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Immersive Virtual Reality Training Module for Active Shooter Events

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Abstract

Active shooter events are not emergencies that can be reasonably anticipated. However, these events do occur more than we think, and there is a critical need for an effective emergency preparedness plan that can increase the likelihood of saving lives and reducing casualties in the event of an active shooting incident. There has been a major concern about the lack of tools available to allow for modeling and simulation of human behavior during emergency response training. Over the past few decades, virtual reality-based training for emergency response and decision making has been recognized as a novel alternative for disaster preparedness. This paper presents an immersive virtual reality (VR) training module for active shooter events for a building emergency response. There are two immersive active shooter modules developed: occupant's module and Security personnel module. We have developed an immersive virtual reality training module for active shooter events using an Oculus for the course of action, visualization, and situational awareness for active shooter events. The immersive environment is implemented in Unity 3D where the user has an option to enter the environment as security personnel or as an occupant in the building. The immersive VR training module offers a unique platform for emergency response and decision making training. The platform allows for collecting data on different what-if scenarios in response to active shooter events that impact the actions of security personnel and occupants in a building. The data collected can be used to educate security personnel on how to reduce response times. Moreover, security personnel can be trained to respond to a variety of emergencies safely and securely without ever being exposed to real-world dangers.

1. Introduction

There has been an increasing interest in an active shooter response training environment for a building evacuation in a collaborative virtual environment [1-2]. There is a need to find new alternatives to traditional active shooter exercises to minimize these tragedies. There is also a need to plan for the future by learning from past disasters and events to identify deficiencies in the emergency response plan for an individual building. Sharma et al. [3] have recreated a past disaster of night club fire in a collaborated virtual reality environment (CVE) to study human behavior and learn from past disasters. The study of these past disasters helps in strategizing for future events and facilitates a more efficient evacuation procedure. Emergency responders also benefit from time management during emergencies. Crowd simulations and CVE are powerful tools for visualizing, analyzing, communicating, and testing evacuations scenarios during emergencies. Recent disasters have revealed how different factors affect the strategies employed during these emergency events [4]. Staged strategies rely on a division of individuals in zones and the subsequent evacuation of zones [5].

To prepare for active shooter events, it is not practically possible to create an emergency in real-time with fire and smoke and ask people to evacuate. Even performing a user study with real fire and smoke is practically impossible because we cannot put people's lives at risk. But there is a need to prepare for these extreme events and learn from past disaster studies. Immersive VR environments offer a great advantage of performing these live experiments in a virtual environment without putting people's lives at risk. The virtual environment can incorporate smoke and fire inside the environment and can re-create real emergencies. The "sense of presence" developed in the immersive VR environments allows for testing scenarios that cannot be tested in real-time due to safety and legal issues. The immersive VR environment gives a fully immersive feel of the situation and allows one to perform virtual evacuation drills for different what-if situations. The traditional performance-based test such as fire emergency evacuation drills is expensive to perform in the real world due to challenges with

- Safety issues.
- Accompanying risk.
- Legal aspects.

It is tough to ensure that people trained through traditional drills will receive sufficient instructions for all the desired actions they may need to perform in a real incident [6]. Another drawback of the traditional training approach is that participants do not get real-time feedback on their performance during the evacuation drill. Although there have been various training programs to increase the active shooter awareness and preparedness of occupants, they are improperly trained in locations [7]. Whereas, in a VR environment, the user actions can be recorded for different what-if scenarios to recommend the deficiencies during their performance. It can lead to much-improved training for emergency response.

During emergencies, the risk to occupants can be drastically improved if someone is familiar with the situation. VR is a highly beneficial technology for emergency responders to get the experience of intense situations through simulation, which can be a way to prepare for unpredictable and challenging situations. VR training is a safer platform as compared to traditional training. Safety allows for the creation of scenarios with intense and dangerous situations that mimic real-life without the consequence to life. VR training allows learners to observe how well they are prepared for various possible what-if conditions, so every individual gets confidence in their performance., which result prepares them for future events.

Our proposed immersive VR environment provides an excellent platform for learning experience by allowing trainers to introduce these high-stress situations to their trainees with the ability to observe and monitor variables like their stress reactions and emotional stability during high-stress conditions. Panic and stress can be induced with the use of fire and smoke as well as the use of audio for noises. The immersive active shooter response training for a building was developed using Unity game engine integrating with Oculus Rift S hardware. Virtual evacuation drills are necessary to study human behavior under panic or stressful situations that cannot be evaluated in the real world. The use of immersive virtual environments allows to

- run virtual evacuation drills for active shooter events
- eliminating risks of injury to participants during the training drill
- allows for the testing of situations that could not be tested in real life due to legal issues and possible health risks to participants.

