

On the Responsible Subjects of Self-Driving Cars Under the SAE System: An Improvement Scheme*

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Abstract—The issue of how to identify the liability of subjects after a traffic accident takes place remains a puzzle regarding the SAE classification system. The SAE system is not good at dealing with the problem of responsibility evaluation; therefore, building a new classification system for self-driving cars from the perspective of the subject's liability is a possible way to solve this problem. This new system divides automated driving into three levels: i) assisted driving based on the will of drivers, ii) automated driving based on the will of the manufacturers, and iii) fully automated driving based on social will. The corresponding responsible subjects for level one, level two, and level three are the drivers, the manufacturers, and society, respectively.

Keywords—self-driving car; responsible subjects; SAE system

I. INTRODUCTION

With the breakthrough of deep learning technology, self-driving cars have become a development direction of the automobile industry. Currently, not only technology-oriented companies such as Google, Apple, Facebook and Tesla but also traditional auto manufacturers are scrambling to enter the self-driving car market. Thus, it can be said that the era of self-driving cars based on AI technology has arrived.

New technology that uses automated driving systems as drivers has brought about a whole new way of driving, but it has also raised new questions regarding legal liability. One of the most important problems is the uncertainty regarding the subject of responsibility after an accident. In the case that it is challenging to determine the responsible party, no sanctions can be implemented, and legal liability cannot be realized (Xiaolin Chen, 2014). More seriously, the issue of responsibility undoubtedly affects the attitudes of the state, automatic vehicle manufacturers, and consumers toward automated vehicles.

There are many recent works focusing on this topic. Most studies say that it is an urgent problem. The German Federal Ministry of Transport and Digital Infrastructure suggests that “In the case of automated and connected driving systems, the accountability that was previously the sole preserve of the individual shifts from the motorist to the manufacturers and operators of the technological systems and to the bodies responsible for taking infrastructure, policy and legal decisions (The German Federal Ministry of Transport and

Digital Infrastructure, 2018).” Some scholars have given a deadline for solving the issue, i.e., once driverless cars are on the road, it must be clear who is responsible for accidents (Hevelke & Nida-Rümelin, 2015).

In regard to the specific subject of responsibility for self-driving cars, some scholars have proposed that it is necessary to investigate such subjects as the drivers, manufacturers and insurance companies or society (Belay, 2015). Among these potential subjects for responsibility, the public tends to insist that carmakers and governments should bear the legal burden and that self-driving cars themselves should not be the agent of responsibility (Li, Jamy, et al., 2016). Legal scholars have different views, including that the responsibility belongs to the driver because the driver still potentially controls the vehicle in the automated driving scenario (Schrader, 2015). Regarding this point, Bodungen and Hoffmann posit that the drivers are not the driving agents because the autopilot system is making its own decision when the accident occurs, and thus, the blame cannot be placed on drivers (Bodungen & Hoffmann, 2016). There is even the view that the danger from self-driving cars may be transformed into a “permitted risk” that cannot belong to drivers or manufacturers (Gless, & Weigend, 2014).

Almost all of these discussions on responsibility are based on the 6-level division of on-road motor vehicle automated driving systems developed by the SAE (Society of Automotive Engineers) in 2014. The SAE classification system clearly shows every stage ranging from full driving automation to no driving automation. This system replaced the 5-level system proposed by NHTSA in 2013 and became the highly recognized as the most authoritative system. However, the main source of oppositions related to this system is the roughness of the technology classification system.

As previously mentioned, the SAE system constructed for technical purposes suffers many difficulties when faced with the responsible subject problem. Most of the previous works have tried to either complete the system or give a reasonable method of responsibility distribution under this system. Our work aims to analyze the disadvantages of the SAE system in responsibility analysis and then try to develop a new analysis system.

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II. THE SAE GRADING SYSTEM OF SELF-DRIVING VEHICLES

Driving and responding share the same subject in the traditional manual driving mode. However, this is yet another difference in the automated driving mode. Specifically, the driving subject, who is the actual operator of the vehicle, is the human driver in a traditional situation. Therefore, the human driver is no doubt also the responsible subject. However, in an automated driving situation, the driving subject is no longer easy to identify, as the human driver and the automated driving system share the same responsibilities. Therefore, the key to determining the accident liability of an automated driving situation is to determine the driving subject.

The SAE system divides self-driving cars into different grades, and it is necessary to understand this system to clarify the driving subjects of self-driving cars at all levels.

