Research on Weather Condition Influence Factors on Intelligent Connected Vehicle

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Abstract. Now, there is no standard test method and flow for the performance of Intelligent Connected Vehicle under the complex weather conditions, which has greatly limited the development of Intelligent Connected Vehicle. This paper test and study the weather conditions that affect the performance of the on-board sensors, then analyse the weather conditions that affect Intelligent Connected Vehicle, the meteorological factors which affect Intelligent Connected Vehicle performance are obtained. It turns out that different conditions such as rain, fog, snow and light have different influence on the Intelligent Connected Vehicle, which provides the foundation for the performance test of Intelligent Connected Vehicle.

1. Introduction
With the development of advanced technology such as internet and artificial intelligence, the automobile industry is transforming to intelligentization and networking. The development of Intelligent Connected Vehicle (ICV) can improve traffic efficiency and solve problems such as energy shortage, environmental pollution and traffic congestion[1]. On April 12, 2018, the Ministry of Industry and Information Technology of the People's Republic of China, the Ministry of Public Security and the Ministry of Transport of the People's Republic of China jointly released the test and Management Specification for Intelligent Connected Vehicle, the management specification claimed that test vehicles shall be fully tested in specific areas such as closed roads, venues, etc., and verified its 14 self-driving functions by the third-party testing institution that approved by the state, then the self-driving road test application can be permitted. However, the test field demonstration area is very homogeneous, and the test mostly focuses on the routine road test. There is no standard test method and flow for the performance of Intelligent Connected Vehicle under the complex weather conditions, which has greatly limited the promotion and application of Intelligent Connected Vehicle.

Therefore, it is great significance to carry out the research on the performance test of Intelligent Connected Vehicle under the complex weather conditions.

2. Research content
As a special condition rarely encountered in the test of open road or closed road, the complex weather condition has a significant impact on the safety of Intelligent Connected Vehicle. By analyzing the performance of Intelligent Connected Vehicle under the complex weather conditions, it is beneficial to compare the test data and establish the database, and then promote the development of Intelligent Connected Vehicle test technology.

Intelligent Connected Vehicle sensing module mainly relies on Lidar, GPS positioning and navigation, camera and other sensors[2]. Each sensing module is affected by the complex weather conditions in different ways, and different weather conditions will have different effects on the performance of the on-board sensors. Therefore, it is necessary to study the influence of complex weather conditions on the performance of on-board sensors and Intelligent Connected Vehicle.
conditions, which will directly affect the performance of Intelligent Connected Vehicle. Therefore, the performance of each sensor under the complex weather conditions is analyzed through the environment simulation test box (as shown in figure 1). The key meteorological factors affecting the performance of Intelligent Connected Vehicle can be derived.

Figure 1. Environment simulation test box

3. Analysising the meteorological factors of affecting the sensors of Intelligent Connected Vehicle

3.1. Analysising the meteorological factors of affecting the performance of the lidar
Lidar has extremely high range resolution, angular resolution and velocity resolution, its wave length is short, the divergence angle is very small, which can directly obtain the information of the target's range, angle, reflection intensity, velocity and so on. Then multi-dimensional image of the target is generated, but in bad weather such as heavy rain, smoke and fog, the laser beam attenuation increases sharply and the propagation distance is greatly affected [3].

The quantitative and qualitative contrast tests were carried out in the environmental simulation test box. For example, the attenuation of the CO$_2$ lidar with a working wavelength of 10.6 μm in bad weather is 2 ~ 8 times than that on a sunny day. Moreover, the atmospheric circulation also cause the laser beam to have the distortion and Jitter, which directly influence the measurement accuracy.

Table 1. The Lidar r attenuation results under different weather conditions (Compared with sunny day)

| Serial number | Weather condition | Order of magnitude | Average attenuation(times) |
|---------------|-------------------|--------------------|---------------------------|
| 1             | Rain              |                    |                           |
|               | Rainstorm         |                    | 7.8                       |
|               | Heavy rain        |                    | 6.3                       |
|               | Moderate rain     |                    | 4.2                       |
| 2             | Fog               |                    |                           |
|               | Thick fog         |                    | 6.4                       |
|               | Heavy fog         |                    | 4.5                       |
|               | Mist              |                    | 2.1                       |

Note: The weather is quantified according to the meteorological standard.

