner.

Many of the control efforts are concentrated on the most upstream VSL section, to match the inflow of the road network with the bottleneck capacity in order to minimize downstream speed variations and suppress shockwave. The length of the most upstream VSL section is treated as a control variable and its lower bound is derived as a necessary condition to achieve convergence. Feasibility constraints are applied to ensure safety and enhance robustness. The lane change controller is implemented to reduce the capacity drop. The RM is used for each on-ramp to restrict the ramp input when the ramp queue capacity is available. The integrated controller shows significant improvements in traffic mobility, safety, and environmental impact, as demonstrated by microscopic simulations of an actual freeway network in Southern California. The closed-loop system is able to tolerate up to 20% uncertainties in sensitive measurements such as mainstream flows and densities.