Interactive Virtual-Reality Fire Extinguisher with Haptic Feedback

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ABSTRACT

We present an interactive virtual-reality (VR) fire extinguisher that provides both realistic viewing using a head-mounted display (HMD) and kinesthetic experiences using a pneumatic muscle and vibrotactile transducer. The VR fire extinguisher is designed to train people to use a fire extinguisher skillfully in real fire situations. We seamlessly integrate three technologies: VR, object motion tracking, and haptic feedback. A fire scene is immersed in the HMD, and a motion tracker is used to replicate a real designed object into the virtual environment to realize augmented reality. In addition, when the handle of the fire extinguisher is squeezed to release the extinguishing agent, the haptic device generates both vibrotactile and air flow tactile feedback signals, providing the same experience as that obtained while using a real fire extinguisher.

CCS CONCEPTS

· Human-centered computing → Virtual reality; Haptic devices;

KEYWORDS

Virtual reality, Haptic feedback, Firefighting

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1 Introduction

Every year, fires kill tens of thousands of people and destroy property worth billions of dollars worldwide. To acquaint people with evacuation procedures in the event of a fire, fire drills are regularly conducted at schools and workplaces. However, the fire evacuation training environment found in these safety drills is very different from an actual fire situation, so most people are not able to respond properly in the event of a fire. In particular, because fire extinguishers are difficult to handle properly and non-recyclable, they are typically not used in actual fire drills.

[Vichitvejpaisal et al., 2016] proposed a firefighting simulation in a virtual environment. However, this fire suppression simulation is simply controlled by a joystick with no interaction between the player and fire extinguisher. Consequently, the player cannot learn the pull, aim, squeeze, and sweep (PASS) technique, which is one of the most important aspect of using a fire extinguisher.

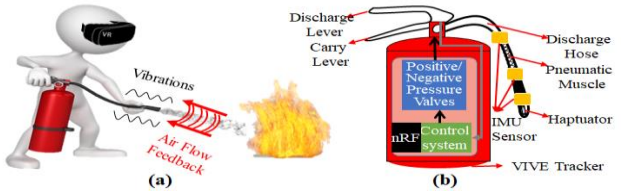

Figure 1: Overview of proposed interactive VR fire extinguisher: (a) feedback types during fire extinguisher operation; (b) conceptual model of the fire extinguisher

In this paper, we propose a fire extinguisher simulation wherein a fire extinguisher model whose functions are similar to those of a real fire extinguisher is implemented. Players interact with the VIVE HMD and the proposed fire extinguisher, on which a VIVE tracker is attached. In addition, when the virtual extinguishing agent is released onto a burning object, the players receive both vibrotactile feedback and air flow feedback generated by a haptuator and pneumatic muscle.

2 Design and implementation

The proposed VR fire extinguisher simulation system has three interactive factors based on three technologies: virtual reality realized using the HMD device, the motion tracking of the fire extinguisher and its hose, and haptic feedback (Figure 1). The simulation allows players to interact with the model as though it is a real object. The players receive visual information through the HMD device. Multiple small inertial measurement unit (IMU) sensors are attached to the hoses and nozzles of the model to estimate the position and posture of the nozzles and ensure that the hoses are visualized as close to reality as possible in the display device. Moreover, when the players squeeze the handle to release the virtual extinguishing agent, the actuators in the hose and nozzle generate vibrotactile and air flow feedback similar to that in a real fire extinguisher.

2.1 Motion tracking of the fire extinguisher

Figure 2: Motion tracking and its visualization: (a) IMU sensor; (b) prototype of the proposed fire extinguisher; (c) visualization of fire extinguisher' hose.

To efficiently estimate the posture and position of the fire extinguisher, we use two different types of tracking systems. A VIVE tracker is used to estimate the global position and posture of the body of the fire extinguisher. In addition, an IMU-based kinematic chain pose estimation method proposed by [Kaczmarek et al., 2016] is applied to estimate the posture of the nozzle and hose. A multiple nine-degrees-of-freedom IMU sensor modules using motion-tracking devices (MPU-9250, Figure 2a) is arranged as shown in Figure 2b. In addition, an attitude and heading reference system described by [Madgwick et al., 2011] algorithm is applied to accurately estimate the posture of each module. The postures are estimated by the IMU sensors attached on the hose and the nozzle, which represent the postures of the hose and nozzle, are rendered in the VR environment using Obi Rope (Figure 2c).

2.2 Haptic feedback

While interacting with a regular fire extinguisher, a user generally perceives two major and distinct types of haptic feedback (Figure 1a). The first feedback is the perception of sudden air flow through the nozzle of the hose. The sudden air flow provides a momentary jerk at the beginning of the process. The second one is the continuous perception of vibration due to the flow of air/carbon particles.

To create a realistic virtual fire extinguisher, we need to replicate the aforementioned haptic perceptions. The jerk at the beginning of the operation is a form of kinesthetic feedback, whereas the continuous vibration is a form of tactile feedback. In the current prototype, the kinesthetic feedback is replicated using a pneumatic muscle which [Talhan and Jeon, 2018] proposed. The pneumatic muscle contracts in length when high-pressure air is pumped into it. The contraction produces a sudden jerk at the start of the operation. The pneumatic valves (positive and negative) are controlled by an Arduino Uno while the air supply comes from a pressurized air source. On the other hand, vibrotactile feedback is provided using a haptuator, which is driven by a 498 Hz pulse-width-modulated signal and produces a constant sensation of air flow throughout the operation. Both the positive valve and a haptuator are driven synchronously to provide the kinesthetic and tactile feedback at the same time (Figure 3).

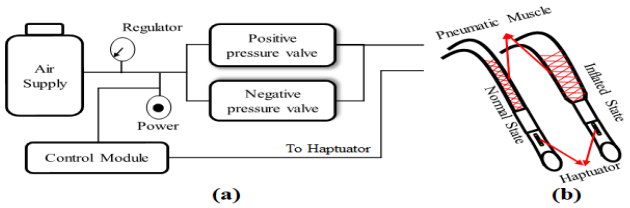

Figure 3: Design of proposed haptic feedback: (a) control schematic of pneumatic system and haptuator; (b) illustration of operation of pneumatic muscle.

3 Conclusion

We developed an interactive VR fire extinguisher with multiple types of haptic feedback. The designed fire extinguisher provides not only realistic viewing in a VR environment but also vibrotactile and air flow tactile feedback. Hence, the designed fire extinguisher can provide the same experience as that obtained while using a real fire extinguisher and can thereby make fire drills more realistic. In the future, we plan to develop scenarios and contents that will allow players to move in virtual environments and practice fire drills in a limited space by utilizing omnidirectional treadmills such as KAT WALK.

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