Hierarchical Hybrid-State Systems for Coordinated Autonomous Driving in Mixed-Traffic Urban Environments

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Introduction
The Cyber-Physical System Research group at the Ohio State University developed tools and algorithms to address the interdisciplinary problem of fully autonomous driving in real-life urban traffic from multiple angles. Mixed-mode traffic, where human-driven cars, motorcycles, bicycles, pedestrians and other autonomous and semi-autonomous vehicles interact, poses a number of unique problems involving large-scale cyber-physical systems. In this poster, a modular hierarchy connecting various units inhabiting the mixed-mode traffic will be proposed, experiments on feasibility of communication and coordination will be presented and the necessary situational awareness tools and representations will be investigated.

Hierarchy
From a higher level and abstract perspective, the overall problem requires communication and coordination between the infrastructure and the mobile agents, autonomous or human controlled. Using the Hybrid-State System (HSS) formulations for vehicle control, where a high-level decision maker commands a low-level continuous controller, and for vehicle control, where a high-level decision maker using the Hybrid-State System (HSS) formulations mobile agents, autonomous or human controlled. From a higher level and abstract perspective, the representations will be investigated.

Communication and Coordination
Wireless communication between vehicles (V2V) and infrastructure elements (V2I) enable the use of driver assistance, collision avoidance, fuel and traffic management algorithms for both autonomous and human-driven vehicles. Coordination of convoys in highway traffic, better utilization of traffic light cycles, warning systems for non-line-of-sight intersection approaches are a few examples benefitting from communication.

OSU-CITR supported Team Mekar from Turkey in a Consortium that entered EU and Okan University in the Grand Cooperative Driving Challenge (GCCD) organized by TNO in the Netherlands in May 2011. GCCD was designed to test cooperative driving between vehicles developed by different teams.

In the ideal scenario, each vehicle is equipped with Dedicated Short-Range Communication (DSRC) radios, and the infrastructure elements such as traffic lights are also capable of communicating on these channels.

As seen in the figure, the region in focus is divided into zones that are similar to the “cells” in a wireless telecommunication example. Each zone is designed to handle a number of mobile agents, some of which are expected to be manually controlled. The human-driven vehicles are tracked via Roadside Units (RSU) such as traffic cameras, the autonomous vehicles talk to one another and to the infrastructure via vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication. The communication-capable lights control the flow of traffic of all the vehicles.

Four OSU-CITR vehicles, one with full autonomy, one longitudinally autonomous, and two human driven, all with DSRC radios. The V2I-enabled prototype traffic light is also seen on the right.

As part of the CPS effort, OSU-CITR developed and continues to test communication, coordination and conveying scenarios on fully autonomous and semi-autonomous vehicles, in interaction with human-driven vehicles.

Interpretation and Awareness
In order to use the data obtained through a number of communication channels and fused into a coherent set of measurements, the situational awareness modules of observing entities need an abstraction of the scenario that is conducive to decision making and management.

For the cases where we cannot realistically expect older vehicles to have the communication equipment, other infrastructure elements such as traffic cameras, LIDAR and RADAR detectors can be tied into the communication units (RSU) can relay the necessary information on non-communicating agents, including pedestrians.

The developed software was tested on actual vehicles in real traffic; tracking, estimating and predicting driver behavior successfully.

The vehicle is tracked while approaching an intersection, decelerating to stop. It is successfully predicted to be stopping seconds before the actual stop.

Conclusions
OSU-CPS group develops and tests tools and methods to solve problems associated with successful autonomous navigation in mixed-mode traffic. There are both conceptual and computational aspects of the problem that still need to be addressed, and our interdisciplinary team of researchers continue to attack the problem, so that one day we can have an autonomous taxi take us to our destination, even in downtown Istanbul.

Acknowledgments
We would like to thank The National Science Foundation and Honda R&D of America, Inc. for their support and the entire OSU-CITR and OSU-CPS team.

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For further information
Please contact Kurt (Kurt@osu.edu) or umit@ece.osu.edu. More information on this and related projects can be obtained at http://www.cps.osu.edu and http://www.cps.osu.edu/citr/

Literature

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