Research on testing method of unmanned delivery vehicle based on typical scenarios

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Abstract: Unmanned delivery has been developed rapidly worldwide in recent years. In China, a number of enterprises have carried out fixed-point trial operation for closed parks, tourist attractions and other areas. It is necessary to study and propose a test method for testing the basic performance and safety design of unmanned delivery vehicles. Scenario-based testing method is more efficient than mileage testing. Based on the typical scenarios faced by the unmanned vehicle in the process of driving, this paper studies and proposes eight specific test scenarios for the unmanned delivery vehicle test, and puts forward the criteria for passing the test. This research can help improve the safety of unmanned delivery vehicles in the design and development process.

1. Introduction

As one of the scenarios where autonomous driving technology may be applied commercially, unmanned delivery has been developed rapidly worldwide in recent years[1]. The application of autonomous driving technology in logistics vehicles can effectively solve the problems of logistics manpower shortage and high human cost[2], greatly improve logistics efficiency and safety, has high application value. The unmanned delivery industry has grown rapidly in China and the United States in recent years[3], some vehicle models have also entered the trial operation stage. In contrast, the unmanned delivery vehicle industry lacks unified and effective testing methods, leaving hidden dangers for vehicle operation[4]. Combined with typical applications of unmanned delivery vehicles, this paper proposes a scenario combination test method for unmanned delivery vehicles testing, which provides reference for the industry to carry out relevant tests.

2. Development status in other countries

In March 2017, the US state of Virginia passed a law allowing self-driving robots to drive on street crosswalks for the first time. Since then, Idaho, Wisconsin, Florida, Ohio, Utah, Arizona, and Washington have enacted laws on such products[5]. So far, eight states have allowed them to be tested on the road, and more than 100,000 commercial orders have been placed so far. In 2020, the US federal Department of Transportation exercised its first regulatory exemption for self-driving vehicles, approving 5,000 unmanned delivery vehicles to enter the small-scale deployment phase within two years. McKinsey, an international consultancy, predicts that 80% of parcel deliveries will be unmanned in the next ten years[6].

3. Domestic development status in China

With years of development, in China, from traditional automobile enterprises to emerging Internet enterprises have taken the logistics industry as the first application field of intelligent connected vehicles with high-level autonomous driving function. A number of enterprises have carried out fixed-point trial operation for closed parks, tourist attractions and other areas. These enterprises are mainly divided into two categories, one is mainly Cainiao, Meituan, Jingdong, Suning and other e-commerce logistics enterprises, another is technology enterprises based on technology solutions.

3.1. E-commerce logistics enterprises

In terms of logistics delivery vehicles with autonomous driving function, domestic enterprises such as Alibaba Cainiao network, Meituan, Jingdong and Suning have made a breakthrough, which can complete autonomous driving and access express and other business content. At the end of May 2018, Alibaba Cainiao Network announced that it had jointly launched a "hump plan" with vehicle manufacturers, lidar suppliers, chip suppliers and companies capable of realizing the landing scenario of autonomous driving function, to promote the landing of autonomous driving technology in the field of logistics. On the site of APSARA Conference opened on
September 19, 2018, Alibaba Cainiao network released two new retail logistics unmanned delivery vehicles, respectively carrying facial recognition cabinets, retail shelves, etc.

The rapid growth of the demand for takeout delivery brings the demand for new transport capacity, which is difficult to meet in a short time depending on the traditional human distribution mode. This is the original intention of Meituan to explore unmanned delivery vehicles to supplement distribution. At present, the unmanned delivery team of Meituan has completed several rounds of research and development iterations in the field of unmanned vehicles. In many scenarios, especially the night scenarios of 24-hour delivery, unmanned delivery vehicles will become the right-hand men of Meituan delivery men, allowing users to receive goods in a shorter time. Jingdong's self-driving logistics delivery vehicles can deliver in bulk to office buildings, residential convenience stores and other places where orders are concentrated in urban environments. Jingdong's self-driving logistics vehicles have been deployed and operated in Changsha. In June 2018, Suning's "Wolong One", a logistics distribution vehicle with automatic driving function, landed in Beijing for the first time and realized normal operation, becoming the first enterprise with normal operation of the vehicles with autonomous driving function in China.

### 3.2. Technology solution-oriented technology enterprises

In terms of technical solutions, technology enterprises developing unmanned delivery vehicles are mainly classified into two types, one is the enterprises such as Idriverplus, Neolithic and Shenlan Technology, which provide overall solutions, another is the enterprises, such as Uisee Technology, Robosense and Beike Tianhui, which provide general solutions such as algorithms and AI chips.

