Data Analysis of Overtaking Test Scene in Blind Spot Detection System

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ABSTRACT

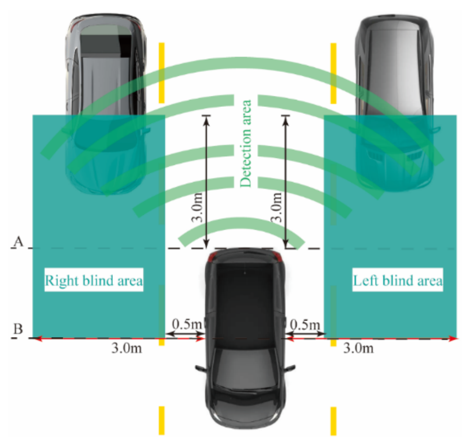
Blind Area Detection System (BSD) plays a positive role in reducing the occurrence of car accidents. This paper selected the test data of 16 cars passing through the C-NCAP(2021 edition) BSD C2C overtaking scene, and the box diagram is used for statistical analysis of the data. It is found that the warning time TTC of vehicles equipped with a BSD system is reasonable at present, which plays a safety warning role and will not cause too much discomfort to users. However, the alarm timing of the BSD system of a few vehicles is not suitable enough, which still needs to be improved. In addition, after the target vehicle crosses the test rear, the BSD system should use a more urgent alarm method to remind it.

Keywords: Blind spot detection system, Box diagram, TTC, C-NCAP

1. INTRODUCTION

With the rapid development of society, cars have entered more families, but at the same time, security risks are also increasing. According to statistics, about one-third of the annual car accidents in China are caused by car blind spots[1]. This is because there is a blind spot in the rearview mirror (such as in Figure 1), it's difficult to see the vehicles in the blind area before changing lanes, and it is difficult to see the vehicles behind when the weather is bad or the light is dim. Daimler-Benz Company's research shows that 60% of rear collisions can be avoided if the driver can get an early warning of 0.5s, and 90% of rear collisions can be avoided if he can get an early warning 1s[2]; Some studies have pointed out that the BSD system can reduce the lane change accident rate by nearly 14% and the injury accident rate by nearly 23%[3].

Based on the above, the Blind spot detection system (BSD) came into being. However, with the increasing deployment rate of BSD systems, we should check whether the corresponding functions can work successfully, and ensure that the vehicle alarm timing is not too conservative to avoid poor user experience. This paper analyzes the alarm timing of the current BSD system by setting up the C-NCAP2021 BSD C2C overtaking scene test condition.



Note: Line A is the trailing edge line of the vehicle;

Line B is parallel to the front edge of the vehicle and located in the center of the 95th percentile eye ellipse.

Figure 1 Schematic diagram of automobile blind area

International Conference on Smart Transportation and City Engineering (STCE 2023), edited by Miroslava Mikusova, Proc. of SPIE Vol. 13018, 130181Q

2. COMPOSITION AND WORKING PRINCIPLE OF THE BSD SYSTEM

BSD system generally carries out real-time sensing detection through the single camera, multi-sensor fusion, or radar sensor[4–8](such as Figure 1), if vehicles or other objects appear in the blind area, the BSD system will send out instructions by the receiving device installed at the edge of the rearview mirror, and inform the driver by sending out alarm information on the rearview mirror or adopting other alarm forms (such as steering wheel vibration, sound warning, seat vibration, etc.) to avoid car accidents.

3. C-NCAP2021 BSD C2C TEST

3.1 Test scenario

At present, the scene about BSD C2C in C-NCAP version 2021 is divided into overtaking scenes (such as Figure 2), the scene speed is as Table 1 as shown.

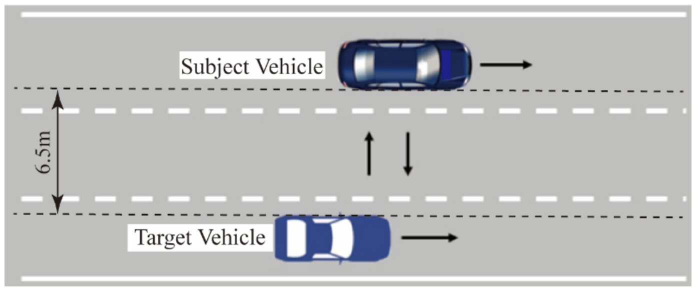


Figure 2 BSD C2C overtaking scene

Table 1 BSD C2C overtaking scene speedometer

Subject vehicle speed /(km/h)	Target type	Target speed /(km/h)	Target action
50	Vehicle	60	Overtake
		65	
		70	