We hypothesis that "sense of presence" provided by the immersive virtual environment will allow running training simulations and conducting evacuation drills. Virtual Evacuation drills are

- More cost-effective
- Take less setup time
- Able to simulate real dangers like smoke and fire
- Have improved response time

Immersive VR gives a 360° view of the surrounding environment and makes it possible for emergency responders to experience high stressful situations without any risk or danger to their lives. It helps them develop critical thinking skills when dealing with these types of emergencies. The significant part of VR training is the "pre-lesson learning" for active shooter events where proper protocols, rules, and regulations are addressed. The VR training then offers them hands-on exercises to implement their learned strategies and protocols into live actions. Thus, making them more confident and prepared for responding to different what-if situations. VR based training offers the following benefits

- Reduce the time and cost burden of live physical training
- Safely include stress and panic during disaster training
- Ability to offer immersive and repeatable VR based training
- Real-time data feedback from the training to evaluate individual and team performance
- Flexibility for individual and team training anywhere and anytime.
- Better training outcomes with a cutting edge training strategy

The rest of the paper is structured as follows. Section 2 briefly describes the related work for the immersive VR environments for emergency response, active shooter response, and disaster evacuation drills. Section 3, describe the design and requirements of the two active shooter modules. Section 4 describes the implementation of the immersive VR environment in five phases. Section 5 discusses the drawn conclusions Finally, Section 6 states acknowledgments.

2. Related Work

The best emergency action plan (EAP) in a building includes the occupants in the planning process by ensuring that occupants receive proper training for emergency situations. It should specify what the building occupants must do during emergencies, where are the safe zones located, and worst-case scenarios. Sharma et al. [8] had used a multi-agent system for emergency evacuation to model human behavior during emergency evacuation using intelligent agents. They show how computer simulations are useful to conduct different what-if scenarios for emergency situations in a user-friendly way that is cost-effective and safe. Van der Kleij et al. [9] study includes the implementation of adaptive and learning behavior for agents using neural networks, genetic algorithm and fuzzy logic. Moreover, Zawacki-Richter et al. [10] had incorporated a goal-oriented artificial agent-based model to incorporate human behavior parameters. Their study includes growing human social behaviors such as queuing and herding behaviors. Over the past few years, Virtual Reality (VR) had progressed from a gaming field to professional development, including military applications, psychological, medical, and education applications, offering an interactive computer-generated world [11-16].

Schweit et al [17] have argued that in evacuation and emergency response decisions for fire occurrences, human knowledge is critical. Gleich-Bope et al [18] have illustrated a model that can be employed during mass shooting to understand an active shooter scenario. Active shooting leads to the occurrence of large casualties and learning from prior disasters and experiences is crucial. According to Green et al [19], web-based training and study of policy choices based upon agent/computer modeling are occasionally used in the planning of active shooter situations. The training protects for the people in the building and for others. The inclusion of human behavior in modeling and simulation of emergency response is critical for decision-making in fire response [20]. Chovaz et al. [21] have described a model for the understanding active shooter events [22]. It is important to learn from past disasters and experiences for Active shooter events [23].

3. Active Shooter Module

We have designed and developed two immersive active shooter modules as shown in figure 1.

1. Occupant or civilian module
    - Run, Hide and Fight.
2. Security personnel module
    - Situational Assessment
    - Individual officer Intervention
    - Contact Officer or team Response
    - Rescue Task Force (RTFs)

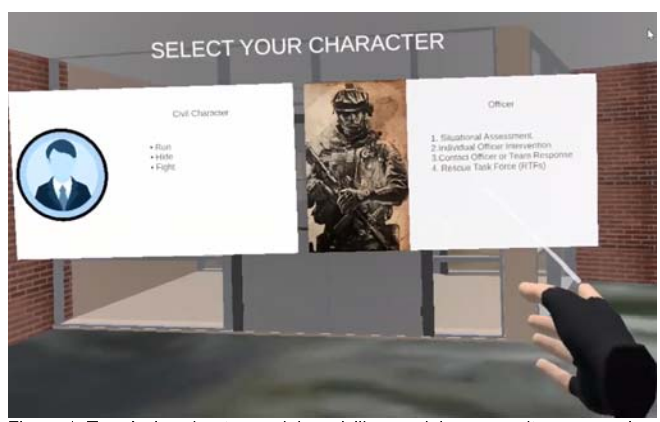

Figure 1. Two Active shooter modules: civilian module or security personnel module.

