A Multi-person collaborative Simulation System for Subway Emergency Based on Virtual Reality

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Abstract. In the operation of urban rail stations, joint emergency drills for different types of work are an important way to ensure the safe operation of urban rail stations. However, due to the lack of equipment and means, at present, the joint emergency drills for urban rail stations are mostly a single-person system. Based on the current status of emergency joint drills in urban rail stations, this article proposes a virtual reality-based multi-person collaborative urban rail station emergency simulation system. Construct a large-scale virtual reality scene through the viewpoint-related LOD quadtree, and use socket technology to achieve multiplayer online interaction. Finally, all models are jointly driven by Unity3d in the simulation scene. An immersive, multi-industry coordinated urban rail station emergency drill simulation system was constructed. Providing a simulation training environment similar to the actual situation for emergency trains in urban rail stations can greatly improve the shortcomings of difficult and inefficient implementation of the organization, and change the difficult situation of insufficient emergency drills for multiple types of rail stations.

Keywords: Virtual Reality, LOD, Socket, Multi-person Collaborative

1 Introduction
With the development of economy and technology, the subway system in major cities mostly uses the automatic driving mechanism, and the drivers and relevant subway station staff usually work under normal conditions. When an emergency occurs, there is often a lack of response and methods, which is quite adverse to the emergency treatment[1]. It is a traditional and effective way to organize subway related staff and rescue personnel to carry out on-site emergency drills regularly in the real environment, but limited by the complex natural environment factors of the subway, the investment cost is high, there are potential safety hazards, affecting the normal work of the subway[2-3].

Compared with the traditional on-site emergency drill, the application of the subway emergency drill system enables the subway staff and rescue personnel to carry out emergency drill in the virtual scene, reduces the cost, increases the training opportunities and breaks the space restrictions. Due to the complex working environment of subway, it needs multi departments and multi personnel to participate in the actual emergency escape and rescue to achieve the desired effect, but the existing subway emergency drill system lacks the content of multi personnel cooperation. In this paper, a
virtual simulation system of subway multi person cooperative emergency drill is designed. By simulating and reproducing the real subway environment and accident scene, and organizing multi department and multi personnel to carry out cooperative drill, the handling ability and cooperative ability of subway staff to deal with the accident can be effectively improved.

2  System Requirement
Virtual reality multi-person collaborative emergency drill involves multi department and multi personnel activities in the same space and time dimension. Static three-dimensional scene and dynamic changes need to be synchronized among different participants. The virtual simulation system of Metro multi person cooperative emergency drill needs to meet the following requirements.

- Status synchronization of participants. Participants can see 3D scenes and other participants through the system, and can see the position and movement changes of other participants in real time.
- Scene status and event synchronization. After the accident, it is necessary to synchronize the accident related information in real time between different participants.
- Scene generation and simulation. The subway station has a wide range, with many elements and personnel involved. How to generate a large terrain system and how to simulate various real objects and elements is an important problem in this system.
- Participants' perception of physical state. The physical state of the participants includes the health state and physical state: the health state indicates the health degree of the body, including whether the body is injured or not, and whether the surrounding harmful gas is harmful to the body; the physical state indicates the action ability of the participants, the participants will consume physical energy during the course of the action, and they need to recover physical energy to continue the action after the physical consumption. The physical state of each participant needs to be synchronized in real time between different participants.
- Communication between participants. Communication and liaison enable effective communication among participants, which is conducive to collaborative activities among participants. Communication includes three forms: handsets, face-to-face calls and voice over the phone.
- Multi person cooperation. In the process of emergency drill, some activities need to be completed by many people, such as two people close the door together, open the door together, many people put out the fire together, many people rescue the wounded together, etc. the participants need to allocate good actions and activity cycle to successfully complete these activities.
- Virtual reality simulation. Through the modeling and simulation equipment and technology, simulate and reproduce the real subway environment and accident scene.
- Drill playback. The drilling process can be played back after the completion of the drilling, providing basis for the effect evaluation of emergency drilling.

