Research on Practical Training Teaching Reform of Nuclear Accident Emergency Response Course Based on Immersive VR Technology

Guo Ming, Xu Zijian, Wang Mohan, and Li Biao

***Abstract*—Aiming at the problems of backward teaching methods and poor effects of nuclear accident emergency practical training, on the basis of combing and analyzing the current situation and problems of nuclear accident emergency practical training teaching, this paper studies the technical difficulties and solutions of immersive VR technology applied to nuclear accident emergency practical training teaching, and researches and explores how immersive VR technology can be integrated into the reform of nuclear accident emergency practical training teaching.**

***Index Terms*—Immersive VR technology, nuclear accident emergency, teaching reform.**

I. Introduction

With the continuous development of computer simulation and virtual reality technology and related hardware matures, immersive VR technology has been developing rapidly, and gradually into the practical phase, and in the military simulation, engineering design, marketing, commercial, cultural entertainment, education, teaching, medical and other fields have a good application [1]. In the practical training teaching of accident emergency, immersive VR technology has gained widespread attention because it can effectively reduce the teaching cost and safety accidents, create a realistic training environment for students, and better overcome the pain points of practical training teaching of accident emergency. In order to solve the problems of high-cost consumption, insecurity and poor expandability in the airport field emergency drill, Weijun Pan et al. developed a virtual drill platform for airport emergency rescue based on VR technology [2]. By setting virtual drill scenes and storing typical plan information, the drill personnel could complete human-computer interaction through the virtual scene and realize the emergency virtual disposal in the airport firefighting process. The drill platform can help emergency personnel find problems in time and quickly improve their ability to deal with emergencies, thus significantly improving the effectiveness of airport emergency drills. Based on Unity3D, Huang Shengjin developed a three-dimensional virtual simulation practical training system for chemical accident emergency rescue [3]. The system can well re-present the emergency rescue work of various chemical accidents, which is convenient for the practical training of fire personnel. Hao Tengfei et al. developed an emergency drill system [4] based on three-dimensional simulation of virtual reality, which can simulate the whole information of power equipment in more detail and be applied in the emergency drill of power grid to greatly improve the level of emergency drill of power grid. In addition, Central South University [5], [6], Jilin University [7], Fujian Special Equipment Inspection and Research Institute [8] and other units have all developed virtual teaching and training platforms for safety accident emergency disposal, and all achieved good effect.

At present, immersive virtual reality technology has been able to achieve the degree of "three-dimensional visualization, real-time feedback, communication and interaction, and immersive experience" [9], and its virtual reality simulation function has been able to meet the basic requirements of on-site nuclear accident emergency disposal teaching and training. Firstly, this paper analyzes and sorts out the problems and causes of the practical teaching of nuclear accident emergency management course. Then, the technical problems that may be encountered in the application of immersive VR technology in nuclear accident emergency training and teaching are analyzed, and the possible solutions are given. Finally, how to integrate immersive VR technology into the practical training teaching reform of nuclear accident emergency is analyzed and studied.

II. Analysis of Current Situation and Problems of Nuclear Accident Emergency Training Teaching

The main purpose of nuclear accident emergency training teaching is to cultivate student's nuclear accident emergency disposal and command, the corresponding practice teaching includes three modules. The first is the emergency equipment operation training module, which mainly trains the operation ability of individual emergency equipment. The second is the multi-person coordinated comprehensive drill module for the whole process of on-site emergency disposal, which is designed for typical accidents. The main training is the multi-person coordinated on-site emergency disposal capability of nuclear accidents. The third module is the preparation and deduction module of the emergency disposal plan of nuclear weapon accident, which mainly trains the emergency command ability at the scene of nuclear accident.

At present, the training of practical teaching and training

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mainly focuses on the operation of individual equipment, and the training of multi-person cooperative ability remains in the traditional way of "paper face process and oral password". The methods and means are single, and the teaching effect is general. There are mainly the following four problems.

A. Due to the Lack of Perceptual Knowledge of Nuclear Accidents, It Is Difficult for Students to Impart Nuclear Emergency Knowledge

Nuclear accidents generally occur inside nuclear facilities, and the emergency response to nuclear accidents is closely related to the nuclear facilities themselves. Generally speaking, it is difficult for students to have access to nuclear facilities before they go to work. Their limited understanding is usually through text or video, and they lack the most direct perceptual understanding of nuclear facilities, which objectively increases the difficulty for teachers to explain relevant knowledge of nuclear accident emergency and for students to understand relevant knowledge.

