Application Analysis of 3D Digital Technology in Power Grid Training

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***Abstract*—With the improvement of computer technology, 3D virtualization technology whose application can achieve a comprehensive sensory simulation to simulate realistic environment has penetrated into various industry fields, and for the development and application of various electrical equipment in power industry equipment information construction, professional technical training and operation are required. Moreover, It is known that using 3D visual virtual reality to realize the training environment can improve the technical level and operational specifications of professionals. Based on the three-dimensional visual virtual reality technology applied in the maintenance and evaluation environment of substation whip and circuit breaker, multi-role interaction technology combined with virtual scene is realized in this paper, which improves the training accuracy and reduces the possibility of operational errors.**

Keywords-3D Digitization; Grid Training; Technical Application

I. INTRODUCTION

Nowadays, two-dimensional visualization technology is widely used in non-physical maintenance training of power systems. Due to the variety of power equipment and complex equipment structure, two-dimensional image lacks three-dimensionality, which leads to the gap between students' understanding and actual situation on equipment structure[1].

The digitization of equipment information model is the key to realizing three-dimensional simulation, which can reflect the information changes of real equipment to the equipment model in the virtual environment. What' s more, virtual environment simulation mainly realizes sensory cognition such as vision, auditory sense, which is similar to that in real environment under virtual scene, and image information is combined with the characters and devices in the virtual scene through transmission, recognition, transformation and processing[2].

Models and algorithms used in 3D visualization technology are analyzed in this paper, and substation panoramic simulation that is based on substation equipment maintenance and training system (hereinafter referred to as "system") where the three-dimensional simulation of the state evaluation and maintenance process of transformers and circuit breakers are achieved and supporting 3D evaluation module is included as well is developed, which can enhance apprentices' ability to accept the training content and reduce the error rate of the apprentices in actual environment so that apprentices will have a more intuitive understanding and obtain better learning results.

II. SYSTEM ARCHITECTURE

A. VRML-based Virtual Reality Visualization System

Based on Windows operating system, development environment is built, and with the help of multi-tasking processing, network communication management and support for graphical development tools in Windows Server 2010, 3DStudioMax is selected as a modeling tool. Besides it, virtual reality modeling language is adopted to establish the connection between virtual models and real entities. The structure of virtual reality visualization system based on VRML is shown in Figure 1[3-4].

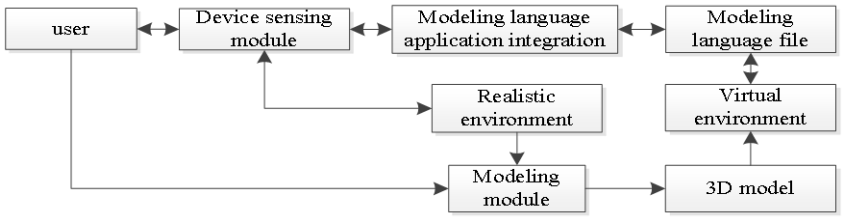

Figure 1. VRML-based Virtual Reality Visualization System

B. Hierarchical Virtual Scene Model

According to the structural characteristics of the substation, hierarchical modeling method is used in this paper to decompose a complex scene into multiple sub-scenes, each of which is composed of basic three-dimensional entities. What's more, 3DStu-dioMax is first used to establish basic 3D solid model such as 3D model with basic components of device, and 3db format file is generated, which is converted into a 3D data file of the virtual model by a format conversion tool, including points, faces, normal vectors, and relative position matrices among models. In 3D space, the most important step is to select the appropriate interpolation algorithm to transform the data of the 3D solid foundation component into the model data in the 3D spatial virtual scene. For example, four vertices have been defined on the plane shown in Figure 2, and v1, v2, v3 and v4 are the four data corresponding to the three-dimensional physical components of the four vertices, where a suitable interpolation algorithm is needed to calculate the fixed point p on the plane twhich corresponds to component model in virtual reality system[5-6].