Neolithic focuses on the overall solution of driving automation for unmanned delivery vehicles, which has mass-produced 100 logistics vehicles equipped with the autonomous driving system, and all of them are deployed in Xiongan and Changzhou.

Robosense is an autonomous laser radar environment awareness solution provider. It is committed to using independently developed robot perception products, combining Lidar sensor hardware scheme, 3D data processing algorithm and deep learning technology, and making robots have the environmental perception ability of eyes through continuous technological innovation.

The companies' partners are e-commerce companies such as JD.com and Cainiao, Internet technology companies such as Baidu, traditional car companies such as Beijing Automobile, Dongfeng, FAW and Geely, and logistics companies such as Puncttime and Manbang Group. In terms of products, the products of these technology enterprises include Idriverplus's Huobida unmanned delivery vehicle, Neolithic retail vehicle, Uisee Technology logistics trailer, etc.

### 4. Research on test method of unmanned delivery vehicle

#### 4.1. Unmanned delivery vehicles' test scheme

In the traditional automotive industry, all technologies from the development stage to mass production, requires complex verification. Verification requirements generally include three aspects: enterprise standard verification, industry standard verification and national standards or laws and regulations verification. Government agencies, research institutes and related enterprises have carried out a lot of research on the standard system, test site conditions and relevant test methods required for the verification process. Before the vehicle enters the verification process, a large number of tests are needed to prove the stability, robustness and reliability of its various application functions and performance. Compared with traditional vehicles, the test and evaluation object of unmanned vehicles has changed from car to human-car-environment-task strongly coupled autonomous driving system. Traditional vehicle testing methods have been unable to meet the requirements of unmanned vehicle testing and verification[7].

Scenario-based testing methods are more flexible, efficient and targeted than those based on mileage. By screening test scenarios, a large number of invalid mileage in mileage test process is reduced, which is conducive to the rapid iteration and improvement of automatic driving function. At present, more and more attention is paid to the field of driverless testing. Although unmanned delivery vehicles have not been clearly defined by the government as the scope of regulation, due to their own characteristics and N1 vehicles are similar, the testing method of autonomous vehicles has important reference significance for them[8].

N1 vehicles, that is, motor vehicles with at least 4 wheels and used to carry goods, and the maximum design total mass does not exceed 3500kg. Based on the functional characteristics and typical applications of unmanned delivery vehicles, this paper designs a test method of unmanned delivery vehicles based on test scenarios[9].

Before carrying out the test, the tester shall arrange the scenario for the test purpose according to the requirements of the scenario design in 4.2, and carry out the test under normal weather and light conditions. Before the test, the vehicle should complete self-check to confirm the normal function and then test. After the test is complete, it is to determine whether the test is successful based on the pass requirements in 4.2.

#### 4.2. Unmanned delivery vehicles' test scenarios.

##### 4.2.1. Loading/Posting/Catering

1) Test scenario

The test road should have a warehouse or distribution site scenario.
2) Test method
The test vehicle stops at the designated parking space and completes loading/delivery/catering.

3) Pass requirement
   a) The vehicle stably arrives at the designated parking space for loading/delivery/catering and completes the precise parking action;
   b) The vehicle verifies the identity information of the staff/sender;
   c) After passing the verification, the vehicle will open the designated box to prompt loading/delivery/catering;
   d) When the vehicle detects that the goods are put into the specified box, check whether the category, quantity and packaging of the goods are correct and complete;
   e) Close the box door, generate the delivery order, and prompt the staff/sender to confirm;
   f) After the staff/sender confirms the information, the vehicle dispatching instruction will be issued.

4.2.2. Enter/exit the park
1) Test scenario
   The test road shall be equipped with an entrance and exit with lifting rod. The initial state of lifting rod is closed, and it will be switched to open state after the test vehicle stops.

2) Test method
   a) No collision with the lifting rod;
   b) The test vehicle shall not start within 5s after the lifting rod is fully raised.

4.2.3. Designated lane driving
1) Test scenario
   The test road should be a long straight road consisting of at least two lanes with a dashed middle lane and one lane marked with a sign/ground indicating that the road is a permitted road for test vehicles.

2) Test method
   a) The test vehicle enters the test section under automatic driving mode.

3) Pass requirement
   a) The test vehicle shall proceed into the permitted lane.

4.2.4. Traffic sign and line identification and response test
1) Test scenario
   The test road should contain at least two lanes in the same direction or one non-mixed lane and one non-motorized lane. The road should contain at least six types of signs, including speed limit sign, no crossing solid line, stop sign, no left turn sign, no right turn sign and crosswalk, as shown in Figure. 1 to Figure. 3.

![Figure 1. Drive at the speed limit sign](image1)

![Figure 2. Drive at the stop sign](image2)
2) Test method
In the automatic driving mode, the test vehicle ran at a speed of 25km/h according to the information conveyed by road signs and road markings\cite{10}.

