Design of Equipment Virtual Reality Teaching System

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Abstract. Equipment teaching plays an extremely important role in post-oriented education. However, due to the limited number of actual equipment, the complexity of training environment construction, the limited training time for a single student, and the difficulty in effectively monitoring the practice process, it affects students' learning autonomy, the efficiency of equipment teaching and the effect of teaching to a certain extent. Correspondingly, utilizing virtual reality (VR) technology to design and develop an equipment teaching system, can quickly and easily build task conditions. Consequently, students can be fully trained in a realistic equipment simulation teaching environment. Meanwhile, it is also convenient for teachers to carry out targeted teaching through process monitoring. This paper studies VR teaching system design for vehicle-mounted emergency command equipment, including system requirement analysis, system design, and system testing. It is shown that the system has the characteristics of high scene fidelity, good human-computer interaction, and smooth operation, which can effectively support and improve the equipment teaching effect.

Keywords: equipment teaching · VR technology · teaching system

1 Introduction

Virtual reality (VR) technology was originally used mainly in the training of astronauts and pilots to reduce the risk of training safety. With the development of technology, the cost of VR software and hardware equipment has been greatly reduced. VR technology, which is in sustained and rapid development, has been widely used in the military, games, education, and other fields [1]. VR technology integrates multimedia, computer, simulation, artificial intelligence, and other information technologies. With the help of glasses, handles, gloves, and other auxiliary devices, it creates a visual and auditory experience and feedback similar to the real-world scene for users.

Applying VR technology to the field of education is an inevitable trend for technology to promote the reform of teaching. In this way, the traditional passive and boring learning model can be transformed into a new model for students to acquire knowledge

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and improve skills through their interaction with the virtual environment [2], which also provides ways for the reform of equipment wisdom teaching [3]. In recent years, VR technology has been widely used in equipment teaching [4–7]. Compared with actual equipment teaching, a teaching system based on VR technology has significant advantages in expanding the teaching scale, flexibly constructing the training environment, reducing safety risks, and realizing quantitative evaluation of training effects [8].

In the research of VR teaching system, S. Yan [2] designed and developed a computer hardware assembly simulation teaching system based on the Unity3D platform., which realized the teaching of three subjects: computer hardware cognition, hardware composing, and troubleshooting. Similarly, the hydraulic transmission throttling speed control loop teaching system designed by Y. Jin [9] for the hydraulic transmission course and the programmable logic controller (PLC) simulation teaching platform designed by H. Wang [10] for the PLC experimental teaching, are developed based on Unity3D as well. Considering that the Unity3D platform has good interactive functions, good cross-platform portability, and strong scalability of model resources, our equipment VR teaching system also uses the Unity3D platform for development.

In this paper, the design of a VR teaching system for vehicle-mounted emergency command equipment is studied. In the following sections, we first analyze the requirements of the equipment VR teaching system from the aspects of function and performance. Then, the teaching system is designed according to requirement analysis. Finally, functional testing and performance testing are performed.

2 System Requirement Analysis

According to the needs of equipment teaching, we analyze the system's functional requirements and operational performance requirements.

2.1 System Functional Requirements

This teaching system is mainly used for equipment practice teaching. In practice teaching, students need to use the system to understand basic principles, operating processes, and methods of the equipment. Therefore, the functional requirements mainly include:

Simulating a realistic practice environment, including the natural environment and various equipment. For vehicle-mounted emergency command equipment, its internal power supply, network, wired communication, wireless communication, video conferencing, and other main devices' three-dimensional (3D) model are simulated.

Providing certain theoretical tips, which is convenient for students to learn the equipment principle and operating process in the practice environment.

Simulating equipment operating and networking process. Since the equipment is mainly used to establish an emergency command network, its networking mode can be flexibly configured in various ways such as wired and wireless. Therefore, the system should not only provide single-device operation training, but also provide multi-device operation training and multi-person cooperation training functions.

Managing the teaching process. The system can realize management functions such as task release, training, assessment, and process monitoring.

Table 1. System performance requirements

Performance criterion	Description or value
Operation flow	Consistent with actual equipment
Interactivity	Friendly
Response time	<0.5 s
Scene running frame rate	>55 fps
CPU utilization	<50%
Memory occupancy	<50%

2.2 System Performance Requirements

The equipment VR teaching system runs in the classroom LAN environment. The hardware is mainly composed of a server, Gigabit switches, customer computers and VR external equipment (VR glasses, operation handles, locators). The system must have good interactivity and be consistent with the actual equipment operation. Besides, the running resource consumption must be reasonable, as shown in Table 1.