The test starts from position 33m behind the rear edge of the Subject vehicle. When any part of the target vehicle is within 30m behind the rear edge of the Subject vehicle, the BSD system should give an alarm, and the alarm time should not be later than 300ms when the front edge of the target vehicle exceeds the rear edge of the Subject vehicle, and the BSD system cannot give an alarm when the target vehicle is outside the blind area (that is, 30m away from the rear edge of the subject vehicle).

3.2 Test sample vehicle and test equipment

3.2.1 Test sample car

To carry out analysis and research, the test data of 16 passenger cars that passed the C-NCAP 2021 BSD overtaking scene test are selected for analysis. Because the test pass rate is not involved in this paper, the selected vehicles are all vehicles that passed the BSD C2C test. The target vehicle uses a small SUV that meets the standard, and the target vehicle is like Figure 3.

Figure 3 Target Vehicle

The selected Subject vehicle type is as follows in Table 2 as shown. To ensure the test's stability, according to the C-NCAP(2021 edition) regulations, each speed point is tested three times in a row, and all three times pass the test. In the analysis, the data used are the average of three test results.

Table 2 Test sample vehicle type

Vehicle type	**Quantity**
Car	Seven
SUV	Eight
Pickup truck	One

3.2.2 Test equipment

The equipment used in this test mainly includes an ABD driving robot (including steering robot and throttle robot), vehicle-mounted computer, Oxford gyro, audio-visual alarm detector -AVAD3, and RC controller. The Subject vehicle is equipped with all the above equipment, and the target vehicle is equipped with other equipment except the audio-visual alarm detector -AVAD3, as Figure 4 as shown.

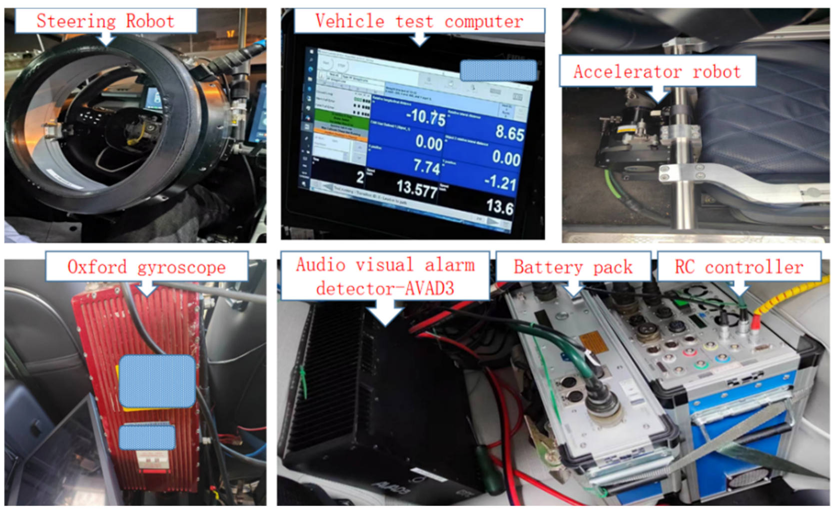


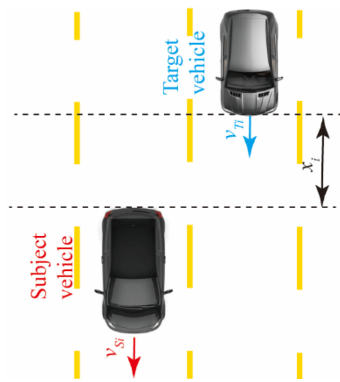
Figure 4 Test equipment diagram

4. STATISTICAL ANALYSIS OF DATA

Box Boxplot, also known as box whisker diagram, box diagram, or box diagram, can be used to show the dispersion of a set of data[9]. Used to reflect the distribution characteristics of the original data, and can compare the distribution characteristics of multiple groups of data. Five statistics of data, including minimum value, maximum value, first quartile Q_1, median Q_2, third quartile Q_3 and maximum value, are mainly used to describe the data. The data used in this paper are data from different models of several different manufacturers, so box boxplot is used for analysis. Q_1-1.5 IQR and Q_3+1.5IQR are the inner limits (IQR is quartile deviation), and the abnormal value mentioned in this paper is defined as the value less than Q_1-1.5 IQR or greater than Q_3+1.5IQR, which is defined concerning the empirical algorithm[10]. At the same time, due to the use of more vehicle data, to avoid the impact of individual outliers on the analysis results, this paper mainly uses the median Q_2 for analysis.

