The Development of the Virtual Testing System of the Self-Driving Cleaning Truck Based on Virtual Reality Technology

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Abstract. With the development of autonomous driving technology, it is possible self-driving cleaning truck being driving and working automatically. However, a lot of field trials are time-consuming and wasteful during the investigation of self-driving truck. In order to reduce lots of on-site and real vehicle tests, we construct a 3D virtual pilotless vehicle testing system for the cleaning truck based on virtual reality technology. 3DMax software is used to build virtual 3D scene static model and cleaning truck model. The established static models are imported into Unity3D to simulate different 3D scenes during cleaning truck self-driving. We designed a UI interface to build a virtual testing system of self-driving cleaning truck which is easy to realize human-computer interaction. we have achieved successfully the avoidance of obstacles and round-the-island driving. And we have successfully completed the identification of traffic lights and the pilotless driving test on crossroad virtual scene. In the virtual testing system, we can quickly experience the virtual testing scenes of the self-driving cleaning truck in various scenarios and get some kinematics information. The virtual testing system can partly replace the field tests and provide methods and theoretical guidance for field test, which can shorten the development cycle and save money, and is also unrestricted and repeatable. At the same time, the researching results provide new ideas and methods for the investigation of vehicle tests and pilotless driving.

1. Introduction
In recent years, with the development of unmanned technology, more and more researchers pay attentions to expand its applications [1]-[2]. It has been reported that unmanned technology is applied to cars, and The self-driving cleaning truck has been put into trial in Shanghai [3]. As everyone knows, lots of the driving environment should be simulated and tested before driverless vehicle working smoothly. However, a lot of field trials are time-consuming, wasteful and unrepeatable.

With the development of computer hardware and software, the virtual scene is getting more and more realistic. The realistic three-dimensional image quality, the amazing three-dimensional special effects, the extremely real physical collision and feedback, the delicate scene details and etc. can make the virtual environment similar to the real world. Using virtual reality technology, we can not only shorten the development cycle and save money, but also be free from environmental constraints and get repeatability
Last century, Virtual reality technology is applied to the design and manufacture of automobiles [6]. GM used the virtual reality technology to design and manufacture cars very early. Recently, virtual reality technology has a wide range of applications in the automotive industry. Ford uses virtual reality technology to simulate components assembly. Major automobile manufacturers in Germany, Sweden, Japan, and the United States have built virtual car driving simulators by using virtual reality technology. Some of them use virtual reality technology in vehicle motion simulation. The simulation results of vehicle motion in the form of stereo images and participants can interactively control the simulation process [7]. This makes it easier to analyse and understand vehicle motion simulation. IPG Automotive uses Drive PX and virtual reality technology for vehicle safety simulation. At present, scientists have found that all road conditions that the driverless vehicles may meet could be tested as much as possible in a virtual environment. Researchers have utilized virtual reality technology to develop many kinds of driving simulation and build virtual three-dimensional scenes, etc. [7] But it is a few reporters about the virtual experiment system of automobile road test [8]. Our group has completed the virtual experiment system of Stability test of automobile freeway and gotten nice result [9]-[10]. On this basis, we are going to develop the virtual driving experiment system of the self-driving cleaning truck.

In this paper, the virtual driving testing system of the self-driving cleaning truck has been developed. we used 3DMax software to build 3D models of scenes and car models. Then we import the established static model into Unity3D to create different 3D virtual scene during cleaning truck driving. We designed a UI interface to build a virtual testing system which is easy to realize human-computer interaction. We have achieved successfully the avoidance of obstacles and round-the-island driving. And we have successfully completed the identification of traffic lights and the pilotless driving test on crossroad virtual scene.

2. Virtual Environment Construction

2.1. Construction of the model of the cleaning truck
As everyone knows, it is difficult to create the 3D model of the cleaning truck because of its irregular and complex shape. We utilized polygon modelling to construct the cleaning truck in 3Dmax software. The cleaning truck modelling takes three steps, and the details are as follows: Firstly, according to features of the cleaning truck shape and the five views of cleaning truck (front view, rear view, top view, left view, right view), we can build a simple cleaning truck shape. On basis of the shape and the five views of the cleaning truck, the primary model of the body was created by the method of dividing, linking, and welding the polygon. The second step is to add horizontal and vertical lines to the primary model and use the commands of link, segmentation, extrusion, extrusion and so on to construct the door, window, anti-collision beam, lamp and other parts. Thirdly, we use the turbine smoothing command to refine the body, wheels, garbage bins, cleaning brushes, etc. and splice the processed parts to complete the modelling of the vehicle model, as shown in figure 1.

