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A Review on the Development of Vehicle Driving Simulator

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Abstract: With the development of the economy, cars have become the common means of transportation for people, and the safety issues related to this and the new technologies are being taken seriously. Vehicle driving simulator, as a kind of simulation equipment, is mostly used in the research, experiment and development of new technology enterprises, meanwhile, it also can realize simulation of car running performance, driving training, and make users get real driving experience. In this paper, present development situation at home and abroad of vehicle driving simulator, and the species, composition and working principle of vehicle driving simulator are introduced and teviewed. Based on vehicle driving simulator "driver-vehicle-road environment" in the simulation environment, the dynamic simulation of virtual driving system, visual simulation system, driving simulation of ABS and ESP control were analyzed.

Keywords: vehicle; dynamic simulative driving simulator; view simulation system; ABS; ESP

1 Introduction

In recent years, along with the level of economic growth, the improvement of people's living standards, automobile industry has been rapid development and the car is moving in high speed vehicle intensive, obviously, most cars are drived by non-professional drivers. Because our country population base is large, slow development of transport infrastructure condition, more and more cars, increasing the number of people killed in accidents each year, therefore, the car is the theme of the development of the same safety. And car driving simulators are the safety training for drivers.

In addition, with the maturity and development of the computer imaging technology and simulation technology, the driving simulator of driving training in aviation had already been applied in the field of automotive engineering research and development. The use of real-time visual simulation system to simulate the kind of design and performance testing can shorten the development cycle and reduce development costs. Vehicle driving simulator as a practical research, training equipment, from the 20th century, has gradually applied in various fields. From simple to apply to vehicles driving training simulation is now a real car performance, with the development of virtual simulation technology and computer graphics technology, the driving simulator structure and function have been improved gradually, and in a number of relevant vehicle engineering, road traffic research practices have also been developed in the application[1-3].

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In the simulation process of the "driver-vehicle-traffic environment" of the vehicle driving simulator, the virtual driving system, the visual simulation system, the ABS control and ESP control based on the driving simulator, driving simulation and vehicle performance research are necessary parts.

2 Vehicle driving simulator overview

The vehicle driving simulator, also known as simulated car driving simulation system, which combines a variety of advanced technology and subject knowledge of virtual reality technology, mechanical drive technology, computer graphics, three-dimensional real-time rendering technology, computer interface technology, data communication technology, is a cross from a number of high-tech technology platforms. With the driving simulator, the car-driver-road environment interaction can be studied and the driver can be trained. The research and development of the driving simulator can not only alleviate the pressure of the driving training system in our country at present, but also avoid the environmental pollution, and the energy consumption and reduce the training cost. Therefore, the research of the virtual driving system has the theoretical and practical significance. Product development has a broad market[4]. At present, the vehicle driving simulator is widely used in the development of new vehicles, driving training, ergonomic research and other scientific research, with the application of the in-depth, driving simulator performance requirements are getting higher and higher. This paper focuses on the important parts of the driving simulator: virtual reality technology, visual simulation system, automotive dynamics modeling, and ABS and ESP simulation in the driving simulator.

2.1 Research status of foreign vehicle driving simulator

By reviewing the relevant literature, developed countries on the vehicle driving simulator earlier, from the 1970s, foreign began to study the driving simulator, and as a practical tool. Initially, for driver training, Japan and the United States began using the driving simulator teaching driving regulations in the 1970s. And many driving schools also promote the use of driving simulators, which Japan Forum8, Toyota, Honda, Mazda have developed a sophisticated driving simulator training vehicles. Toyota has developed a driving simulator by using real car parts made of high simulation driver's seat, equipped with powerful feedback devices[5].

