https://doi.org/10.2352/EI.2025.37.13.ERVR-169

A Collaborative Virtual Reality Environment Module for Active Shooter Response Training and Decision Making

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Abstract

Emergency response and active shooter training drills and exercises are necessary to train for emergencies as we are unable to predict when they do occur. There has been progress in understanding human behavior, unpredictability, human motion synthesis, crowd dynamics, and their relationships with active shooter events, but challenges remain. With continuing advancements in technology, virtual reality (VR) based training incorporates real-life experience that creates a "sense of presence" in the environment and becomes a viable alternative to traditional based training. This paper presents a collaborative virtual reality environment (CVE) module for performing active shooter training drills using immersive and non-immersive environments. The collaborative immersive environment is implemented in Unity 3D and is based on run, hide, and fight modes for emergency response. We present two ways of modeling user behavior. First, rules for AI agents or NPCs (Non-Player Characters) are defined. Second, controls to the users-controlled agents or PCs (Player characters) to navigate in the VR environment as autonomous agents with a keyboard/ joystick or with an immersive VR headset are provided. The users can enter the CVE as user-controlled agents and respond to emergencies like active shooter events, bomb blasts, fire, and smoke. A user study was conducted to evaluate the effectiveness of our CVE module for active shooter response training and decision-making using the Group Environment Questionnaire (GEQ), Presence Questionnaire (PQ), System Usability Scale (SUS), and Technology Acceptance Model (TAM) Questionnaire. The results show that the majority of users agreed that the sense of presence intrinsic motivation, and self-efficacy was increased when using the immersive emergency response training module for an active shooter evacuation environment.

1. Introduction

Recently, there has been a sharp increase in active shooter events, but there has been no introduction of new technology or tactics capable of increasing preparedness and training for active shooter events. The use of gaming and Virtual Reality (VR) has significantly increased in recent years as a tool for emergency response and virtual evacuation training. The use of immersive VR allows trainees to experience realistic and interactive simulations of emergency response situations such as natural disasters, fires, and active shooter response drills. By replicating real-time scenarios, VR provides a safe and secure way for first responders, healthcare workers, building occupants, and security personnel to practice skills, make quick decisions, and improve response time without the risk associated with real-world training. Sharma et al. [1-5] have developed an immersive active shooter response training environment for a building evacuation in a collaborative virtual environment. They have presented two immersive active shooter training modules: the occupant's module and the security personnel module. Both training modules use VR head-mounted displays (oculus/meta-quest) for the course of action, visualization, and situational awareness during active shooter training drills.

Figure 1. CVE training module for active shooter events using Meta Quest 3 Touch controllers

This paper presents a hybrid platform where experiments for active shooter response can be conducted using AI agents and user-controlled agents. This platform can be used as a teaching and educational tool for navigation and performing VR evacuation drills for active shooter response. This innovative approach can enhance learning outcomes and prepare individuals for real-world emergencies without putting people's lives at risk. The user can enter the active shooter training simulation in CVE using both immersive and non-immersive environments. The user can enter the CVE using a mouse and keyboard in a non-immersive environment or enter the CVE in an immersive environment using meta Quest 3 head-mounted display and touch controllers. Figure 1 shows our developed CVE module for active shooter events using a Meta Quest 3 Touch controllers for the course of action, visualization, and situational awareness for active shooter events. Figure 2 shows the user study conducted for active shooter response training drills in the CVE for both immersive and non-immersive environments.

Figure 2. User study in a CVE for both immersive and non-immersive environments

The rest of the paper is structured as follows. Section 2 briefly describes the related work for the collaborative VR environments for active shooter response and emergency evacuation drills. Section 3, describes the implementation of the immersive CVE. Section 4, describes the user study and the evaluation of the active shooter training drills in CVE. Section 5 lists the conclusion and future work. Finally, Section 6 states acknowledgments.

2. Related Work

An Emergency Action Plan (EAP) is important for any building's safety strategy. It is prepared to guide building occupants to safety through potential emergencies, such as fires or natural disasters. EAP ensures that all building occupants receive training for a variety of emergencies. This includes training for knowing and familiarizing evacuation routes, exit points, assembly points, shelter areas, and the use of emergency equipment such as fire extinguishers, and AEDs. The EAP also ensures that individuals with disabilities or special needs can evacuate safely and without undue delay. Chovaz et al. [6] have described a model for understanding active shooter events with the incorporation of medical service professionals. Building preparedness becomes very critical during active shooter events 7]. It is important to learn from past disasters and experiences for Active shooter events. Virtual reality has been used as a training and educational tool for homeland security applications [8]. Virtual reality training and drills have been studied in past disasters such as nightclub [9], subway [10], Megacity [11], aircraft [12], library [13], campus [14], city [15], and building [16].