3 System Design and Development

In this section, the system's overall design and specified function module design are introduced due to the system requirement analysis.

3.1 The Overall Design

According to the current hardware conditions, the teaching system runs on the LAN environment for data interaction, which topology is shown in Fig. 1(a).

According to the system's functional requirements, it is necessary to meet the integrated process of theoretical learning, immersive training, and assessment. The core

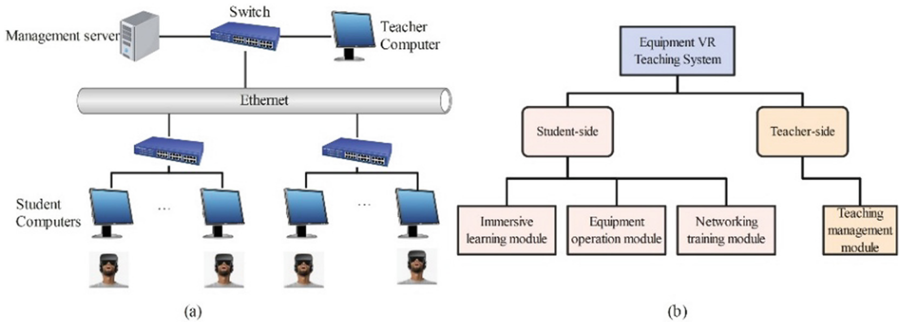


Fig. 1. System design. (a) System hardware topology. (b)System function module design.

functions of the system can be designed as four main modules: immersive learning, equipment operating, networking training, and teaching management, as shown in Fig. 1(b). The first three modules are mainly for students and the teaching management module is used by teachers to manage student information and the training process on the teacher's computer. Besides, the server is mainly used for system background services and log storage.

3.2 System Function Module Design

The immersive learning subsystem mainly realizes the 3D roaming of the scene by establishing 3D models of the scene and equipment. Meanwhile, students can realize the text display or visual/audio explanation of the device name, function, and technical performance by operating the handle to click. Its function modules consist of the 3D roaming module (including the three-dimensional scene, equipment cabinets, equipment external interfaces, and main devices), the system working principle introduction module, and the system operating demonstration module.

The equipment operating subsystem mainly realizes the simulation operation of each key, knob, and switch through interaction, and simulates the functional feedback consistent with the actual equipment operating effect. From the perspective of the module function, it is divided into content selection (including scene selection and device selection), interactive operation, information prompt, training playback, and data display function. From the perspective of the device type, it can be divided into operation modules of video conferencing devices, networking devices, power supply devices, wired communication devices, wireless communication devices, and other onboard devices.

The networking training subsystem realizes the configuration and comparison of equipment parameters through interaction and simulates the feedback consistent with the actual equipment network connection effect. Based on the equipment operating subsystem, the subsystem is divided into two modules: the single-person multi-device integrated networking training module and the multi-person collaborative networking training module.

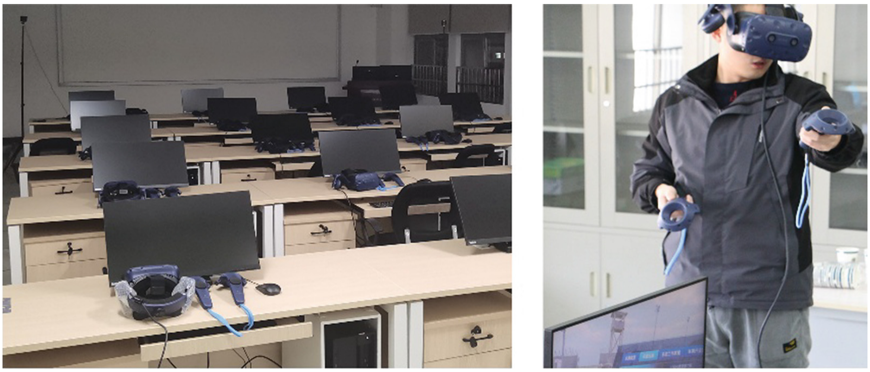
The teaching management subsystem is divided into training, assessment, and user management modules. After logging into the system and selecting subjects, students can conduct training and assessment of all immersive autonomous learning, onboard equipment operating, and networking training. During training or assessment, the teacher releases the training or assessment tasks. Then, students receive task information and begin operating, while the system synchronously records the operation of the students. After the training or assessment, it can be stored locally in the form of playback files for students to self-check and the teachers to retrieve and analyze. In assessment mode, the system no longer gives prompts like in training mode, and students should complete all the operations of the process within the specified time. After submitting their operating results, the system autonomously scores.

