Expanding the Scope of Testing and Simulation to Improve Integration of Autonomous Vehicles with the Public

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MEMORANDUM

TO: The IEEE Intelligent Transportation Systems Society (ITSS)

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SUBJECT: Expanding autonomous vehicle test and simulation research to improve integration with the public

Background

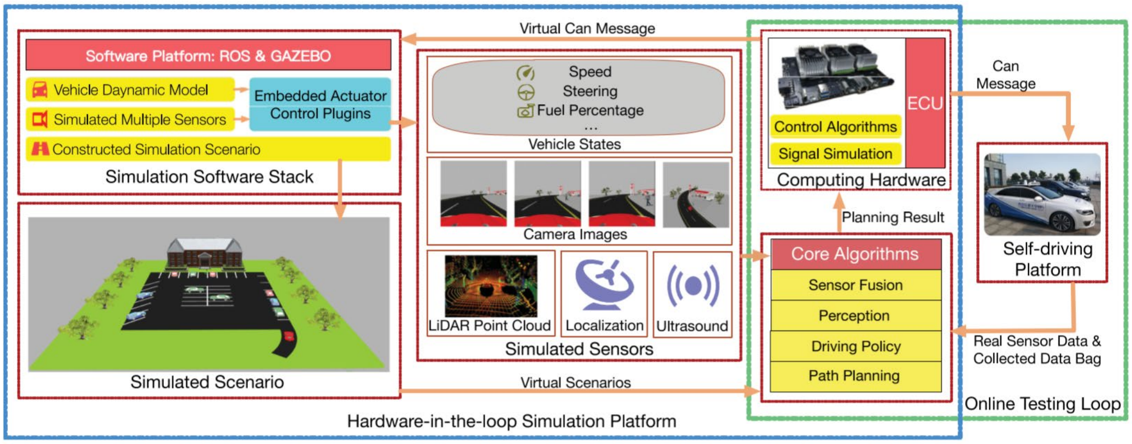
The international Society of Automobile Engineers (SAE) released a scholarly article in 2018, updating the descriptions of six distinct “levels of driving automation” (“Taxonomy and definitions”, p. 19). This publication offers experts a frame of reference to classify their autonomous vehicle research developments and goals. Level 0 involved no driving automation and Level 5 describes full driving automation. There are a lot of Level 0 cars on the road today. Most cars however, especially newer models, are classified as Level 1 because they include some sort of driving assistance system, such as adaptive cruise control and parking assistants (Coicheci & Filip, 2020, p. 000255). With each advancing level of automation, the driver has fewer responsibilities and decisions to make. Despite language commonly used in mass media, most “self-driving” cars are not fully autonomous. Tesla’s Autopilot system, for example, qualifies as Level 2 because the car can control all key aspects of driving, but the driver must be capable of taking control back at any moment (Coicheci & Filip, 2020, p. 000255).

The rapid advancement of autonomous vehicle research warrants complex and comprehensive testing before releasing technology to the public. Two main methods for testing are described as online vs. offline (Chen et al., 2019, p. 425). Online tests use the vehicles in the test scenes, while offline tests use virtual scenarios for simulation. Offline plans are typically less expensive and safer. They include extensive software tests to assess and validate the sophisticated algorithms. There are a few completed platforms developed and available for use, such as TORCS, Carla, PreScan and CarSim (Chen et al., 2019, p. 425). These tests predominantly rely on the use and collection of large amounts of data, which can require a lot of time to execute. In a scholarly journal from 2020, expert researchers developed methods for generating simulated GPS, IMU and lidar sensor data (Elmquist & Negrut, 2020, p. 684). This development contributes to the verification of hardware performance, an especially important component in virtual simulations. The most common methods of testing have a variety of advantages, but a particular standard for approving test procedures for autonomous vehicle technology has not been defined yet.

There are a lot of limitations to the existing methods for testing autonomous vehicles. Not only do virtual simulations generate large amounts of data, but the artificial intelligence and machine learning algorithms involved in highly developed systems must be trained before successful testing. Even with “more than 30 million kilometers on public roads without a fatal accident” Waymo, Google’s autonomous vehicle project, evolves through development, training, and testing for continued improved performance (Coicheci & Filip, 2020, p. 000255). Additionally, the disconnect between some online and offline testing can stark. Chen et al. proposed a new simulation method in their expert research article, explicitly including the real hardware electronic control unit in their closed loop system (2019, p. 425). Chen et al. describes this method as Hardware-in-the-Loop.

Figure 1.

Proposed Hardware-in-the-Loop (HiL) Simulation System Diagram



Note: The system diagram visually distinguishes the components involved in the complex system. The outlined rectangles categorize different elements of the simulation and the arrows indicate how elements interact and communicate. From "A novel integrated simulation and testing platform for self-driving cars with hardware in the loop" by S. Chen, Y. Chen, S. Zhang, and N. Zheng, 2019, *IEEE Transactions on Intelligent Vehicles*, *4(*3*)*, p. 426 (https://doi.org/10.1109/TIV.2019.2919470).

Another alternative method, described as Scenario-in-the-Loop, simulates real traffic scenarios in a test environment that are otherwise too difficult or dangerous to recreate (Szalay et al., 2019, p. 1). Both closed loop research developments aim to improve the autonomous vehicle testing process, but unfortunately simulations cannot capture every possible driving scenario and real-driving tests become expensive. In an effort to evaluate the proving grounds of autonomous vehicles, Chen et al. notes that failures in testing reveal the imperfections in algorithms and the "ineffectiveness of testing approaches" (Chen et al., 2020, p. 1). The limitations of isolated test methods highlight a knowledge gap in the field of autonomous vehicle technology. Simulated tests are typically created to assess explicitly different qualities in an autonomous vehicle than the hardware tests. Though both types of tests are effective, there are few combined methods that are widely implemented. There are many ways for researchers to smoothly add more elements of closed loop testing to existing testing procedures.

