

Research on Scenario and Testing Method of Auto-driving Vehicle Collaborative Testing on Expressway

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Abstract: With the development of intelligent network and automobile industry, self-driving automobile has become the focus of all walks of life. In the face of vehicles with autonomous traffic logic, government departments of various countries are actively introducing relevant policies and regulations to guide and standardize the development of self-driving automobile industry, and regard self-driving and intelligent automobiles as important strategic goals of the country. But at the same time of rapid development, the relevant security issues are prominent. Based on the research on the cooperative conditions of expressway self-driving vehicles, this paper puts forward the construction target of expressway self-driving system. Aiming at the safety problems in the development of auto-driving, based on the similarity between driver and auto-driving system, a systematic and comprehensive auto-driving test method is proposed. At the same time, it also analyzes and designs the scene for the relevant contents that need to be tested urgently in China. Based on the existing conditions of expressways, this paper puts forward corresponding countermeasures to the problems faced by the realization of roadside systems, and discusses and looks forward to the positive impact of cooperative automatic driving of vehicles on the future of expressways in China.

1. Introduction

Since the 21st century, the rapid development of computer technology, Internet and Internet of Things thinking has brought brand-new changes to the traditional automobile manufacturing industry[1]. Research shows that self-driving technology can greatly improve the efficiency of the transportation system and the safety of travel. Self-driving automobile has become an inevitable trend in the development of the world automobile industry[2]. As the ultimate solution to the problems of road safety and traffic congestion, the significance of self-driving cars lies not only in the upgrading of automobile products and technologies, but also in the reshaping of automobile, related industrial structure and value chain system[3]. Foreign mainstream auto companies and Internet companies are vigorously developing automatic driving. Google has completed the prototype of its first unmanned car, which will have a top speed of about 40 kilometers per hour and can “see” a distance up to the length of two football fields under clear road conditions[4]. China's self-driving auto start is late, but it has also developed rapidly under the strong support of government departments and the strong promotion of major scientific research institutions and enterprises.

Starting from the four elements of car, road, people and environmental transportation, we will realize that the development of autonomous driving technology will realize that the intelligent driving of the car first has its own pragmatic considerations[5]. Such as the need to face a variety of conditions of the road, different visibility, mixed with ordinary cars and other complex conditions. With the rapid development of China's economy, the scale of expressways has been expanding, and the level of intelligence and information has been continuously improved[6]. Through the construction of highway state awareness system, highway basic communication system and highway road management platform system, a complete set of comprehensive intelligent interaction system based on expressway can be constructed to provide a wider range of perception and risk for autonomous driving. Pre-judgment and path planning. China's highways are relatively closed

independent toll operation systems, and roadside facilities are constantly improving[7]. The Smart Highway provides a good application scenario for the implementation of autonomous driving. Long-distance transportation logistics vehicles facing fixed lines such as trucks and trucks are expected to be the first automatic driving application scenarios[8].

2. Conditions of Auto-driving Vehicle Collaboration on Expressway

2.1 Advantage Conditions

Our country's expressways are basically closed roads, with strict control over people entering the expressways. In this way, the adverse impact of people on traffic is greatly curbed, which is the biggest reason for the simple traffic environment. Secondly, the expressway has excellent road conditions, with smooth road surface, simple linear and simple intercommunication structure. These conditions are more conducive to the realization of cooperative automatic driving. Although expressways belong to public infrastructure, the rights and responsibilities of the main operators are clear and belong to the nature of enterprises. With benefits as the goal, under the "investment-return" mode, there is an incentive to improve road transport capacity and provide services on the basis of ensuring safety. Vehicle coordinated automatic driving has a great role in promoting safety and improving road operation efficiency, attracting high attention from highway operators. After 30 years of development, the expressway has developed a full range of electromechanical facilities including toll collection, monitoring and communication. In the construction, management, maintenance, maintenance and other aspects have accumulated a wealth of experience, which is conducive to the construction of autonomous vehicle cooperative system.