3  Key Technology

3.1 Virtual Reality
Virtual Reality (VR) is a technology which allows a user to interact with computer-simulated environment. Recently, VR is wildly used in education and training, commonly associated with its immersive, highly visual, three dimension (3D) environments. As a new learning medium, VR can provide learners a hand-on experience with its interactive character, which can improve the learning performance effectively. Practicing assembly tasks in the virtual environment helps facilitate training and aids in transferring that knowledge to real life. At the same time, VR can effectively resolve the time, space and security constraints problems brought about by actual equipments[1].

3.2 Viewpoint-Related LOD Quadtree
The generation of stereo parallax in the virtual reality scene belongs to the research hotspot in the field of computer vision research[1]. The technology has a wide range of applications, including virtual reality scene monitoring, human-computer interaction, etc. [2-3]. However, virtual reality scenes have
unique features, so their face representation is more difficult[4]. And it is affected by other things such as light and shelter[5-6]. Current perspective-based LOD quadtrees have formed a variety of stereoscopic parallax virtual reality scenarios[7]. Currently, there is not much research on the application of viewpoint-related LOD quadtree in the field of stereoscopic parallax generation in virtual reality scenes[8]. The use of viewpoint-related LOD quadtree technology makes it very easy to obtain many untagged virtual reality scenes[4-5].

It is important to capture the important parts, appearances, spatial patterns, etc. of the virtual reality scene through the viewpoint-related LOD quadtree technology, and the corresponding coordinate position is represented in the coordinates. In total, there are a number of important parts and spatial patterns, including the center point of the trunk, and the spatial patterns of the right and left wrists, the left and right geography, and so on. The poles are set with the center point, and other nodes can be effectively converted through coordinate transformation. Finally, the coordinates shown in the following formula (1) are obtained:

\[
(r_i, \varphi_i) = \begin{cases} 
    r_i = \sqrt{(y_i - y_c)^2 + (x_i - x_c)^2} \\
    \varphi_i = \arctan \left( \frac{y_i - y_c}{x_i - x_c} \right) 
\end{cases}, i = 1, \ldots, 11
\]

(1)

The coordinates of the center point and other geography in the plane coordinate system are shown in \((x_c, y_c)\) \((x_i, y_i)\) in turn, as shown in Figure 1:

![Fig 1. Skeleton Geographic Coordinate Transformation of Virtual Reality Scene](image)

3.3 Socket
Sockets means socket in English. For the communication between computers completed by using TCP/IP protocol, socket provides the communication interface between the two sides. It is a basic operation unit and a mutual agreement between the two parties. Its functions have been packed in the DLL and completed by corresponding functions. There are two types of sockets[9]:

- Stream socket. It provides the receiver and the sender, according to a certain order, no repetition and no record boundary data flow interaction, which is more suitable for processing a large number of data, and finally through the analysis and processing of the network transmission layer.

- Datagram socket. It also supports the data communication between the sender and the receiver, but in the process of transmission, its reliability, subordination and non-repeatability cannot be guaranteed.

4 System Design
The multi person cooperative emergency subway system is divided into three layers: presentation layer, service layer and storage layer[6-7], as shown in Figure 2.
4.1 Presentation Layer
The presentation layer uses unity3d's three-dimensional scene rendering, particle system, animation, sound and other modules to realize three-dimensional scene rendering, water, fire, elevator stop and other accident special effects, character animation, voice communication and service layer communication through JSON message[8].

4.2 Service Layer
The service layer provides login, exercise scheme and exercise management, participants' state synchronization, participants' body state perception, participants' virtual, real-time voice communication, environment simulation, log services, etc.

4.2.1 System Data Structure. The system includes three-dimensional scene, drill role, drill event, voice recording, scoring and other information. The data structure is shown in Figure 3.

4.2.2 System State Synchronization. The drill is built on the basis of the drill program. It uses socket technology to realize TCP network services and. Net framework to manage the drill program and drill.

