Chapter 46
Low-Cost Virtual Driving Simulator Design and Its Application

Xingquan Cai and Limei Sun

Abstract In this paper, we present one method to develop and design low-cost driving simulator, and this simulator can be used in pilot training, marketing strategy, entertainment, digital education, etc. Firstly, we explore the framework of the driving simulator. The driving simulator is divided into several modules, including loading models, visual simulation, scene interaction, collision detection and audio effects modules, etc. All these modules are designed particularly. Finally, we present the results and the results show that our method is feasible and valid. Our virtual driving simulator has been used in practical projects.

Keywords Driving simulation · Loading models · Scene interaction · Cylinder controlling

46.1 Introduction

Virtual driving simulator is a kind of equipment of raining-driving which is also a kind of equipment of interactive experience [1]. In China, there is one of the worst traffic conditions in the world. Nearly millions of people were dead because of the traffic accident every year, so it is necessary to train drivers all kinds of conditions. Virtual driving simulator can reproduce all kinds of complicated situation which leads drivers to complete all kinds of training. However, the actual cost is higher on training, and it is hard to reproduce complex conditions of road. Therefore, this

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article mainly research and design a low-cost Virtual Driving Simulator. This system can be used in marketing, entertainment, pilot training and drivers' test, etc.

This paper researches and designs a low-cost and propagable virtual driving simulator particularly. It can be applied to pilot training, drivers' test, marketing and entertainment, etc. The paper explains the framework of virtual driving simulator. And the system can be divided into loading, visual simulation, interaction, collision detection and audio effects module, and then all the modules are designed particularly. Finally the results and analyses of the experiment are presented.

46.2 Related Work

Recent data shows that the study of virtual driving simulator has been began earlier in the United States, Japan, Europe and other developed countries. As to driving simulator, in 2005, Zeng [2] designed a kind of passive low-cost driving simulator. This driving simulator could train new drivers effectively by simulating all different kinds of roads, weather and complicated traffic conditions, moreover, setting up dangerous conditions to train drivers how to deal with risky situations. In 2011, Han [3] designed the armored vehicles to simulate driving training system in 2011. This system was based on the movement rule of armored vehicles, making use of data glove with virtual operating bar to construct the virtual environment of armored vehicles. In 2012, Fu [4] designed and realized a 6-DOF platform virtual driving system. Those simulation systems have their own advantages, but they are not put into production.

There are several other simulators. In 2009, Ma [5] provided high-speed rail simulation system. In 2011, Hu [6] developed Simulation of Tower Crane, Zhang [7] designed tank driving and training simulation system, and Han [8] armored vehicles driving training system, provided.

Virtual Reality technology has been used in our life. So in this paper, we focus on study and design a kind of low-cost virtual driving simulator which can be popularized and can be used for training new drivers and marketing entertainment.

46.3 Design and Implementation of Virtual Driving Simulator

46.3.1 The Framework of Our System

Virtual driving simulation system includes hardware and software systems. Hardware system simulates real driving environment as far as possible, providing real interoperability. Software system drives hardware system, making virtual driving environment realistic strongly. In this paper the hardware system includes

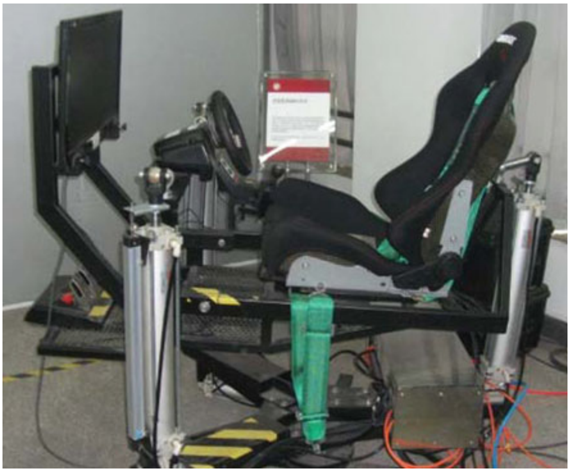

Fig. 46.1 Physical appearance of our driving simulator

the big screen, dashboard, the components, n-DOF platform, computer, etc. The big screen is responsible for displaying the photos of virtual driving and interaction. The dashboard is responsible for displaying the speed of virtual driving, distance of travel and the remaining oil content, etc. Components include accelerator, the steering wheel, the brake, etc. It is responsible for the control of turning and speed while virtual driving. The n-DOF platform includes four cylinders, and they are responsible for providing the feelings of acceleration, slowing down, turning, uphill, and downhill. Computer installs related software and control systems. It is responsible for the operation of the system. The appearance of simulation system shows in Fig. 46.1.

Software system includes underlying hardware driver and interactive applications. Underlying hardware driver is responsible for driving hardware system. Interactive applications shall be responsible for providing the interface of virtual driving system. The software system is divided into five modules when designing specifically, namely model loading, visual simulation, scene interaction, collision detection and audio effects module, as shown in Fig. 46.2. The man–machine interactive module is divided into four subsystems modules, namely the cylinder control, the steering wheel, the brake and accelerator interaction.

