Oil Depot Safety Inspection and Emergency Training System Based on Virtual Reality Technology

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Abstract. An oil depot safety inspection and emergency training system based on VR technology is proposed in this paper for the safety inspection and emergency training with the problems of high cost, high risk, difficulty to repeat, unsatisfactory training effect and single form in hazardous chemical industry such as oil-gas storage. The system utilizes VR development engine, applies 3D Max, Unity 3D and Visual Studio and other development software to complete 3D scenarios building and visualization of the oil depot, furthermore, achieves highly realistic picture effects by HD scriptable render pipeline technology, so as to realize dynamic simulation of various application scenarios such as realistic three-dimensional roaming, knowledge learning, safety inspection and typical fire accident emergency drill. The application results show that the system can effectively improve the pertinence, interesting, operability and implementation effect of oil depot safety inspection and emergency training, so as to achieve the purposes for improving the level of safety knowledge and skill and reducing safety accident.

1. Introduction

Finished oil depot is a place for storage and distribution of gasoline, diesel and other oil materials. The safety work of oil depots is the premise of other work. The medium (oil products) stored by oil depots is inflammable, explosive, volatile, etc. Improper management process may led to huge economic loss or personal injury accidents. Therefore, the safety management of oil depots is of great significance. Firstly, the training of professional and technical personnel should be strengthened, especially the safety technical training of potential hazard detection and emergency response of on-site oil depot workers, which is of vital significance to the safety management and risk control of the whole oil depots. However, traditional safety training is generally carried out through the combination of theoretical learning and practical operation, but it has great limitations [1-3], and most training contents are explained by text materials, which makes the training less interesting, while the trainees can not really reproduce and feel the real scene by watching multimedia courseware or video, so it is difficult to achieve a good training effect.
In recent years, Virtual Reality (VR) technology has made great progress, which has greatly reduced the use cost while enhancing the sense of immersion and interactivity. It is used in more and more fields. The virtual reality technology is applied in security training for fully displaying the training experience combining video, sound, animation and human-computer interaction, which has the following advantages [4-7]:

1) Real and interactive: real environment and scene are recreated for students to participate in the process immersively;

2) Controlled and safe: trainees are trained in a completely controlled environment without worrying about their own safety.

3) Flexible and efficient: as long as the required equipment and software are available, the training can be conducted anytime and anywhere. It can be practiced by individuals or multiple people collaboratively.

4) Cost saving: some upfront investment is required by VR training, but it costs less than the coach fees, travel expenses and even professional training equipment and facilities required by traditional training.

The virtual reality technology has been applied in fire fighting, electric shock and safety knowledge training experience of public community, building, etc. at present. Virtual reality technology is also used in coal mine safety and other industries for developing safety training systems in different categories and functions, and it is applied in practice [8-10]. However, safety management and training fields of dangerous chemicals industry of oil gas storage, etc. are not yet mature, and the technology can not be systematically applied [1-3]. On the basis, virtual reality technology is applied in the oil depot safety training, hidden trouble screening, emergency disposal and other technology training in the paper, VR development engine is utilized, 3D simulation, computer graphics and other technologies are applied to realize 3D modeling and visualization of oil depot environment and operation scene thereof, realistic 3D environment is simulated to show oil depot basic layout, facility equipment information, security issue guidance, typical fire accident emergency disposal operation process, etc., a virtual simulation, hidden trouble shooting and emergency training system for oil depots is developed, and the following application scenes are dynamically simulated, including oil depot 3D environment tour, knowledge learning, hidden trouble shooting training, typical fire emergency disposal drills, etc.

2. System development tools

2.1. 3D Max

3D Max belongs to 3D design software, which is very powerful in modeling, rendering, animation, special effects and other aspects. In addition, 3D Max is flexible with a variety of plug-ins, thereby expanding its applicability. 3D Max is usually used for character modeling and animation, as well as rendering of realistic images of buildings and other objects, and 3D Max speed and simplicity are incomparable in modeling [11-13]. The system has high requirements for the authenticity of models, scenes and animations, and 3D Max is an ideal tool for creating models and animations.

2.2. Unity 3D

Unity 3D is a powerful and comprehensive cross-platform 3D engine with an integrated development environment, which can be used to develop games for multiple platforms and create high-quality VR applications. It is easy to understand for basic users meanwhile, possible complete functions can be provided for experienced professionals, such as Unity 3D support C#, Boo, and JavaScript scripting [14, 15]. The system is provided with Unity 3D as the development engine.

2.3. Visual Studio 2017

Microsoft Visual Studio (VS for short) is series product of development kits of Microsoft, and it is the most popular integrated development environment of Windows platform applications. VS 2017 is easy
to learn and use, which has complete functions. It supports C#, C++, Python, Node.js, JavaScript and other major programming languages. It also can be applied by many platforms to develop native applications and carry out team and community collaboration efficiently and promptly [16]. VS is used for script editing and debugging in system development.