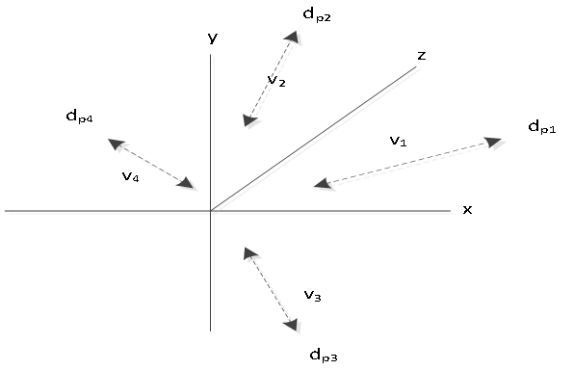

Figure 2. Example of Spatial Interpolation Algorithm

The task of the spatial interpolation algorithm is to calculate the position vp of the point p. The common calculation method is the square inverse ratio algorithm of distance. The formula is as follows.

$$v_p = \frac{\sum_{i=1}^{n} \frac{v_i}{d_{pi}^2}}{\sum_{i=1}^{n} \frac{1}{d_{pi}^2}} \quad (1)$$

In formula (1) n is the number of known data points, and dpi refers to the distance from the data point i (i = 1, 2, ..., N) to p.

The virtual reality model data file corresponding to the 3D solid component data is calculated according to interpolation algorithm. Then 3D data is recombined with the help of Unity3D graphics processing function to create a 3D frame model and obtain realistic 3D image through illumination and texture mapping. Finally, super-connected Anchor node and the inline node are adopted to combine the sub-scene to generate the required simulation scene.

C. Control of Interaction Behavior

Events are treated as the trigger mechanism of state or action, and VRML and C# are adopted as development language of human-computer interaction in this paper. In VRML, a node that consists of a domain and an event which includes an eventin (EventIn) and an eventout (EventOut) and provides the node with the ability to accept external messages and send messages to the outside world is a basic unit that constitutes a virtual scene, and the value of the domain determines the value of the node so that the current state of the virtual state is determined. In addition, events can dynamically change the state of the virtual state. Since most of the nodes in the VRML technical specification have special data specifications, they are difficult to expand. However, the script node has an independent uniform resource location field (url), which can be mixed with other languages to realize the interaction between the VRML space and the external information source[7].

C# can realize the interaction among VRML node objects and the ability to process messages, and specific C# class will generate a series of actions when the corresponding Script node accepts the event. Meanwhile, it can modify the domain value of the node to realize human-computer interaction and complete the operation of moving, opening, closing, disassembling, etc. In virtual scene, when a sensor node generates an initial event (InitialEvent), the event will be propagated from the event logic output (EventOut) to event logic inputs (EventIn) of other node along the route defined by the route keyword. Meanwhile, other nodes may receive, generate, and execute other events until the end of all events, which is shown in Figure 3.

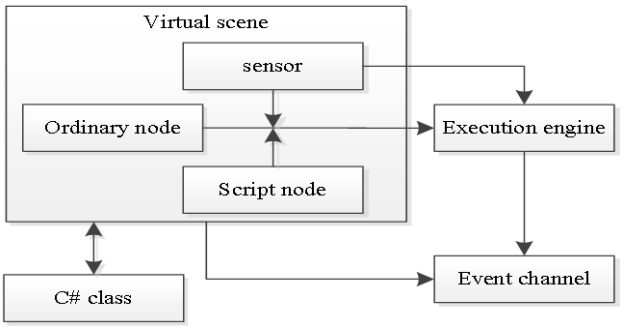

Figure 3. C# and VRML Combined Diagram

III. RECONSTRUCTION OF REAL SCENE MODEL

A. 3D Modeling Requirements

The 3D modeling of the switchgear for substation training is required to meet the function such as equipment cognition, structural analysis, secondary loop identification, mechanical action and so on. Taking the secondary circuit as an example, the direction of the cable and the individual arrangement of the terminal block are exactly the same as the scene in real-life model so that through the training of the

real-life model, the maintenance personnel can not only be familiar with the common features of the switchgear, but also the personality characteristics of the specific switchgear. Based on the accurate 3D point cloud data, the reconstruction of 3D model in switch cabinet is implemented in this paper according to the following process[8-10].