With the maturity of virtual technology and computer technology and the needs of research, national experts are committed to the study of vehicle driving safety and simulator development, using virtual driving technology to construct human, car and environment, three interactive driving safety analysis and to improve the motor performance in all aspects of the car[6]. For example, in Germany, Sweden, Japan and the United States, some manufacturers and scientific research institutions were established to develop simulator. In 1985, after years of efforts, the German Daimler-Benz Motor Company built a six-degree-of-freedom car driving simulator[7]. In 1989, the German Volkswagen applied new technology to improve and update the original visual system[8]. In 1993, the United States Iowa Vehicle Center began to launch research and development of vehicle driving with total investment of 13 million US dollars simulator[7,9], in 1996 an additional $30 million was costed to do a comprehensive upgrade and improvement of the simulation system by TRW company. The simulator is known as the national advanced motor driving simulator (NDAS). In 1991, Japan's Mazda company established a car driving simulator specializing in sports car in order to develop its sports car series of vehicles[10-11]. In 1995, the Japanese Institute of Automotive Research built a somatosensory simulation system of vehicle driving simulator in

order to study the simulation in the process of driving the importance of the driver's body[11-12].

In 2001, Japan's Honda company successfully developed a new six-axis driving simulator. In 2008, Yonekawa et al[13-14] built a driving simulator equipped with a real car cockpit, a 360° spherical dome screen, a six-degree-of-freedom mobile platform, a vertical vibration system and movements along the X and Y axes. Meanwhile, Koo[15] and others developed the GPS simulator of simulated GPS satellite signal. In 2011, Arioui[16] established a driving simulator equipped with a low-cost 2-DOF motion platform that allows longitudinal movement and yaw movement, which is mainly used for driver evaluation and education. In 2012, Monga[17], in the platform of based on high-performance reconfigurable enabled real-time simulation of the dynamic model, and presented a design and implementation of real-time simulation algorithm method, which is based on FPGA (Field-programmable gate array) technology to improve response time model. Katzourakis[18] realized the parameterization of the driving simulator using the two-lane turn indicator recorded on five modern cars. Gechter et al[19] established virtual intelligent city vehicle simulator to be used in vehicle platform assessment. In 2013, Sharaf[20] proposed two different driving simulators for testing real-time traffic in a virtual experimental field environment, both of which were based on a vehicle model with a reasonable number of degrees of freedom and acceptable level of accuracy. Shiiba et al[21] had compared the linear and nonlinear multi-body models in real-time simulation, and the calculation time had been verified based on the real-time analysis environment.

IOWA University Computer Aided Design Center developed the IOWA driving simulator; In 2008, Ford developed the VIRTTEX driving simulator based on the image generation technology provided by Quantum3D. The simulator used three-dimensional virtual reality technology to simulate the driving environment, including highway, mountain, building and traffic sign. The three-dimensional scene image was displayed through the projector. Ring screen, providing a deep immersive visual experience; simulator through the built-in camera and sensor records the driver's physiological response to the car's safety performance research to provide data. With the development of technology, Ford has repeatedly improved the simulator, still in use today, as shown in Figure 1[22].

Figure 1 VIRTTEX driving simulator developed by ford

2.2 Research status of domestic vehicle driving simulator

In the early 1970s, foreign driving simulator began to study, while China started relatively late in this area. Before the domestic technical limitations, it has experienced from the introduction of foreign products to independent development process. Currently, some domestic companies, universities and research departments developed a vehicle driving training simulator, but there is still a wide gap with the international advanced level. Overall, the development of China's driving simulator has a lot of harvest, driving simulator training as Figure 2.

Figure 2 Training driving simulator

The Ref[23] summarizes the domestic driving simulator development and research, as shown in Table 1.