The system clearly divides the degrees of automated driving into six levels by three discriminant properties:

Standard 1: control subject

Standard 2: environmental monitoring subject

Standard 3: system capability (driving modes)

The control subject is divided into both a control subject under normal driving conditions and a control subject in an emergency. We can understand them simply as nonemergent control subjects (normal driving conditions) and emergent control subjects (emergency driving conditions).

There are two possibilities for the environmental monitoring subject, namely, drivers and systems. The environmental monitoring subject not only needs to continuously obtain environmental information around the car, but more importantly, the subject must judge the driving environment safety status based on the acquired information.

The driving mode is a type of driving scenario with specific dynamic driving task requirements (e.g., expressway merging, high-speed cruising, low-speed traffic jam). The driving modes supported by the system are different at different levels.

Following these three standards, SAE divides self-driving cars into six levels, namely, no driving automation, driver assistance, partial driving automation, conditional driving automation, high driving automation, and full driving automation.

The SAE grading system divides the levels of self-driving cars by examining the driving modes supported by the control subjects, the environmental monitoring subjects, and the system. The grading system is shown in Table 1.

In the Level 0 stage, the driver has absolute control during the driving of the vehicle.

In the Level 1 stage of the SAE grading system, the system has partial control most of the time, i.e., either to control the steering or to control the throttle and brakes; thus, the main subject of control is both the driver and the system. In the event of an emergency, the driver needs to be ready to take over control immediately; thus, the control subject in the emergency

driving environment is the driver. In addition, because the system cannot monitor the environment, the main subject of the environmental monitoring is still the driver, with the system only providing support during partial driving modes.

Unlike Level 1, in Level 2, the control transferred to the system changes from partial to all; that is, in a typical driving environment, the driver can transfer both horizontal and vertical control to the system. Therefore, the control subject in the normal driving environment is the system, and the control subject of the emergency driving environment is the driver. In addition, the main subject of the environmental monitoring is the driver, and the system only partially supports the driving mode.

Level 3 is referred to as conditional driving automation and refers to the stage in which the system performs most of the driving operations; only when an emergency occurs does the driver conduct an appropriate response.

An appropriate response means that when an emergency occurs, the driver will respond as much as possible and replace the system as the main subject of control. However, the human driver may be unable to respond in some cases and thus be unable to take over control. At this point, the system continues to control the vehicle and tries to minimize the risk.

In the Level 4 stage, the automated driving system can complete all driving operations without the driver having to respond. Therefore, the control subject in both the normal driving environment and the emergency driving environment in the system, and the main subject of environmental monitoring is also the system. In this situation, the system only supports partial driving modes.

TABLE I. THE SAE CLASSIFICATION SYSTEM

Level	Controller		Environmental Monitoring Subject	System-Supported Driving Mode
	Ordinary Driving Environment	Emergency Driving Environment		
0	Driver	Driver	Driver	Unsupported
1	Driver & System	Driver	Driver	Partial Driving Mode
2	System	Driver	Driver	Partial Driving Mode
3	System	Driver & System	System	Partial Driving Mode
4	System	System	System	Partial Driving Mode
5	System	System	System	Full Driving Mode

The main difference between Level 4 and Level 5 is that the system can support all driving modes in Level 5. In this phase, it may no longer be possible to allow the driver to become the controlling subject.

Therefore, in the Level 5 stage, the control subject in both the normal driving environment and the emergency driving environment is the system, and the main subject of the environmental monitoring is also the system. In addition, the system supports all driving modes.

As we can see, we can easily identify the driving subject because of the identification between the control subject and the environmental monitoring subject in the traditional driving situation. However, in the situation of automated driving, we often cannot directly confirm who the control subject is because these two subjects are not always identical, which leads to difficulties in the assessment of responsibility.

III. THE RESPONSIBILITY ANALYSIS DILEMMA IN THE SAE SYSTEM

As previously analyzed, we can make a clear division of responsibilities only when we determine the driving subject. We have explained in the above section that the SAE system faces certain difficulties regarding this process. In this section, we will carry out further research.

In the SAE system, there are three least controversial stages for determining the responsible subject: Level 0, Level 4 and Level 5. Level 0 is the no driving automation stage. It can be said that human drivers are regarded as the driving subject at the level in the legal systems of all countries.

However, at Level 5, the system is the driving subject in all of the driving processes. Thus, the system is undoubtedly the responsible subject.

Therefore, it can be concluded that the key issue for determining the responsible subject at Level 5 is whether the automated driving system can serve as the subject of responsibility.

