Construction safety education system based on virtual reality

Feng Bin, Zhao Xi, Chen Yi, Wang Gui Ping

School of electronic and control engineering, Chang'an university, Xi'an, 710064, China
Email: 1229420572@qq.com

Abstract. In view of the shortage of traditional construction safety education in China, this paper introduces virtual reality technology into the field of safety education. The virtual reality construction safety training system designed allows multiple experiencers to be physically, visually and tactfully present at the same time. In the virtual scene of construction accident safety hazard, the experiencer completes the consciousness migration that corresponds the virtual scene to the real scene, thereby avoiding the safety accident in the real construction and maximizing the safety education effect. The overall architecture of this work includes the virtual reality system and the vibration system. The scene model in the virtual reality system is mainly 3D modeling with 3Dmax, and the Unity game engine is used for animation and interaction design. Because the system is mainly for traffic construction and construction units, the design scene mainly includes three major parts: bridge construction scene, road construction scene and tunnel construction scene. The vibrating system is designed to enhance the virtual experience. The system communicates with the host to acquire the corresponding vibration signal and drive six low-frequency vibrating horns, so that the experiencer have a strong sense of vibration.

1. Introduction

With the development of the times, China's traffic construction project has also arisen. The construction safety of traffic construction projects is related to the life of construction workers and the development of construction enterprises. It is an important part of traffic construction engineering construction. In the construction of traffic construction projects, it is very necessary for construction companies to take corresponding measures to prevent the occurrence of safety accidents.

Strengthening safety training and management is one of the most effective measures to effectively reduce safety accidents in construction projects. The traditional safety training mode is difficult to achieve the “immersive” state. In addition, the general education level of the construction workers is low and the safety awareness is poor. The actual training effect of this mode is not ideal. The rapid development of virtual technology has made it possible to diversify the form of training, which provides a lively learning environment for training activities and enables them to actively participate in learning activities.

In view of the problems existing in the construction safety education of this existing enterprise, we designed a virtual reality security education system and replaced the traditional physical security experience area with the virtual reality experience room. Compared with the traditional safety education and training methods, the floor space is occupied. Smaller, lower cost, more experienced, and able to experience accident scenarios that are difficult to simulate in reality, realize one-to-many experience, multiple experiencers can simultaneously conduct safety education, greatly improving the efficiency of safety education; The self-designed vibration table, the vibration table will emit vibration
in accordance with the picture in the corresponding scene, enhancing the sense of experience. This system greatly enriches the practicality and value of the security education platform.

2. System framework
The overall architecture of the system is divided into a virtual reality system (hereinafter referred to as VR system) and a shaking table system. The system structure is shown in figure 1.

![Virtual reality system composition](image)

**Figure 1. Virtual reality system composition**

The VR system can be used to simulate various scenes in the construction, allowing the experiencer to roam and interact in the scene. The part of the vibrating table allows the experiencer to experience more shock and reality in each scene.

The whole system is host-centric, and the virtual security education software runs on the host of the Windows operating system; the HDMI splitter, display and stream box are connected to the host. The industrial computer and the host transmit the audio signal through the TCP/IP protocol, and the transmitted signal drives the vibration of the vibration table through the audio distributor and the power amplifier.

3. The design of VR system
The VR system is used to simulate the scene of a construction accident, enabling the experiencer to observe the simulated construction environment through the VR helmet.

3.1 The hardware of VR system
The hardware of the system mainly includes a host, a distributor, a stream box, a helmet, a positioner and a handle. After the VR virtual experience software is created, you need to use the corresponding hardware facilities to experience each scene. Its hardware connection diagram is shown in figure 2.

![Hardware connection diagram](image)

**Figure 2. Hardware connection diagram of VR virtual experience system**
The host is used to run the VR virtual experience software. The HDMI port of the host is connected to the input end of the HDMI splitter; the USB port of the host computer is connected to the input end of the stream box, and the HDMI port of the stream box is connected to the HDMI splitter. Read the EDID port. The output of the HDMI splitter is connected to the input of the active extender. The HDMI line of the head-mounted display device is connected to the output of the active extender.

The system connection diagram is shown in figure 3.

The meanings of the symbols in the figure are as follows:
- PC: computer host;
- PDA: distributor;
- STBPWR: stream box power supply;
- STB: stream box;
- Active Extender: active extender;
- HM: Head-mounted display device

3.2 The software of VR system

3.2.1 Creation of real terrain

In order to enhance the immersion of the VR scene, we use first EI-shayalSmart, GoogleEarth, GlobalMapper and WorldMachine to create the real terrain of the construction site. The overall process is shown in figure 4.
First, we use EI-shayalSmart software to link GoogleEarth, intercept the satellite image in GoogleEarth through EI-shayalSmart, and fuse the required terrain satellite image together in EI-shayalSmart, as shown in figure 5. Secondly, according to GlobalMapper The DEMO data is downloaded from the latitude and longitude data, and then the downloaded DEMO data is imported into the GlobalMapper output elevation grid mode again, and the target terrain is determined again by using the latitude and longitude, and the length, width and altitude of the final terrain are measured, as shown in figure 6.