Table 1 Driving simulator domestic development and research results

Year	Research results	Remarks
1970	Self-development point light source, rotary table electromechanical vehicle driving simulator	
1995	The MUL-QJM vehicle driving simulator can realize the automobile driving training, and can do scientific research	Academy of Armored Engineering Wu Yaowu, Pan Wuchao
1996	ADSL automobile development simulator with 17-DOF vehicle dynamics model	National key laboratory of automobile dynamic simulation, Jilin University
1999	Development of driving simulator of WM	Traffic comprehensive simulation laboratory, Kunming University of Science and Technology
	A design scheme of semi-active vehicle training simulator is proposed	Beijing Simulation Center, Yang Fangting
2000	The active 3D automobile driving simulator is developed, and the driving rule expert system is built by artificial intelligence technology and the intelligent objects control in the virtual scene is realized	Nanjing University, Ding Haojie
2004	A vehicle driving simulator based on distributed virtual reality technology integrated with virtual reality environment and network environment is built	Wuhan University of Technology, Chen Dingfang, Li Xunxiang
2005	Six-DOF training vehicle driving simulator, visual simulation software Creator and OpenGVS development visual scene system (as shown in Figure 3)	Jilin University
2006	A distributed multi-user vehicle driving visual system is established, and some technical problems, such as area segmentation and collision detection, are solved	Wuhan University of Technology, Yin Niandong, Chen Dingfang
	A virtual environment simulator based on virtual prototype technology and on-line interactive control mechanical dynamics system is built	Zhejiang University, Wang Zheng, Liu Zhenyu
2009	A driving simulation experiment platform consisting of the moving end module and the control terminal module was built	Tsinghua University
2010	Improving the model precision of the dynamic model of ADSL driving simulator	Jilin University, Zhan Jun, Guan Xin
2012	Design and implementation of the visual system of airport fire vehicle simulator	Civil Aviation University of China Wang Liwen, Li Hongshuai
	A hybrid electric vehicle simulator based on LabVIEW is developed	Jilin University, Wang Honglei
2013	The terrain rendering technology based on GPU is used to create a realistic visual appearance excavation pit and tilting hill model, which provides a virtual scene for the excavator simulator	Jilin University, Ji Nitao, Zhang Hongyan
2014	Tongji University cooperated with Beijing PREACH company to develop "dynamic traffic research system"	
2017	A hybrid reality holographic glasses case advanced driving assistant system (ADAS) simulator is passed at CES 2017	Auto parts[24]

Figure 3 Six degrees of freedom driving simulator of Jilin University

3 The current type of vehicle simulator, composition and working principle

3.1 Types of vehicle simulator

Vehicle simulator is also known as virtual driving simulator, after years of development, from technical research to practical application, vehicle driving simulator has undergone great changes and there are many types. According to its function, requirements and the wide range of applications nowadays, the vehicle driving simulator can be divided into scientific research (Figure 1) and training (Figure 3). In addition, according to the different visual systems, vehicle driving training simulator is divided into active and passive; its movement type can be divided into seat fixed, vehicle drum and seat movable. Scientific research driving simulator is generally a large set of experimental equipment, usually combined with unloading theory, electronic technology, hydraulic technology and other technologies, and a set of hardware and software design. Due to the large-scale technology collection of scientific research simulator, the development cycle is long and the development cost is expensive. But it is widely used in large-scale experiments: automotive safety experiments, road surface acquisition experiments, automotive component life research experiments, traffic rules and regulatory theoretical research, and play a very important role in the application. In contrast, the training-type driving simulator is closer to life and it can meet daily training, general experimentation and driving safety education[6,25-27].

3.2 Composition of vehicle simulator

For different types of driving simulator, the system composition is different, but the system basically has simulation software control part, hardware control system part and mechanical part. The software control part includes the computer real-time animation generation of the road environment, the automobile movement dynamic simulation, the sound simulation, the network control, the operation platform and so on. The hardware control system part generally includes the cockpit, the computer, the projector, the display screen, the movement hydraulic system and so on. The vehicle driving simulator is mainly composed of driving operation input system, vehicle dynamic model, motion simulation model, real-time operation model and some model library, as shown in Figure 4, the relationship between the components of the car driving simulator[1,5,28].