During the drill, the drill operation of participants is transmitted to the drill server in the form of instructions. The drill server will broadcast the received instructions among all participants on the
Internet to realize the state synchronization among participants. Based on socket technology, the network communication broadcast and high-speed network transmission of drill server are realized.

The command delivery protocol between the teacher server and the student client is shown in the figure below.

![Diagram of system state synchronization](image1)

**Fig 4.** System state synchronization

### 4.2.3 Realtime voice communication

The system includes three-dimensional scene, drill role, drill event, voice recording, scoring and other information. The data structure is shown in Figure 5.

![Diagram of real-time voice communication](image2)

**Fig 5.** Real-time voice communication

### 4.2.4 Character virtual

Unity behavior tree AI is a high-performance logical judgment framework, which provides basic artificial intelligence support. At present, the characteristics of support include perception, decision-making, action, etc.

The virtual function of participants is realized by the behavior tree in unity. Each virtual participant corresponds to a behavior tree, which is organized into different judgment logic nodes according to the status and actions of participants.
4.2.5 Log service. The whole drill process is recorded in chronological order through log information, including all event information occurred in the drill process, state change of participants and other dynamic contents. The time corresponding to the log is represented by a time slice. The timer in the Net framework is used to time and save the log information[10].

4.3 Storage Layer
The storage layer includes three parts: system data structure, 3D model and 3D scene file, providing data storage services. Data structure is saved in XML file, 3D model and 3D scene data are in file form, which is convenient for program calling.

5 Test And Result
The development and operation of subway emergency drill system based on virtual reality are realized on Windows 10 operating system. The hardware environment is CPU i7-7500k, memory 8GB, video card NVIDIA geforce gtx1060, software environment is unity3d 2017 and 3ds max2016. the system can be published to PC, web and other platforms, and can run smoothly, and get better results. It is proved that the system has good portability and can run on a variety of hardware and software platforms.

6 Conclusion
From the point of view of multi person cooperation and virtual reality, this paper analyzes the application requirements of multi person cooperation in the subway emergency drill, and designs the subway multi person cooperation emergency drill system. The test results show that the system can meet the needs of nearly 100 people online collaborative emergency drill, and provide a repeatable, safe and efficient emergency drill simulation training platform for participants, which effectively improves the emergency response ability of participants.

References
[1] Xiangchun Cheng: A Virtual Assembly System on Automobile Engine for Assembly Skills Training. American Society for Engineering Education (2010).
[2] Jing Fan and Lirong Xiong: Intelligent Driving Training Simulation System Based on Virtual Reality IEEE (2003)
[3] Gang Chen, ZhiChun Gan: Equipment Simulation Training System Based on Virtual Reality ICCEE(2008).
[4] Li fang, Jiang Tao: Analysis of 3D reconstruction of large-scale architectural scene based on virtual reality. ICCSEC 718-722(2017)
[5] Jiang Tao, Li fang: A Stereoscopic Parallax Generation Algorithm in a Virtual Reality Scene that Takes the Viewpoint-Related LOD Quadtree into Account. ICSGEA 245-248 (2018)
[6] Wenxiang Xiang: Research on 3D Inspection Simulation Training System of 500kV Power Transmission Lines. Applied Mechanics and Materials Vol. 482 394-399 (2014)
[7] MA Yiru: Design of multi—person cooperative emergency exercise system in coal mine. Industry and Mine Automation Vol. 44 93-96 (2018)
[8] LI Qun， DAI Dejun. Research on assessment method， techn0109y and system of emergency exercise[J]. Journal of Safety Science and Technology， 12(7)： 49—54. （2016）
[9] LI Wenh， LU Jianfeng， LIU Yan jao. Research and realization of remote three dimensional monitoring system based on Unity3D[J]. Manufacturing Automation， 37(24) 108-109 (2015).
[10] JIA Xuqing， TIAN Wende， YANG Yue. Chemical accident ev01utionary scenario study based on Unity3D[J]. Journal of Qingdao University of Science and Techn0109y(Natural Science Edition) 38(S1):81-83(2017).