Active shooter events lead to mass causalities [17] and loss of life, highlighting the need to learn from past disasters and previous experiences to prepare for future events [18]. By studying the data from past disasters and active shooter situations, we can identify patterns, strengths, and weaknesses in preparation and response and the suitability of EAP. The lessons learned from analyzing data from past disasters can help prevent future tragedies and improve response time. It is also important to train for collaboration and coordination among various authorities such as law enforcement, medical personnel, school officials, and workplace managers while responding to active shooter training events.

Schools have been paying extra attention to providing knowledge and resources to their employees and students to effectively handle stressful situations. Gleich-Bope et al. [19] have mentioned that the US Department of Education has recommended a "Run, Hide, Fight" protocol to school districts when developing school safety procedures. They have introduced the ALICE intruder alert program and training for school districts [18]. Sikes et al [20] have stressed the importance of Simple Triage and Rapid Treatment, or START, which is a rapid assessment method used to triage victims during a mass casualty event. They have stressed the importance of proper planning and training to increase survival and decrease the number of potential casualties during emergencies.

3. System Architecture of Collaborative Virtual Environment (CVE)

Figure 3 shows the user interaction in a dynamic virtual environment designed for both immersive (e.g., Meta Quest 3) and non-immersive (e.g., PC-based) platforms. A user can enter the CVE using a

- Computer, mouse, and keyboard (non-immersive environment)
- Meta Quest 3 (immersive environment using VR Head-mounted display and touch controllers).

The CVE is developed using Unity3D (gaming engine) and integrated with Photon PUN for networking capabilities. The CVE supports up to 20 simultaneous participants. This synergy between Unity3D and Photon PUN enables real-time multiplayer functionality. Upon entering the collaborative virtual environment, users are directed to a lobby where initial configuration occurs. The first user to join is assigned the role of determining the number of NPCs (non-player characters) or AI agents. NPC behaviors are pre-defined and include categories such as hostile, non-hostile, selfish, and goal-following behaviors (refer to figure 4). Then, non-immersive users are prompted to select an avatar to represent their presence, while immersive users are automatically assigned avatars for ease of integration. Once instantiated in the environment, all users are free to navigate and explore the virtual space autonomously. We present two ways of modeling user behavior.

1. By defining rules for AI agents or NPCs (Non-Player Characters).
2. By providing controls to the users-controlled agents or PCs (Player characters) to navigate in the CVE as autonomous agents in immersive and non-immersive environments.

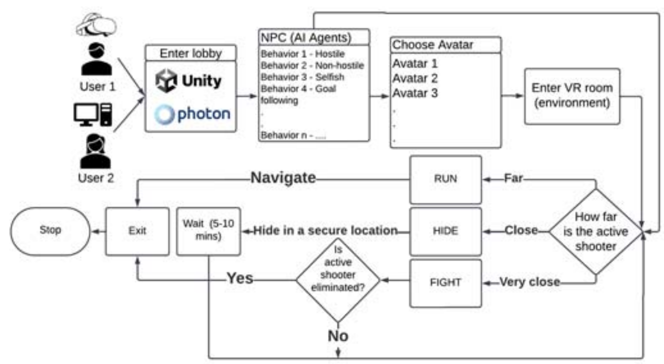

Figure 3. System Architecture diagram: User interaction in a dynamic virtual environment designed for both immersive and non-immersive environments

The simulation is centered around the "active shooter scenario", where users must make strategic decisions aligned with the "Run, Hide, Fight" protocol based on their spatial proximity to the active shooter. Each decision dynamically affects user actions and NPC behaviors, ensuring an adaptive and realistic training experience. These decisions are made by the users based on the distance between the user and the active shooter. The CVE follows the recommended standard of the "run, hide, and fight" approach for responding to active shooter situations [18].

1. Run: Escape, if possible
    - Get as far away from the shooter or shooters as a top priority.
    - Leave belongings
    - Evacuate and help others escape, if possible
    - Warn others and prevent individuals from entering an area where the active shooter might be.
2. Hide: If escape is not possible
    - Get out of the active shooter's view and stay quiet.
    - Silence all electronic devices.

- o Lock and block doors, close blinds, and turn off lights.
- o Stay in place until law enforcement gives all clear.

3. Fight: As an absolute last resort
   - o Commit to your actions and act as aggressively as possible against the shooter.
   - o Throw items and improvise weapons to distract and disarm the shooter.

Figure 4. Shows the NPCs (non-player characters) or AI agents

When the distance between the user and the active shooter is sufficiently large, the optimal decision is to locate and navigate to the nearest exit point. Users can initiate the "Run" protocol through the user interface, which simultaneously triggers an override of default NPC behaviors to goal-following behavior. NPCs in the vicinity adopt an exit-seeking behavior, dynamically calculating the safest path to the closest exit then navigating towards the exit and ceasing movement upon successful evacuation. The simulation stops when the user safely reaches the exit point.