In other words, the issue faced is whether the automated driving system itself should bear moral and even legal responsibility or whether the manufacturers or organizations represented by the automated driving system should bear moral and even legal responsibility.

However, this problem is not the focus of our concern because we can at least determine that one subject of responsibility is the autopilot system, and whether the manufacturers or organizations behind the system should take responsibility is another question. However, we can be sure that the moral and even legal liability of the autopilot situation is currently borne by the manufacturers or organizations.

There is not much difference between Level 4 and Level 5. The Level 4 stage can only support partial driving modes (limited scenarios) due to technical factors, and the Level 5 stage can support the full driving mode scenario. Thus, accident responsibility is easily defined clearly at this level (Si Xiao, Cao Jianfeng, 2017).

We can also easily identify the subject of responsibility for Level 1 and Level 2. In Level 1, the automated driving system provides auxiliary functions for the driver, which is why it is also termed "driver assistance".

In this stage, the system has at most simultaneous partial control, i.e., either through longitudinal (accelerating, braking) or lateral (steering) dynamic driving tasks. In addition, the system determines when the activation or deactivation of the driver assistance system is appropriate, except for systems that automatically intervene in an emergency. Humans are the

driving subjects, the environmental monitoring subjects, and the responsible subjects because human drivers should take over immediately when required.

Different from Level 1, Level 2 executes longitudinal and lateral dynamic driving tasks at the same time, and the system constantly supervises dynamic driving tasks executed by the partial automation system and determines when the activation or deactivation of the partial automation system is appropriate, except for systems that automatically intervene in an emergency. That is, the human driver can completely transfer all control to the system under normal driving conditions, except for the rights of environmental monitoring. However, humans should take over immediately in an emergency environment. Both the control subject and the environmental monitoring subject are human drivers; thus, both the driving subject and the responsible subject are of course human.

The main problem arises in Level 3, which is called partial automation.

Level 3 is the part-time or driving mode-dependent performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene. This means that the system controls most of the driving elements, and the human driver conducts an appropriate response when an emergency occurs.

An appropriate response means that when an emergency occurs, the driver will respond as much as possible and replace the system as the control subject. However, it is also possible for the human driver to fail to respond and thus not be able to take control.

At this point, the control subject may be either the human driver or the system, but this distinction cannot be confirmed. If it is the former, then the control subject conflicts with the environmental monitoring subject, and we cannot confirm the driving subject; thus, we cannot confirm the responsible subject. In fact, most practitioners believe that the liability dilemma of automated driving lies in the Level 3 stage.

It can be seen that there are many problems with the SAE classification system. In the Level 3 phase, the responsible subject may be either the driver or the system. Therefore, it is impossible to make a clear judgment, which is contrary to the clarity and accuracy of the classification system. While the SAE grading system may have no problem as a general standard for describing the advanced automatic levels, there are obvious limitations regarding its scope of responsibility analysis.

These limitations prompted us to build a new classification framework that can distinguish the responsible subject easily.

IV. ESTABLISHMENT OF A GRADING SYSTEM BASED ON RESPONSIBLE SUBJECTS

The SAE automated driving grading system is based on a technical perspective to describe the advanced level of automated driving vehicles. With pure technology as the starting point, perhaps this kind of automated driving grading system is difficult to apply to the field of responsible subject

analysis. To establish a grading system suitable for discussing responsibility issues, we must reconstruct the grading system from a different perspective.

The purpose of our system is to accurately determine the responsible subjects of self-driving cars. Therefore, referring to the technical development method of the autopilot function constitutes a system of classification, which is based on distinguishing different responsible subjects and is a more feasible method.

First, the human driver is the most basic responsible subject because unless you reach the highest stage of automated driving technology and achieve automated driving across the full range of situations, the human driver is still needed in the automated driving processes of the remaining stages.

Second, the manufacturer is also a basic responsible subject.

Third, if we consider the accident liability of automated driving vehicles to be implemented similarly to a social security system, society as a whole can also be the subject of responsibility (Hevelke & Nidarümelin, 2015).

Additionally, it is possible to have a sense of autonomy in the future of automated driving vehicle systems. In this case, the system itself has the possibility of being the subject of responsibility. However, if it is assumed to be the subject of responsibility, the system must have the right to both property and liberty. However, the current paper's length is limited, and this idea will not be discussed herein.

Meanwhile, the division of the four subjects of responsibility also conforms to the development method of self-driving cars.

Stage 1, which includes human drivers as the responsible subjects, corresponds to the Level 0, Level 1 and Level 2 stages of the SAE system. Stage 1 has a low technical level.

