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Fire Immersive Response and Evacuation in Extended Reality

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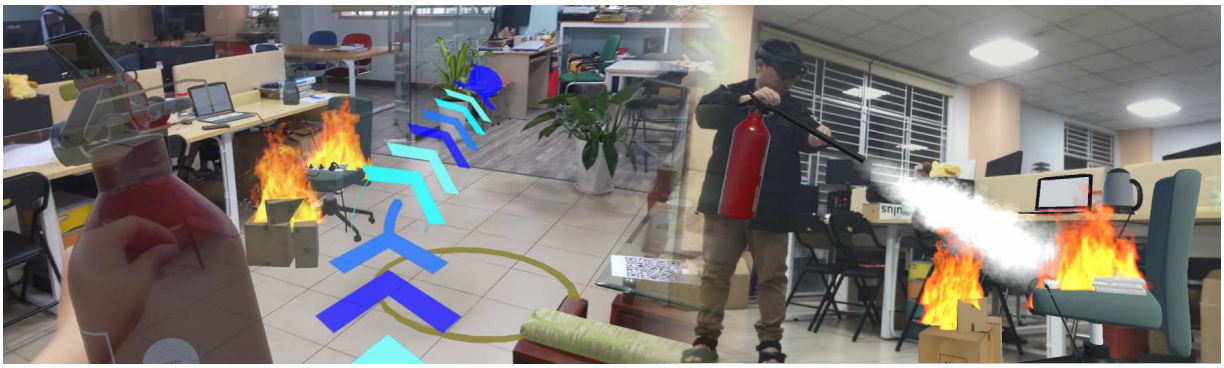

Figure 1: The illustration of our fire immersive response and evacuation in extended reality.

Abstract

In Extended Reality (XR) environments, navigation is a crucial part that makes up a satisfying user experience. Effective navigation allows users to move through and interact with the digital world easily and naturally. Virtual Reality (VR) and Mixed Reality (MR) technologies, although both aim to provide an immersive experience, approach navigation and user interactions significantly different. The purpose of this study is to examine the effects of navigating through different XR environments on user experience. To thoroughly understand the impacts, we created and conducted surveys on a fire safety training course in three different formats, namely, video-based, VR-based and MR-based training. According to the user study, the VR application tends to be more immersive but can cause motion sickness, whereas the MR version excels by allowing intuitive interactions and enhancing users' awareness of real-world prop locations. Our findings help identify which XR environment promotes ease of use, reduces motion sickness and enhances spatial awareness, ultimately inform design choices for more effective and user-friendly XR applications.

Index Terms: Navigation, extended reality, virtual reality, mixed reality, user experience, spatial awareness, fire safety.

1 Introduction

Virtual navigation in an extended reality (XR) environment allows participants to interact directly with virtual objects through actions, manipulations, and movements. This capability not only enhances the realism of the training experience but also significantly improves memory retention, adaptability, and response to specific incidents and emergencies in their working environment. XR technology enables the creation of highly accurate fire safety training scenarios within real-world terrains and environments, leveraging spatial awareness in a safe manner. This makes it exceptionally suitable for training and practicing fire safety skills, controlling risks, and reducing the occurrence of motion sickness compared to other virtual reality methods. The integration of both virtual and augmented reality elements in XR offers a versatile and robust platform for effective fire safety training, highlighting its potential as a transformative tool in the realm of emergency preparedness and response training.

Some research has been conducted to create realistic representations of hazards such as smoke and fire in VR-based fire training simulators [1, 5]. Çakiroğlu and Gökoğlu [6] developed a VR environment for fire training using the behavioral skills training (BST) method. A more recent study examined the effectiveness of XR in training for total hip arthroplasty [4]. However, these studies do not address the impact of XR navigation on user experience. Therefore, in this paper, we aim to explore how navigating different XR environments affects user experience in a fire safety training application, focusing on usability, intuitiveness, and comfort to identify navigation methods that improve user experience and minimize issues like motion sickness or cognitive overload (shown in Figure 1).

2 Methods

In this work, we investigate three variants of a fire safety training course, namely, video-based, VR-based, and MR-based training.

First, based on the national fire fighting regulations, we structure the course around four key steps to take when a fire occurs: push the fire alarm, cut off the electricity, use the fire extinguisher and call the fire department. The training video was created in a presentation style. The only difference from the outline is that users will watch a video demonstrating how to locate the equipment, without interactive capabilities.

For VR and MR-based training, a set of arrows serves a dual purpose: it both shows the direction to fire safety equipment, allowing users to interact with it (as seen in Figures 2 - VR and Figure 3 - MR), and guides them to the nearest safe exit for evacuation. The VR version takes place inside a virtual office, with fire safety equipment placed at relative positions across the room. Users can move around and steer the character using left and right joysticks on the controllers. In terms of interactions with the virtual objects, the grip and trigger buttons can be used in combination to perform certain actions like pinching, poking or grabbing an object.