![The 3D model of the cleaning truck.](image)

**Figure 1.** The 3D model of the cleaning truck.

2.2. Virtual scene construction
In order to build complete virtual scenes, so many 3D virtual environment models should be prepared,
such as the building in the scene, roads, houses, traffic lights, guardrails, and street lights in the scene by 3D Max software and model trees with Unity 3D's built-in modelling tools [11]. After 3D virtual environment models are completed and built 3D virtual environment scene, the model of the cleaning truck should be added the texture and put into 3D virtual environment scenes to integrate different driving virtual scenes [12]. Seven different driving virtual scenes are established such as round-the-island driving scene, straight road driving scene, turning road driving scene, ramp driving scene, crossroads Scenes, obstacle avoidance driving scenes and community driving scenes [13]-[15]. Next, we will introduce the above 7 scenes in turn.

2.2.1 Round-the-island driving scene. The 3D models being imported into the unity3D software, we set up round-the-island driving scene as shown in figure 2.

![Figure 2. Round-the-island driving scene.](image)

The cleaning truck in the scene travels along the setting route. In the Hierarchy, the “path” is the path of the cleaning truck. It is shown as a green line in the figure. According to the scale of the scene, some parameters of the cleaning truck was set as following: The mass of the cleaning truck is set 1700. The maximum speed is 50km/h. The minimum engine RPM is 1000. The maximum engine RPM is 6000. The engine’s torque is 1250. The brake torque is 1750. The cleaning truck is front-wheel drive and has up to five gears. Due to the large angle at the corner of the road, a brake zone is set to reduce the speed before the right turn of the truck to ensure the cleaning truck making a normal turn, as shown the red area in figure 3.

![Figure 3. The Brake zone.](image)
We utilize the Navigation Mesh technology in unity3D to realize the automatic path finding of the vehicle to ensure that the cleaning truck can normally follow the route after the program starts [15]. Before the program starts, we should bake the road as shown in figure 4. The road was marked out by blue. This shows that the cleaning truck will automatically navigate on the blue area. After the program running, the cleaning truck automatically travels along to the path, and some kinematics information displays during the self-driving of the cleaning truck, as shown in figure 5. When the system is working, the distance from the truck could be changed with the change of the current angle of view. The result shows that the cleaning truck can self-drive in round-the-island driving virtual scene.

![Figure 4. Navigation Mesh.](image)

![Figure 5. Round-the-island driving scene.](image)

2.2.2 Straight road scene. The method and the technique of creating this straight road virtual scene are the same as those of the round-the-island driving virtual scene, which will not be described in details. Figure 6 shows the straight-line driving motion of the cleaning truck. a trigger could work automatically to stop the truck at the destination.
2.2.3 Turning road driving scene. Figure 7 shows the turning virtual scene of the cleaning vehicle. Here we have chosen the left turn of the cleaning truck. It automatically reduces the speed and turns when the truck turns, without slowing down at the bake zone [15].
2.2.4 Crossroad scene. Figure 8 shows the Crossroad virtual scene. In this scene we have combined traffic lights and the cleaning truck could identify traffic lights. Traffic lights are grouped in the same direction and are divided into two groups. We use the Coroutine program in C# language to control traffic lights. The duration of the green and red lights is 20s. The green light is on 17s and the flash time is 3s, and the yellow light is on 2s. We set a transparent cube at a distance from the signal light as a trigger for collision detection. If the signal light is red or yellow and the cleaning truck touches the trigger but has not touched the transparent cube, the transparent cube will be added. A cube collider stops the truck when it reaches the intersection. If the truck touches the transparent cube directly below the signal light and the traffic light turns green, the cube collider will not be added to ensure that the truck can run normally [15]. The result shows that we have successfully completed the identification of traffic lights and the pilotless driving test on crossroad virtual scene.