3.1 Occupant or civilian module

In 2013, "Run-Hide-Fight" was identified as the standard response to active shooting response by the US federal guide for developing high-quality school emergency operations plans [7]. This work presents an immersive VR environment for performing virtual evacuation drills and active shooter training scenarios using Oculus Rift S HMD. The immersive VR environment offers a unique way for training in emergencies for campus safety. The occupant VR training module is based on run, hide, and fight mode for active shooter response as recommended by the standard.

1. Run
    - Escape, if possible
    - Get as far away from the shooter or shooters as a top priority.
    - Leave belongings behind
    - Help others escape, if possible
    - Warn and prevent individuals from entering an area where the active shooter may be.
2. Hide
    - If escape is not possible
    - Get out of the shooter's view and stay quiet.
    - Silence all electronic devices and make sure they do not vibrate.
    - Lock and block doors, close blinds, and turn off lights.
    - Stay in place until law enforcement gives all clear.
3. Fight
    - As an absolute last resort.
    - Commit to your actions and act as aggressively as possible against the shooter.
    - Throw items and improvise weapons to distract and disarm the shooter.

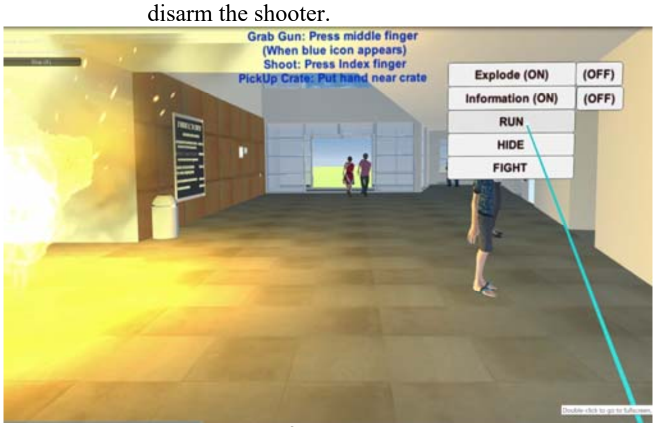

Figure 2. Active shooter response for the run

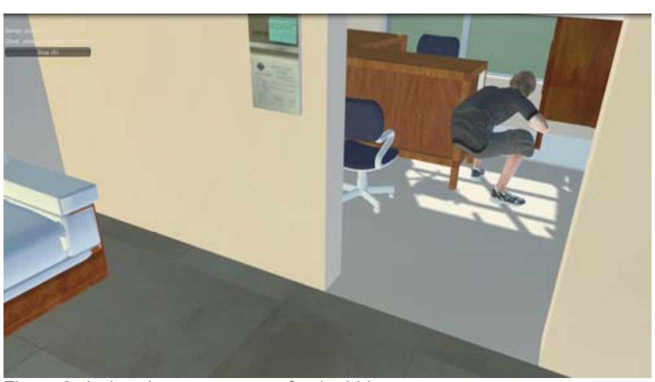
Figure 3. Active shooter response for the hide

Figure 4. Active shooter response for the fight

Active shooter response for run, hide and fight are shown in Figure 2, Figure 3, and Figure 4 respectively. The use of the laser pointer triggers the use of the menus in the VR environment. The menus help the user in triggering explosions and help feature the use of oculus controllers. The presence of fire and smoke in the environment gives the feel of an actual disaster condition. The user can grab a gun or grab objects to throw at the active shooter as shown in Figure 4.

3.2 Security Personnel Module

As shown in figure 5, the security personnel module was divided into four modules.

Figure 5. Security personnel module divided into four modules

1) Situational Assessment

The main aim of this module is to get information about the emergency situation inside the building. The dispatched officer will verify the active shooter situation in the building. The security personnel should find a safe zone in the building and secure the people in that area. Based on the noise in the building and visibility of the area, a security person should be able to estimate the number of active shooters in the building and the weapons that they may have. The security personnel should also find the number and location of persons in possible jeopardy. Upon completion of the initial assessment, the first security personnel shall advise communications and request resources as deemed necessary. This will allow to determine whether to take immediate action alone or with another officer or wait until additional resources are available. After successfully gathering the information, the personnel need to update the info to their officer through a communication device.