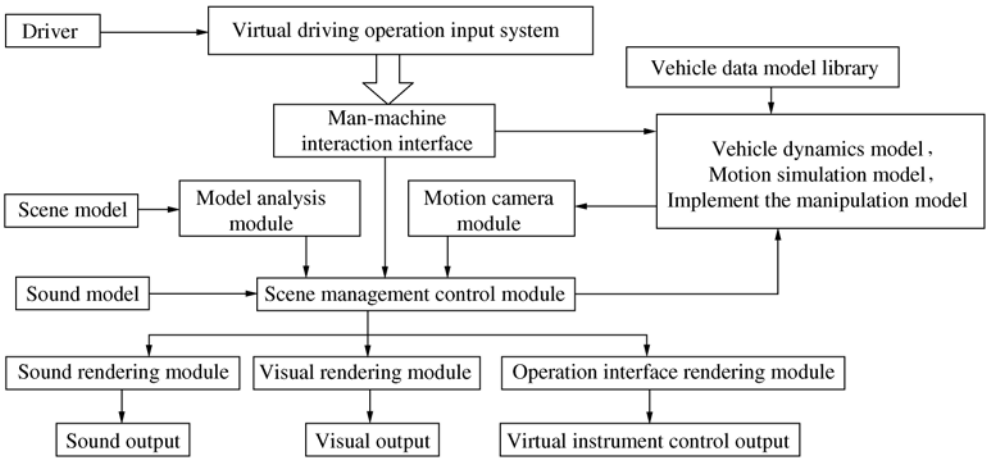

Figure 4 Relationship between the components of driving simulator

3.3 Working principle of vehicle simulator

Vehicle simulator is a useful tool to simulate driving of a vehicle, with the implementation of analog functions visual, auditory and tactile body. The composition of each part of the driving simulator analyzes its working principle, as shown in Figure 5.

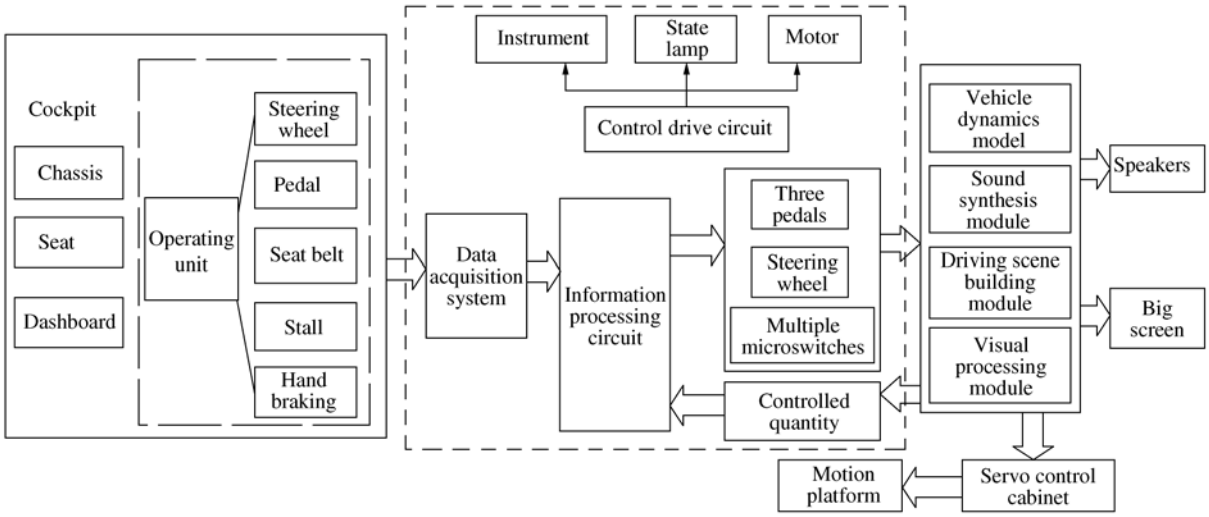

Figure 5 Working process of driving simulator

The control capacity of the cockpit control mechanism is collected by the data acquisition system, and then the collected information is transmitted to the signal conditioning and control circuit. Comprehensive experimental study, through the vehicle dynamics model characteristics of the collected data processing, and then selecting the communication protocol will process the data and send to it the master computer. The master computer calls the vehicle dynamics model and the last time motion state of the vehicle simulator. Through the research and calculation of the previous data, the host computer can get the current state of motion of the virtual vehicle in the three-dimensional scene. The vehicle motion parameters such as vehicle speed, engine speed and output torque are calculated by the collected acquisition signals. The motion state data obtained by the kinetic simulation operation is transmitted to the servo control cabinet, and finally the movement of the cockpit is driven by

controlling the motion platform motor. The master computer transmits the vehicle own data information and the virtual scene traffic information of the vehicle driving simulator to the information processing control circuit. By the control of the external control of the drive circuit, in order to achieve the status of the vehicle lights, meters, steering wheel motor control. While the emulation information displayed on the dashboard, simulate the various actions of the steering wheel. Call the visual processing module to generate real-time view, the visual scene is displayed in front of the driver's display screen, to achieve driving simulation of the scene. Call the sound synthesis module, the synthesis of the current driving scene of the movement of sound, through the speaker to play, to achieve the vehicle driving sound simulation[1,26-27,30].

