Automated Driving System Disengagement Analysis and Testing Recommendations

Siyuan Liu
University of Western Ontario, Department of Electrical and Computer Engineering, London ON Canada N6A 3K7
E-mail: siisilsy@gmail.com

Luiz Fernando Capretz
University of Western Ontario, Department of Electrical and Computer Engineering, London ON Canada N6A 3K7
E-mail: lcapretz@uwo.ca

Abstract. Automated Driving System refers to a vehicle system where hardware and software are collectively capable of on-road operational and tactical functions. Therefore, appropriate verification and validation procedures should be followed to mitigate unreliability and hazardousness. Autonomous Vehicle Disengagement Reports and Autonomous Vehicle Collision Reports from the Department of Motor Vehicles (DMV), California, USA are collectively used for the purpose of this research. Influencing factors are generated and consolidated from the mentioned reports and are proposed in addition to a Society of Automotive Engineers International (SAE International) standard. Stakeholders will benefit from the presented rationales and should consider the suggestive parameters throughout their developing and testing activities. This paper further recommends testing management, especially test driver management and test routes planning, for automated driving systems in accordance with the analytical results and feedback from KPMG’s Global Automotive Executive Surveys.

1. Introduction

Autonomous vehicle refers to a vehicle that is capable of observing, identifying and distinguishing its surrounding static and dynamic environments, and handling, operating and maneuvering itself under unmanned conditions [1]. The technological development has shown an emerging transition from no automation to full automation along the way.

According to the Global Automotive Executive Survey for 2016 and 2017 [2] [3], the surveyed companies, including premium Original Equipment Makers (OEM) like BMW and newcomers like Google or Waymo, have increased their investments significantly in automated driving systems and self-driving vehicles compared to 2014, when the survey started to take self-driving into account. Ranked as the 9th among all 11 trends with 37% rating of importance, automated driving is not just a disruptive concept that only researchers are interested in, it has become fashionable for almost all major car makers who are putting effort into this area in order to

Dr. L.F. Capretz is currently spending his sabbatical leave as a visiting professor of Computer Science at New York University in Abu Dhabi, UAE.
maintain their status in the field as major players and also transforming their business models to service- and data-oriented models.

Given the fact that automation in commercialized and mass-produced cars serves as an essential enabling factor to urban transportation, this paper will discuss the current development of automated driving systems and recommend testing strategies. The terminology and taxonomy used in this paper are in accordance with J3016™ (R) Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles from SAE International [4].

Data about disengagements and collisions used in this paper are based those released by Department of Motor Vehicles, State of California, USA (DMV) [5] and collision reports from California Highway Patrol, State of California, USA (CHP) [6]. The recommendations presented in this paper are referring to J3018™ Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS) [7].

2. Background

2.1. Automated Driving System

Automated Driving System, ADS, is deployed to cover a wider spectrum of functionalities and automation levels in modern vehicles. As per SAE-J3016™, ADS refers to a system of a vehicle where hardware and software are collectively capable of performing all aspects of Dynamic Driving Tasks (DDT). DDT refers to on-road operational and tactical functions which involve detection, recognition, classification and response to objects and events [4]. The National Highway Traffic Safety Administration (NHTSA) of USA is currently adopting this standard, and so as other major players in automobile industry.

2.2. Levels of Driving Automation

Based on SAE-J3016, total of 6 standardized levels should be followed by the media, manufactures, suppliers and the public. A flow chart, refers to Figure 1, is presented and it illustrates how does the automation level being determined. In the flow chart, ODD denotes Operational Design Domain which specifies those appropriate conditions for a driving automation system to work properly and OEDR is a subtask of DDT which focuses on detecting, recognizing, classifying objects and prepare to response.

2.3. Roles of Driver

As per ADS, drivers are classified into two subdivisions, expert test drivers and human drivers.

Expert test drivers are distinctively trained personnel with special skillsets and are able to safely monitor the ADS after successfully activate the system. Moreover, expert drivers need to know how to deactivate the ADS under certain circumstances especially in hazardous situations. All these actions are performed with the aid of experimental compound.

Human drivers, on the other hand, are personnel operating a particular vehicle equipped with ADS and interact with the system to perform DDT.

3. Current Development

3.1. Impact Assessment

Since the drawbacks of public transportation system do exist. For instance, people with impairment would rather stay indoor than taking a bus simply to avoid all the inconveniences. According to Canadian Survey on Disabilities (CSD) 2012, an estimated 3.8 million adults, which accounts 13.7% of total adult populations, are reported with disabilities [8]. Another factor is that the worldwide demographic shift toward aging. In 2017, about 13% of the global population which is estimated as 962 million people, are aged 60 or over. This number is projected to reach 2.1 billion by year 2050 according to United Nations (UN) [9] [10]. Despite the fact that the
roads are also aging, the drastic increment itself is bring demands and pressures to the current transportation system. This leads to another needing factor of disrupting current automobile systems and work on something radical.

3.2. Industrial Status as of 2018
Table 1 is presented with collective highlights regarding automated driving related technologies and prototypes exhibited at Consumer Electronics Show (CES) International 2018. Some of the participating companies are also permit holders with DMV and they are authorized to perform automated driving system testing on public roads in California.