Objectives

Further research is possible, and I hope to contribute to the continued development of effective testing and thus successful autonomous vehicles with the help of expert researchers and professionals. Autonomous vehicle technology is an interdisciplinary topic, reliant on the advancement of computer science, electrical and mechanical engineering. The smooth integration of software and hardware testing will allow for better vehicle performance in the future. Professional organizations like the Intelligent Transportation Systems Society (ITSS) can dedicate resources and funding to a broader scope of research. Testing and simulating vehicle-to-vehicle communication, for example, may be the key to autonomous vehicle transportation networks. Further, researchers may consider testing the range of variables in real-world environments, such as unplanned damage in roads and infrastructure, various weather conditions and temperatures, or specific emergency system failures with missing information. Testing the artificial intelligence that makes decisions regarding safety is also crucial when preparing to deploy technology to the public. Researchers will have to consider all environmental factors such as drivers, passengers, pedestrians, and other vehicles on the road. Waymo, the autonomous vehicle company from Google, has had success with testing their fully autonomous vehicles. They have tested their autonomous driver in “complex environments” with pedestrians before launching their ride-hailing system in Arizona (Waymo, 2021). Still, experts and technical professionals in the field will need to regularly reevaluate how autonomous vehicles “should” and “could” interact with others. Waymo engineers, for example, can anticipate the nature of future connections between autonomous vehicles and other systems. As more people adopt autonomous vehicles, data security will also be an important part of research. I hope that new autonomous vehicle research and testing will quickly prove applicable beyond personal vehicles.

The expansion of autonomous technology into the greater transportation network could impact ride-hail systems, existing public transportation networks, and commercial trucking routes.

Methods

Step 1: Build a Team

The first step in my research plan is to build a reliable team of experts. In my literature review, I found many scholarly research articles published by sub-groups within The Institute of Electrical and Electronics Engineers (IEEE). I would like to create a diverse research team that includes expert engineers from these sub-groups, such as the Intelligent Transportation Systems Society (ITSS). ITSS has an organized leadership team and access to funding for autonomous vehicle research. I would choose 3-5 engineers of different engineering disciplines to lead a sub-team. Additionally, I will invite industry-professionals to collaborate with me in research. I believe that grouping people with diverse backgrounds together is the best way to consider all possible solutions to a problem. Engineers and executives at Tesla, Waymo, Audi, or Toyota, for example, will likely all have different principle values, personal preferences, and limits to their resources. I would choose 3-5 professionals from these different companies to lead their own sub-team. Ideally, this collaboration between researchers and professionals will form a long-term partnership that leads to both groups succeeding. My research may span a year or two, but over time, these advanced autonomous vehicle companies and academic research groups may share their findings together in the future to pursue new projects.

Step 2: Apply Existing Information

The immediate next step for improved autonomous vehicle research is the collection and organization of existing test and simulation data. Because online and offline tests yield different types of data and results, existing data should be categorized according to a variety of groups and classifications. These groups may range from sensor type and literal data format to vehicle model and target level of autonomy. Data generated by an offline simulation, for example, should be evaluated differently than real-driving test data collected by the cameras mounted on a vehicle. The decision to share and organize a portion of data between major companies and researchers will save time and money. Experts in the field will take advantage of the organized information in a different way than the researchers. This development will allow researchers to push the limits of technology, while professionals can experiment with the limits of reality.

Step 3: Develop Holistic Testing

Another crucial component of new research is the continued development of holistic interdisciplinary test systems. Though online and offline tests have separate benefits long term, merging the two when possible will allow for more realistic testing. When these vehicles are used, customers rely on the successful communication between flexible artificial intelligence and static vehicle hardware. Simulation systems like the Hardware-in-the-Loop (HiL) and Scenario-in-the-Loop (SciL) designs proposed by expert researchers form a foundation for more reliable and effective vehicle testing methods (Chen et al., 2019; Szalay et al., 2019). I hope that the commitment to develop new autonomous vehicle tests and simulations will result in a better wide-spread understanding of these technologies. New research that sets a standardized test procedure, for Level 2 autonomous vehicles for example, provides the foundation for clear channels of communication across the disciple. Experts may gain the ability to pinpoint where their weaknesses resulted in the data, as well as quantify their successful performances.

Outcomes

Continuously collecting large amounts of test and simulation data will allow experts in the field to understand autonomous vehicle technology more deeply. Setting a standard for data handling and testing will allow more technical professionals to join the movement to advance autonomous vehicle technology. Sharing resources will be beneficial in the long term, promoting the education of more researchers. Existing traditional automotive companies can recognize the distinct levels of autonomy and update their goals accordingly. Full autonomy does not have to be the end all, be all goal for every community. Though, existing autonomous vehicle companies can benefit from the holistic testing methods. Waymo, for example, has adapted their language to reflect their mission to develop a "fully autonomous" vehicle driving system (The Waymo Team, 2021). Waymo engineers have the chance to adopt a standard testing practice and promote their methods alongside the launch of new projects. The expansion of interdisciplinary testing can offer an effortless transition from Level 0 personal car transportation, to higher-level networks of transportation.

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