When building the MR variation, we chose to run the app in our lab environment and on an optical see-through head-mounted

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Figure 2: A scene from the virtual reality (VR) version of our fire safety training.

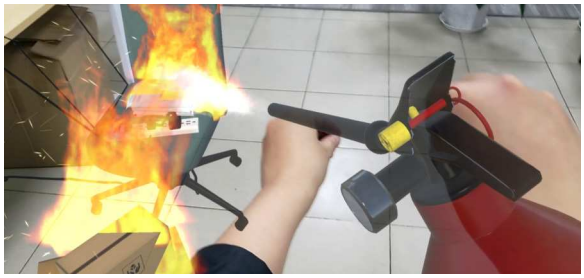

Figure 3: A scene from the mixed reality (MR) version from the headset's perspective.

display such as HoloLens 2 headset [2]. In this version, the virtual equipment (e.g. fire alarm, circuit breaker, fire extinguisher) are overlaid onto the real world, next to their real-life counterpart. The idea is that users can interact with the virtual objects and do so at their real-life location. This helps them remember where these equipment are situated in the room, enabling them to respond quickly in case of an actual fire. The way we position props at specific locations in the room is by utilizing the device's spatial anchors feature. It allows the HoloLens to map and remember physical locations, so virtual objects can be placed accurately and consistently in the same spots even after the device is restarted or moved away and back to the room. For our app, we chose to register one anchor point in the middle of the room, and then save it along with the spatial mesh. Since this point remains in the same location between app sessions (provided the user does not leave the room and the anchor point is not obstructed), we used it as a reference point to position other virtual props. The HoloLens version also allows users to use a real extinguisher to put out the virtual fire as demonstrated in Figure 4. We implement this mechanism by tracking the relative positions between the hands. Once the user's dominant hands form the trigger pose, a "spray" effect is activated on their non-dominant hand and can be used to interact with the virtual fire scene.

3 User Study and Evaluation

Following the system implementation, we conducted a user study with 20 participants, averaging 23.3 years in age. Among them, 60% had never participated in fire safety training in real-life scenarios. However, 80% of the participants responded that their first action upon encountering a fire would be to alert and notify everyone around. This action aligns with the initial step in fire safety protocols, demonstrating a high level of awareness among participants regarding fire safety, despite their lack of formal training. Participants experienced fire safety training through three methods: watching a video, using Meta Quest 2 VR with controllers [3], and HoloLens 2 Mixed Reality.

The user study results presented in Figure 5 indicated that the training using Mixed Reality (MR) with virtual navigation and interaction provided superior outcomes across all evaluation criteria compared to the other two methods. Participants felt more excited, engaged, immersed, and found it easier to remember procedures and their real-life locations when using MR. Motion sickness occurred in VR and MR methods, with more dizziness and disorientation reported in VR. Some participants felt slight dizziness with MR, mainly due to unfamiliarity with the technology. Finally, participants suggested enhancing MR training by adding dynamic fire and smoke scenarios to improve adaptation and situational response.

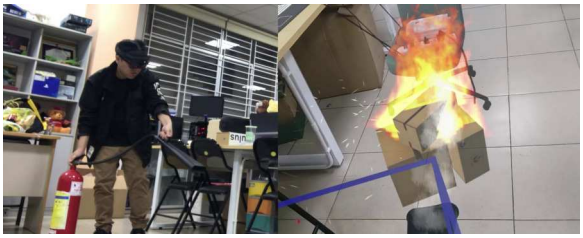

Figure 4: The usage of a real extinguisher along with our mixed reality application.

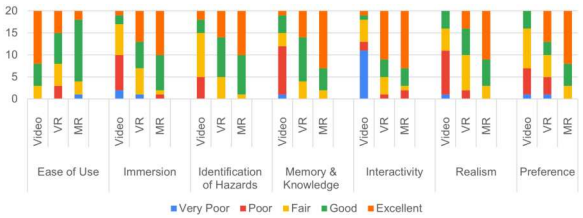

Figure 5: The feedback from participants on seven criteria of the survey, for each of the three formats, namely, video-based, VR-based and MR-based training.

4 Conclusion

In this paper, we developed a virtual navigation system in XR for fire safety and evacuation training in real environments. We conducted user studies and surveys using video, VR headsets, and XR. The results showed that navigation in MR's real environments is highly effective for fire safety training in terms of realism, user experience, interaction, practical skills, and retention of training content. Our findings highlight the potential of MR to significantly improve the quality and effectiveness of fire safety training programs.

Our future work will focus on developing tools to adapt the application to any environment, as well as exploring MR training's feasibility in large, complex settings.

Acknowledgments

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