B. Emergency Equipment Costs a Lot and Cannot Be Updated in Time

The operational capability of individual emergency equipment is the basis of on-site emergency handling of nuclear accidents. At present, practical training and teaching mainly rely on the limited types of practical equipment. Some emergency equipment is too special, expensive and large, and the practical training rooms of universities are rarely equipped. At the same time, limited by funds and space, the number of emergency equipment is very limited. When the number of students is large, individual emergency equipment operation training can only be organized and implemented by dividing the students into several groups. Moreover, the training equipment is easy to cause equipment wear and failure because of long time continuous work. At the same time, due to the large investment of actual equipment, it is difficult to realize the replacement of emergency equipment, resulting in obsolete emergency equipment, late update, high maintenance cost and other disadvantages, which directly affect the development of practical training teaching.

C. Distortion of Teaching and Training Scenes and Poor Teaching Effect

Teaching and training scenes can be composed of physical scenes and accident scenes. At present, the physical scenes used in the practical training of nuclear emergency response are mainly in the training room, which is greatly different from the real nuclear facilities. The distortion of the physical scenes in the training reduces students' sense of substitution and participation in the whole skill training significantly, and the teaching and training effect is obviously poor.

Another important aspect of the teaching and training scene is the accident scene. Because nuclear radiation is harmful to human body and difficult to control, it is usually difficult to physically reproduce and physically simulate the scene of nuclear accident. Therefore, in the process of practical training teaching and training, accident scenes generally require students to make assumptions in their thinking. Due to the lack of radiation sources for nuclear accidents, most of the operation training of emergency equipment can only be carried out in accordance with the operating procedures, while the measurement values displayed by the equipment can not reflect the hypothetical accident environment. In addition, since nuclear radiation accidents are generally invisible and cannot be touched, but have obvious harm to human body, the real nuclear accident site emergency personnel will have obvious psychological changes, so psychological training is also an important part of nuclear accident emergency training. The distortion of the accident scene will dilute this psychological change, making the whole training distorted and unable to achieve the established training goal.

D. Traditional Nuclear Accident Emergency Teaching and Training Methods Are not Flexible, Limited by Time and Space, and Difficult to Organize

Emergency response to a nuclear accident at a nuclear facility is a multi-person, coordinated and comprehensive task based on the emergency response capability of a single person. It involves a variety of roles, including on-site command, equipment disposal, radiation monitoring, and pollution suppression. The equipment involved includes damaged nuclear equipment, containment materials, personal protective equipment, radiation monitoring equipment, contamination suppression and removal equipment, as well as some online emergency monitoring equipment at nuclear facilities. As for the training of personal practical operation skills, due to the limitation of the quantity and type of practical equipment, students have relatively limited opportunities for real operation in the limited time of practical teaching, and the operation training after class is also difficult to meet. Moreover, due to the limitation of practical teaching conditions in general universities, it is difficult for some large equipment to carry out practical operation teaching and training. At the same time, the whole process of emergency comprehensive drill requires the participation of many people at the same time, if one or several students are not skilled and need to repeat the training, all the students participating in the training should cooperate with them to conduct the training. In addition, in the preparation and deduction training of nuclear emergency preparedness plans, teachers mainly provide paper maps of typical nuclear facilities for group deduction. Generally, nuclear facilities cover a large area, so it is difficult to achieve clear display even if only partial printing is carried out on conventional paper. Moreover, all student-held deductions are directly marked on the paper map. It is difficult to make clean marks, which is also very bad for the final deduction and summary and revision of the plan.

III. Key Technologies of Immersive VR Applied in Nuclear Accident Emergency Training Teaching

Generally speaking, the development of an immersive VR training teaching system mainly includes the scenario model building, the character roaming and real equipment operation simulation of three basic steps. Firstly, the construction of the scene model is mainly to create a virtual training environment for the virtual practical training. The training environment should be consistent with the actual scene as much as possible, which is conducive to the creation of the sense of

reality and immersion. Then, the realization of character roaming enables the virtual characters controlled by students to move in the virtual scene. Finally, the simulation of real equipment operation is based on the structure and working principle of the actual equipment, through observing and analyzing the operation state of the physical equipment in the actual working environment, and then writing the corresponding control script to control the equipment, which is the key point of virtual practical training. In addition, in the practical training teaching and training system of nuclear accident emergency response, due to the particularity of nuclear accident and the particularity of nuclear accident emergency response to students' ability requirements, the application of immersive VR technology in the practical training teaching of nuclear accident emergency response will encounter more technical problems.

