Simulation test of driving assistance system based on virtual scene

Xing Meng[1], Haiyun Gan[1,*] and Ying Yan[1,2]

[1]National and Local Joint Engineering Center for Intelligent Vehicle-Road Collaboration and Safety Technology, Tianjin University of Technology and Education, China

[2]E-mail: yanying@tute.edu.cn

Abstract. Assisted driving technology has received increasing attention. In order to verify the function of the assisted driving technology, this paper takes the automatic emergency braking system as an example and uses CarMaker simulation software to construct a standardized test scenario. Build a vehicle model and add sensors to detect the environment around the vehicle. Set up the Simulink control model. Use the PID control to brake the vehicle. The simulation test of the automatic emergency braking system was completed and the dynamic characteristics of the test vehicle were analyzed. Finally, through simulation experiments, it is verified that the simulation test can achieve extremely dangerous working conditions and reduce the possibility of accidents. Simulation tests can improve the efficiency of the test, and can repeat the test multiple times, reducing the cost of testing.

1. Introduction

With the development of the automotive industry, assisted driving and automatic driving technology has become a development trend. The assisted driving technology can not only reduce traffic accidents caused by driver human factors, but also reduce traffic congestion [1]. The core issue of this technology is functional reliability. As shown in Table 1, from 2016 to 2018, there have been nearly 10 traffic accidents caused by autonomous driving in the world [2]. Therefore, assisted driving and autonomous driving technologies require a large number of functional tests to improve safety. Therefore, assisted driving and autonomous driving techniques require a large number of functional tests to improve safety [3]. RAND Corporation said: to prove that autonomous vehicles can reduce traffic accidents by 20% compared to human driving, it requires about 5 billion miles of public road testing, using a fleet of 100 vehicles. It is tested at an average speed of 25 mph 24 hours a day, 365 days a year, and will take about 225 years [4].

In the process of car V process development, testing and verifying the control system is a very important step [5]. At present, commonly used driving assistance systems include adaptive cruise control system (ACC), front collision warning system (FCWS), automatic emergency control system (AEB), lane departure warning (LDW), lane keeping assist system (LKAS) and so on. This paper selects the automatic emergency braking system (AEB) for simulation test for functional verification [6].

Table 1. Global autopilot traffic accidents in 2016-2018.

Time	Company	Autopilot level	Accident Cause	Casualties
January 2016	Tesla	L2	The driver did not operate as required by the system	1 death
February 2016	Waymo	L2	Automatic driving design imperfect, predicting rear vehicle behavior errors	No casualties, vehicle collision
May 2016	Tesla	L2	Automatic driving design imperfect, unable to identify large objects docked	1 death
March 2017	Uber	L3	Ordinary vehicle fault	No casualties vehicle rollover
August 2017	Waymo	L4	Automatic driving safety officer intervention fault	No casualties vehicle collision
March 2018	Uber	L4	Automatic driving system software does not recognize pedestrians	1 death
March 2018	Tesla	L2	The driver did not operate as required by the system	1 death
May 2018	Waymo	L4	Ordinary vehicle fault	1 minor injury

2. Automatic emergency control system

The task of the Automatic Emergency Brake (AEB) system is to decelerate the vehicle to the speed of the target object. To do this, the system compares the time-to-collision t_{tc} with a time-threshold-brake t_{tb} to decide if a braking intervention is required

For a stationary or a very slow moving target object, the time-to-collision t_{tc} is calculated as follows:

$$t_{tc} = \frac{d}{v_{rel}} \tag{1}$$

with relative distance d and relative velocity v_{rel} between the ego vehicle and the target object.

If the target object is decelerating, the time-to-collision is calculated as follows:

$$t_{tc} = \frac{\sqrt{v_{rel}^{2} - 2 \cdot \mathrm{d} \cdot D_{\mathrm{rel}}} - v_{rel}}{D_{rel}} \tag{2}$$

with relative deceleration D_{rel}.

The time-threshold-brake t_{tb} for a stationary target object is calculated in following way:

$$t_{tb} = \tau_B + \frac{v_{rel}}{2 \cdot D_{\max}} \tag{3}$$

with brake loss time τ_B.