46.3.2 Models Loading

Virtual driving simulation system mainly construct virtual environment with strong sense, including driving roads, the surrounding terrain, the surrounding buildings, plants, traffic signs, etc. As a result, a lot of 3D models are needed. The qualities of 3D models affect the authenticity of the system directly, and then influence experience of the users.

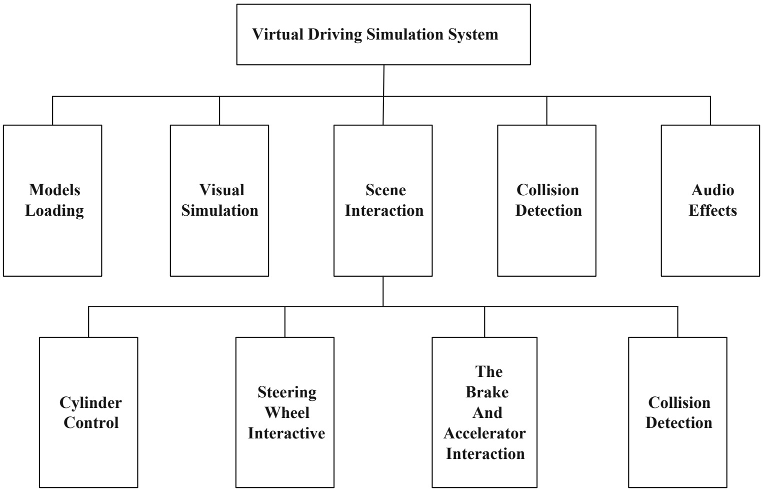

Fig. 46.2 Framework of our driving simulator system

From the properties of some 3D models, we can conclude that the more the geometric figures of triangle strips, the more fine and realistic the construction of models. Conversely, they are more rough, and false. But if the model of the geometry of the picture is more, loading models will spend more time relatively. This system is designed based on the level of detail control algorithm. On complex virtual scene, the visual important degree of objects is higher from the near viewpoint, the requirements to fine degree of model is higher. On the contrary, the visual important degree of objects is lower from the far viewpoint, the requirements to fine degree of model is lower. So it can not only to ensure the requirements of the authenticity of virtual scene that the user needs, but also can ensure the speed of computer rendering and processing.

46.3.3 Visual Simulation

The main purpose of visual simulation module is to provide users the image interface that can be watched. By looking output real-time image information at the screen, users can have personally feeling, realize the natural interaction directly between users and the environment. It mainly includes two aspects, the simulation environment making and simulation environment driving. Simulation environment making is to construct the virtual scene which is similar to the real environment, it mainly includes: model design, texture, special efficiency design, structural scene making, etc. By the production of these aspects, it can construct a three-dimensional scene with lifelike texture and special efficiency. The simulation drive is mainly to be able to mobilize the simulation environment that has been made, making the virtual objects in the scene can simulate real environment.

The simulation driving part mainly includes: model transfer processing, topographical condition processing, distributed interactive, scenario-driven, etc. If it completes these contents, it can represent a real environment, response interactive operation in time.

46.3.4 Scene Interaction

The part of scene interaction in the virtual driving simulation system is the hard core. When the user needs to “talk with” the computer, it must use the interactive module. The traditional interactive devices are mainly mouse, keyboard, etc. In order to generate realistic simulation of virtual driving environment, the system adopts the real car interactive equipment, such as the steering wheel, the brake and accelerator, etc. So it can simulate realistic environment preferably.

46.3.4.1 Cylinder Control

In order to generate the virtual environment, such as acceleration, slowing down, uphill, downhill, the system adopts n-DOF platform with four cylinders. So it can not only simulate forward and backward, uphill, downhill as the car in the real environment, these are tactile changes from normal operating, but also can rotate with more than a multi-angle and multi-directional, so that it can be used in collision of traffic accidents or deviation scene when turning rapidly, which has more real effect. The part of cylinder control can control the cylinder accelerated speed (that is the rate of the seat), the movement direction of the cylinder, the working state of each cylinder (that is which cylinders working together at the same time), and it can also control the movement of the parameters like the cylinder height. The Fig. 46.3 shows that. Through the real-time control to the cylinder, it can adjust the movement of seat in virtual car, and react all kinds of complicated situations in the process of the virtual driving in real-time.

46.3.4.2 Steering Wheel Interactive

In order to simulate the real situation, making the user immersed in the virtual driving better, the system is equipped with a special input device that is used in virtual driving—the steering wheel. It is the same with the steering wheel of a real car, turning the steering wheel can control the direction of virtual car, such as when the driver turns the steering wheel left, virtual car will move to left.

