

Development of VR Fire Evacuation Simulation Using Locomotion Platform^{*}

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Abstract

This study developed a simulation system utilizing VR technology and a VR treadmill to enhance the immersion and safety of fire evacuation training. To address the spatial constraints and limitations in responding to unexpected situations of existing HMD-based simulations, the VR treadmill was incorporated to implement real walking and running movements in the virtual environment. This system can be applied to various disaster scenarios and is expected to provide effective evacuation training.

Keywords

VR Treadmill, Fire Evacuation, Simulation, Locomotion

1 Introduction

With the increase in industrial complexes, fire accidents in factories have also risen, with the main causes of death being smoke inhalation and carbon monoxide poisoning[1]. Rapid evacuation and training that closely resembles real situations are essential, and VR technology serves as a valuable tool for safely simulating dangerous scenarios. Previous studies have utilized HMDs for evacuation training, but safety personnel were required to constantly assist participants[2,3]. This study aims to provide a more immersive evacuation training environment by combining HMDs with VR treadmills. Using only HMDs can lead to limitations in the field of view, the need for large spaces, and reduced immersion due to controller-based movement. In contrast, treadmills limit participants' actual movement, enhancing safety and immersion. The research goal is to maximize the effectiveness of safe and realistic fire evacuation training.

2 Development of VR fire evacuation simulation system



Figure 1 Simulation flowchart

Figure 1 shows the overall flow of the simulation. The simulation proceeds in the order of pre-fire, fire outbreak, start of evacuation, and success of evacuation. Participants first check the evacuation guide and, 30 seconds later, a fire breaks out with the sound of an explosion. Then, they begin to evacuate in a crouching position with a handkerchief, and they receive a visual audible warning when they remain in an upright position. Also, smoke reduces vision, and fires cause red vision. If certain elements are

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triggered during evacuation, risks such as dropping shelves or explosions are activated, and participants must avoid these obstacles in order to safely reach the exit. When evacuation is complete, the simulation ends and an evacuation time is displayed. The participant's gaze in the HMD is mirrored at the same time on a computer monitor running the engine, allowing people other than the participant to see the participant's field of view, which also makes it possible for participants to observe their behavior upon contextual assignment. The simulation was developed using Unreal Engine 5, and it implements interaction in virtual space using HMD (Meta Quest Pro) and VR treadmill (Kat Walk C 2 Plus).

3 Result



Figure 2 Simulation demonstration

Figure 2 shows a demonstration of the simulation, where participants wear an HMD and begin the simulation on a VR treadmill. As participants walk or run, they move at corresponding speeds in the virtual environment, and actions such as lowering their bodies or leaning forward naturally adjust their field of view, enhancing realism. Thanks to the VR treadmill, participants can engage in the simulation safely without constraints from the surrounding environment, eliminating the need to replicate the actual environment in the simulation setup.

4 Conclusion

In this study, we propose a system that uses VR technology and VR treadmills to enhance the realism and immersion of fire evacuation simulations while providing a safe training environment. To address the spatial limitations and low immersion of existing HMD-based simulations, VR treadmills were added to allow participants to walk or run smoothly within a virtual environment. By naturally changing the field of view to increase the realism and move without physical conflict, it is possible to establish an efficient training environment while minimizing the risk of injury. The system can be applied not only to fire evacuation but also to various disaster scenarios, providing effective evacuation training by safely simulating dangerous situations. In the future, we plan to conduct experiments comparing with existing methods to specifically verify the effectiveness of this system, and to conduct research to improve immersion and safety by integrating various sensory stimuli and quantitatively evaluating the effectiveness of training by analyzing participant's behavioral data. This will increase the possibility of utilizing VR-based evacuation training systems.

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