![Figure 5. EI-shayalSmart satellite imagery](image1)

![Figure 6. Final terrain parameter determination](image2)

3.2.2 Model creation

This system selects 3ds Max 2014 for the creation of character characters and the basic model of the scene. As shown in figure 7 and figure 8.

![Figure 7. Character model](image3)

![Figure 8. The scenario model](image4)

4. The design of vibration platform system

The main goal of the vibrating table system is to vibrate the table to make the experiencer immersive, thus enhancing the safety awareness of the experience. The vibrating table system can select the appropriate low-frequency sound source through the vibration signal transmitted from the VR system, and synchronous vibration occurs on the vibrating table, so that the experiencer can truly experience the strong shock of the accident, thereby enhancing the safety awareness of the experience. The experiencer can establish a solid security concept. The hardware part of the system includes industrial control machine, audio distributor, vibrating horn, etc. The software part mainly cooperates with the host to realize the vibration function of the vibration table.

4.1 The hardware design of vibration platform system

The connection method of the vibration table hardware is shown in figure 9.
The controller of the vibrating table section adopts a Mini industrial control machine, and an application program is installed in the industrial control machine, which is connected to a computer equipped with a safety education experience system through a network cable, and is connected to the audio distributor through an audio cable. The industrial control unit receives commands from the virtual experience system through the network cable. After parsing the command, the corresponding audio output signal is sent, and the audio signal is transmitted to the vibrating horn under the vibration table through the audio distributor.

4.2 The software design of vibration platform system

The industrial control unit in the shaker system is equipped with a self-developed application that accepts signals from the VR experience system via the TCP/IP protocol. The industrial control machine stores the vibration table audio signals that have been processed and can be imported, and decides whether to transmit the audio signals and transmit the audio signals to the audio distributor and the power amplifier according to the contents transmitted by the TCP/IP protocol. The flow chart of the shaker software is shown in figure 10.

![Software flow chart of vibration platform](image)

Figure 10. Software flow chart of vibration platform

5. Experimental verification

The VR system has three major categories, 17 related common accidents on the construction site, and the vibration table system is linked with it. When entering the system, touch the corresponding sphere with the handle to trigger the corresponding scene selection page. Trigger the trigger button of the handle to enter the corresponding scene for experience.

In this chapter, two scenarios are selected for testing, namely road fire escape and bridge fall. Figure 11 shows the escape simulation scene of the fire. Figure 12 shows the scene of the bridge falling from a high altitude.

![A simulated fire scene](image)

Figure 11. A simulated fire scene
According to the test, during the scene experience, the VR virtual education system and the shaking table system can work normally, and the test results are normal.

6. In conclusion
Traditional construction safety education cannot truly simulate the scene of an accident, and its education is not effective. The existing VR security education is not real, because it does not increase the sense of body, resulting in poor experience. And the existing experience can only drive a VR device, resulting in extremely low efficiency, greatly increasing human and material resources. In response to the above problems, the education experience system designed by the team offer multiple VR devices which can be operated by one host at the same time, which greatly improving the efficiency of training. The system combine the VR virtual experience with the vibration table to make the animation interaction more realistic and build an immersive experience.

With the continuous development of society, China's traffic construction project has also arisen. This system relies on virtual reality technology to enable science and technology to serve in the construction of traffic safety education and training. Its application scope is large, the market prospect is broad, and the design itself has obvious advantages. At the same time, it adds some forward-looking design to maintain competitiveness and save social costs. The market demand and development potential are huge.

References
[1] Cui Mingxiang. A review of the research on education and training of migrant workers since the reform and opening up [J]. Journal of Hebei Normal University. 2009(03): 93-96.
[2] Wang Yingming. Research on the operation mode of education and training of migrant workers [J]. Legal Society. 2009(14): 92-94.
[3] Hao Chenglin, Du Zhimin. Discussion on improving the quality of safety training with standardized training mode [J]. Building Safety. 2005,12(20):5-6.
[4] Guo Jianming. Exploring the improvement of the quality of migrant workers' safety training [J]. Career Time and Space. 2010: 20-21.
[5] Gao Lixin. Research on training methods of agricultural famous workers in the city [D]. Xi'an: Xi'an University of Architecture and Technology, 2011.
[6] Wang Chunlin. The application of modern information technology in the education and training of migrant workers [J]. Higher Agricultural Education. 2013 (10): 108-111.
[7] Wu Xuezheng. Application of VR (Virtual Reality) Technology in College Students' Safety Education [J]. Nanjing: Nanjing University of Posts and Telecommunications. 2016: 134-135.