The Future of Autonomy and Safety

in Mixed Traffic Urban Environments

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We are at the mid-point of an NSF CPS Program supported project on Autonomous Driving in Urban Environments. The objective of this research is to "scale up" the capabilities of fully autonomous vehicles so they are capable of operating in mixed-traffic urban environments: realistic large-city driving situations with many other (mostly human-driven) vehicles. The approach is to integrate interdisciplinary advances in software, sensing and control, and modeling to address the most serious weaknesses in autonomous vehicle design revealed recently by, e.g., the DARPA Urban Challenge. Our ongoing project is therefore intimately related to the topic of this Workshop and my Position Paper will mention both some ongoing research addressing the relevant topics and present some issues substantially beyond what we can address during the tenure of our project.

Automotive Secure High Confidence Platforms

Research on collaborative driving, specifically in convoy type applications, has been initiated. Testing of hybrid systems is also being investigated

Hybrid-State System (HSS) modeling of mobile agents has been and is being used in a number of studies including mobile robots, autonomous and human-driven vehicles. The overall architecture of an abstract decision maker over a continuous-state mobile system captures the interaction between the Cyber and the Physical in a way that lets us define and analyze complicated scenarios in a structured manner. We advocate a model in which a finite-state machine high-level controller interacts with a classical continuous-state feedback controller to emulate driver-vehicle operations in an urban environment. We have used this in the DARPA Urban Challenge, and further exploited the driver/vehicle dichotomy for driver assistance systems in collaboration with an automotive company, in which the intention and decisions of the driver were estimated and predicted via the behavior of the vehicle, observed on a vehicle-to-vehicle (V2V) communication link.

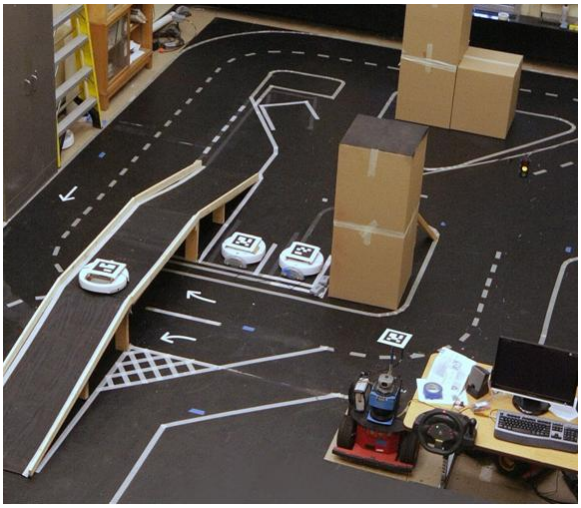
* : Representing the OSU CPS Group, see http://cps.osc.edu

A newer, more tactical hybrid-state autonomous controller was developed and tested for multi-robot exploration scenarios for DSTO Multi Autonomous Ground-robotic International Challenge (MAGIC 2010) and the automotive convoy-based scenarios of the Grand Cooperative Driving Challenge (May 2011) are being evaluated. In all the above computational issues and testing aspects are under investigation.

The specific long-term needs we see in this domain is in fault tolerance, in a number of different domains. (a) Fault tolerant operation is needed for the distributed network of the future where retaining the health of the connected graph linking data centers to vehicles is important, (b) Security of the communication network (both V2V and V2I) has to be guaranteed with real-time key exchanges and verification in an evolving set of participants are required, (c) The control algorithms utilized need to be robust and the overall systems need to degrade and fail gracefully, (d) Software needs to be verified and tested.

Open Experimental Platforms/Challenge Problems

The OSU Simulator-Testbed Environment with Virtual Sensors and Objects



SimVille was created after the 2007 DARPA Urban Challenge in order to continue research efforts in urban environment scenarios. A road network was created to be 1/7 scale with 0.5 m wide lengths in order to use the Create robots as urban vehicles. The road network was designed to provide areas for testing many diverse scenarios without the need to change the test environment. Several intersections were included both with and without traffic lights. An overpass and several simulated buildings were added in order to test GPS dropout situations. SimVille is particularly suited for testing CPS applications: (a) Since all data is centrally known, “virtual” sensors and objects can be created in this world. (b) The layout can be repeated full scale (with real cars) in a large open area on campus. (We presently have three autonomous vehicles.) This provides a transition from simulation to lab-level testing to full-scale testing, an approach essential for reaching eventual deployment.

Human in the Loop

Driver Intent Modeling for Estimation and Tracking in Complex Mobile Environments.

As a part of the driver behavior modeling part of the CPS project, we have developed an approach using hybrid system estimation, for driver intent in approaching an intersection.

We have also been developing applications of Hidden Markov Models (HMMs) for a single task for a single vehicle. This is a large and important area which includes both modeling and estimation issues, and also a number of technology related issues.

We are specifically interested in evaluating driver EEG's together with phenomena like body motion, gaze etc. to understand human driver intent early enough to create danger indicators. These indicators can then be broadcast through V2V to warn other drivers. We believe that if human driven and autonomous vehicles are going to occupy the same roadway in the future (say in twenty years) then extensive effort has to be expanded in understanding the thoughts and behavior of human drivers, so as to create a driving environment that is safe for all.

Prof. Umit Ozguner has been with the Ohio State University since 1981 where he is Professor of Electrical and Computer Engineering and holds the TRC Inc. Chair on ITS. His areas of research interest are in Intelligent Transportation Systems, decentralized control and autonomy in large systems. He is a Fellow of the IEEE.

He was the first President of the IEEE ITS Council in 1999 and has also served the IEEE Control Society in many positions. He has been the General Chair of the 2002 CDC. He was the Program Chair for the 1997 IEEE ITS Conference, which he helped initiate, and served as the General Chair for the 2003 Intelligent Vehicles Symposium.

The team he coordinated participated successfully in the (US DOT supported) 1997 Automated Highway System Technology Demonstration in San Diego, where they demonstrated 3 fully automated cars doing lane-keeping, convoying and passing. Groups he led developed autonomous vehicles and participated in the DARPA 2004 and 2005 Grand Challenges, and 2007 Urban Challenge. Professor Ozguner is the author of over 400 publications and has been an invited plenary speaker in many international meetings in the US, Japan, China, India, Turkey and Italy.