Figure 5. Shows the NPCs (non-player characters) or AI agents and "Player 1" as user-controlled autonomous agents in a CVE.

Figure 5 shows the user entering the CVE using Meta-quest 3 and touch controllers to navigate the environment. The environment also shows "Player 1" another user-controlled agent in the same environment. The environment also includes NPCs (non-player characters) or AI agents. If the active shooter is in closer proximity, users are advised to identify and move to a secure hiding spot, preferably behind a barricade or in an enclosed space. Activating the "Hide" protocol via the interface prompts (refer to figure 6) NPCs to override their default behaviors and switch to a goal-following behavior that prioritizes locating and occupying safe hiding spots. Users and NPCs remain in their chosen locations for a designated period (5–10 minutes) while continuously assessing the distance to the active shooter. If the active shooter moves farther away, users are instructed to switch to the "Run" protocol and proceed to the nearest exit.

In situations where the active shooter is in immediate proximity, users are encouraged to utilize available resources to neutralize the threat. The virtual environment allows users to pick up some objects (such as furniture and boxes) and throw them at the active shooter. NPC behaviors remain unaffected in this mode, as the focus shifts to user actions. Success in neutralizing the active shooter allows users to proceed to the exit, which concludes the simulation. Otherwise, users are required to reassess their position and distance from the shooter and adapt accordingly.

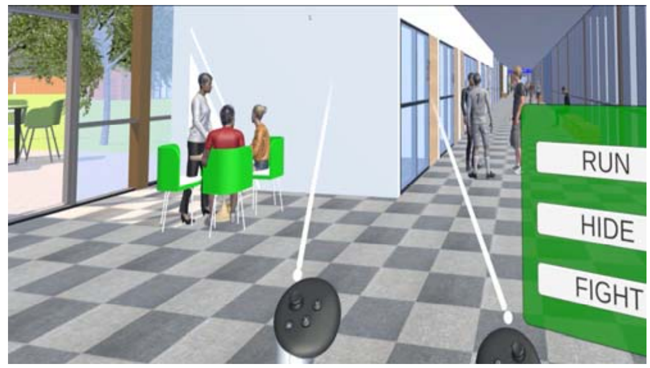

Figure 6. Shows the GUI for an immersive environment with touch controllers and a menu for run, hide, and fight.

This interactive simulation framework focuses on user-driven decision-making while dynamically influencing NPC behaviors. By integrating spatial proximity as a key determinant of protocol activation, the system replicates realistic scenarios to enhance user preparedness for emergency response.

4. Evaluation and Results

A user study was conducted to evaluate the CVE for active shooter response training based on run, hide, and fight. The study included a total of 195 participants in the university campus building. The study included two phases:

- Phase 1 of the user study included 80 participants. This user study included all participants in a multi-user VR environment using a monitor, mouse, and keyboard (non-immersive).
- Phase 2 of the user study included 115 participants. This user study included 2 users on Meta Quest 3 (immersive environment) and 2 users on computer and keyboard (non-immersive) in the same multi-user environment.

Each session included 4 participants in the user study. The scenario included 4 participants entering the CVE inside the building and the active shooter arriving from one entrance. The participants act as user-controlled agents and are free to interact with AI agents or NPCs. Once the emergency starts the behavior of the agent's changes. The simulation user study sought to examine how the proposed active shooter CVE influenced participants' understanding of the safest actions to take during an active shooter situation. The post-evaluation includes questions on the Group Environment Questionnaire (GEQ) [21], Presence Questionnaire (PQ) [22], System Usability Scale (SUS) [23], and Technology Acceptance Model (TAM) Questionnaire [24]. Figure 2 shows the user study conducted for the evaluation of the active shooter response training environment.

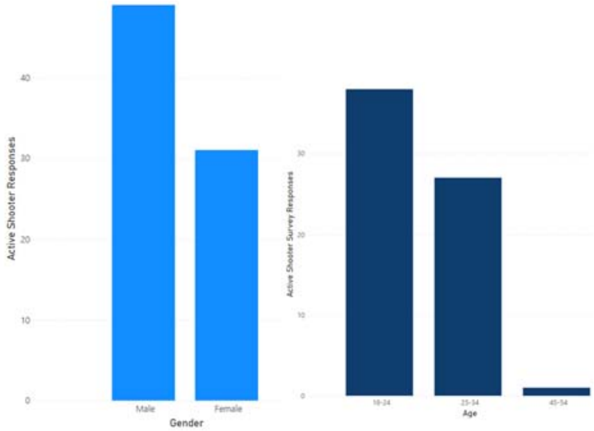

Figure 7. Active Shooter Survey Responses by Gender and Age

As seen in Figure 7, the number of male active shooter users are more than double that of female users. Fig 7 also shows that the participants were younger that indicates greater engagement or concern among younger individuals regarding active shooter scenarios.

