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Exploration of the feasibility of steering wheelless cars based on Robotaxi operation data

Haolin Bian

Queen's University Canada, Ontario, Kingston, EG3369995

bianhaolin@gmail.com

Abstract. With the development of autonomous driving technology, higher-level autonomous driving is hopeful to be applied in vehicles, and drivers' control of the car will also be replaced by intelligent algorithms. At the same time, a question has been raised as to whether the traditional steering wheel can be replaced when advanced autonomous driving becomes commonplace. To this end, a survey on steering wheelless cars was conducted to explore the feasibility of autonomous vehicles without the steering wheel. As a result, the operational data of Waymo and Apollo, two Robotaxi (a self-driving car operated by a ridesharing company) companies in the United States and China, is analyzed. The results show that at this stage, autonomous driving cannot fully control the car, and the driver still needs to take over the vehicle in complex situations. Of course, according to the data, Miles per Intervention (MPI) is gradually rising and is expected to reach a reasonable expectation, so steering wheelless cars still have a certain feasibility in the future.

Keywords: Robotaxi, Self Driving, Wheeless Car, Autonomous Driving, Machine Learning.

1. Introduction

Today, vehicles are already capable of providing driver assistance (supervised automation), where control is always shared between the vehicle and the driver [1]. That is, the vehicle assists a focused and attentive driver with longitudinal and lateral vehicle control. Already, the autonomous driving of some manufacturers can reach a very high level of safety. Safe vehicle automation has great potential to save lives by overcoming human limitations, as 94% of serious crashes are due to human error [2]. A series of related investigations have shown that automated vehicles are predictably good at staying in their own lane and not getting too close to the cars ahead. They could be safer than vehicles operated by humans, but need a lot of additional engineering to prevent the specific kinds of cognitive blind spots that can easily lead to accidents and even fatalities [3]. Therefore, it is a future trend to hand over the right of control of vehicles to advanced algorithms. This, however, also raises the question: is it necessary for the steering wheel to play an essential role in the car? According to Linda Pipkorn's investigation, the mere act of keeping a driver's hand on the steering wheel was not enough to prevent a collision or cause an early reaction [4]. High trust in automation was associated with delayed responses and crashes, while low trust was associated with appropriate driver responses [5]. Therefore, there is no significant correlation between accidents in autonomous vehicles and the presence or absence of a steering wheel in the car. This paper analyzes two cases of Robotaxi's operation of driverless cars, discussing the differences between steering wheelless cars and traditional

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cars. This study aims to understand: (a) whether cars without a steering wheel have more accidents and (b) whether steering wheelless cars can handle emergencies.

2. Method

2.1. Introduction to relevant technologies

Autonomous driving technology is a large and complex project involving many technologies, both at the hardware and software level. At the hardware level, a CAN card is required to retrieve data such as vehicle speed and steering wheel angle, which is transcoded by the CAN card into a signal recognizable by the chassis and connected to the CAN bus via an external interface [6]. It also requires the support of GPS and IMU units. On one hand, GPS can inform the vehicle's latitude, longitude, heading, etc. [7]. On the other hand, IMU can provide information on the angular velocity of the transverse pendulum, angular speed, etc., which facilitates the positioning and decision control of the autonomous driving vehicle. In addition, autonomous driving vehicles require a variety of sensing sensors, including vision sensors, radar sensors, laser sensors, etc. The software consists of four layers, namely sensing, fusion, decision-making and control. Code needs to be written between the various layers to translate the information. Robotaxi vehicles are based on a combination of hardware and software from autonomous driving vehicles, which allows the vehicle to make intelligent lane changes depending on the road conditions, as well as to determine the driving conditions of surrounding vehicles and to automatically avoid situations such as close overtaking [8]. Waymo and Apollo, the industry leaders in China and the US, have also launched robotaxi that comply with the relevant structure [9].

2.2. Waymo

Waymo is an American Google-owned company that develops self-driving cars and has accumulated the most miles in real-world road testing, with Waymo self-driving vehicles driving 32.18 million kilometers on the road in 2019 [10]. In terms of robotaxi operations, Waymo began piloting RoboTaxi in Phoenix, Arizona, USA before 2017. Waymo is based on intelligent routing, real-time sensors, processors, and controllers to perceive recognition, make decisions, and simulate human driver-like behavior without coordinating with relevant departments to build dedicated roads [11]. In addition, Waymo provided 4,678 services with the Pacifica in California in its first month, and 12 other services for educational purposes, carrying a total of 6, 299 passengers. According to mileage and crash data from Waymo’s self-driving car testing operations in Phoenix, the public road testing data covers Waymo’s self-driving operations in Phoenix from January 2019 through September 2020. More than 300 vehicles operate in an approximately 100-square-mile service area. Waymo has driven 6.1 million miles in vehicles with trained and safe drivers. In addition, from January 2019 to September 2020, its fully driverless vehicles travelled 65,000 miles and its vehicles had 47 “contact events” with other road users (including other vehicles, pedestrians, and cyclists) [12]. Eighteen of these events occurred in real life, while 29 were in simulation. The National Highway Traffic Safety Administration’s “first-of-its-kind” data shows that from June 29th, 2021 (when the NHTSA issued an order requesting such data) to May 15th, 2022, there were 130 accidents involving ADS-equipped Waymo vehicles and one accident resulting in serious injury, with 108 accidents resulting in no injuries. Of the 130 accidents reported by ADS (Automated Driving System), 108 involved collisions with another vehicle and 11 involved vulnerable road users, such as pedestrians or cyclists. Under the regulations, companies holding autonomous driving test permits issued by the DMV are required to submit an annual report on January 1 each year, including fleet numbers, vehicle details, total mileage tested, total number of disengagements (also known as a “disengagement”) and status, etc. [13]. One of the core measures of autonomous driving is the Mean Takeover Mileage (MPI), which is the average mileage driven between each manual takeover, calculated from the total number of miles tested and the number of takeovers throughout the year [14]. Because of the perception system, Waymo is unable to disengage by correctly detecting objects. With an average takeover distance of just 7, 965 miles in 2021, the significant increase in fleet size and test mileage could be the main reason for its more frequent exposure to complex road conditions and more frequent disengagements. In the presence of a safety officer taking over, Waymo still reported nearly 140 accidents from 2015 to 2021 (California Public Utilities Commission (PUC) and California Department of Motor Vehicles (DMV)), an average of one accident every 210,000 kilometers, which is much higher than the National Highway Traffic Safety Administration's published figure of one crash every 436,000 miles (700,000 km) driven in the US [15][16]. It follows that the cancellation of the steering wheel is not feasible at this stage, as fully autonomous cars have a higher accident rate than conventional cars.