3.2. Analysising the meteorological factors of affecting the performance of the camera
Intelligent Connected Vehicle installs many camera sensors, the camera sensor resolution is high, the obstacle type recognition is accurate, it also can capture the object shape, the detail and excel to processing the complex driving environment. But in heavy rain, strong illumination or luminosity transient, video images will appear mold, distortion. Therefore, the illumination, rain and snow are the main factors that affect the performance of the camera sensor.
3.3. Analysising the meteorological factors of affecting the performance of the inertial navigation equipment
Inertial navigation system is an autonomous navigation that uses gyroscopes and accelerometers to measure the acceleration and angular velocity of the vehicle. The performance of the system is decided by the sensor noise, deviation, scale factor and system calibration. Its sampling rate is high and the operation speed is fast. Therefore, the complex weather conditions have little influence on the inertial navigation equipment[4].

3.4. Analysising the meteorological factors of affecting the performance of the ultrasonic radar
There are two common types of ultrasonic radar, one is mounted on the front and rear bumpers of the car, it is used to measure obstacles in front and behind the car, the other is mounted on the side of the car, which is used to measure the distance of obstacles in the side. The energy consumption of ultrasonic wave is very slow, the propagation distance in the medium is long, the penetration is strong, the distance measurement method is simple and the cost is low. But by testing, the precision is reduced by 30% in heavy rain, so the rain and fog is the main reason that affects the performance of the sensor.

3.5. Analysising the meteorological factors of affecting the performance of the millimeter-wave radar
The millimeter-wave radar on the vehicle transmits millimeter-wave to the outside through the antenna, and receives the target reflection signal, it can quickly and accurately obtain the physical environment information around the vehicle after processing. The stable detection performance of millimeter-wave radar is not affected by the shape and color of the object surface, and it has similar working principle with the lidar. Therefore, rain and fog are also the main factors that affect the performance of the millimeter-wave radar[5].

3.6. Analysising the meteorological factors of affecting the performance of V2X equipment
The vehicle can get the unknown parameters of the surrounding environment and the running state of the nearby vehicles by using V2X, the active security algorithm on the vehicle will process the acquired information and classify the information according to the priority. The vehicle executor can be used to control the vehicle in case of emergency to avoid the risk. So, V2X is the only vehicle sensing technology that is not affected by weather conditions, whether it is rain, fog or bright light. However, the attenuation, fluctuation and even failure of its performance will directly affect the safety of drivers and passengers in the complex electromagnetic environment, so electromagnetic interference is the main reason that affects the performance of V2X equipment[6].

According to the above analysis and test results, different conditions such as rain, fog, snow and light will have different influence on the Intelligent Connected Vehicle. The main meteorological influencing factor of the key sensors are shown in Table 2:

| Serial number | On-board sensor       | Meteorological factor       |
|---------------|-----------------------|-----------------------------|
| 1             | Lidar                 | Rain, fog                   |
| 2             | Camera                | Light, rain, fog, snow      |
| 3             | Inertial navigation equipment | None                       |
| 4             | Ultrasonic radar      | Rain, fog                   |
| 5             | Millimeter-wave radar | Rain, fog                   |
| 6             | V2X                   | None                        |

It can cause many problems, such as the reduction of measurement accuracy, the increase of ranging error, the deterioration of video quality, and the wrong identification of traffic signs, which will directly reduce the whole vehicle performance, and even affect the normal operation. Therefore, it has important significance to studying the performance of on-board sensor under the complex weather conditions.
4. Conclusion
This paper study the characteristics of complex weather conditions that affect the performance of Intelligent Connected Vehicle by analyzing the influence factors of complex weather conditions on the performance of on-board sensors, complex weather scenes such as rain, fog, snow and light are put forward, which can directly affect and even reduce the whole vehicle performance. Therefore, it has important significance to studying the complex weather conditions, which provides a basis for the further study for the characteristics and control index of complex meteorological scenes.

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References
[1] Huang ZJ. (2018) Intelligent traffic and unmanned driving. Chemical Industry Press, Beijing
[2] Yu LF, Song C. (2011) Research progress of vehicle-borne sensor networks [J]. Computer Science, p319-322.
[3] Cui SM. (2016) New technology of Intelligent Connected Vehicle. Chemical Industry Press, Beijing
[4] Cui SM, Yu TY, Wang ZH. (2019)Key technologies of advanced driving assistance system for Intelligent Connected Vehicle. Chemical Industry Press, Beijing
[5] Zhu T, Yang QW. (2015) Application and development of Intelligent Vehicle Technology [J]. Technology Outlook
[6] Zhao J. (2018) Current situation and prospect of V2X technology. Guangdong communication technology, Guangzhou