2) *Individual Officer Intervention*

The aim of this module is for the security personnel user to secure the civilians in the building and gather information about the shooter. Information mainly contains location, the physical appearance of the shooter, weapons that they are carrying, number of injured people in the building. All this information will be updated to the outside law-enforced officer's team that will guide them to enter into the building. The officers shall identify themselves as law enforcement officers, and display their badges or other law enforcement identification to alert security personnel, arriving officers, or civilians who may be armed. Based on the experience and skills users can take the decision to attack the shooter or not. If the officer is unarmed, the security personnel user can still play a critical role in active shooter response facilitating evacuation through the following actions

- locate points of egress and directing people to those evacuation points if reasonably safe for them to do so.
- locate and direct persons hiding in unsecure locations to evacuation points.
- If evacuation is not possible, help civilians by directing them to safe locations, directing individuals to silence all personal electronic devices, take cover, and remain silent.
- when possible, assist with the injured and direct incoming teams to injured persons.

3) *Contact Officer or Team Response*

In the previous module, the main threat was neutralized. In this module, the officer team will enter the building and bring all necessary medical needs to the people in the building. The aim of the officer or team is to locate and stop the threat. Even if the threat has been terminated, contact officers or teams are required to render the location safe, assist in screening and the orderly evacuation of persons to a designated area, and locate any other persons still in hiding. After identifying the threat is neutralized, the team will try to evacuate the building slowly and at the same time scan the building for hidden threats. The contact officer or team shall provide a clear communications channel to supply the types of information such as

- The officer or team's progress and location.
- The location and number of victims and their medical needs.
- The estimated number of suspects involved,
- The suspect's description and weapons if known.
- The location of any booby traps or explosives.

4) *Rescue Task Force (RTFs)*

Rescue Task Force (RTF) will not be needed in all emergency situations. Only when the situation is out of control in the officer's team, RTF will arrive. If active shooters are uncontrollable and damage is more the RTF will enter into the building. RTFs will be deployed only after the contact officer or team has made entry, provided a status report, notified the command post of the location of victims, established warm zones, and determined that rescue efforts may begin. If RTF has reasonable time, they will evacuate the civilians and injured people. Then proceed to the location of the situation and neutralize the threat. They will scan all the rooms and try to secure the building. They will also help in searching for injured people quickly and providing the medical need to the injured people in the building.

4. Implementation of immersive VR active shooter modules

The immersive VR environment was developed using Unity 3D gaming engine software and sketch-up application software, whiles virtual agents were also modeled using the make human application software. The implementation was done for both immersive environments as well as non-immersive environment. With a non-immersive environment, participants can navigate the active shooter environment using a desktop computer, joystick, and keyboard whereas the immersive environment makes use of the head-mounted device, the Oculus Rift S that gives the participant a complete immersion of the modeled active shooter environment. The implementation of the immersive VR environment was done in five phases:

4.1 Phase 1: Modeling and Unity 3D

We have recreated a real-time campus building environment using Unity 3D gaming engine, 3D max, and google sketch-up. The building was modeled to scale. We have incorporated C# behavior scripts, looping, and key triggered animations. The use of smoke and fire as well as some consistent colored light flickering functionality was made possible through C# programming. Figures 2 and 4 show the modeled active shooter environment with smoke and fire with the virtual agents navigating to safety. The modeled virtual agents in the environment have a waypoint algorithm attached as a component to enable them to navigate towards their goal in the environment. The cumulative interactions by the agents and the environmental hazard provided a more realistic feel for both immersive and non-immersive participants.

4.2 Phase 2: User and Computer Controlled Agent Behavior

There are two kinds of agents present in the environment, user-controlled agents and computer-controlled agents (AI Agents).

Figure 6. System Architecture for immersive active shooter module

We have presented two ways for controlling crowd behavior. First, by defining rules for AI agents or NPCs (Non-Player Characters). Second, by providing controls to the users as user-controlled agents or PCs (Player characters) to navigate in the VR environment as autonomous agents with a keyboard/ joystick along with an immersive VR headset in real-time. The NPCs for active shooters was made to be hostile, their hostility is seen in their distraction and detraction tendencies coupled with their level of aggression. The active shooting attack were simulated using a non-player character (NPC), as shown in Figure 6, We did not incorporate any blood effects and direct gunshots were employed in this simulation due to moral considerations. The gunshots audio clip was used shooting or initiating the event of the attack.