4 Vehicle driving simulator application technology

With the advance of science and technology, the emergence and rapid development of virtual reality technology, virtual simulation technology based on virtual reality technology and the development of driving simulator system are used in the research of automobile transmission system to realize the vehicle driving in the virtual environment, constituting a person-car-road (environment) interaction. Based on the literature of virtual driving simulator system, this paper summarizes the key technologies of virtual driving simulator system, and analyzes the virtual driving system based on vehicle dynamics simulation, visual simulation system, driving simulation of the ABS control and ESP control.

4.1 Virtual driving system based on vehicle dynamics simulation

The virtual driving system of automobile dynamics simulation can carry out vehicle experiment test, program design and so on in virtual environment, and has more methods and techniques. The application of virtual reality technology involves computer graphics technology, computer simulation technology, artificial intelligence, sensor technology, display technology, network parallel processing technology, multi-view stereoscopic display technology. In the Ref[31], the key technology of virtual driving system based on multi-view stereoscopic display technology is studied deeply, including multi-view stereoscopic display technology, eye tracking technology and force feedback technology. By establishing the acceleration, deceleration and steering dynamic model in the vehicle driving process, and then using the Bullet physics engine in the driving simulator virtual environment to achieve the dynamic model, which reflects the effect of force feedback technology.

In order to make the vehicle dynamics model in accordance with the driver operation input, to meet the loop traffic system simulation research, the Ref[32] using object-oriented theory combined with the characteristics of the various subsystems of vehicles, with object-oriented modeling method, magic formula tire model and the vehicle dynamics system simulation program based on Microsoft Visual C++6.0 is used to build the vehicle dynamics model, and the model is applied to the driving simulator to carry on the road traffic safety simulation research. Ref[1] using single-chip microcomputer technology, data acquisition technology, sensor technology, modern communication technology, integrated circuit technology to manipulate the control device, single-chip control device, host computer control interface three modules based on the design and implementation to control the control device, single-chip control device, host computer control interface three modules based vehicle driving simulator control system, through the information processing will control the computer and control components, through the data acquisition technology collect data in real time, so that the functions of the various

subsystems of vehicles can be linked and controlled together through the technologies. In the Ref[28] Kunming University of Science and Technology Road Traffic Simulation Laboratory established advanced driving simulator for stationary traffic to carry out real-time data acquisition and processing and through the data acquisition and conversion system to reflect the object-oriented theory in the driving simulation of the feasibility of the application and by real simulation of the speed odometer and engine tachometer work conditions, highlight the driving simulator control system on the driving simulator for the study and improve driving realistic, in addition, to lay the foundation for driving simulator improvements. The database model and the database system established in the Ref[33] can optimize the overall structure of the driving simulator database by driving the simulator control system.

It is understood from the related literature[34] that the National Key Laboratory of Automotive Dynamic Simulation of Jilin University is based on the ASCL vehicle dynamics model for 'ASCL Solver' solver design and simulation in Simulink. There are 29 degrees of freedom vehicle dynamics model based on the development of a model parameter setting, simulation, analysis of the integrated environment. In conjunction with this model, the helmet-type display head tracking technique in the Ref[4] is used to establish the data helmet and man-machine interaction mode to better manipulate the movement of the vehicle in a virtual environment. And the Ref[35] developed a car driving simulation system of visual software through the game engine Unity 3D and three-dimensional modeling software 3ds Max, and used the Lab VIEW software simulate the object with the headset glasses Oculus Rift as a viewing device to achieve the head position tracking and 3D display, which is closer to reality than traditional method displays.

In addition, the other literature also uses Quest3D software to develop the virtual environment of automobile driving training simulator. It adopts human-computer interaction technology, collision detection technology, scene effect generation technology, detail level modeling technology and scene visualization modeling technology and other technologies. On the basis of virtual reality technology, two degrees of freedom, six degrees of freedom, 29 degrees of freedom and other degrees of freedom virtual driving system platform were set up.