2.2.5 Ramp driving scene. Figure 9 shows the ramp driving virtual scene. This scene is divided into an uphill driving scene and a downhill driving scene. The left side is the uphill driving scene, and the right side is the downhill one. In the virtual environment, when the value of the Y-axis of the vehicle position changes greatly, it is determined that the truck is traveling uphill and downhill. When the value of the Y-axis increases very large, it means the truck is driving uphill. Then the engine torque is set to 2250. When the value of the Y-axis falls very large, it means the truck is driving downhill. Then the brake torque is set to 2750, the engine torque is set to 1750. Because of its own gravity, the pre-bake zone is set in front of the ramp to reduce the speed of the cleaning truck to avoid the truck rushing downhill. A bake zone is provided to ensure that the cleaning truck can slow down. Through the above method, we simulated successfully the test of the ramp driving scene of the cleaning truck.

2.2.6 Village Scene. Figure 10 shows the Village virtual scene. This scene is relatively simple with a few pedestrians and other vehicles. The cleaning truck around the community once a week.
2.2.7 Obstacle avoidance driving scene. Figure 11 shows the obstacle avoidance driving virtual scene. We demonstrate the obstacle avoidance process in the village scene. If it is put into other scenes, the method of obstacle avoidance is the same. The obstacle is a stationary car, which is set as navigation statics collision body. The Road was baked while the obstacles are not baked. Four rays from the direction of the current vehicle were projected by the method of Physics.Raycast. Then we assume the length of two front ray is half the length of the cleaning truck and one on each side of the cleaning truck is twice the width of the body of the cleaning truck. The cleaning truck and the obstacle are at the same layer. When the front rays touch an obstacle, the cleaning truck can actively avoid the obstacle. After avoiding obstacles, it can return to the original path. Other obstacles on the road can also be treated in such a way [16]-[17]. That is to say, we achieve successfully the avoidance of obstacles in the automatic driving process of the cleaning truck.

3. The virtual testing system of self-driving cleaning truck
After the various 3D virtual test scenes of the self-driving cleaning truck being completed, the virtual testing system of self-driving cleaning truck should be built. UI interface is as a platform for human-machine interaction of the virtual testing system. The UI system and animation system in Uity3D was use to design the interface [18]-[19].
Figure 12. The program running scene.

The performance of switching functions between interfaces is implemented by the Game-Object.SetActive() function in C language. There are 8 virtual scenes of tests in which the ramp scene was divided into uphill driving scenes and downhill driving scenes as shown in figure 12. The instant switch between different scenarios was achieved by the SceneManager.LoadScene() method in C#. The virtual testing system of self-driving cleaning truck was constructed by the combination of different virtual testing scenes of the self-driving cleaning truck and UI interfaces. In this system, we can quickly experience the virtual testing scenes of the self-driving cleaning truck in various scenarios and get some kinematics information. The results show that the virtual testing system can partly replace the field tests and provide methods and theoretical guidance for field test.

4. Conclusion
In this paper, a 3D virtual pilotless vehicle testing system for the cleaning truck based on virtual reality technology was prepared. In summary, the methods are as follows. Firstly, 3D virtual environment models and the cleaning truck were built, such as the building in the scene, roads, houses, traffic lights, guardrails, and street lights in the scene by 3D Max software and model trees with Unity 3D's built-in modelling tools. Secondly, seven different driving virtual testing scenes of the cleaning truck were established, such as round-the-island driving scene, straight road driving scene, corner driving scene, ramp driving scene, crossroads Scenes, obstacle avoidance driving scenes and community driving scenes. Thirdly, the virtual testing system of self-driving cleaning truck was built by UI interface, which is as a platform for human-machine interaction of the virtual testing system. The results show that we completed successfully different virtual tests of self-driving of the cleaning truck. Especially, it is innovative in the virtual tests of the obstacle avoidance and round-the-island driving. And we have successfully completed the identification of traffic lights and the pilotless driving test on crossroad virtual scene. In the virtual testing system, we can quickly experience the virtual testing scenes of the self-driving cleaning truck in various scenarios and get some kinematics information. The results show
that the virtual testing system can partly replace the field test and provide methods and theoretical
guidance for field tests, which can shorten the development cycle and save money, and is also
unrestricted and repeatable. At the same time, the researching results provide new ideas and methods
for the investigation of vehicle tests and pilotless driving.

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