2.4. HD Rendering Pipeline
HD Rendering Pipeline (hereinafter referred to as HDRP) is a Scriptable Render Pipeline (SRP) established by Unity. SRP is a C# script-controlled method that is configured and rendered in Unity. SRP can achieve the transformation of rendering control from hard coding to full project-driven mode compared with Unity's traditional rendering method. HDRP is suitable for newer hardware platforms (namely compatible with Compute Shader) and PBR illumination, linear illumination, and HDR illumination are also considered at the same time during design [17-19].

![Image](image_url)

**Figure 1.** System development interface

3. System development process
The system development can be divided into client development and server development. The system client develops and utilizes 3D Max to make various models (including oil depot building model, equipment facilities and pipeline model, character model, road and other models), equipment animation and character bone animation based on collected materials. Meanwhile UI is provided. Then, the model and UI are imported into Unity 3D development engine for scene integration and rendering, and 3D simulation oil depot is built. Finally, function development is carried out to realize safety training such as hidden trouble detection, emergency drill, etc. System server development is developed based on .net platform through using C# language. The server processes trigger logic and event process as well as special effects such as fire, foam, etc. The server supports multi-user interaction functions under local area net, thereby realizing frame synchronization, supporting communication among multiple clients (voice and text), recording and clearing the training examination results of operation personnel.

The main development process of the system is shown in figure 2.
4. System function design

4.1. System functional structure
The system is mainly composed of three core modules: oil depot cognition training, safety inspection training and emergency response training, as well as auxiliary modules such as user management and
log management aiming at the functions and purposes of carrying out oil depot hidden trouble detection, typical fire and explosion and other accident emergency rescue drills.

4.2. Oil depot cognitive training module

A highly realistic 3D simulation oil depot (including loading area, exhaust gas recovery area, pump shed area, oil tank area, fire fighting area, etc.) is constructed by the system based on real oil depots, and highly realistic picture effect is realized by HD Rendering Pipeline (HDRP). Operators can conduct immersive experience in the simulated oil depot with the help of VR equipment. The system is equipped with three experience mode functions, namely bird's eye view, roaming and fixed route visit, which can be switched freely.

(1) The operator viewpoints are located above the oil depots under the bird's eye view mode, which can be moved forwards, backwards, leftwards and rightwards. Meanwhile, the perspective can be rotated for 720 degrees, and the view can be freely reduced and enlarged. The bird's eye view mode facilitates operators to comprehend overall layout of oil depots and large facility equipment quickly, such as gasoline tanks of 30000 cubic meters with diameter of 23m, height of 21 m and dome top of 24m, oil and gas recovery unit, etc. as well as many foam pipes (red), fire hoses (green) and oil pipelines (silver gray) in the oil depot. We can quickly establish the overall understanding of these equipment and facilities through aerial bird's eye view.

(2) The operator can walk freely in the simulation scene to watch and learn as in the real oil depot under the roaming mode. When operators enter a certain area for the first time, basic situation, function description, regional layout, etc. of the area can be displayed. Key equipment in the oil depot is provided with interactive UI to introduce equipment and facilities. There are also explosion diagrams, 3D animations and other modes. The location of the operator in the oil depot can be displayed in real time, and the location can be redirected by clicking the map in addition to pictures, text and voice. During roaming, such as redirecting from the current loading area to the tank area.

(3) Operators can travel in the oil depot according to the preset route and speed to check the equipment, process and data along the way under the fixed route visit mode. It is ensured that the operator will not miss important learning content through reasonable route planning, UI design and voice prompts under the mode. In addition, the learning time of each visit is fixed accordingly since the travel speed is set, the autonomy of operators is limited to some extent by the mode, the learning progress and learning effect are more controllable, and it is especially suitable for the learning and training of new trainees.

Figure 4. System function structure diagram
4.3. Safety inspection training module

The system is provided a variety of common, typical and representative security hidden troubles of oil depots in many places during modeling, thereby vividly showing the scenes of all hidden troubles. A brief introduction of several hidden trouble screening items is described in Table 1. Operators can experience the learning and training of oil depot hidden trouble detection in simulated real environment for safety inspection training. The module is provided with two functional modes of learning and examination.

(1) All hidden troubles have UI prompts in the learning mode, operators use the handle to trigger the UI for displaying content and correct treatment methods of hidden troubles. After the operators carry out correct operation treatment of eliminating hidden troubles, it is prompted that the hidden troubles are removed successfully, thereby realizing the hidden trouble detection operation training, trainees can understand and be familiar with common safe hidden trouble of oil depots and correct handling method of eliminating the hidden trouble.