4.2 Visual simulation system

4.2.1 Composition of visual simulation system

The visual simulation system is an important part of the car driving simulator. It mainly includes the motion simulation system and the visual system which is the use of computer, graphics, image processing, communication and other high-tech, according to driving scenes, virtual car sports posture and real-time traffic scene. The driver makes judgments to achieve the purpose of manipulation of the car through the traffic scene and it is based on the car dynamics with the graphics and animation to express the numerical simulation process or results. The visual simulation system realizes the real-time communication with other systems of the car driving simulator through the computer network, obtains the current running status of the vehicle and controls the execution status of the control system, and completes the execution state of the visual simulation system, thus forming a complete real-time simulation system.

Virtual vision system is a part of virtual reality system, whose essence is the observer felt the image, sound and other virtual elements. The four-dimensional visual structure is extended by the observer as the center, namely virtual window, virtual scene, virtual sound and virtual environment. The view of the visual system is shown in Figure 6.

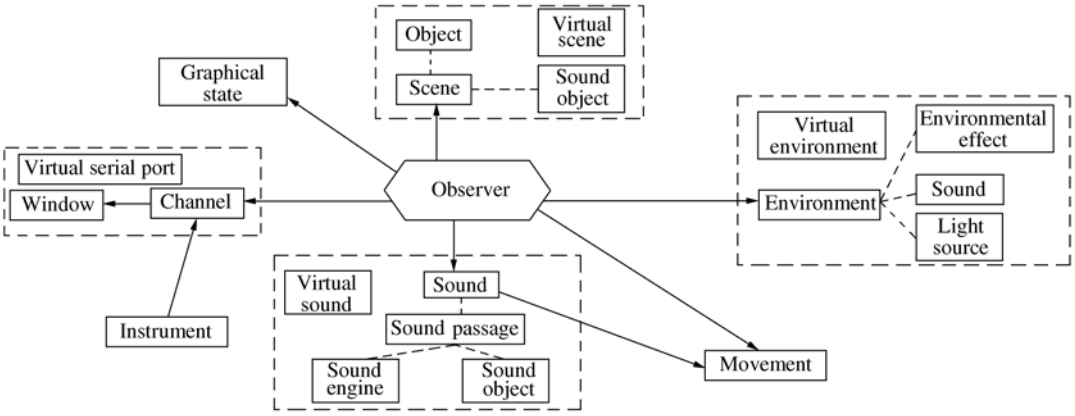

Figure 6 Schematic diagram of the visual simulation system

4.2.2 Application of visual simulation system

From the beginning of the 20th century, the development of the visual system has gone through quite a long time, visual simulation and comprehensive integration of multiple technologies, which includes computer imaging technology, image processing technology, audio technology, display technology, etc. In the development of visual simulation aspects of the system, it is based on the early low-level development way; now vision display systems use the film-type, box-type model, and computer-generated images of formula[36].

In the whole simulation process of the vehicle driving simulator, the visual simulation system needs to meet the following requirements: 1) The system-generated graphics screen has a certain performance and quality, which can accurately reflect the virtual factors in the driving process; 2) The speed of system operation is faster and there is no obvious delay phenomenon; 3) The virtual scene has a more realistic three-dimensional, when the driver in the simulation is driving a certain distance to the depth of field; 4) Visual system has a certain management functions with the use of the corresponding database to load or delete the model; 5) The system has a better expansion of the function, which can add a new visual function to meet different needs based on the original function.

In the Ref[8], the scene modeling software MultiGen-Creator and the visual-driven rendering software Vega Prime were selected for the visual simulation requirements. Three-dimensional scene modeling technology of vehicle driving simulator is mainly used to study terrain modeling technology, and the terrain generation method based on random midpoint displacement method and texture mapping based on texture mapping technology are proposed, and the modeling of landscape is optimized. Simulator real-time rendering focuses on the simulation of collision simulation and the establishment of appropriate models, through the relevant parameters of the particle system to control, so as to achieve better rendering results. Similarly, in the Ref[37], in order to achieve the virtual reality environment driving car simulation research interaction, immersed sense, the paper uses the visual system modeling technology, special effects technology, distributed multi-channel display technology, distribution customer and interactive technology, etc.