Among them, the alarm distance is defined as the longitudinal distance between the front of the target vehicle and the rear of the Subject vehicle when the BSD system of the subject vehicle alarms (such as Figure 5); The alarm time TTC is defined as the longitudinal time between the front of the target vehicle and the rear of the subject vehicle when the BSD system of the subject vehicle alarms. TTC is calculated as follows:

$$TTC = \frac{x_i}{|v_{Si} - v_{Ti}|} \tag{1}$$



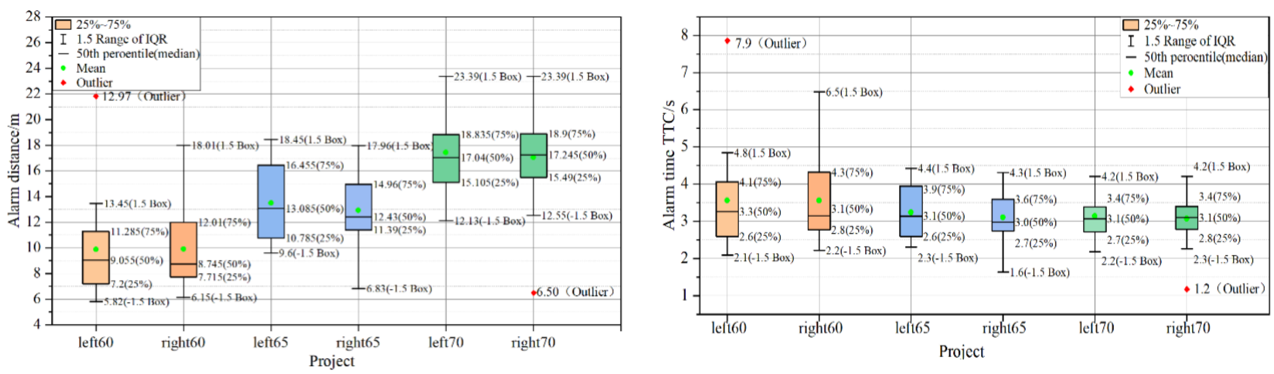
Wherein: x_i-the longitudinal distance between the subject vehicle and the target vehicle is carved for a certain time;

v_{Si}-Carve the speed of the main car for a certain time;

v_{Ti}-Mark the speed of the target car for a certain time.

Figure 5 Schematic diagram of the definition of longitudinal distance and alarm time

Statistical analysis of overtaking scene test data, such as Figure 6 as shown.



(a) Statistics of alarm distance data in different test scenarios

(b) Statistical charts of TTC data of alarm time under different test scenarios.

Note: direction um: direction in the abscissa mentioned in the above figure refers to the orientation of the target vehicle relative to the subject vehicle, Num refers to the target vehicle speed, and eg: left60 refers to the target vehicle speed of 60km/h, which is located on the left side of the subject vehicle.

Figure 6 Statistical chart of overtaking scene data

4.1 Abnormal data analysis

There are two data outliers in the vehicle data used in this paper, namely: when the target speed of the left overtaking scene is 60km/h, the warning distance is 12.97m (the warning time TTC is 4.7 s); When the target speed of the overtaking scene on the right is 70km/h, the warning distance is 6.50m (the warning time TTC is 1.2s). The abnormal data is the data of the same vehicle type, and its BSD system leaves the driver with a long reaction time when the target vehicle is low (that is when the relative speed between the target vehicle and the subject vehicle is low), but the reaction time left for the driver is shorter when the target vehicle is high (that is, when the relative speed between the target vehicle and the subject vehicle is high). This design logic is considered to be unreasonable.

4.2 Analysis of speed data of different targets on the same side

The data analysis of the alarm distance and the alarm time TTC of different target speeds on the same side shows that: from the median point of view, with the increase of target speed, the alarm distance of the BSD system shows an increasing trend (such as Figure 6 (a)); However, the alarm time TTC does not increase, and even decreases (such as Figure 6(b)); From the internal value (such as Figure 6), although the alarm distance changes obviously at different speeds on the same side, the alarm time TTC does not change.

