Research on Simulation Training System of Immersive Substation Based on Virtual Reality

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Abstract: Virtual reality technology has been widely used by constructing a virtual space to simulate and restore the real world. The system uses 3ds MAX and Unity3D software to establish a 500kV substation virtual simulation system. The system completely establishes the 3D models of primary and secondary equipment of 500kV substations, and truly restores the overall layout of the substations. At the same time, the Unity3D engine, VR technology and interactive equipment are used at the same time to make this system able to provide trainees with an immersive training experience, which is more realistic than the application over the same period. The system completes the realization of substation training, station roaming and fault simulation functions, including substation equipment technical parameter display and synchronous voice introduction, interface design, basic operation, and fault phenomenon simulation; the infrastructure of the system is developed well and has strong expandability, which lays a foundation for subsequent function development. This system satisfies the substation training needs and can be used for related staff training of substations and to help students in electrical major to gain cognitive learning.

Keywords: immersive virtual reality, substation, simulation training, 3ds MAX modeling, fault simulation

1. Instruction
In recent years, with the continuous development of science and technology, computer technology advancement has been advancing by leaps and bounds. New technologies such as artificial intelligence, big data, and cloud computing are constantly being integrated into production and life. At the same time, virtual reality technology is also ushered in a new development climax.

Virtual reality is a scientific method and technology created by human beings in the process of exploring nature to understand nature, simulate nature, and better adapt and utilize nature [1]. Virtual reality technology has the characteristics of interactivity, immersion and imagination, and it can maximize the real world. Some scholars have made in-depth research on virtual reality technology in these fields because VR technology is used in various fields, such as military, medical, mining security, and rescue [2-8]. Apply this technology to power system simulation training will provide safety training tools for power industry related personnel, improve work efficiency and save costs. Compared with the traditional desktop training mode, the virtual substation system described in this paper increases the real experience of training, improves the interaction and operability of training, and can greatly improve the training effect.
The system adopts virtual reality technology to rely on the substation facilities in real production. And virtual space which avoids the limitation of routine training by external environment and time was built through modeling technology and rendering technology.

Compared with the previous research results: (1) Using 3ds MAX lightweight modeling method to study the 500kV substation modeling method, and creating 3D models including main transformer, high voltage power distribution device, reactive power compensation and other equipment; (2) With the updated Unity3D engine, it realizes functions such as device learning, station scene roaming and fault simulation training; (3) human-computer interaction with HTC-Vive device, and the immersion is stronger; (4) the system has clear picture quality. The underlying system is well developed and scalable, laying the foundation for subsequent functional development.

2. Overall Design

2.1. Selection of development tools

In the development process of this system, we adopts 3ds MAX software produced by Autodesk as the 3D modeling tool, which is flexible and convenient in solid modeling and animation to meet the modeling requirements of this system. Use the Unity3D engine as a feature development tool. Since its release, the software has quickly become the darling of people from all walks of life with its powerful features. In the system we use HTC-Vive as a virtual interactive device, which mainly includes a stream box, a positioning base station, a head mounted display and a pair of handle controller.

Among them, 3ds MAX and Unity3D engine have basically the same performance requirements for PC. The operating system requires Windows 7 SP1+ and above 64-bit operating system; GPU needs DX10 (shader model 4.0) function graphics card and 4G+ RAM. HTC Vive requires higher PC configuration. The GPU requires NVIDIA GeForce GTX970 and AMD Radeon R9 290 to be equal or higher. The CPU requires Intel i5-4590 equal or higher. This system develops a PC using Intel i7-7700HQ+NVIDIA GeForce GTX1060+8GRAM to meet development needs.

2.2. The design of system

At the beginning of the system design, the substation and training base of different voltage levels in Henan Province were investigated in the field. Finally, a 500kV substation in Henan Province was taken as the prototype, and the standardization design of the substation engineering of Henan Electric Power Company was adopted as the standard.

3ds MAX for physical model, the physical model of the system finally obtained. Then, through the Unity3D engine, the physical model is reprocessed and attributed, and the script is written in C# language to realize function development. Finally, the VR helmet and the handle of the HTC Vive device interact. The system development process is shown in figure 1.