However, Waymo is still doing some exploration of steering wheelless cars. Waymo and Geely have integrated Waymo's robot driver, the Waymo Driver, into a brand new electric vehicle, the Zeekr, into a fully driverless Robotaxi model that Waymo plans to deploy in the United States [17]. However, it has still not announced a specific timeline. This passenger-centric vehicle has the LIDAR prominently positioned on the roof, at odds with the vast majority of current designs that incorporate LIDAR into the bodywork.

2.3. Apollo

Apollo is a software platform released by Baidu on April 19, 2017 in the automotive industry and in the field of autonomous driving. Currently, Baidu has tested over 32 million kilometers of autonomous driving and has obtained 672 autonomous driving test licenses in China, including 498 manned test licenses and 144 commercial pilot licenses. Like Waymo, Baidu also conducted tests in California, where the four vehicles tested covered a total of 108,300 miles, with six takeovers and an average mileage travelled (MPI) between each manual intervention of 18,050 miles [18]. Apollo says that its self-driving cars have difficulty making choices at certain points in their journey when they encounter complex scenarios, which can lead to stopping. Unlike Waymo, Baidu uses the "5G Cloud Driver" to remotely take over the self-driving car and return it to the driver's seat after it has been removed from the current scenario [19].

According to the CIDAS database analysis of the causes of autonomous vehicle accidents, 84% of accidents were caused by other road traffic participants and 16% were caused by autonomous vehicles themselves [20]. In fact, autonomous driving does not rely on single-vehicle intelligence alone to achieve this; vehicle-road collaboration will be an important complement to improve safety. In addition, Baidu Apollo has also explored further of steering wheelless self-driving cars, with a new generation of self-driving minibuses that can signal and sound safety alerts to pedestrians. As the demand for self-driving cars increases, their convenience and safety will also be reflected.

3. Discussion

The case contributes to the research community in terms of: (1) in-depth analysis of Robotaxi operational data, and (2) a superficial analysis of the use of autonomous driving technology on a commercial level. As the data from the Robotaxi runs are not satisfactory, this paper will look at future improvements to the Waymo algorithm. Waymo will enhance its perception module to better avoid accidents, which is the basis and core of autonomous driving. Its main focus is to enable the estimation of the distance to obstacles and the positioning of the vehicle. Waymo's perception system uses a combination of cameras, LIDAR, and radar. Most of the work of the perception module is completed by four LiDARs, so its technical route is just the opposite of Tesla's. Waymo uses perceptrons to better identify information related to the road, and it will enhance its Machine learning in the future, a process Waymo uses called active learning. The idea behind active learning is that Waymo uses active learning to train the model, using TPUs (Tensor Processing Units) and Google's deep learning framework TensorFlow, which is a closed-loop and circular iteration [21]. Another machine learning module is named Agent RNN, which is a network that generates trajectories for autonomous driving vehicles [22]. These trajectorieske into ac will tacount heading (feasibility), speed (traffic rules), waypoints (length), etc. In particular, Road Mask Net is used to ensure that the generated trajectory is a travel lane and to prevent the generated trajectory from containing non-motorized lanes. Finally, the trajectory also considers repellers and attractors for maintaining the vehicle in the lane and avoiding roadblocks [23]. Also, the process of generating trajectories uses inverse reinforcement learning techniques. In inverse reinforcement learning, an attempt is made to look at a real human trajectory and determine what makes that trajectory a good one, which facilitates the improvement of the generated trajectory and brings it closer to human behaviour. As time progresses, autonomous driving technology will become more accurate at recognizing objects, and the MPI for both Waymo and Apollo will decrease as the correct rate increases.

4. Conclusion

Based on the data from Waymo and Apollo, both companies have their own countermeasures for unforeseen situations. Waymo is by handing over control of the self-driving car to a safety officer, while Baidu is handing over remote driving via 5g cloud control. Both solutions require the intervention of a real person. At this stage, the algorithms of self-driving cars are still not able to be separated from human intervention. Fully autonomous cars still have a very high takeover rate and, according to Waymo's operational data, also have a higher accident rate, so steering wheel-free cars are not ripe for popularization. However, both companies have explored steering wheelless cars and are constantly updating and iterating their autonomous driving algorithms to reduce accident rates, so steering wheelless cars could be feasible in the future with improved code and the implementation of relevant legislation. This paper is more based on the existing statistical data and literature. For future study, the author would like to further implement deep learning method into other experiments and compare the results with wheelless vehicles.

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