For a non-stationary target object the time-threshold-brake is calculated with:

$$t_{tb} = \tau_B + \frac{v_{rel} + D_{rel} \cdot \tau_B}{2 \cdot (D_{\max} - D_{obs})} \tag{4}$$

with maximum allowed deceleration of ego vehicle D_{max} and the actual target object deceleration D_{obs}.

If $t_{tc} < t_{tb}$, the AEB system sets as target acceleration for the controller the maximum allowed deceleration D_{max}.

3. Simulation text

3.1. Simulation tool

CarMaker is a passenger vehicle dynamics simulation software for vehicle component development, controller development and vehicle development. CarMaker is mainly composed of two parts that one is CarMaker Interface Toolbox which mainly includes Graphic User Interface that provides all the functions of CarMaker; virtual instrument which displays information such as pedal and vehicle status; IPGControl is a visualization tool that can observe selected output variables such as speed acceleration etc; IPGMovie used to display 3D animations in real time during simulation. The other part is the Virtual Vehicle Environment which is the core of the entire simulation including CarMaker executable files control software such as CarMaker for Simulink and some external models.

3.2. Testing scenario
China Automotive Technology and Research Center has carried out extensive domestic and international technical exchanges and practical tests based on the in-depth study and analysis of foreign Euro-NCAP [7] by combining China's automobile standard regulations, road traffic conditions and vehicle characteristics. Finally, China Automotive Technology and Research Center confirmed the test and scoring rules for C-NCAP for China. This paper selects one of the typical AEB test scenarios in the C-NCAP management rules [8].

The description of scene two is as follows:

Site requirements for scenario two: sunny weather, there is no precipitation and snowfall, the wind speed is no more than 10m/s, the road surface is dry and level, the peak braking force coefficient is greater than 0.9, the test area is 30m ahead of the test end point within 6m from the driver's side of the test center line and 4m on the passenger side. There are no other vehicles obstacles or other protrusions inside.

The movement of pedestrians in scene two: the path of the pedestrian is perpendicular to the path of the test vehicle. The lateral distance between the pedestrian and the test vehicle is 4m. The pedestrian accelerates from the static state to 5km/h from the left side of the test vehicle, and the acceleration distance is 1m. The pedestrian walks in a straight line at a speed of 5km/h. In the absence of braking measures, the test vehicle collides with the pedestrian crossing, with the collision location at 25% of the transverse section of the vehicle itself.

3.3. Vehicle model
The target vehicle constructed is a three-seat five-seat passenger car. The weight of the car is 1714kg, 4.44m long, 1.93m wide and 1.24m high. Vehicle centroid position coordinates is (2.275, 0, 0.5). The suspension spring has a stiffness of 35000 N/m. Add an object sensor. Sensor position coordinates is (4, 0, 0.5), field of view angle is 60°, and maximum sensing range is 15m, as shown in Table 2.

Table 2. Vehicle parameters.

Serial Number	Parameter	Definition
1	vehicle weight	1714kg
2	Vehicle length	4.44m
3	Vehicle width	1.93m
4	Vehicle height	1.24m
5	Centroid position coordinates	(2.275, 0, 0.5)
6	Suspension spring stiffness	35000N/m
7	Sensor position coordinates	(4, 0, 0.5)
8	Sensor field Angle	60°
9	The maximum sensing range of the sensor	15m

3.4. Driver model
The cruising speed of the driver model is 30km/h. The driver's foot is stepped from the accelerator pedal to the brake pedal for 0.5s. The maximum longitudinal acceleration is $3m/s^2$, the maximum longitudinal deceleration is $4m/s^2$, and the maximum lateral acceleration is $4m/s^2$, as shown in Table 3.

Table 3. Drive parameters.

Serial Number	Parameter	Value
1	Cruising speed	30km/h
2	The time the driver's foot stepped on the brake pedal from the accelerator pedal	0.5s
3	Maximum longitudinal acceleration	3m/s^2
4	maximum longitudinal deceleration	4 m/s^2
5	maximum lateral acceleration	4 m/s^2

3.5. Control model
The test vehicle continuously acquires the road information ahead through the sensor during driving. When an obstacle is detected in front of the vehicle, the test vehicle will feed back the speed and position information of the obstacle acquired by the sensor to the vehicle brake system. The braking system adjusts the opening of the vehicle throttle and pedal by the distance and relative speed of the obstacle, thereby achieving the braking of the test vehicle. The Simulink block diagram of the brake system of this experimental car is shown in Fig.1. In addition, the control algorithm of this braking system is PID control, as shown in Fig.2. The accelerator pedal is used as the input of the controller to output the wheel torque of the front and rear wheels of the vehicle to realize the vehicle speed control.