4.3 Phase 3: Cloud Client/Server Networking

Multi-user participation, engagement, and communication were achieved through the photon cloud network asset in Unity 3D. Photon unity networking allows participants from any part of the world to connect via the internet. The immersive VR environment is connected to the clusters of servers on the photon cloud network. Users can create a room on the server using a unique application ID number. Other users/players are also able to join the room for participating in the active shooter environment. Once a full connection is established, the photon network makes it possible for all users to view and engage other virtual agents in real-time.

4.4 Phase 4: Integrating Oculus Rift S

The components of the Oculus Rift S (an immersive VR system) include an HMD and two hand controllers. Tracking of the user's movement is also possible from the inbuilt sensors in the HMD. The oculus hand controllers serve as an interactive tool with the design objects within the application. The controllers are used for choosing objects via the use of a virtual laser to guide the user. The left and right controllers are used for generating the menus and selecting the objects from the menu for navigation respectively. The system architecture of the immersive active shooter module is shown in figure 7.

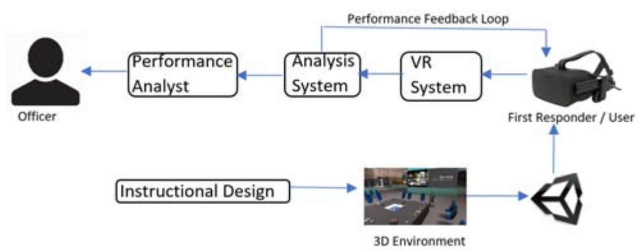

Figure 7. System architecture for immersive active shooter module

4.5 Phase 5: Menu design and Grabbing

Once the user selects the desired module through a laser pointer trigger, the user is transformed to the respective training module. In the occupant module, the menu design includes options for run, hide, and fight as well as triggering the explosion. There is also an option to grab the objects and throw them at the active shooter. C# scripts were developed to integrate Oculus Touch controllers that give haptic feedback to the user when using objects such as guns and the selection laser pointer.

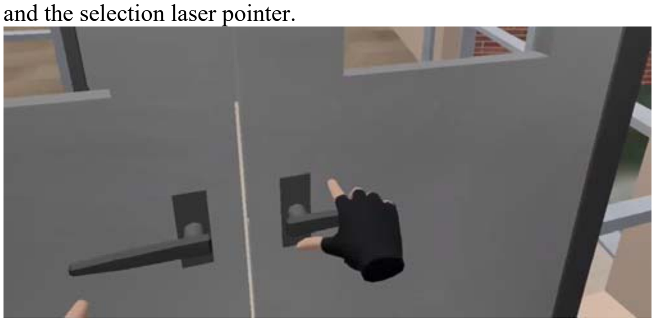

Figure 8. Grab option: User opens the door.

In the security module, the user can select the desired training module (Situational Assessment, Individual officer Intervention, Contact Officer or team Response, Rescue Task Force), the user is transported to the selected environment. The menu design includes options for triggering instructions to the user that can be toggled on/off. The user can also anytime during the module trigger the individual instructions or goal for the agent. The instructions menu is attached to the left-hand controller and the laser pointer to the right-hand controller. There are C# scripts written to grab and open the door and also for interacting with various objects in the environment. Figure 9 shows the menu of instructions attached to the left-hand controller and laser beam triggered for clicking through the right-hand controller.

Figure 9. Menu of instructions during the security personnel module

5. Conclusions

We have used game creation as a metaphor for creating an experimental setup to study active shooter events and human behavior for emergency response, decision-making strategies, and what-if scenarios. The traditional performance-based test, for active shooter events or fire emergency evacuation drill, are expensive to perform in real-world situations due to challenges with safety issues and legal aspects. It is very difficult to gather data on how humans are likely to behave in emergencies because human behavior is unpredictable. The formation of leadership or degree of trust during emergencies is critical in the study of active shooter events. Our proposed immersive training module for active shooter events offers a platform for conducting virtual evacuation drills for active shooter events for different what-if scenarios. The VR environment can be set up on the cloud and users can participate in the virtual evacuation drill or active shooter training simulations which leads to considerable cost advantages over large-scale real-life exercises. We have presented a hybrid platform where experiments for active shooter response can be conducted using computer-controlled (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.

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Ms. Sri Teja Bodempudi is a doctoral candidate in Department of Computer Science at Bowie State University, Bowie, MD 20715 USA. He works as a research assistant in Virtual Reality Laboratory at the Bowie State University. His research interest includes virtual reality, augmented reality, software engineering, artificial intelligence and collaborative virtual environment.