MPC-433

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Project Title:
Real-Time Traffic Management to Maximize Throughput of Automated Vehicles

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Utah State University

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Research Needs:
To increase capacity and the efficiency of the U.S. highways and interstates, common maneuvers performed by automated vehicles such as lane changing, exiting, and merging should be accomplished in such as way as to maximize throughput and reduce, if not eliminate, accidents. Existing work on lane changes, which either assumes restricted number of lanes on a given road e.g., [Habenicht2011, Naranjo2008] or focuses on the collision avoidance aspect of the problem e.g., [Jula2000, Wakasugi2005], does not attempt to reduce congestion by maximizing throughput.

Research Objectives:
The overarching goal of this project is to design a framework to maximize the throughput of automated vehicles during typical maneuvers such as lane changes, exiting, and merging. The framework will consider a transportation system that consists of both automated vehicles and vehicle platoons. The successful completion of this project will result in an increase number of lane changes during a given time interval, less congestion, and fewer accidents.

Research Methods:
The problem of throughput maximization of automated vehicles during lane changes will be modeled after real-time task scheduling on a microprocessor [Liu1973] and will be divided into two major subparts. In the first subpart, each vehicle intending to change lanes will be assigned a priority value denoting its lane change urgency. In the second subpart, vehicles will be scheduled for lane changes according to a real-time task scheduling policy [Liu1973]. Together, the subparts will help to answer the question on how to maximize the throughput of automated vehicles during lane changes given an arbitrary number of lanes.

To assign a priority value to a given vehicle, the time that a given vehicle has to change lane must be determined based on that vehicle's position, velocity, and acceleration, those of the vehicles around it, and other variables such as the total number of lanes and the behaviors of other vehicles. Since making such a calculation typically requires large and frequent data transmissions among the vehicles, some theoretical results concerning the minimum V2V or V2I data transmissions will be derived.

Once a priority value is associated with each vehicle intending to change lanes, a real-time task scheduling policy will be applied to determine the order of lane changes as to maximize the total number of lane changes. It is expected that the least-slack first scheduling policy [Buttazzo2011] will be an appropriate scheduling algorithm for the problem at hand.

The next step is to derive locally optimal algorithms to solve the aforementioned problem locally instead of globally. In other words, it is unrealistic to assume that a vehicle or an infrastructure will take on the role of deciding the priority and order of lane changes of each vehicle on the road. Localized algorithms will be designed to solve the problem efficiently and with high solution quality.

Once a set of distributed algorithms are designed and their effectiveness validated, the implications of merging, exiting, changing speed limits, and co-existence with platoons will be considered and the algorithms modified as necessary. Due to the complex nature of the problem, it is expected that heuristic algorithms be designed instead of optimal algorithms.

Finally, extensive simulations on the NCTUns simulation platform will be conducted to ensure the effectiveness of the proposed algorithms, as well as their feasibility in terms of runtime overhead.

Expected Outcomes:
The proposed project has several expected outcomes. First, a novel traffic management model based on real-time scheduling theory will be given. Second, a collection of algorithms to manage the throughput of automated vehicles during typical maneuvers such as lane changes will be provided. Third, extensive simulations will be performed to ensure feasibility. Fourth, the proposed project will result in journal publications co-authored by a Master's student.

The completion of the proposed project will result in a more efficient and safer transportation system. Along with research results involving novel transportation infrastructures and communication protocols, it is expected that more research will be needed to tightly integrate the knowledge from different fields before an actual implementation of the system will be possible.

Relevance to Strategic Goals:
Safety
The proposed project directly supports the U.S. DOT strategic plan of reducing transportation-related fatalities and injuries by making it safer for automated vehicles to perform several maneuvers such as lane changes, exiting, and merging without slowing down traffic or causing accidents even in the presence of platoons.

Environmental Sustainability

The proposed project will results in traffic management algorithms that reduces or eliminates unnecessary increases/decreases in vehicle speeds, or braking, in order to perform maneuvers such as lane changes, exiting, and merging. As a result, the automated vehicles will consumed less fuel and output less emissions.

Educational Benefits:

This project requires a full-time Master's student to (i) design traffic management algorithms based on real-time scheduling theory and optimization theory, and (ii) to carry out simulations showing the effectiveness of the proposed algorithms. It is expected that the aforementioned Master's student will be able to use the research resulted from this project as his/her Master's thesis. An undergraduate student will also be employed during the course of the project to help gather simulation data.

In addition, the research results from this project will be integrated into a lecture module on Cyber-Physical Systems in the Real-Time Systems course (ECE 5780) taught by the PI at Utah State University. This course has a typical enrollment of about 15-20 students per year and undergraduate students make up about 50% of the class roster.

Work Plan:

Table 1 shows the timeline to be followed during the course of the project.

Table 1: Project Timeline

Task Number	Task Description	Timeline (Months)
1	Design distributed algorithms to manage lane changes of automated vehicles	1-3
2	Gather simulation data on the NCTUns simulation platform	4
3	Submit the first manuscript to a journal	5
4	Leverage distributed algorithms to include merging, exiting, and lowered speed limits	6-9
5	Modify algorithms to work with both automated vehicles and platoons	10-12
6	Submit the second manuscript to a journal	12
7	Prepare data, algorithms, additional code (if applicable) for public release	12

Project Cost:

Total Project Costs: $100,000.00
MPC Funds Requested: $50,000.00
Matching Funds: $50,000.00

Source of Matching Funds: Academic Year Faculty Salary

TRB Keywords: Automated vehicles, automated highway system, dynamic traffic management, congestion management systems, merging traffic, lane changing

References:

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