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Augmented Reality and Connected Automated Vehicles

Connected and automated vehicles (CAVs) must be tested extensively before they can be deployed and accepted by the general public. Currently, CAV testing and evaluation are primarily conducted in two ways: on public roads and in closed test facilities. There are two significant limitations of public road testing. First, safety is a critical issue because the technology is still at the development stage. Forty-nine traffic accidents involving autonomous vehicles have been reported to the California Department of Motor Vehicles (DMV) as of October 30, 2017 (1). In addition, a fatal crash occurred between a car operating with automated vehicle control systems and a truck in Florida in 2016 (2).The second critical problem is the testing efficiency. According to the National Highway Traffic Safety Administration (NHTSA), a fatal crash occurs once in about every 100 million miles of driving (3). From the testing perspective, researchers are more interested in those “edge cases,” which represent the most dangerous driving situations or road conditions to human drivers. As a result, an alternative is to test the vehicle in closed test facilities where “edge cases” can be created repeatedly without jeopardizing public safety. However, the closed testing facility can’t provide the same realistic traffic environment as found in the real-world, where multiple road users can interact with the testing CAVs.

To address this limitation, researchers at the University of Michigan have developed an augmented reality (AR) environment for CAV testing and evaluation, and are conducting research sponsored by the Center for Connected and Automated Transportation (CCAT), the Region 5 University Transportation Center. The AR environment combines a real-world testing facility and a simulation platform. Background traffic is generated in microscopic simulation (4) and provided to testing CAVs through wireless communication to augment the functionality of a test facility. At the same time, movements of testing CAVs in the real world are also synchronized in simulation by generating virtual testing CAVs. Moreover, traffic signals in the real-world and simulation are synchronized, so that both virtual vehicles and testing CAVs react to the same signal indication. As a result, testing CAVs can interact with virtual background traffic as if in a realistic traffic environment. Test scenarios that require interactions with other vehicles or modes of travelers (e.g., pedestrians, cyclists, trains) can be performed. Using this environment, numerous new traffic scenarios can be created, which greatly enhance the capabilities of the testing facility.

Compared to using real vehicles, simulated virtual vehicles can be easily controlled and manipulated in generating different scenarios with much less cost and concern for safety. For instance, when the testing CAV fails in a safety-related test and a collision occurs between the testing CAV and a simulated virtual vehicle, neither vehicle is damaged. Such tests can be repeated over and over again. The AR environment can serve as a pre-step before real vehicle testing to ensure algorithms are thoroughly examined, and parameters are fine-tuned.

The AR environment is implemented in Mcity, a newly established closed CAV testing facility at the University of Michigan. Mcity is the world’s first full-scale simulated city designed solely for testing the performance of CAVs. A Lincoln MKZ Hybrid is used as the testing vehicle; this vehicle is fully connected and automated and equipped with various sensors, including LiDAR, radar, camera, high-resolution GPS, and a dedicated short range communication (DSRC) device, to communicate with the simulation environment through the roadside units (RSUs) installed in Mcity. A Mcity simulation model is built in VISSIM (5), a microscopic traffic simulation tool, to generate virtual vehicles.

Two examples of testing scenarios that can be designed within this framework are railway crossing and red light running. In the railway crossing scenario, a virtual train is generated in VISSIM when the testing CAV is approaching a rail crossing located in Mcity. The testing CAV should stop before the rail-crossing and wait for the train as shown in the photo. The photo shows the views from both simulation and the real world. A blue train is generated and traveling on the track in the left part of the figure

https://mcity.umich.edu/u-m-offers-open-access-automated-cars-to-advance-driverless-research/