2.2 Guarantee Requirements

According to different levels of autopilot, the charging methods that autopilot can adapt to are also different. Freeways have already realized automatic toll collection technologies such as automatic toll collection and free flow toll collection. However, the current situation is a mixture of manual toll collection, automatic toll collection and free-flow lane system. Autopilot vehicles need to navigate in the automatic toll collection lane when entering or leaving high speed. Vehicle coordination, as the name suggests, means that the vehicle can understand and use the information of the roadside system, and the roadside sensing equipment can also provide information and partial calculation results according to the needs of the vehicle. If only the transmission of the original information is caused, the bandwidth of the vehicle communication will be too high, and the on-board computing system will be too large, which will cause obstacles to the realization of the entire system. Therefore, the roadside sensing layer is obliged to provide the necessary and sufficient information required by the vehicle to effectively support the coordinated driving of the road. At present, major changes are taking place in the toll collection methods of expressways. ETC portal systems have been set up between interchanges, adopting the mode of piecewise charging and piecewise deduction. For vehicles with ETC labels, check the exit lane of the toll station to quickly pass through the toll station. At present, the national policy advocates the coordination of cars and roads, not the intelligence of bicycles. RSU and edge server are built on the side of the intelligent expressway, which will not cause the problems of too high bandwidth of vehicle communication and too large on-board computing system.

3. Collaborative Testing Method for Auto-driving Vehicles

3.1 Establishment of Comprehensive Test Verification Environment

The most urgent demand of auto-driving related industries is the planning and construction of industrial chain system. Fair third-party authentication, testing and verification provide guarantee for their interoperability. For industrial development layout, build a platform of comprehensive test and verification environment, promote the development of key technologies and service product research and development. To establish a comprehensive test and verification environment, the key

lies in dealing with test and verification related standard systems and quality assurance issues, and the core lies in the need to provide interconnection standards. As shown in Table 1, all self-driving cars, systems, components, applications, etc. that meet these standards and quality requirements can be tested and verified on this integrated platform, and the results obtained by these tests can be reversed. The standards for the vehicle-end application layer middleware or cloud application layer middleware have been experimentally verified. In order to promote to a larger scale, and at the same time promote the test verification and progress of the key technologies of autonomous driving, as shown in Table 2.

Table 1 Intelligent Network Autopilot Related System

Cloud	TSP	Dynamic Operation Monitoring	Road Traffic Early Warning
Signal communication	3G/4G Infinite LAN	GPS	TCP/UCP
	OBD Box	TBOX	DSRC/LTE-V
Vehicle end	ADAS Application	Vehicle Application Software	V2X Application
	Long Range Radar	Night vision camera	Ultrasound
	3D Video camera	Laser Scanning	Medium Range Radar

Table 2 Comprehensive Test and Verification Environment Promotes Key Technologies

Standard system	Cloud	TSP	Dynamic Operation Monitoring	Road Traffic Early Warning	Quality assurance
	Signal communication	Multi-source Information Fusion Technology	Vehicle Collaborative Control Technology	Data Security and Platform Software	
	Vehicle end	Long Range Radar	Night vision camera	Ultrasound	
		3D Video camera	Laser Scanning	Medium Range Radar	

3.2 Carry out the Safety Assessment of Automatic Driving

Self-driving automobile fundamentally changed the traditional “man-car-road” closed-loop control mode, adopting an automatic driving system to replace the driver from the closed-loop system. It not only greatly improves the efficiency and safety of the transportation system, but also brings more possibilities to people's travel and lifestyle. The core purpose of the automatic driving system is to ensure that the automatic driving system can safely and reliably replace or partially replace the operation of the driver. The similarities between the automatic driving system and the driver include the corresponding four key links of perception, communication, decision-making and execution. Whether these four links are normal or not is the key factor to check whether the qualified driver can drive the vehicle safely and reliably. Countries around the world “approve” whether drivers can go on the road mainly by taking a driver's license test. Learning from this process, the automatic driving system should follow a similar assessment system to effectively supervise the safe driving of automatic driving vehicles when it gets a “license plate” to go on the road. There are three steps to carry out automatic driving evaluation in China.

In the first step, before the autopilot car is tested on the road, it is approved whether it has the basic on-road test capability requirements. This includes the driver's needs and the basic safety requirements that autonomous vehicles need to meet. Once these requirements are met, they are allowed to test on certain simple roads that do not affect traffic. In the second step, after a period of testing on the road, the self-driving car is evaluated for its behavioral safety in different complex environments. Only after its driving behavior meets certain safety requirements, it is allowed to test on complicated roads. In the third step, after the self-driving car meets the behavioral safety assessment, it must conduct all-round and meticulous evaluation before it can officially run on the road and promote the market. In the three-step thinking mentioned above, the focus is on the second step. Before testing autonomous vehicles to more complex road conditions, we need to conduct a

safety assessment of the driving behavior of the autonomous driving system as early as possible. At the same time, it is necessary to establish an implementation platform for safety test of automatic driving behavior, including real-time collection of test data, analysis and processing of test data, and calculation of evaluation indicators.