A. Real-Scene Modeling of Complex Large-Scale Scenes

Nuclear facility modeling belongs to large area, real complex scene modeling. According to the traditional modeling methods, not only the modeling speed is slow, but also the location of facilities in various positions is not accurate, which affects the accuracy of nuclear facility model. In order to solve this problem, a scene modeling method based on 3D laser scanning is adopted to solve the problem of complex large-area real scene modeling. 3D laser scanning technology, also known as real scene reproduction technology, is a technical revolution in surveying and mapping field after GPS technology. It breaks through the traditional single point measurement method and has the unique advantages of high efficiency and high precision. 3D laser scanning technology can provide 3D point cloud data of scanning object surface, so it can be used to obtain high precision and high-resolution digital terrain model. The general steps are as follows: survey area inspection, site layout, equipment installation, parameter settings, 3D scene scanning, and point cloud processing, so as to realize 3D data collection of all rooms, channels, installed equipment and facilities of the entire nuclear facility, as shown in Fig. 1.

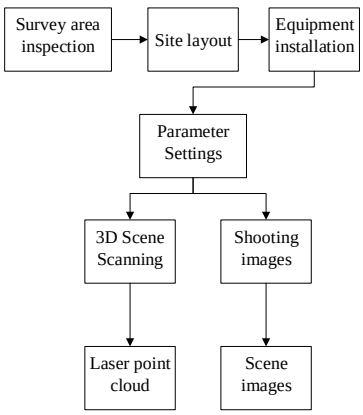


Fig. 1. 3D data acquisition process.

The main purpose of survey area inspection is to understand the terrain and pattern of the area to be mapped, and to have an overall understanding of the area to be mapped.

The main task of site layout is to select a suitable location as the scanning site for mapping based on the survey area Inspection. There should be some common area overlap between adjacent scanning sites. So when choosing a scanning site, you should make sure that the two sites can be viewed. In order to ensure the density of the laser point cloud, the distance between the two adjacent scanning stations should be less than 25m. To ensure data integrity within the scenario room, four or more sites should be set up in each room.

The equipment to be installed includes a laser scanner, tripod, laptop, power supply, tape measure, reflector, etc. It is important to note that the installation of the laser scanner should be horizontal and centered, and the reflective film should be posted in the public area of the adjacent site.

Before carrying out 3D scene scanning, parameters such as horizontal resolution, vertical resolution, horizontal starting angle of scanning, vertical starting angle of scanning and scanning frequency should be set according to the actual situation.

After 3D data collection, the initial point cloud data is formed. Some preprocessing procedures for point cloud data, such as denoising and outfield culling, should be performed before the data is used by 3D modeling software.

After the point cloud data preprocessing, the point cloud data can be processed by 3D modeling software, such as 3DMAX and Maya, and finally the accurate 3D data is formed. The modeling objects mainly include the infrastructure, equipment and equipment in nuclear facilities. The real size of the model is based on the point cloud, and the material of the model is based on the image data bit. On this basis, a realistic 3D position model can be restored as far as possible.

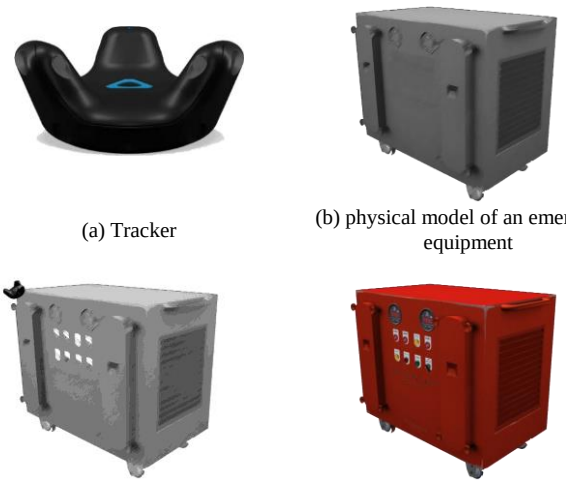
B. Virtual Mapping of Emergency Equipment