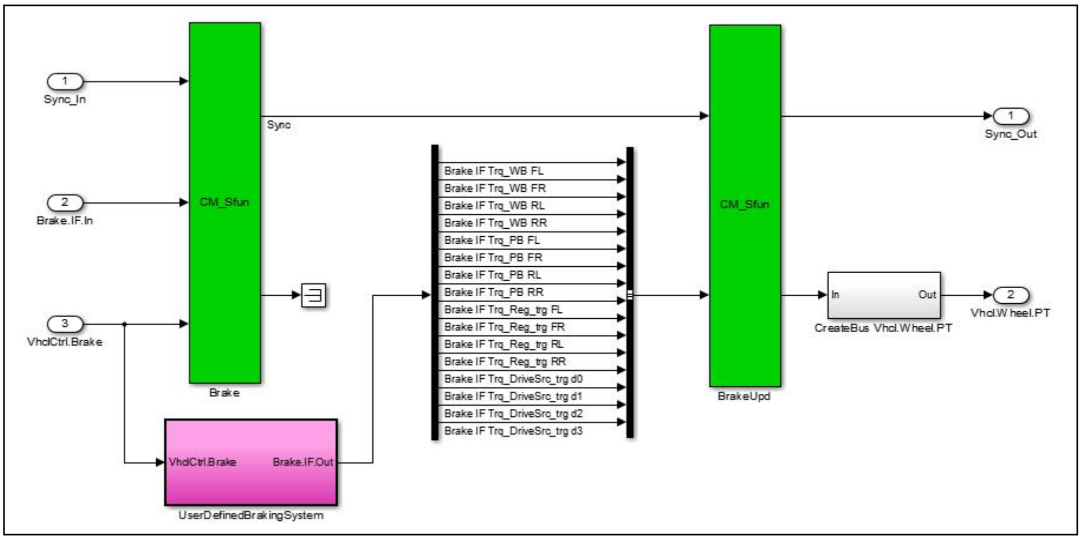

Figure 1. Brake model.

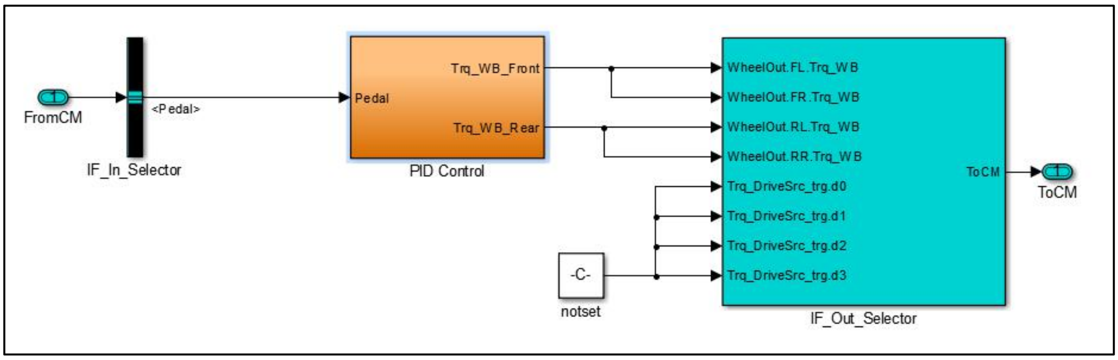

Figure 2. Control module.

4. Analysis of results

Figure 3 is a simulated animation of the scene. Multiple result information can be obtained through the IPGControl subroutine.