Table 3 Automatic driving system test driver assessment

Assessment project	People	Autopilot
Physical examination	Flexibility of hands and feet	Control Execution
	Good health	Functional safety
	Good immune system	Information safety
	Adult	Software maturity
Site Examination	Clarity of mind	Behavioral decision-making
	Good sense of direction	Path Planning
Road test	Skillful driving	Integrated Intelligence

4. Automated Vehicle Collaborative Test Scenario

4.1 Key Scene Recognition

One of the major challenges for autonomous vehicles is testing and verification. On the one hand, new testing methods are needed to improve the traditional road testing methods and solve some problems caused by the large number of driving mileage in the traditional testing. On the other hand, due to the limited market penetration in the early stage of development, the test and verification process also needs to consider the significant impact of the driving behavior of other human traffic participants on the function of self-driving cars under the mixed traffic environment. The simulation-based universal tool chain for autonomous vehicles is used for model identification in the loop of key scenes, taking into account the behaviors of other traffic participants. Key scenarios are identified and screened through safety indicators and traffic quality indicators. It is relatively simple to introduce such a car without considering the driving behavior of other traffic participants, but it will face enormous challenges in completing a driving task in a mixed traffic environment including a human driver. Even if the automation functions are working properly and the driving behavior is in compliance, other traffic participants may cause the autonomous vehicle to face critical scenarios.

4.2 Test scenario classification

Our institute will continue to promote and perfect the test environment for self-driving closed highways, and continuously enrich the test scenarios and test cases. Adhering to the concepts of openness, cooperation and innovation, and carrying out in-depth cooperation with enterprises, universities and scientific research institutes, Qi Li has built a safety testing and evaluation system for self-driving vehicles with Chinese characteristics to promote the ecological high-quality and sustainable development of China's self-driving industry. The reason why self-driving cars are difficult to hit the road in China is the complex traffic environment, frequent and unpredictable accidents. In order to ensure a comprehensive inspection of the function and operation safety of the automatic driving system, we divide the design of automatic driving test scenarios into three categories: one is based on the realization mechanism of automatic driving. The second is to design test scenarios for the four links of perception, decision-making, control and effect of self-driving cars. The third is to carry out targeted tests. Based on the safe driving performance of self-driving cars, it can be divided into driving adaptability test, driving skill test and driving safety awareness test. Based on the actual road traffic patterns and the characteristics of China's road traffic, the types of traffic accidents and incidents are studied. Analyze the causes of traffic accidents, simulate traffic accidents and elements of the accidents, reproduce the scene, and carry out tests. At the same time, for the design of the test scene, the construction of the test site is a necessary condition. It can be divided into closed test field test, semi-closed test field test and open test field test, and test cases suitable for different test fields are designed. For example, closed test field tests can be divided into

virtual scene tests and physical scene tests. The virtual scene can include video signal simulation, radar signal simulation and satellite positioning signal simulation. The design of test cases should ensure their diversification, so as to ensure that they conform to the complexity and particularity of the automatic driving system and ensure the comprehensive coverage of the functions of the automatic driving system.

4.3 Major test scenario building techniques

The data in the scene library include virtual data and real data, but the source of virtual data is still real data. Therefore, the collection of real data in the driving environment plays a fundamental role in the construction of the test scene database. There are many ways and means to collect data, including laser radar, radar, camera, etc. Among them, visual analysis technology is routine and easily available due to its large amount of information, wide range of scene elements mining. The advantages of more accurate classification of scene participants have become the most important scene mining technology. The scene mining based on visual analysis needs to decompose the video, identify the objects in each frame of pictures, and store and track the object list extracted in each frame. Attribute analysis and behavior discrimination are carried out on the objects in the frame, data are analyzed through sensors, typical data scenes are formed, and scene databases are classified and constructed. The typicality requirement of scene coverage is getting higher and higher. Today, with the continuous development of scene mining technology, the construction of scene library requires the perfection of industrial chain. The scene library construction and testing service system oriented to industrial chain includes scene data service, scene mining service, accelerated testing service, customized scene library service, etc. Through industrialization, the market-oriented and efficient operation of scene testing is realized.