During the virtual operation training of emergency equipment, students immersed themselves in the virtual scene consistent with the actual scene with the help of VR data headset, and completed the interaction with the emergency equipment in the virtual scene by manipulating the 3D handle. VR data headsets immerse people's vision in the virtual scene. However, the operation of using a handle to replace human hands only completes relevant functions in the virtual scene, and people cannot receive feedback from the senses. For example, in the virtual scene, we press a button on the emergency equipment, but in the physical world, we just use the handle to make a hand movement in the air without actually pressing the button, which will reduce the reality of the virtual operation training to a certain extent. Of course, using force feedback data gloves can solve this problem, but force feedback gloves with good performance are usually very expensive and not suitable for large-scale use in school training rooms.

To solve this problem, the emergency equipment model and VR Tracker (as shown in Fig. 2 (a)) can be adopted to map the appearance model of the emergency equipment in the real world to the virtual world, and the application of the emergency equipment can be reflected by computer. An emergency equipment is taken as an example to illustrate its basic steps as follows:

1) Establish the solid model of the emergency equipment by 3D printing or other methods (as shown in Fig. 2 (b)).

2) Fix the VR Tracker on the solid model (shown in Fig. 2 (c)).
3) Through registration, accurate mapping between the entity model of the configuration Tracker and the three-dimensional model in the virtual scene (as shown in Fig. 2 (d)) is realized.



(a) Tracker

(b) physical model of an emergency equipment

(c) physical model of an emergency device with VR Tracker configured

(d) emergency device is mapped in the virtual world

Fig. 2. Virtual mapping diagram of emergency equipment.

C. Estimation of Virtual Instrument Readings

In practical equipment operation training, because of the difficulty in using radiation sources, most of the operation of emergency equipment is carried out under atmospheric background conditions, and the reading of equipment can only reflect the normal environment in reality. On the other hand, in the process of nuclear accident emergency management, emergency workers need to wear personal dose, whose reading also needs to reflect the accident scene. Therefore, these technical issues should be considered in order to improve the authenticity of virtual teaching and training in virtual scenarios.

These problems can be simulated by numerical method. Firstly, the three-dimensional gamma radiation field, neutron radiation field and radioactive aerosol concentration field in nuclear facilities are calculated. Then, the internal three-dimensional dynamic radiation field of the accident site of nuclear facilities is obtained by integrating the three factors. Finally, based on the discrete mesh three-dimensional radiation field, the readings of the radiation monitoring virtual device and the readings of the personal dosimeter are obtained respectively by interpolation and inversion methods.

D. Computer-Aided Training of Virtual Characters

Virtual emergency response teaching and training in the whole process need to be completed by multiple people, and different roles have different difficulties in nuclear emergency response tasks. For a role with a complex character, it may require repeated practice in practice and the participation of all other role students. This requires a lot of manpower, and for some roles with simple tasks, their participation excitement will be greatly reduced with the increase of training times, which will affect the effect of joint training throughout the whole process of nuclear emergency response.

A rule-based method can be used to generate the virtual role of auxiliary training to participate in the whole process of collaborative training. Firstly, according to the emergency plan and possible behaviors, the behavior library and behavior rule library of co-training assistant virtual characters are designed. On this basis, in the process of system operation, combined with the division of tasks of the virtual role, the computer-aided virtual role will automatically search and match the behaviors in the behavior database according to the status and instructions of the virtual role controlled by the real person, and drive the computer-aided virtual role accordingly, so as to achieve the function of multi-person cooperation exercise in the whole process with the real person.

IV. Integration of Immersive VR Technology in the Reform of Nuclear Accident Emergency Training Teaching

The integration of immersive VR technology can effectively change the current situation of nuclear accident emergency training teaching, improve the authenticity of practical training, reduce the cost of practical training, and improve the effect of practical training. Therefore, attention should be paid to the introduction of this technology and the construction and application of virtual simulation system of nuclear accident emergency training should be vigorously promoted in the teaching reform of nuclear accident emergency training.

A. Visualization of Theoretical Knowledge

First of all, the tour of the entire nuclear facility can be realized through the virtual tour technology. Teachers' explanation of the functions and components of nuclear facilities can be carried out in a three-dimensional virtual environment consistent with the actual environment. Through immersive virtual tour experience, students' perceptual knowledge of nuclear weapons and nuclear facilities can be greatly improved.