Stage 2, which includes manufacturers as the responsible subjects, corresponds to the Level 3 stage of the SAE system but is not identical. The difference lies in the difficulty of attribution; specifically, we need a role to stand up and endorse the responsibility. The most appropriate option for this role is the manufacturers, based on commercial reasons.

In Stage 3, in which the further development of automated driving technology becomes a common situation in society, the government is needed to promote the technology. Thus, the government may become the responsible subject.

Based on the above outline, we can try to construct a new automated driving system. Starting from the different responsible subjects, automated driving is divided into three levels: assisted driving as the will of the driver, automated driving as the will of the manufacturer, and fully automated driving as a social will.

A. Level 1: Assisted Driving as the Will of Driver

Level 1 can be referred to as "assisted driving as the will of the driver", meaning that the system has no way to independently control the car to complete the corresponding driving task at any time or under any conditions. The various

auxiliary means of the automated driving vehicles are only the extension of the driver's limbs and are the embodiment of the driver's will.

Precisely because the control system is based on the driver's will, the driver must be responsible for the entire driving process.

In this case, both the driving subject and the responsible subject of the self-driving car are the human drivers. Thus, the driver will carefully drive to reduce the incidence rate of accidents, which is more conducive to the reduction of risk.

B. Level 2: Automated Driving as the Manufacturer's Will

Level 2 can be called "automated driving as the will of the manufacturers", which means that automated driving vehicles can be used to complete the entire driving task independently through the system preset by the manufacturer.

The automated driving systems of different manufacturers have been developed for profit and engraved with the brand of the manufacturer; thus, they appear as the will of the automaker. When an accident occurs, it is the manufacturer who is liable for compensation. It can be seen that the main subject of responsibility should be the manufacturer.

From the perspective of accident risk, when the main subject of the accident is the manufacturer, the lower the accident risk rate is, the higher the profit of the manufacturer is (i.e., less compensation). Therefore, based on the consideration of interests, manufacturers will continue to improve their technology more positively, thus making the next generation of automated driving vehicles more secure. In contrast, if the responsible party of the accident has nothing to do with the manufacturer, then the manufacturer lacks the motivation to improve the safety of their automated driving vehicles. Thus, the safety of their self-driving cars will never be effectively promoted, which is not conducive to the reduction of risk. It should be noted that while the improvement of safety performance can encourage more consumers to buy the car of a certain manufacturer, which results in an increase in profits, this incentive effect is not related to the responsible subject, so it is not considered in the current study.

C. Level 3: Automated Driving as a Social Will

Level 3 can be called "automated driving as a social will", which means that the automated driving vehicle system can upgrade according to society's preset goals.

Preset goals refer to security goals and popularity goals. At this stage, on the one hand, as much data as possible is needed to optimize the system, and the core technologies need to be shared among vendors to increase the reliability of the system. On the other hand, more people are needed to try this relatively more reliable driving mode; that is, a high-confidence subject is required for automated driving vehicle endorsement. These two points cannot be achieved by the efforts of automobile manufacturers alone.

If the development of automated driving vehicles is necessary, then this will create a moral obligation, which makes society as a whole responsible for the development of

automated driving vehicles (Hevelke & Nidarümelin, 2015). Once the responsible subject of an automated driving vehicle needs to be served by a subject that is strong enough to promote its evolution, society will be responsible for the risks posed by automated driving vehicles in the form of insurance systems.

When the responsible subject is society, society has the right to set goals for the evolution of the automated driving system. On the one hand, society can require more data and more technical solutions to improve the safety of the system; on the other hand, society acts as the responsible subject of automated driving vehicles, which plays a role in endorsing automated driving vehicles and promotes people's involvement. Trust in automated driving technology inspires more people to try this safer new technology.

V. CONCLUSION

The existing automated driving grading system divides the technical levels of self-driving cars, but it neglects to recognize the responsible subjects, which makes it difficult for us to distinguish the responsible subject of Level 3 in the SAE system.

Building a new classification system of automated driving vehicles from the perspective of the subject's liability is a better way to solve this problem. We have built a classification system of automated driving based on responsible subjects, which involves human drivers, manufacturers, and society.

This new grading system based on responsible subjects is not only beneficial to the analysis of the liability of those subjects but also more conducive to the development of the automated driving vehicle industry in that the responsible subjects form a joint force to continuously improve automated

driving technology, which has endless benefits for the automobile industry, consumers and traffic safety.

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