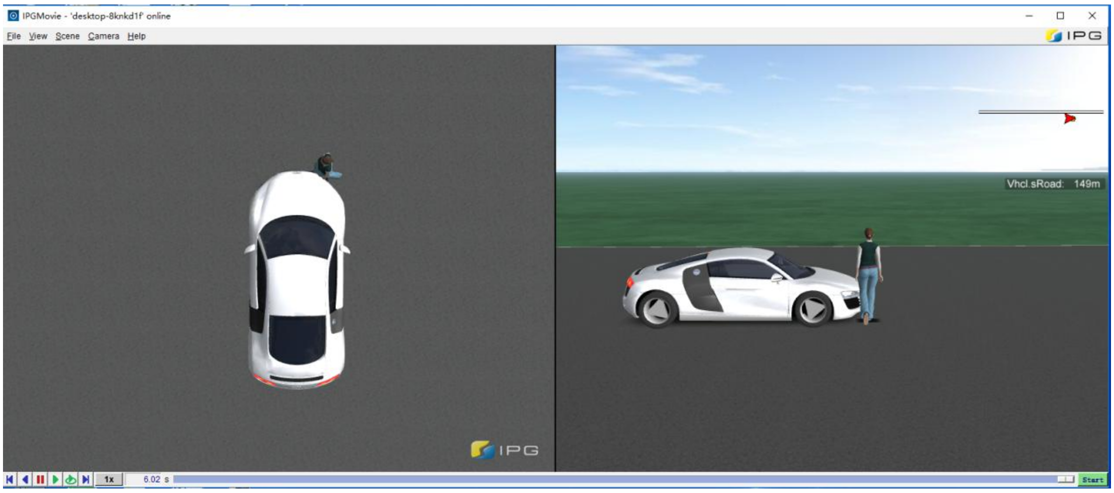

Figure 3. Simulation animation.

Figure 4 is a velocity-time image of the test vehicle. It can be analyzed from the figure that the entire driving time of the test vehicle is about 7s. The initial speed of the test vehicle is approximately 30 km/h. When the current party detects a pedestrian, the test vehicle begins to brake until it stops.

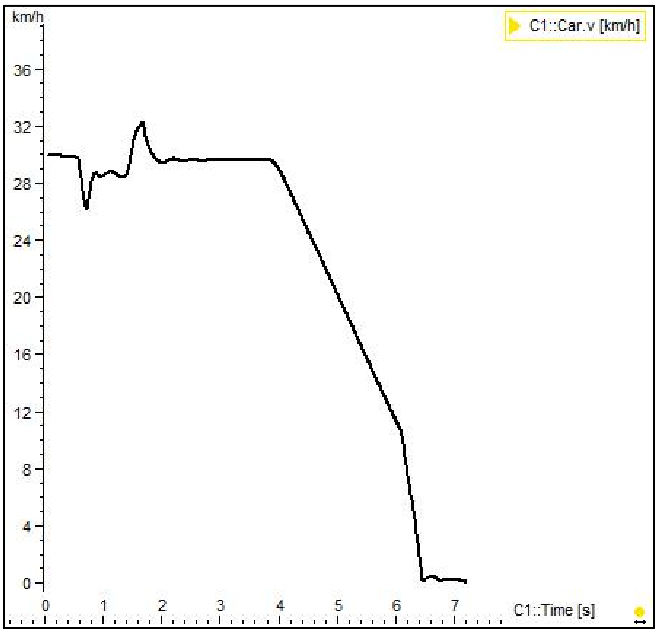

Figure 4. Test vehicle v-t image.

Of the four tires, two tires act as a brake. Figure 5 is the left front wheel braking torque image. Small fluctuations occurred when the vehicle started to drive. When the sensor detects a pedestrian in front, the braking torque increases. From the 6s to the 7s, the braking torque reaches the maximum value. When the vehicle is completely stopped, the braking torque is zero. Figure 6 is the right rear wheel braking torque, the principle of action is similar to the left front wheel.