4 System Testing

To verify the feasibility of the equipment VR teaching system, the system's function and its running performance are tested. Client computers, which are the system's main hardware running environment, consist of an inter-core i7 processor with a 2.4 GHz dominant frequency, 16 GB RAM, NVIDIA GTX1080 graphics card, and 128 GB Solid State + 1 TB Mechanical (7200 RPM) hard disk. Meanwhile, HTC VIVE PRO2 glasses are selected as the corresponding interactive devices to form the immersive VR training environment, as illustrated in Fig. 2.

In terms of system performance, 100 times system response time and running frame rate are recorded randomly by a team of one teacher and two students using the system at the same time. The average values of system response time and running frame rate are 0.237 s and 58.6 fps respectively, which meet the design requirements. The Test results of CPU utilization and memory occupancy of the system changing along with the system's continuous running time are shown in Table 2. From the results, it can be seen that the system can meet the system performance requirements.

The system function test process and screenshots of some test results are demonstrated in Fig. 3. Taking the vehicle computer network configuration task as an example, after teachers and students log in, students can roam and learn in the realistic scene. Students receive training tasks from the teacher's computer and configure parameters in the virtual environment. During the whole training process, teachers can monitor all student progress through the system in real-time. The test results show that the existing



(a) (b)

Fig. 2. System testing. (a) Test Environment. (b) Test demonstration.

Table 2. CPU utilization and Memory occupancy rates

	5min	10min	30min	3h	Average rate
CPU utilization	40%	48%	43%	65%	49%
Memory occupancy	25%	38%	36%	49%	37%

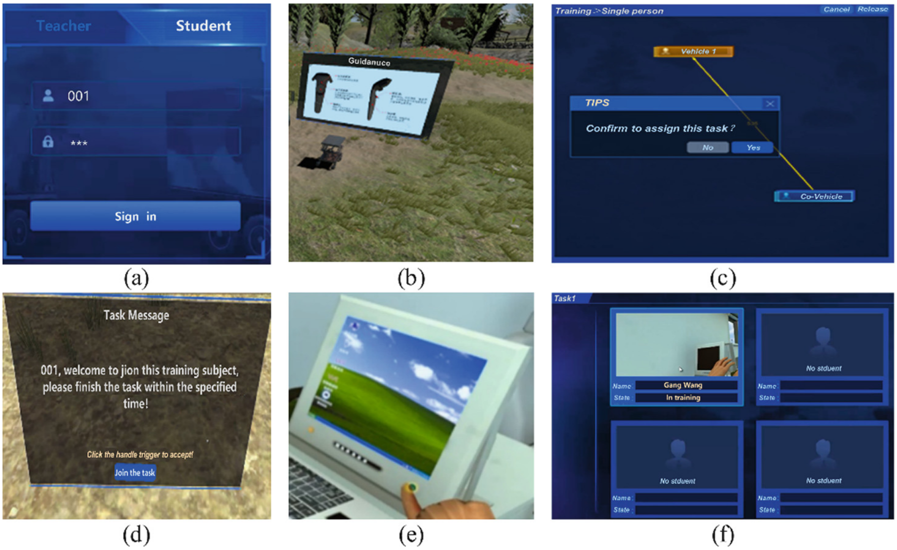


Fig. 3. Function test of the system. (a) System login. (b) Scene roaming. (c) Task releasing. (d) Task receiving. (e) Equipment operating. (f) Process monitoring.

equipment VR teaching system can provide a realistic immersive training environment, and the equipment configuration process is consistent with the actual equipment. The system has friendly operating interactivity and can satisfy the functional requirements of equipment teaching.

5 Conclusions

In this paper, aiming at the problems existing in actual equipment practice teaching, we study the design of the VR teaching system for practice teaching of emergency command equipment from three aspects: system requirement analysis, system overall and function module design, and system testing. The test results show that the system has the advantages of strong immersion and friendly interaction. By using this system in equipment teaching, it can change the traditional teaching modes, improve the efficiency of teaching organization, inspire students' interest in learning, and improve the efficiency of classroom teaching quality management. With the continuous development of VR technology, our future work will mainly focus on continuously improving and optimizing the system functions and performance, adding more device models, and selecting better interactive VR glove sensors. Through iterative improvement, the system could provide more realistic operating experiences to serve the equipment teaching.

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