1) Characteristic analysis and structure division of the switchgear are performed.

2) In 3D modeling software, complete components and structural models of the switchgear are constructed based on the point cloud.

3) Model splicing is performed to obtain a three-dimensional black and white model of switchgear.

4) The texture color collected in the scene is assigned to three-dimensional model to realize three-dimensional real-time visualization of switchgear model.

5) According to the first and second equipment schematic of the switchgear as well as the layout drawing of the terminal block and other related drawings, the model is named to realize the complete coding of the components.

6) Based on the training needs, the components are stratified and grouped reasonably.

B. Model Release and Application Strategy

The three-dimensional model constructed by the above process has plenty of functions. For example, it can be rotated and disassembled arbitrarily, and it can be observed at 360 degrees without dead angle. In addition, it can be displayed hierarchically. In addition, the realized 3D real-life model also has six features such as complete components, real-life restoration, rich details, accurate model coding, multi-format publishing, and multi-terminal support. In order to provide convenience for training personnel, the model can be released both in professional 3D format and the most popular PDF format, and it supports various platforms such as computers, smart phones, and tablets.

IV. SYSTEM FUNCTION INTRODUCTION

Based on the three-dimensional visualization technology, the internal structure and operation principle of the equipment, the state maintenance process of the substation equipment, the status evaluation guide of the substation equipment, the typical fault handling of the substation equipment, and the theoretical assessment are used to develop the simulation training function under the virtual scene in this paper.

A. Equipment Internal Structure and Principle Simulation

According to the actual structure of substation equipment, a three-dimensional simulation model of equipment is established, and the actual operation of the equipment is simulated through dynamic interactive language so that the apprentices can intuitively understand the internal structure and operation principle of the equipment. Taking the circuit breaker operating structure as an example, three-dimensional simulations of the main components such as the energy storage motor and the spring are performed to reproduce the internal structure of the circuit breaker. What's more, apprentices can clearly see the composition and working principle of the circuit breaker transmission mechanism through simulating the opening and closing operation of circuit breaker. When the opening and closing operation fails, apprentices analyze and judge malfunction according to the abnormal situation of the site to determine the cause of the fault and select the treatment measures. The three-dimensional simulation diagram of the circuit breaker operating mechanism is shown in Fig. 4.

Figure 4. 3D Simulation Diagram of the Circuit Breaker Operating Mechanism

B. Virtual Scene Roaming

The system refers to the real substation and builds a 220kV three-dimensional analog substation, which covers different types of equipment in line spacing, bus spacing, and main transformer interval. Moreover, in combination with the substation equipment model, the model is associated with the actual configuration, technical parameters, and functional location relationships of the device, and the device information can be viewed in real time under virtual scenario. Therefore, apprentices can roam in the virtual scene from the perspective of the first person, and get familiar with the electrical equipment and connection principle of substation from different angles.

C. Maintenance Procedures Training

According to the maintenance rules of transformers and circuit breakers, the equipment maintenance process in the virtual scene and the maintenance operation under each process (including the bushing of the transformer and circuit breaker, the appearance inspection of the fuel tank, the appearance of the fuel tank, etc.) are constructed. Maintenance training includes two modes teaching and practice. In teaching mode, instructor performs various maintenance operations on the basis of maintenance process in the virtual scene, and according to system prompt, controls the virtual character is controled to reach the specified position in the process, and the correct maintenance tool is selected, and corresponding maintenance operation is performed as well. Moreover, in practice mode, apprentices control the avatar without system prompt and related operations are performed in the maintenance procedure.