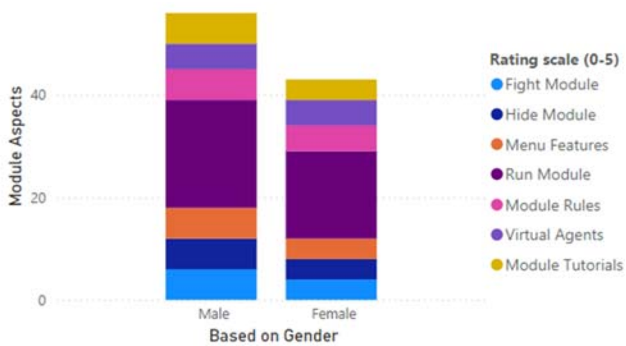

Figure 8. VR Module Individual Learning Support Aspect

As shown in the figure 12, Females rated "Menu Features" higher than males. Males give better feedback on the "Fight Module. Both genders have similar ratings for "Hide Module" and "Virtual Agents."

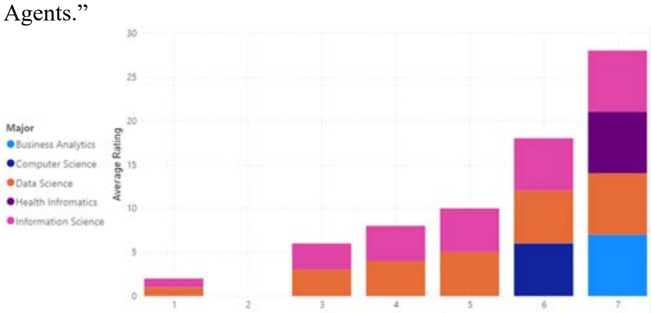

Figure 9. Learning Impact on Run, Hide, and Fight

Figure 9 shows the "Run Hide Fight" module had different learning impacts across various academic disciplines. Some majors found it highly impactful, while others rated it lower. Understanding these differences can help improve future safety training and emergency response programs. This also suggests the VR module effectively addressed the core user needs in emergency scenarios.

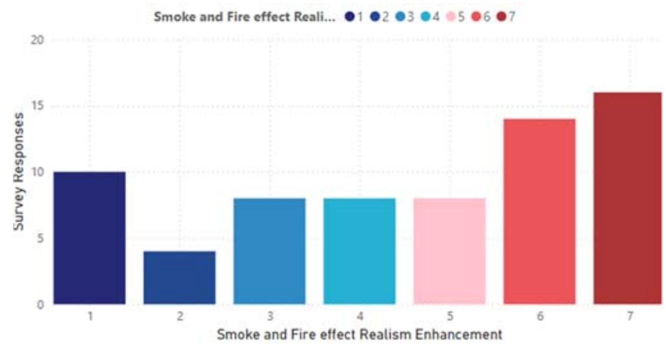

Figure 10. Realism of the VRI Module Environment

The bar chart in Figure 10 shows the realism of the CVE module. It shows how realistic users found the CVE module environment based on various elements. The addition of smoke and fire effects had the greatest impact on realism, with an average rating around of 6.5 on a 7-point scale. Other factors like background noise and virtual objects also seem to contribute to a more realistic experience, but to a lesser extent according to the average ratings.

5. Conclusions

This paper presents a collaborative virtual reality environment module for active shooter response training and decision-making. The CVE was developed using the Unity 3D gaming engine for both immersive (Meta Quest 3 and touch controllers.) and non-immersive environments (monitor, mouse, and keyboard). The inclusion of Photon PUN enabled real-time multiplayer functionality in the CVE. The users can enter the CVE as user-controlled agents and can interact with other user-controlled agents as well as AI agents (or computer-controlled) and participate in the active shooter training drills based on run, hide, and fight. AI agents have pre-defined behaviors implemented such as hostile, non-hostile, selfish, and goal-following behaviors. The users are prompted to select an avatar to represent their presence before entering the CVE.

A user study was conducted that included 195 participants to evaluate the CVE module for active shooter scenarios. The participants were younger age group between 18-34 and were 60% male. A detailed evaluation was conducted that included post-survey questions from Group Environment Questionnaire (GEQ), Presence Questionnaire (PQ), System Usability Scale (SUS), and Technology Acceptance Model (TAM) Questionnaire. All participants found the immersive menus and run, fight, and hide options. The results from the user studies indicate that participants experienced a notable increase in their knowledge and learning after the training.

Acknowledgments

This work is funded in part by the NSF award 2321539. The authors would also like to acknowledge the support of NSF Award 2319752, NSF Award 2321574, and Sub Award No. NSF00123-08 for NSF Award 2118285

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