Figure1. System development flow chart

The system is released in two modes, one is immersive and the other is desktop. The immersive training system brings the trainees into the virtual scene by VR equipment. Trainees can walk in the scene and be located by the VR helmet and the base station, and interacts with the human-machine through the handle. This training method can increase the sense of reality and ensure the quality of training.

Figure2. Substation rendering
The desktop training system is used by the instructor. And instructor can monitor and monitor the operation of the students through the microcomputer, so that the training function can be realized more conveniently and quickly. Both training modes can also be run separately.

3. Key technologies

3.1. 3D modeling technology
In the development process of this system, the basic work is to build 3D models of the substation equipment. In order to ensure the authenticity of the virtual scene, it is necessary to establish a model of all equipment in the substation with a 1:1 scale in the system, including the general level, power distribution room, main control building, outlet circuit, outlet tower and primary equipment such as busbar, isolating switch, circuit breakers, transformers and arresters.

Texture mapping is a key step in fleshing out the device model and the last important step in the modeling process. First of all, a large number of photos taken on site should be selected, and Photoshop software should be used to cut, perspective, transform and fill the photo. Then, the 3ds MAX - material editor - map to a bitmap, give material selection is fixed images. By adding different bitmaps to each material ball, a complete material library can be established. Then the corresponding model material added to make it achieve the desired real effect. The effect diagram of substation is shown in figure 2.

3.2. Unity3D rendering technology
After the modeling is completed in 3ds MAX software, it needs to be rendered and added with functions. This work needs to be done in the Unity engine. First, the model output from the previous modeling software is in the. FBX format file. Then, it was imported into Unity3D for later development to realize model optimization and function improvement.

In Unity3D engine, the following functions are mainly used.
(1) Scene Optimization. The Skybox resource package of Unity3D engine can be made to simulate the real environment, which can effectively enhance the immersion effect. In addition, when the FBX file is imported into Unity3D, the system defaults to a parallel Light, which allows the visual effects of a full set of scenes by adding a scene Light. Adding collision bodies to the model imported by 3ds MAX can avoid the phenomenon such as passing through the wall and effectively improve the sense of immersion. In addition, Unity3D particle system is mainly applied to the fault simulation of substation. The parameters of particle system are set to simulate the smoke effect, flame effect and the arc effect generated by misoperation with power.
(2) GUI Functions. In the training system, the main menu design is completed by the GUI in Unity3D. This function is very convenient and fast in the UI making process. For example, the login interface is to create canvas through GUI as the carrier of the login interface, and then add controls such as button, text, panel and input field to build the entire login interface. Then call functions through C# script to add functions for the control to realize user registration, information storage and user login functions.
(3) Animation Control. In the training system, the animation controller is used for editing and controlling animation. In the animation control component, animation behavior state is set through the Animator Controller, and animation development is completed in combination with C# script.

4. Function introduction
After the function was improved in Unity3D, the system mainly realized the following functions through man-machine interaction: basic learning, roaming, fault simulation.

4.1. Basic learning
4.1.1. Equipment learning. To master the function and structure of substation equipment is a basic skill that every substation worker must have. Therefore, in this system, the equipment learning function is
developed. This system added the speech introduction of equipment function information through the sound system of Unity3D engine, and explained the equipment in an all-round way with text introduction. When the operator roamed in the virtual scene, he could interact with the device through the HTC handle and send out rays by clicking the trigger key of the handle. When the detection ray collided with the device model, the information of the device was displayed. Including: (1) the current scene; (2) current device name; (3) function of equipment parameters. The introduction of circuit breaker is shown in figure 3.

Figure 3. Circuit breaker

4.1.2. Basic operations. For the substation staff, in addition to keep in mind the basic information of substation equipment, but also should be familiar with the basic substation operation process. In the normal operation of the substation, the common basic operations are equipment maintenance, standby switching, line shutdown and bus switching operation and so on.

Take the outgoing circuit maintenance as an example, the circuit breaker and two side disconnecting switches shall be disconnected successively during the equipment maintenance. The opening and closing of the circuit breaker is controlled by microcomputer in the main control building, while the corresponding isolation switch and grounding switch need to be operated manually in the site. When performing this operation drill, the trainer firstly brings up the menu through the VR handle and selects the circuit breaker device to be operated on the menu interface. After the selection, the trainer will be automatically transmitted to the isolation switch device to be operated. In order to judge the correct operation process of training personnel, this system lists out the correct operation process through the GUI interface design function. When trainees complete each correct operation, they check the corresponding steps before. The trainee uses the handle to emit rays to the operating object and controls the animation execution through ray collision detection. In the desktop system, due to the high position of the action arm of the device model, it is not convenient to observe, so a small window is activated when the animation is activated to display the animation action, and the small window is closed at the end of the animation.