D. State Evaluation Guide Training

The guideline for state evaluation of substation equipment is the main basis for achieving state maintenance where various aspects such as equipment operation, test and online monitoring are involved. Through status evaluation, health status of the equipment is objectively evaluated, which is the basis for maintenance. In order to allow the trainees to fully grasp the guidelines for the evaluation of the status in substation equipment, the system transforms the state evaluation guide training for transformers and circuit breakers from traditional two-dimensional picture to three-dimensional scene where the deduction item is associated with the actual part in the equipment to realize the visualization of the deduction item and unification between theory and object. In addition, through the simulation of deduction points, the status of the device is dynamically displayed, and the understanding of the device status evaluation guidelines is deepened.

E. Multi-role Interaction Fault Simulation

When socket-based multi-role communication server is processed, it needs apprentices to open the training system through a web browser, and register the local virtual client to the server, then the plurality of registered apprentices can collaborate in the same virtual scenario through the server. Besides it, based on the experience of Guangxi power grid equipment fault handling, a typical fault is selecyed as a case in the system where multi-role operation scenario such as fault handling on breaker SF6 with gas pressure shortage and transformer fire. Therefore, participants who participate in the training can understand the troubleshooting process more clearly through multi-person collaboration, and apprentices' ability to solve problems on the spot and coordinate with each other in the actual work can be improved through learning the experience of past troubleshooting.

F. Training Assessment

During the three-dimensional virtual assessment in system, apprentices enter equipment maintenance or status evaluation guide to train the virtual scene through the virtual client, and test questions created by the web browser can be invoked according to the process steps. What's more, answers and submissions can be completed in the virtual scene. After the assessment is completed, the assessment results can be viewed in the virtual scene. Instructors can start, suspend, and stop the training and assessment process through task management. Besides it, training and assessment process of a certain apprentice can be allowed or suspended, and the operation process of the apprentices can be recorded and reproduced, which is convenient for instructors and apprentices to judge and study on their own. When it comes to assessment in 3D virtual scene, apprentices can enter the process that needs to be evaluated through the virtual client, and each step in the virtual scenario will invoke the test questions created by the Web browser, so after completing the test questions for each step, apprentices can submit the test paper.

V. Application Effect Analysis

In order to apply the entire training assessment system into actual grid so that state evaluation and maintenance training can be assited, No. 1 main transformer casing is selected as maintenance assessment project by management personnel during the apprentices training. After setting up the assessment project and the assessment time in system, the designated student A will conduct the whole process assessment (including the actual operation and the theoretical examination). When formal assessment begins, apprentices A is first required to patrol the entire substation after entering the substation, and follow the prompts to reach the No. 1 main transformer within the specified time. Then, according to the existing state and evaluation guidelines of the equipment, the equipment evaluation of the main transformer is carried out, and it will be found that the casing has accumulated dirt and slight oil leakage. Finally, based on the evaluation results, it will be decided to carry out maintenance of casing leakage oil. In addition, another apprentice logs into the server and enters the system, and according to the rules, one person monitors one person to wipe the casing. After the actual operation, the theoretical test is carried out, and system administrator issues the test questions according to apprentices's grades and assessment content. Then, apprentices conduct the online test. After the test is over, the system automatically scores and judges whether it is qualified.

VI. Conclusion

3D modeling technology is used to establish the virtual scene of the substation equipment maintenance in this paper, and dynamic simulation of the equipment status is realized by the data driven model. Meanwhile, VRML is used to realize the virtual interaction between personnel and equipment, and build a virtual environment for equipment maintenance operations for the participants in the training. Combining the multi-role interaction technology in the virtual scene, the collaboration among instructors and apprentices is realized, where practical operation ability, teamwork spirit and participation enthusiasm of apprentices are greatly improved.

Combined with virtual reality technology such as 3D panoramic camera rapid modeling and somatosensory technology, 3D visualization training method can not only reduce the material and labor costs required for training, but also enhance practical skills. In the future, 3D visualization will be applied to more occasions in power systems, such as equipment test simulation, line disaster warning simulation, power equipment life assessment simulation, and power engineering construction simulation.

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