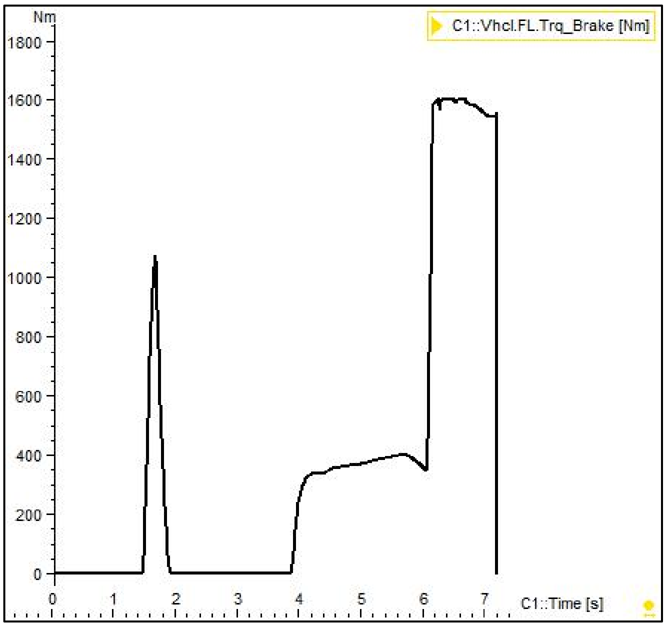

Figure 5. Left front wheel braking torque.

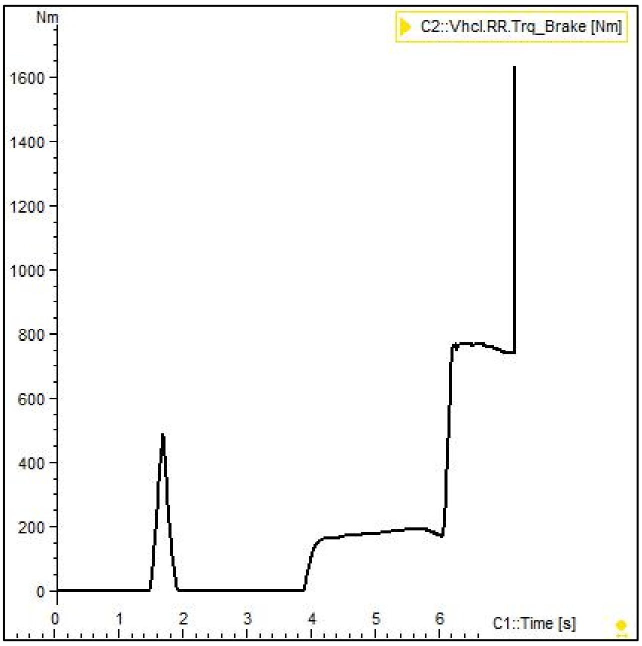

Figure 6. Rear right wheel braking torque.

5. Conclusion

This paper completed a virtual road scene ADAS function test based on CarMaker software, and used an AEB scene in the C-NCAP standardized test scenario as an example to verify the simulation. Through simulation experiments, the efficiency and accuracy of ADAS simulation are improved, the test cost is saved, and the test cycle is reduced, which brings great convenience to vehicle development.

Acknowledgments

This work was finally supported by the National Science Foundation of Tianjin (18JCTPJC68500).

Journal of Physics: Conference Series **1419** (2019) 012047 doi:10.1088/1742-6596/1419/1/012047

References

[1] Felipe Jiménez, José Eugenio Naranjo, José Javier Anaya, Fernando García, Aurelio Ponz and José María Armingol 2016 Advanced Driver Assistance System for road environments to improve safety and efficiency *Transportation Research Procedia* **14** pp 2245-2254

[2] Marius Feilhauer, Juergen Haering 2016 Current Approaches in HIL-Based ADAS Testing *SAE International* (09): 63-69

[3] Maria Staubach 2009 Factors Correlated with Traffic Accidents as a Basis for Evaluating Advanced Driver Assistance Systems *Accident Analysis and Prevention* (06): 1025-1033

[4] Daza I G, Bergasa L M and Bronte S 2014 Fusion of Optimized Indicators from Advanced Driver Assistance System (ADAS) for Driver Drowsiness Detection *Sensors* **14** (1): 1106-1131

[5] Lijun Jiang, Jinpeng He and Weiguo Liu 2014 Research on Automatic Emergency Braking System Test Scenario *Automotive Technology* (01): 39-43

[6] Pengfei Li, Ziqi Zhan 2018 Research on ADAS Simulation Test Based on Scene Standardization *Conf. of China Automotive Engineering Society* pp 463-468

[7] Chinese Automotive Technology and Research Center 2018 *C-NCAP Management Rules* [Z]

[8] Yu J, Lee G and Lee H 2016 Validation of Automotive Body ECU Using Hardware-in-the-Loop Simulation *SAE 2016 World Congress and Exhibition*