Compared with the static model in the equipment learning, the equipment models in the basic operation module are all dynamic models. Model animation is mainly produced by keyframe in 3ds MAX and realized by controlling program in Unity3D engine. First, import the animation completed by 3ds MAX into unity and capture a valid fragment. Then, create an animation Controller in the Project interface. In the Animator view, add a Bool type to each animation to control the animation action state. Finally, the control code is written in C# to realize the complete animation control flow. Simpler animations, such as door opening and closing animation of operating mechanism, can be achieved through Rotate Around function in the Unity3D engine.
4.2. Roaming
In order to facilitate the staff to understand the substation structure from the overall situation and be familiar with the daily patrol exercise, the system has developed the roaming patrol function. According to the different roaming modes, roaming patrol functions can be divided into two modes: automatic roaming and independent roaming.

Automatic roaming is to add the camera to the patrol robot model and realize the purpose of patrol substation by controlling the movement of the patrol robot. The robot's moving path and speed are controlled by program. In the C# script control program, call the DOPPath function of the Tweening plug-in to set the roaming path and specify the roaming route. Patrol robot can automatically patrol according to the established route. Automatic roaming tour is shown in figure 4.

Autonomous roaming refers to the virtual scene that will be automatically entered into the system development after the trainer puts on the VR helmet. The trainer can drive the VR helmet displacement to realize roaming in the scene through autonomous walking. The VR controller is then used to interact with the device model.

4.3. Fault simulation
Substation equipment due to the weather, equipment aging, personnel error operation and other reasons, will be inevitable failure phenomenon. Therefore, timely detection and correct handling of problems is to ensure the safety of power supply to avoid economic losses is an important method. Substation common faults mainly includes transformer oil leakage, temperature anomaly, insulating bushing flashover discharge oil level, oil color is unusual, the breaker points, sulfur hexafluoride gas pressure is reduced, isolating switch from points from the same period, not in place or not, capacitor abnormal voice, local overheating, post insulator porcelain insulator rupture, the main insulation breakdown, etc.

In this system, fault simulation is mainly divided into two categories, static fault simulation and dynamic fault simulation. Static fault, mainly including insulator crack, operation box door is not locked, equipment nameplate off, etc. Such fault handling is mainly realized through the RotateAround function of C# control program. Dynamic fault simulation, mainly through the particle system in Unity3D to simulate the phenomenon of device overheating, smoke or fire. For example, when simulating the phenomenon of reactor overload and smoke, create a Particle System object named Smoke from GameObject Particle System command in the menu bar of Unity3D. Then adjust the parameters of Duration, Looping, Prewarm, Start Delay, Start Lifetime, Start Speed and Start Color to perfect the smoke effect.

5. Conclusion
(1) This system based on virtual reality technology, using the Unity3D engine combined with 3ds MAX software, complete the creation method and process of transformer substation, and with HTC Vive as the hardware platform, to realize the function of part of human-computer interaction, VR technology to simulate the real scene, substation training for trainees with immersive experience, improve the training effect.
(2) The system can not only improve the effect of safety training, but also reduce the training time, equipment investment, travel costs and other conditions, and has important application significance in reducing the training cost. The system is classified according to the typical equipment type, not limited to a certain substation, has a wide range of application, has a wide range of application prospects.
(3) Unity3D engine and 3ds MAX software are simple to operate and have strong compatibility. HTC Vive has moderate price, low development cost, easy entry and suitable for students to develop and improve.
(4) The fault simulation module mainly targets at transformer, circuit breaker, mutual inductor and other parts of primary equipment at present. It can conduct further field investigation, collect more fault types and treatment methods, and enrich the training content of the system.
(5) The functional development of the system is mainly focused on the primary part of the substation,
which can further determine whether the fault is caused by real-time parameters such as voltage and current, and participate in the accident drill.

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