At present, in order to ensure the safety of public roads, a large number of test systems and test scenes associated with actual scenes need to be established to support the operation of these functions before automatic driving on public roads is tested. Furthermore, the correctness of the function and the reliability of the performance of the self-driving car are investigated. The key point of interactive assessment is to assess the perception and coping ability of vehicles to traffic environment. It is a test for vehicle-to-vehicle coupling system, vehicle-to-road coupling system, vehicle-to-person coupling system, human-to-vehicle coupling system, and vehicle-to-road coupling system. Therefore, it is necessary to establish a brand-new testing and evaluation system suitable for people-cars-roads. The communication of vehicle networking should also prevent the attack of digital hackers, and safety should be an important consideration in the auto-driving industry. Autopilot vehicles rely on the communication between vehicles and vehicles (V2V) and the connection between vehicles and infrastructure (V2I). It is very important to maintain the safety of these channels and the personal electronic communication of passengers such as e-mail, telephone, short message, Internet access and location data. Finally, after the comprehensive evaluation results are passed, it is necessary to supervise and manage the vehicles tested on public roads. In the event of an accident, timely collect vehicle information for systematic analysis. This will lay a foundation for standardizing the driving of self-driving cars on public roads and for demonstrating the application of civilized driving.

5. Construction target of highway vehicle cooperative automatic driving system

5.1 Safety and efficiency

The construction objectives of expressway cooperative automatic driving system mainly include safety, efficiency, economy, energy consumption, development, etc. The construction target should be specifically set in combination with the automatic driving level. Generally speaking, the higher the automatic driving level, the higher the target requirement will be. For highway management, safety is the first priority, without which there is no benefit. For self-driving, safety is life. Without safety, life is in danger. Therefore, safety is the first priority of cooperative automatic driving, and all other goals should be based on safety. The safety goal of highway and roadway automatic driving

should include both the macro safety level accident rate and the traffic accident mortality rate, as well as technical indicators such as system security, data security and reliability. Efficiency is the most fundamental pursuit of automation. Vehicle-assisted automatic driving is a branch of automation. Efficiency is naturally one of its important goals. Efficiency should include highway traffic efficiency improvement, emergency response efficiency, and labor cost reduction.

5.2 Economy and Energy Consumption

Highway vehicle-road cooperative automatic driving involves the construction of roadside system. Input and output need to pass the economic test. At the same time, energy consumption indicators should also meet the relevant requirements. However, the vehicle-road collaboration system has obvious spillover and public service characteristics, so its public and social benefits should be fully considered in terms of economy and energy consumption objectives. As a new and promising vehicle-road cooperative autopilot technology, we should be aware of its inadequate development, unbalanced technology in all links and unreasonable industrial convergence. Therefore, it is necessary to conduct a large number of experiments, establish a simulation environment for inspection and testing, and conduct large-scale trials. And according to the level of automatic driving to develop development goals and refine the index system, only to meet the low level of achievement and fully pass the conditions of the advanced stage evaluation before entering the next advanced stage. Only by providing sufficient roadside information to intelligent vehicles through LTE-V communication according to the corresponding automatic driving level can a complete vehicle-road cooperative automatic driving system be formed. In this way, according to the plan, the application of vehicle-road cooperative automatic driving technology in expressways will be steadily realized.

6. Conclusion

As an independent closed toll collection and operation system, with the improvement of intelligence and networking, the construction of a collaborative intelligent interaction system between highways and vehicles will most likely become the first commercial scene of automatic driving in the near future. Highway operating units should give full play to their own advantages in the process of highway infrastructure construction. Through demonstration projects, pilot operations and other means to promote the formulation of industry standards, to promote the development of automatic driving and intelligent network expressway. From the perspective of technical realization, the vehicle-assisted automatic driving system distinguishes the private and universality of the vehicle from the public and specificity of the infrastructure, and each realizes intelligence. Then through collaborative communication, it constitutes an automatic driving environment for digital operation. This undoubtedly has a high degree of achievability. Through the automatic driving of vehicles and roads, the expressway is expected to achieve breakthroughs in five aspects: high security, speedy traffic, fine management, all-weather communication, and complete free flow.

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