Mcity and Testing CAV

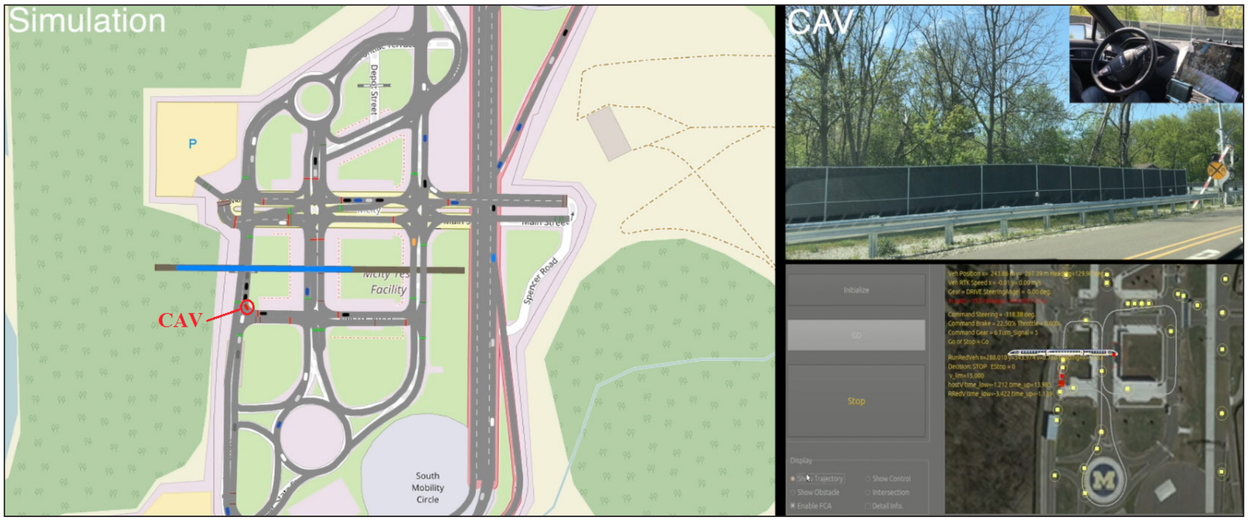

Illustration of the System with Railway Crossing Scenario, University of Michigan

(simulation). Several vehicles are waiting behind the rail-crossing including the testing CAV (the red vehicle in the circle). The upper right part of the figure shows the view from the testing CAV's windshield as well as from inside of the vehicle. It can be seen that the testing CAV stopped at the corner behind three virtual vehicles, although there are no real vehicles in front of it. The lower right part of the figure shows the view from the testing CAV's control system. The red rectangle is the testing CAV, and all smaller rectangles represent virtual vehicles from the simulation.

The red-light running scenario serves two purposes: how the testing CAV interacts with traffic signals and how it reacts to a red-light running vehicle. During the test, the CAV should be able to identify the signal status of the approaching lane and make stop-or-go decisions. Also, the CAV should be able to monitor and predict the simulated red-light running vehicle's trajectory and calculate potential location and time of the collision. Because the red light running vehicle is virtual, its generation time, generation location, and approaching trajectory can be easily set and modified to test the CAV's reaction under different circumstances, which greatly improve the test efficiency while ensuring safety.

Ultimately, researchers plan to construct a CAV test scenario library and use the AR testing environment to conduct the test. The test library should include many "edge" scenarios that can repeatedly be tested using this framework; accessing crash databases and naturalistic driving data and parameterize representative crash and near-miss scenarios. Parameterization also enables us to create artificial "edge" cases that can challenge the intelligence of CAV. These are left for future research.

References

[1] California Department of Motor Vehicles. Report of Traffic Accident Involving and Autonomous Vehicle (OL 316). 2017. URL: https://www.dmv.ca.gov/portal/dmv/detail/vr/autonomous/autonomousveh_ol316+

[2] National Transportation Safety Board. Highway Accident Report: Collision Between a Car Operating With Automated Vehicle Control Systems and a Tractor-Semitrailer Truck Near Williston, Florida. 2016. URL: https://www.ntsb.gov/investigations/AccidentReports/Reports/HAR1702.pdf

[3] National Highway Traffic Safety Administration, 2016 Fatal Motor Vehicle Crashes: Overview, 2017. URL: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812456

[4] Microscopic simulation", sometimes called microsimulation, means each entity (car, train, person) of reality is simulated individually, i.e. it is represented by a corresponding entity in the simulation, thereby considering all relevant properties. The same holds for the interactions between the entities. The opposite would be a "macroscopic simulation", in which the description of reality is shifted from individuals to "averaged" variables like flow and density. Source: https://en.wikipedia.org/wiki/PTV_VISSIM.

[5] Verkehr In Stadten-SIMulationsmodel
URL: https://en.wikipedia.org/wiki/PTV_VISSIM

About This Project

This project is led by Prof. Henry Liu (the UTC director) from the Department of Civil and Environmental Engineering and Yiheng Feng, Ph.D., from the Transportation Research Institute at the University of Michigan. The augmented reality testing environment will be presented at the Transportation Research Board 97th Annual Meeting in Washington, D.C. An introduction video can be found here: https://www.youtube.com/watch?v=qeAZE0jQUMM