3) Pass requirement
a) Fail to drive according to the speed limit sign, fail to pass;
   b) Do not cross the solid line, do not pass;
   c) Fail to stop at the stop sign and fail to pass;
   d) Fail to drive according to the no turning sign, and fail to pass;
   e) Do not slow down before the crosswalk to give way, do not pass;
   f) The test times of this project are 3. If one test fails, the test project fails.

4.2.5 Motor vehicle signal light recognition and response test

1) Test scenario
The test road shall contain an intersection section of the non-mixed lane with motor vehicle signal lights, as shown in Figure 4.

2) Test method
The test vehicle ran at a speed of 25km/h in automatic driving mode, following the information transmitted by traffic lights.

3) Pass requirement
a) When the green light is on, the vehicle does not start within 5s, and the vehicle does not pass;
   b) When the red light is on, the vehicle does not pass;
   c) When the traffic light is not working, the vehicle fails to pass;
   d) The test times of this project are 3. If one test fails, the test project fails.

4.2.6 Non-motor vehicle signal light recognition and response test

1) Test scenario
The test road shall include a non-motor road junction section with non-motor vehicle signal lights, as shown in Figure 5.

2) Test method
The test vehicle ran at a speed of 25km/h in automatic driving mode, following the information transmitted by traffic lights.

3) Pass requirement
a) When the green light is on, the vehicle does not start within 5s, and the vehicle does not pass;
   b) When the red light is on, the vehicle does not cross the stop line and fails to pass;
   c) The vehicle did not work, the vehicle cannot pass the intersection normally;
   d) The project for the number of test three times, once the test is not passed, is not through the test project.

4.2.7 Wave to stop

1) Test scenario
The test road was a long straight road consisting of at least two lanes with a dashed middle lane and a pedestrian waving 100m in front of the test vehicle.

2) Test method
The test vehicle entered the test section at a speed no higher than 30km/h under automatic driving. When the distance was 4s, the pedestrian waved to the vehicle.

3) Pass requirement
The test vehicle should park near pedestrians.

4.2.8 Unload/Pick up/Sell meals

1) Test scenario
The test road should have a standard sidewalk scene.

2) Test method
The test vehicle shall meet the test requirements of precision parking and park in the designated parking space to complete the unloading/pickup/meal sale actions.

3) Pass requirement
a) Stop the vehicle stably near the receiving staff/recipient/consumer and complete the precise stopping action;
   b) Keep a safe distance from other road participants (greater than 2m), and sound and video images will be issued to prompt receiving staff/recipient/consumer after parking.
c) The vehicle verifies the identity information of the receiving staff/recipient and prompts consumers to choose the required food;
d) After the receiving staff/recipient passes the identity verification, or the consumer completes the payment by scanning code, the vehicle will open the designated box to remind the receiving staff/recipient to unload/pick up/pick up food;
e) The vehicle detects that the goods are taken out of the specified compartment;
f) Close the container door and prompt the receiving staff/recipient/consumer to finish unloading/picking up/selling meals.

4.2.9. Pedestrian crossing

1) Test scenario
   The test road is a long straight road consisting of at least two lanes, with a dashed middle lane and a pedestrian crossing 100m in front of the test vehicle.

2) Test method
   The test vehicle entered the test section at a speed of no more than 30km/h under the automatic driving state. When the distance was 4s, the pedestrian crossed the road at a speed of 5-6.5 km/h

3) Pass requirement
   The test vehicle should be able to avoid pedestrians and avoid collisions.

5. Conclusion

At present, the unmanned delivery vehicle industry lacks effective testing methods to verify whether they meet the functional requirements and safe operating conditions. Based on the functional characteristics and typical applications of unmanned delivery vehicles, this paper designs a test method of unmanned delivery vehicles based on test scenarios. The scenarios are sequential in the combination from 4.2.1 to 4.2.8, including “Loading/Posting/Catering”, “Enter/exit the park”, “Designated lane driving”, “Traffic sign and line identification and response test”, “Motor vehicle signal light recognition and response test”, “Non-motor vehicle signal light recognition and response test”, “Wave to stop”, “Unload/Pick up/Sell meals”. The settings of these scenarios can test the fundamental ability of unmanned delivery vehicles to cope with typical external environments in actual operation. Parameters in the scenarios are given in combination with the application environment of unmanned delivery vehicles.

With the development of technology and the improvement of management policies, the speed of unmanned delivery vehicles will increase. The relevant parameters in the test method should be adjusted according to the actual vehicle speed. In the future, the author will follow up the relevant content and improve the test method in combination with the development of the industry.

References