The basic principle based on the visual simulation technology: real-time calculation of traffic scene shows that the real-time interaction of objects in three-dimensional complex environment is controlled. In order to realize the real-time dynamic display of 3D model, meet the requirements of highly realistic the 3D scene and vehicle model and compare with a variety of 3D modeling software and simulation software, the literature[38] chooses visual simulation theory based on creator and OpenGVS software, with the application of virtual reality development software OpenGVS and OpenGL combined creator to develop real-time visual simulation system, the

scene simulation scene display management, to achieve interaction simulation, and then to achieve the development of the visual simulation system. In the Ref[25], the United States MultiGen-Paradigm Vega developed virtual reality, real-time visual simulation, sound simulation and other visualization applications software tool to combine commonly used software tools and advanced simulation capabilities. And it uses the Quest3 virtual reality technology to develop visual simulation system to achieve the "channel" as a unit of virtual reality application programming. The Ref[29] generates a variety of driving scenarios and combines with vehicle dynamics model to achieve realistic driving training, with the three-dimensional visual modeling software SCANeR II developed by the French OKTAL.

Through the analysis of the relevant literature, the driving simulator for information collection, development control system and visual simulation system make the driving simulator to achieve realistic, dynamic experimental results and according to the specific needs of selected modeling software, simulation software and integration use of more methods and technologies, so as to develop more practical value of the visual simulation system.

4.3 ABS control based on driving simulator

The anti-lock braking system, referred to as ABS (Anti-lock brake system), is one of the key components of the modern automobile brake system. It is used to prevent the wheel from being completely locked during the braking process, with improving the directional stability and steering ability, and shortening the braking distance of a safety device in the process. The main functions are the following three points: 1) To improve the braking process in the direction of vehicle driving stability; 2) To ensure that in the car brake process the driver can still control the steering wheel, so as to avoid obstacles; 3) Due to shortening braking distance depends on many factors, in order to ensure directional stability and control, pressure regulation is required. Thus, the loose layer when braking on gravel roads, ice and snow, the braking distance may be slightly increased[39].

Automotive ABS in addition to the poor environment of the car itself requires a strong anti-interference system and high reliability, but also requires a rapid control process. The control methods are commonly used in automobile control systems include frequency response, linear optimal control theory, sliding mode variable structure control, adaptive control, fuzzy control, neural network control and logic threshold control method[39-42].

The Ref[42] uses the automotive anti-lock brake system of a dual gate threshold control strategy, through the driving simulator program control simulation test and the driver in the ring ABS simulation test, to perform a comparative analysis program control and the influence of driver's simulation experiment on ring. Under the control of the driver, the driver can adjust the operation according to his own judgment; the data is more random, more in line with the actual situation, more suitable for detecting the control effect of ABS. In the Ref[42], the vehicle wheel acceleration and deceleration threshold control logic is used to control the ABS, and the ABS road test simulation is carried out by MATLAB/Simulink to simulate the brake condition of the ABS vehicle under different working conditions. Although the simulation of vehicle ABS is not exactly consistent with the experimental curve on the actual road surface, it is consistent with the trend of road test. In the Ref[43], the Burckhardt tire model was used to study the ABS road surface recognition algorithm and the simulation was performed on the driving simulator test bed. The Ref[44] proposed a slip control based on the fuzzy control method, the use of MATLAB fuzzy toolbox to establish a fuzzy control system and this method can control the slip rate stably in the ideal value, at the same time, simulate the vehicle braking process.

Through the comparative analysis of the literature and the actual experiment, the ABS program control simulation of the driving simulator and the simulation of the ABS in the ring are compared with the simulation or

experiment without ABS. The direction of the vehicle driving is stable in the braking process, and the steering wheel can still be controlled, but also shorten the braking distance. In the absence of ABS simulation and experiment, the brake prone to lock the situation, the vehicle is easy to run away, not according to the original vehicle driving trajectory, but also easy to lose the steering capacity and other dangerous situations. Simulation results on the driving simulator are particularly evident.