Secondly, based on 3D visualization technology, in the accident scene, computer generated from nuclear weapons development to the nuclear accident, accident consequences the perspective of the life cycle of a better understanding of nuclear weapons nuclear accident, understand the accident source term, nuclide image diffusion and three-dimensional radiation field distribution are abstract knowledge.

In addition, in the immersive virtual scene, teachers can vividly explain and observe the whole process of emergency response and operation process, so that students can have a deeper understanding of the timing and operation of emergency response.

B. Equipment Practical Operation Auxiliary Training

For the emergency equipment with actual equipment, the training of equipment practical operation ability can be improved from two aspects.

Firstly, before the operation of real equipment, students can get familiar with the emergency equipment in advance through the virtual emergency equipment operation. On the

one hand, this can alleviate the problem of insufficient real equipment and increase the operation opportunities of students. On the other hand, after the operation training on the virtual equipment, its operation ability has been effectively improved, and the mis-operation rate has been greatly reduced when students operate the real emergency equipment, which can also play a role in protecting the real equipment to a certain extent. Through the consolidation and improvement of virtual equipment operation to real equipment operation and then to virtual equipment operation, the training of equipment operation skills integrating virtual and real can be realized.

Second, virtual equipment training can increase the authenticity of equipment operation scenarios and improve the emergency capacity of equipment operation. In the case of actual operation, there is no nuclear radiation in the laboratory environment, so the operation of emergency equipment also stays on the level of correct operation procedure implementation, and there is no need to do targeted operations according to the actual situation, such as adjusting the range and other operations. The operation of the virtual emergency equipment in the immersive virtual environment can be completed in the accident scene, and the response of the emergency equipment to the environment is basically the same as that in the real radiation environment, which greatly improves the authenticity and targeted of the equipment operation training, and also improves the effect of the equipment operation training.

C. Multi-person Collaborative Virtual Emergency Response Training for the Whole Process

Based on immersive virtual reality technology, in the three-dimensional virtual nuclear facility scene consistent with the real scene, the nuclear weapon accident scene of typical nuclear facilities can be generated by computer. All the participants played different roles according to the emergency plan and performed their own duties. According to their own operating procedures, they conducted multi-person collaborative virtual emergency handling training for the whole process of typical accidents. After the training, the students can review and analyze the emergency disposal tasks according to the video replay of the operation process, summarize the advantages and disadvantages of the training process, and at the same time, put forward targeted opinions and suggestions for the improvement of students' skills.

D. Emergency Response Training for the Whole Process Based on Computer-Aided Training Virtual Roles

On the basis of multi-person collaborative virtual emergency response training for the whole process, computer-aided training virtual roles with certain intelligence can be developed for various roles relying on artificial intelligence technology. In the role that does not need the participation of real people, these intelligent virtual roles can be used to replace, so that even if only one person can independently carry out targeted training for the whole process. It greatly improves the flexibility of the teaching and training organization.

E. Nuclear Emergency Plan Deduction Based on Three-Dimensional Virtual Scene

In the preparation and deduction of nuclear emergency response plans, after students complete the preparation of emergency response plans for nuclear accidents at typical nuclear facilities based on their existing knowledge and skills, they can use virtual reality technology to conduct virtual deduction with virtual emergency equipment in the scenario of virtual nuclear facilities. Compared with the desktop deduction on the paper map, all the students' running positions, commands and virtual equipment operations are completed in the same three-dimensional virtual scene that is highly similar to the actual situation, which is convenient for students to find the problems in their preparation plans and is also more conducive to the modification and improvement of the preparation plans.

V. Conclusion

Introducing immersive VR technology into the practical training teaching of nuclear accident emergency management is conducive to improving the authenticity of the practical training, breaking through the time and space limitations in the traditional practical training teaching of nuclear accident emergency management, and changing the traditional practical training mode in the training room. At the same time, the use of virtual emergency equipment can effectively solve the problems of incomplete model and small quantity of emergency equipment, which is of great significance for reducing teaching cost and improving teaching effect.

Conflict Of Interest

No other potential conflict of interest relevant to this article was reported.

Author Contributions

Guo Ming wrote the paper; Others analyzed the data; all authors had approved the final version.

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