It is evident that the industry has progressed significantly over the past few years, many emerging players have shown their abilities by bringing prototypes or even commercialized cars to the show, e.g. Torc. Moreover, many major premium players like BMW, Tesla and Waymo, Google’s former self-driving project, have already reached a pivotal point by successfully demonstrating their capabilities in the industry.

4. Disengagement and Accident
4.1. Disengagement
As per DMV, disengagements are categorized into two types. One for automated driving with driver present, one for automated driving without driver present. For the former, from technological perspective it can be further classified as technical disengagement and non-technical disengagement. For driverless car, disengagements are accounted for the purposes of safety of the vehicle, the occupant of the vehicle and public needs.

4.2. Data from DMV, California, USA
In order to legally test prototyped motor vehicles with automated driving systems, companies need to apply for permits and report on collision and disengagement to DMV on annual basis. The reports have become available since 2015. People may think the disengagement ratio should be proportional to the miles travelled. However, there is no clear relationship between these two elements.
Table 1: Industrial Status as of 2018

| Organization          | Software                                      | Year | Hardware                                      | Year |
|-----------------------|-----------------------------------------------|------|-----------------------------------------------|------|
| ALMOTIVE INC          | aiDrive, aiSim                                | 2018 | aiWare                                        | 2018 |
| APTIV                 | Centralized Sensing Localization Planning (CSLP) platform, high-speed sensing and networking systems | 2019 | Work with Singapore Land Transport Authority (LTA) | 2019 |
| BAIDU USA LLC         | Level 4 automation                            |      | Commercializing                               | 2018 |
| CLARION               | Smart Cockpit Solutions                       |      |                                               |      |
| INTEL CORP A          | Intel® GO™ Automotive Development Platforms    |      |                                               |      |
| NAVYA INC.            | Work with Keolis on autonomous robotaxis       |      |                                               | 2018 |
| TORC                  | Asimov self-driving system                    | 2007 | Self-driving car                               | 2018 |
| TRANSDEV              |                                               |      | Autonomous electric vehicles for public use   | 2018 |

4.3. Collision
As of April 4, 2018, a total of 63 reports were received by DMV. A collision for autonomous car epitomizes the situation when operating the vehicle on a public road causes damage to property or results in casualty. When a collision occurs, regardless of the responsibilities, the traffic authority should be informed. DMV requires companies to file Report of Traffic Collision Involving an Autonomous Vehicle, within 10 days after the accident.

4.4. Possible Causes
Based on DMV’s data, there are two types of disengagement reported, one is auto disengagement which refers to technical failure of the system and the other one is manual disengagement which means that driver has to take control of the car over the system.

Regarding the rationales, DMV has provided some indicative examples including weather conditions, road surface conditions, constructions, emergencies, accidents or collisions. Moreover, for both types of disengagements, the following root causes appear to be more frequently reported by company than those indicative causes. Unwanted manoeuvre, Perception discrepancy, Software discrepancy, Hardware discrepancy, Behaviour prediction failure and Reckless behaviours from other road users.

5. Developing and Testing Recommendations
5.1. System Development and Modification
Currently the test cars used for testing are prototypes built on existing commercial vehicles and equipped with embedded automated driving system. Commercialized vehicles refer to those cars that have already developed and are mass produced by OEMs. The electronic components in these cars are flashed with pre-defined software and such software has its own architecture.
ADS can either be flashed into existing Electronic Control Units (ECU) through CAN reprogramming or serve with an additional external hardware as add-on. Either way, interfaces between software and hardware should not collide and should not cause any conflict. The software needs to be validated and verified as per standard software testing conventions. The modules should be able to perform self-diagnostics and should be monitored all the time along with all other pre-equipped electronic modules. And prior to perform dynamic on-road testing, static stationary testing should be performed on compound and safety critical measurements should be performed.

Upon completion of necessary modifications, companies are advised to carry out an impact analysis and making sure ADS does not cause any side effects to the existing system.

5.2. Test Routes Planning

Since most of the testing activities are performed either on test tracks or public roads, many interrelated variables are needed to be taken into consideration. For instance, speed handling on wet or dry road during daytime and nighttime. If each condition is treated as one parameter, then a matrix could be formed by linking one parameter to another. Based on such matrix, almost all scenarios could be covered. However, some of the scenarios could be hypothesis and are not feasible, such scenarios could be eliminated during test routes planning.

Below are some suggestions of parameters that can be considered to build the matrix,

- **Type of road**: Freeway, expressway, driveway, intersections, roundabout
- **Timing**: Peak hour, non-peak hour, nighttime, daytime
- **Weather condition**: Dry, raining, snowing, windy
- **Season**: Spring, summer, fall, winter
- **Traffic**: Heavy vehicle, pedestrian, cyclist
- **Sign**: Speed limit, place of interest, directions, signals
- **Road condition**: Curb, slope, uphill, highway barrier
- **Location**: Car park, residential neighborhood, military base

Additionally, special testing in irregular environment should also be considered and only need to be carried out when condition permits. Testing on construction sites or testing during extreme weather conditions, these can also be added to the standard testing procedures providing that safety can be ensured.

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