4.4 ESP control based on driving simulator

ESP (Automotive electronic stability program control system) is the abbreviation of electronic stability program, which actually includes anti-lock braking system (ABS), electronic brake force distribution (EBD) and traction control (TCS), and a new type of vehicle active safety control system is developed after anti-lock braking system, and traction control system, stablilizing the car driving conditions when the car is steering, braking, or sliding[45]. ESP applies the different brake wheel yoke torque on the vehicle to prevent the car out of control, so that the vehicle yaw angular speed response is responded by the driver's intention.

ESP has the following advantages: 1) Due to increased adhesion, improve the starting performance and acceleration performance, especially on different adhesion of the road, its advantages are more obvious as well as in the steering; 2) When the wheel slides, it will immediately eliminate the lateral control loss, so that the car has the best driving ability, thus effectively improve the dynamic security; 3) When the driver accelerates too much, it can automatically make the engine torque to adapt to the wheel on the ground transmission capacity; 4) Reduces the risk of slipping under various road conditions by automatic stabilization when braking, accelerating or falling at constant speed; 5) When the steering within the limits, it greatly improves the stability of the car. 6) Reduces the braking distance when turning or running on ice slippery road[39].

Based on the structural principle and control strategy of ESP, the paper analyzes the parameters related to vehicle stability, selects the yaw rate as the control variable, designs the feedback PID controller, and then carries on the simulation experiment, and loads the ESP system of the driving simulator in a variety of conditions of driving stability. It is concluded that the driver is more likely to control the vehicle's instability than the driving simulator without the ESP system and can feel the effect of ESP on the stability of the vehicle. In the Ref[47], a hardware-in-the-loop simulation system based on the electronic stability program of the driving simulator is constructed. The driving simulator is used to carry out the road test on a certain vehicle. Through the analysis of the input signal processing of the electronic stability program controller, the time and frequency domain of the experimental data are analyzed to obtain the variation range of the amplitude and frequency of the yaw rate, lateral acceleration, wheel speed and steering wheel angle. The hardware and software settings and programming of the input and output interfaces of the driving simulator, so that the driving simulator can output the input signal yaw rate, lateral acceleration, wheel speed and steering wheel angle required for the automotive electronic stabilization program control system. The Ref[48] uses the vehicle driving simulator technology and hardware in the loop simulation technology, establishes the automotive electronic stability system (ESP) hardware and the driver in the circuit simulation test stand and then uses the test bench to carry out the ESP implementation of hardware and drivers of the "car environment" closed-loop simulation.

Therefore, it is great significance to achieve ESP in the driving simulator on the simulation experiment, apply ESP in the real car, do the automotive test and make the automotive development and design and other fields. Figure 7. is the comparison of the results of the ESP vehicle running experiment. Through the summary analysis and the existing experiments we can see that a variety of ways are used to get better experimental results.

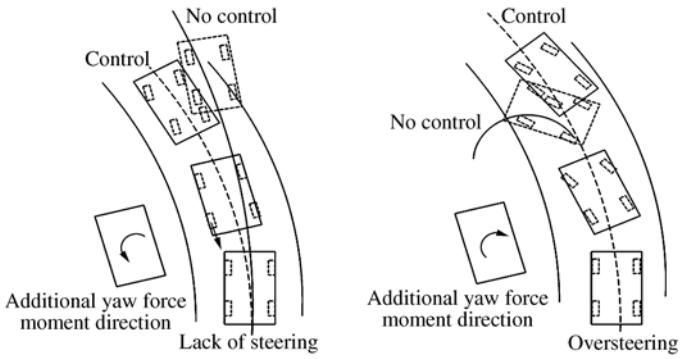

Figure 7 ESP vehicle operating state diagram comparison

5 Conclusions

With the development of virtual reality technology, the improvement of visual technology, the research and application of ABS control method and the application of ESP in driving simulator, the domestic training driving simulator and scientific research driving simulation have a certain scale, and developed related software systems and hardware systems, carried out a number of related experiments and simulation, for vehicle development and optimization, highway planning and design, university research and government monitoring to provide a convenient.

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