4.3 Data analysis of different sides of the same target speed

The data analysis of the alarm distance and the alarm time TTC on different sides of the same vehicle speed shows that the alarm distance on the left and right sides is slightly different, but basically the same (such as Figure 6(a)); For the alarm time TTC, when the target speed is 60km/h and 65km/h respectively, the left side is slightly earlier than the right side, and when the speed is 70km/h, the left and right sides are consistent (such as Figure 6 (b)).

4.4 Comprehensive analysis of test data of overtaking scene

According to the survey, the average reaction time of the driver is 1.35s, while that of the braking system is about 0.15s[11]. Therefore, under normal circumstances, when the vehicle is in a stable car-following state, the time distance between the front of the target vehicle and the rear of the subject vehicle is not less than 1.5s, which can be considered relatively safe. According to the above data analysis, except for abnormal data, when the minimum distance of the selected vehicle is 65km/h, the warning time TTC is 1.6s, but it is still 1.5s longer than the safety time.

In addition to the abnormal value, the maximum warning TTC of statistical vehicles is 6.5s (the target speed of overtaking scene on the right is 60kph), which is four times higher than the safe time interval. It is considered that the system is conservative in design, which may lead to poor user experience and affect the timing of lane changes.

Judging from the overall alarm time TTC (such as Figure 6 (b)), except for abnormal values and values that may cause discomfort to users, the alarm time TTC of the BSD system of the selected vehicle is between 1.6 and 4.8s when the target speed is 60km/h~70km/h, which can play a warning role without causing excessive discomfort to users.

In addition, such as Figure 7 shows the scene alarm signal and relative longitudinal distance diagram of overtaking on the right side of a certain vehicle (the target speed is 70km/h). It can be seen that the BSD alarm signal is still a normally bright signal when the front of the target vehicle passes the rear of the subject vehicle (that is after the relative longitudinal distance in the figure is greater than 0), and the alarm signal of overtaking scene in the selected vehicle is mostly in this form. It is a dangerous situation if the subject vehicle changes lanes in the direction of the target vehicle after the front of the target vehicle crosses the rear of the subject vehicle. Therefore, it is suggested that after the front of the target vehicle passes the rear of the subject vehicle, the BSD system of the subject vehicle should give an alarm in a more urgent form (such as an optical flashing alarm or a more urgent sound alarm).

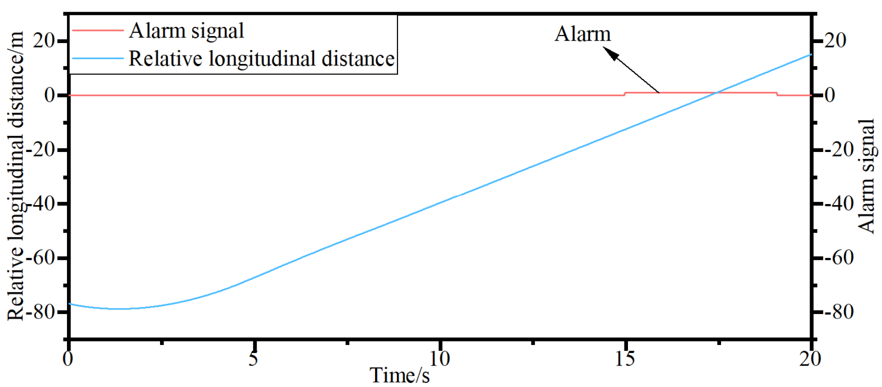


Figure 7 Scene alarm and relative longitudinal distance diagram of overtaking on the right side of a certain vehicle (target speed 70km/h)

5. CONCLUDING REMARKS

This paper selects and analyzes the test data of 16 passenger cars that passed the C-NCAP 2021 BSD overtaking scene test by box diagram. The BSD system of some vehicles has a more radical or conservative design, and there is room for improvement to ensure safety and improve user experience, but the alarm time of most vehicles is reasonable, which can not only play a warning role but also cause discomfort to users. In addition, at present, most BSD systems use the way that the alarm device on the rearview mirror is always on, but to enssure safety, BSD systems should use a more urgent alarm mode to remind after the target vehicle crosses the test rear.

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