In the module of steering wheel interactive, by binding a control script to the virtual vehicle model to receive the returned information from the steering wheel, and make the corresponding response. The script defines sundry movement states

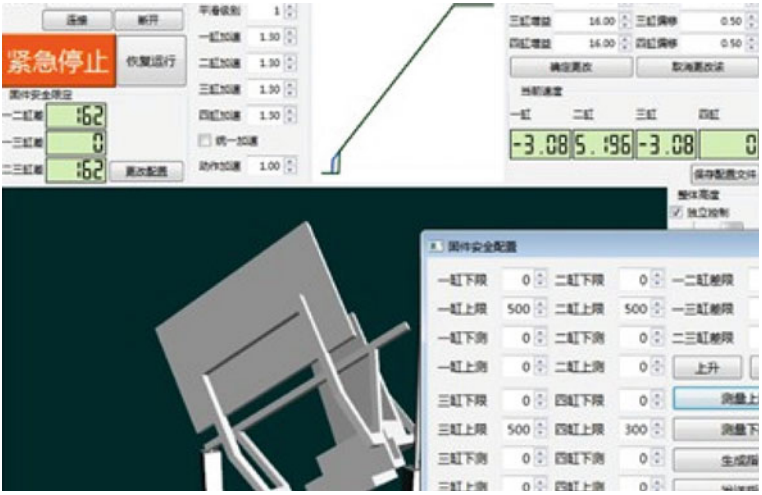

Fig. 46.3 Cylinder controlling system

of steering wheel. When the user turned the steering wheel, the control script will obtain the current state of the steering wheel, and then the state will be mapped to the virtual vehicle model. So it completed turning interaction.

46.3.4.3 The Brake and Accelerator Interaction

Under the seat of the virtual driving simulation system, there are brake, accelerator and clutch. On your right hand you also can see gear with an emergency brake button and forward, backward, left, right and direction control button, etc. So it can control cars in time to simulate real driving cockpit, making the user have authentic feeling, thereby realizing experience closed to real car driving. In addition, the system also constructed the emergency brake button. When meeting emergency situation we can press the button by hand, while pressing the button, the cylinder will stop moving, virtual car also stop and wait for a next command.

When the user hit the brake, the virtual car stopped moving. There is no difference in the true situation. The system controls program to let the virtual car stop moving by capturing brake signal.

46.3.5 Collision Detection

The collision between objects often happens when the user driving in the virtual driving simulation system, at this time in order to guarantee the authenticity of the environment, we need to detect the position of the collision which just happened in time and deal with it like in the real environment, or the phenomenon that objects through other collision object will happen, that will lose authenticity.

In this system, we use bounding box method. The method using different cubes surround different objects, then calculate whether the cubes have contact or through each other, if they have, we say that they have a collision. Though the intersection detection between the bounding box, we can find and get rid of those won't intersecting objects as early as possible. Then further detect the bounding box collisions to the overlap part. This can improve the speed of detecting the complex objects. When the object in a collision, we need to simulate real situation after collision happened. Such as when the car crashed into a virtual roadside guardrail, the car should slow down, according to the collision location to change direction and displacement, etc.

46.3.6 Audio Effects

In order to react out the actual traffic environment and improve the immersed sense of the system, this system has set up audio effects module. Audio effects module mainly used to simulate the voice in the process of driving cars and the scene special effects in the surrounding. It uses many kinds of realistic sound, including the sound of the engine when starting and driving the car, the sound of urgent brake and collision, the siren of cars and the sound of wind around the car, etc. When the user speeded up, the roar of the engine will enlarge along with the speed increases.

46.4 Research

In order to verify the design of the virtual driving simulation system is feasible and effective, we have implemented a verification system. The hardware environment of the verification system includes a big screen, a dashboard, the components, n-DOF platform, computer, etc. The software environment is Inter(R) Core(TM) i5 2.53 GHz CPU, 2 GB ram, ATI Mobility Radeon HD 5470 GRAPHICS CARDS, LCD screen, Windows7, Microsoft Visual Studio 2010, Unity3D, 3DMax.

This system has been fully realized, and has been tested and used. The appearance of the simulator like Fig. 46.1 shows. User can drive under a bridge normally, like it shows in Fig. 46.4a. User can turn the steering wheel to finish it, just as Fig. 46.4b shows. As Fig. 46.4c shows, user can put on the brakes to stop the car quickly in an emergency situation. When the user put on the brakes, the virtual car will produce the fiction between the car tires and the surface and two brake friction marks before stop moving like the real car. In addition, this system can also realize an angle switching in the virtual driving. Figure 46.4d shows the snowing scene in our system.

Fig. 46.4 Normal situation of a driving virtual car

46.5 Conclusions and Future Work

In this paper, we present one method to develop and design low-cost driving simulator, and this simulator can be used in pilot training, marketing strategy, entertainment, digital education, etc. Firstly, we explore the framework of the driving simulator. The driving simulator is divided into several modules, including loading models, visual simulation, scene interaction, collision detection and audio effects modules, etc. All these modules are designed particularly. Finally, we present the results and the results show that our method is feasible and valid. Our virtual driving simulator has been used in practical projects.

As to future work, our research is focus on improving interactive operability, adding driving score, etc.

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