(2) Most hidden trouble points are not clearly indicated, and operators need to find hidden trouble points by themselves in the examination mode; some hidden trouble points are indicated, such hidden trouble points include missing grounding line of oil pipes, unclear color identification of water pipes and foam pipes, breathing valve on top of tank, etc. The operator should find the hidden trouble and handle it correctly for scoring. When all examination questions are finished or all examination time is used up, the examination is finished. The test results and final scores are output at the end of the test so as to realize the training and assessment of operators' hidden trouble detection ability.

| Hidden trouble content                                                                 | Area            | Preset scene | Prompt                                                                 | Correct operation                                                                 | Score | Textbox content                                                                 |
|---------------------------------------------------------------------------------------|-----------------|--------------|------------------------------------------------------------------------|--------------------------------------------------------------------------------|-------|--------------------------------------------------------------------------------|
| Non-explosion-proof electronic equipment is delivered to the controlled area.          | Loading area    | The character model make a call in the empty position of the loading area, and the LOGO of iphone can be clearly seen. | None                                                                   | The beam is aligned to character model, blue text box appears, please correct option and confirm. | 5     | A. The operator talks too loudly. B. The operator can not make a call. C. The operator enters with non-explosion-proof electronic equipment. |
| The operator does not touch the static eliminator when he enters the loading area      | Loading entrance | A static eliminator is set at the entrance of the loading area.               | None                                                                   | Please touch the static eliminator for more than 3 seconds until the handle is vibrated before you enter the loading area. | 5     | None                                                                 |
| There is no emergency automatic cut-off valve at the root of oil tank inlet and outlet pipeline. | Oil tank area   | There is no emergency automatic cut-off valve at the inlet and outlet of oil pipes to the oil tank. | None                                                                   | The beam is aligned to the position of the oil pipeline connected with the oil tank. Blue text box appears, please select correct option and confirm. | 5     | A. There is no pressure pump here. B. There is no emergency automatic cut-off valve here. C. There is no flange connection device here. |

4.4. Emergency response training module

We can set a variety of accident response scenarios for fire and explosion on the basis of 3D simulation of oil depot aiming at typical accident emergency response training. Emergency response training is different from safety inspection training conducted by individual trainees in that the emergency response training is conducted by multiple operators in coordination online. In addition, a VR universal treadmill is introduced to simulate rapid walking of longer distance in the accident scene in order to better simulate the real experience of emergency response operation, thereby assisting to
realize the tension of operators in the accident situation and helping operators to obtain more realistic and immersive training experience.

(1) Accident scene and disposal plan are realistic: the typical fire accident of the oil tank is adopted as an example, and the dangerous situation of the tank area is truly reproduced through modeling the fire, smoke and other scenes. Meanwhile, real special fire accident emergency response plans of oil depot enterprises are adopted as blueprints in the system, and the accident emergency drill process (see figure 5) is set, which is technically implemented, the operator can realistically experience the entire operation process of emergency response and disposal in the system during accidents, and simulate the real accident scenes for emergency drills, thereby helping operator to learn and master the accident emergency disposal operation skills, and assisting enterprises to improve the practicality and scientific nature of emergency response plans.

(2) Collaborative operation: emergency training of the system is completed by multiple teams. The team can be composed of 1 commander and 3 executive team members. Frame synchronization can be realized through local area network connection. Members can freely communicate as they hold walkie talkies (including voice, text, etc.). The commander is responsible for issuing orders and monitoring the whole process. 3 members are responsible for emergency disposal tasks of accident sites according to the operation flow of the accident emergency disposal, including accident report alarm, fire control, personnel evacuation, later disposal as well as other treatments and operations, thereby realizing coordinated operation emergency drills of mutual division and mutual cooperation.

(3) Process control and scoring mechanism: The emergency training fire location, fire situation and fire extinguishing difficulty (time limit) each time can be configured by the manager in order to make the practice training similar to real environment, exercise psychological quality and the emergency response ability of training staff. In addition, specific process of each drill training may also be different according to on-the-spot operation of training personnel. The starting score for each member of the team is 100 points. Wrong operation and timeout will trigger the point deduction mechanism, and the final score (including score and time, etc.) will be displayed at the end of the task. Trainers must be familiar with emergency response strategies in different situations and operate them correctly to achieve good results so as to help enterprises scientifically carry out emergency training and evaluate the effect of drill training.

5. Conclusion
3D simulation oil depots are established in the hidden trouble screening and emergency training system of oil depots based on the actual oil depots, thereby developing three major training modules of oil depot recognition, hidden trouble screening, emergency treatment, etc. A more comprehensive, system and practical oil depot safety training system with strong applicability is constructed, operators can get close to the practical experience of safety training. It has solved the problems of high cost, high risk, difficult repetition, unsatisfactory training effect, single form, etc. faced by oil depot safety training and emergency drill. Basic research and development of system modeling and all functional modules have been completed at present. Corresponding functions can be realized, which will be piloted and applied in related departments and typical enterprises of safety production supervised by governments in Guangdong Province. Meanwhile, system functions are optimized and upgraded, we can use the system for application in a wide range as soon as possible, thereby greatly improving the training effect of government regulators and enterprise staff, improving the knowledge and technical skill level of related personnel in the industry, thereby providing scientific guarantee for safe development of dangerous chemicals enterprises, such as oil and gas storage, etc.
Figure 5. Typical fire accident emergency drill process framework

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